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Effect of somatic cell count on milk yield and milk components in Holstein cows in a semi-arid climate in Brazil

Efeito da contagem de células somáticas na produção e componentes do leite em vacas holandesas criadas no clima semiárido brasileiro

SILVA, José Edmário da[1]; BARBOSA, Severino Benone Paes[1*]; ABREU, Bueno da Silva[1]; SANTORO, Kleber Regis[2]; SILVA, Elizabete Cristina da[1]; BATISTA, Ângela Maria Vieira[1]; MARTINEZ, Rafael Leonardo Vargas[3]

[1]Universidade Federal Rural de Pernambuco, Recife, Pernambuco, Brasil.
[2]Universidade Federal Rural de Pernambuco, Garanhuns, Pernambuco, Brasil.
[3]Associação de Criadores de Pernambuco, Recife, Pernambuco, Brasil.
*Endereço para correspondência: severino.pbarbosa@ufrpe.br

SUMMARY

This study aimed to investigate the relationship among somatic cell scores (SCS) and currently selected traits (milk yield, and fat, protein, lactose, total solids and no-fat-solids contents) in Holstein dairy cows in a semi-arid climate. The data were collected from available records of 272 Holstein cows from January 2007 to December 2016. Farms were located in Agreste region of Pernambuco whose climatic characteristics according to Instituto Nacional de Meteorologia-INMET were: average annual temperature of 25.21 ºC; average annual precipitation 562.07 mm, and average annual relative humidity 75.61%.. A total of 4,586 records of somatic cell counts (SCC) in the milk, milk yield and milk components was analyzed. The SCC was transformed logarithmically into SCS (SCS = $\log_2$ (SCC/100,000) + 3) before statistical investigation. Ten SCS were obtained for determining their effects on milk yield and composition. Data were processed using PROC GLM and PROC CORR procedures in SAS. Results showed positive correlations among SCS and fat, protein, total solids and solids-non-fat contents, while the SCS and lactose content and milk yield were negatively correlated. The highest milk yield (34.43 kg/cow/day) was obtained for the lowest SCS (0; 0 to 24 cells x 1000/mL).The milk yield and lactose decreased while protein and fat contents increased when SCS increased mostly above score five (400 to 799 cells x 1000/mL). It was observed that the increase in SCS influenced negatively milk yield and composition in Holstein cows created in the semi-arid climate in Brazil.

Keywords: lactose, mammary gland, mastitis, milk quality, protein

RESUMO

Para investigar a relação entre contagens de células somáticas (CCS) e características atualmente selecionadas (produção de leite, gordura, proteína, lactose, sólidos totais e sólidos não gordurosos) em vacas leiteiras holandesas em clima semiárido brasileiro, foram coletados dados de 272 vacas de janeiro de 2007 a dezembro 2016. As fazendas foram localizadas na região Agreste do estado de Pernambuco, cujas características climáticas, de acordo com o Instituto Nacional de meteorologia-INMET, foram: temperatura média anual de 25,21ºC; precipitação média anual de 562,07 mm e umidade relativa média anual de 75,61%. Foi analisado um total de 4.586 registros de contagens de células somáticas (CCS) no leite, produção de leite e componentes lácteos. A CCS foi transformada logaritmicamente em ECS (ECS=$\log_2$(CCS/100.000)+3). Dez ECS foram obtidos para determinar seus efeitos sobre a produção e composição do leite. Os dados foram processados usando os comandos PROC GLM e PROC CORR do SAS. Os resultados mostraram correlações positivas entre ECS e gordura, proteína, sólidos totais e teores de sólidos não gordurosos, enquanto o ECS e o teor de lactose e o rendimento do leite foram correlacionados negativamente. A maior produção de leite (34,43 kg/vaca/dia) foi obtida para o menor ECS (0; 0 a 24 células x 1000/mL). A produção de leite e a lactose diminuíram quando os percentuais de proteína e gordura aumentaram, principalmente quando o ECS foi acima de cinco. O aumento da ECS influenciou negativamente a produção e a composição do leite em vacas de holandesas criadas no clima semiárido brasileiro.

Palavras-chave: lactose, glândula mamária, mastite, qualidade do leite, proteína

INTRODUCTION

Over recent decades, there has been a remarkable increase in the world's milk yield (OLTENACU & ALGERS, 2005), which may be attributed to the recognition of milk as a valuable food in the human diet and the fast-growing population as well as important initiatives surged to increase the productivity of dairy herds such as improving quality of feed, milking technology, breeds acquisition of high genetic potential for milk yield and selective breeding of dairy animals.

The increase in milk yield obtained in modern dairy cows and it has introduced various problems in dairy herds that affect negatively the ability to reproduce, increasing incidence of health problems, and declining longevity of the cows according to Oltenacu & Algers (2005). Thus, the quality and amount of the produced milk for human consumption has been one of the most discussed topics by the dairy farmers and researchers in the world.

Information about concentration of somatic cells (SCC) and milk composition are of fundamental importance because defines various properties sensory and industrial, milk quality and milk yield (ZHONG et al., 2010; CINAR et al., 2015) and also define the dairy farm's profitability (El-TAHAWY & El-FAR, 2010; CINAR et al., 2015). SCC in milk is used worldwide, mainly in industrialized countries, as a means to evaluate infections in the mammary gland and also already diffused as a standard to control milk quality (BARBOSA et al., 2007; RIBAS et al., 2014) and milk yield (JIA-ZHONG et al., 2010), but this technique has not yet been adopted in many countries in the tropics (FAO, 2014).

Researchers reported that genetic correlation of clinical mastitis and SCC range from moderate to high, so selection for low SCC is an important way to reduce the incidence of mastitis (CARLÉN et al., 2004) in dairy herds. Mastitis is defined as a mammary gland inflammation that is generally due to bacterial infections and non-infections etiological agents (SANTOS et al., 2003, ABERA et al., 2012) that not only affects milk yield but also has a negative impact on milk composition and physic-chemical characteristics (FAO, 2014). It is considered as one of the most costly disease in dairy cattle because of its biological effects (HERINGSTAD et al., 2000), economic losses (BARDHAN, 2013, SINHA et al., 2014) and also reduction in animal welfare (KHEIRABADI & RAZMKABIR, 2016).

Therefore, the objective of the current study was to investigate the relation among scores of somatic cells (SCS) and currently selected traits (milk yield, and fat, protein, lactose, total solids and solids-non-fat contents) in Holstein dairy cows in a semi-arid climate.

MATERIAL AND METHODS

All information used in this study was obtained from an existing database and therefore its use was not subject to ethics approval.

In this study were used milk yield and milk composition data from 3

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commercial dairy herds of Holstein cows located in Gravatá and São Bento do Una cities, in Agreste region of Pernambuco State, Brazil. The time frame of all data collections was from 2007 to 2016. The herds were characterized by the production of milk under semi-arid climate and food supplementation with commercial soy and corn concentrate, forage palm, corn silage and Tifton hay throughout the years.

The climatic characteristics for the 10 years of data collect according to Instituto Nacional de Meteorologia-INMET were: average annual temperature of 25.21 ºC (minimum 20.39 °C and maximum 30.4 °C); average annual precipitation 562.07 mm (minimum 376.6 mm and maximum 859.4 mm), and average annual relative humidity 75.61% (minimum 73.30% and maximum 78.14%). . The milk activity is expressive, being developed in the integration system in an intensive system. The herds evaluated in this study can be defined within the confinement system, with supplementation of silages, concentrates and hay.

Analyzes of milk composition including lactose, fat, protein, total solids and solids-non-fat were using infrared technique (Bentley 2000, Bentley Instruments, USA) and somatic cell count (SCC) by flow cytometry (Somacount 500 , Bentley Instruments, USA). Milk yield data were obtained monthly from the dairy control reports in the selected herds. The data used were obtained from the official reports issued by the dairy herd management program of the Northeast region of Brazil (PROGENE) and Pernambuco Breeders' Association (ACP).

The SCS were calculated from SCC as SCS = $\log_2$(SCC/100,000) + 3) in order to obtain the distribution close to normal (Ali& Shook, 1980) based on the amplitude of the CCS variation, which establishes scores between 0 and 9. The scores analyzed were: (0) SCC 0-24 x 1,000 cells / mL; (1) SCC 25-49 x 1,000 cells / mL; (2) SCC 50-99 x 1,000 cells / mL; (3) SCC 100-199 x 1,000 cells / mL; (4) SCC 200-399 x 1,000 cells / mL; (5) SCC 400-799 x 1,000 cells / mL; (6) SCC 802-1591 x 1,000 cells / mL; (7) SCC 1600-3193 x 1,000 cells / mL; (8) SCC 3207-6391 x 1,000 cells / mL and (9) SCC 6403-9999 x 1,000 cells / mL.

The data were first analyzed following a frequencies distribution and all results that extrapolate the values suggested by Ribas et al. (2014) were eliminated. Subsequently, 4,586 records (for milk yield, protein, lactose and fat contents) and 4,583 records (for total and solids-non-fat) of 272 cows in the statistical analysis were used. Then, analysis of variance was performed using the general linear model procedure (PROC GLM). In the statistical model, the following environmental effects were used: Year of calving (2007 to 2016); Month or season of calving (rainy and dry); Age class at calving (1 to 6); this classification was based on the age distribution at calving and interval between calving, as follows: 1*st* class - from 20 to 32 months of age; 2*nd* class - from 33 to 45 months of age; 3*rd* class - from 46 to 58 months of age; 4*th* class - from 59 to 71 months of age; 5*th* class- from 72 to 84 months of age; 6*th* grade - above 85 months of age.

Local (São Bento do Una and Gravatá);

Somatic cell score (0to 9);

The following model was used:

Yijklm = μ + Loci + APj + MPk + AP x MPjk + SCSl + b1(I – Iijkl) + b2(I – Iijkl)2 + eijklm

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Where Yijklm is the characteristic (daily milk production or milk composition); μ is the general mean; Loci is the effect of the i-*th* place of rearing of the i = 1,2; APj is the effect of the j*th* year of calving, to j = 2007,...,2016; EPk is the effect of the k-*th* cow calving season, to k = 1, 2; APj x EPk is the effect of the interaction between the calving year and the calving season of the cow; SCSl is the effect of the 1st class somatic cell score on milk, for l = 0 to 9; b1 e b2 are the coefficients of linear and quadratic regression, respectively, of cow age, in months, on the characteristic Yijkl; I e Iijkl are the cow age and mean age of cows, respectively, considered in the study; eijklm is the random error associated with each observation.

Pearson's correlations coefficient among SCS and milk yield and milk composition were analyzed using PROC CORR procedure. All statistical analyzes were done in SAS®software.

RESULTS AND DISCUSSION

The descriptive statistics for milk yield, milk composition and SCS of 272 Holstein cows in a semi-arid climate in Brazil are presented in Table 1. There was considerable variation in these analyzed traits, mainly in the SCS. The cows demonstrated a good production with a mean milk yield of32.08 ± 8.79 kg/day and a mean SCS of 3.5 ± 2.38 (range from 200 to 300 x 1,000 cells / mL).

Table 1. Number of samples, averages observed and standard deviations (Mean ± SD), and coefficients of variation (CV) of fat, protein, lactose, total solids, not-fat-solids and milk somatic cell score and milk yield

Parameters	Nº of samples	Mean ± SD	CV (%)
Fat (%)	4,586	3.23 ± 0.69	21.48
Protein (%)	4,586	3.20 ± 0.39	12.39
Lactose (%)	4,586	4.56 ± 0.23	5.19
Total Solids (%)	4,583	11.99 ± 0.88	7.38
Solids not-fat(%)	4,583	8.76 ± 0.46	5.28
Somatic cell score*	4,586	3.50 ± 2.38	68.10
Milk yield (kg / cow / day)	4,586	32.08 ± 8.79	27.41

* SCS = log2 (SCC / 100,000) + 3).

The mean contents of protein, lactose and fat were close to those reported in previous studies for Holstein cows (TOFFANIN et al., 2015; COSTA et al., 2018). However, milk yield and SCS values were not in accordance with the results of these authors, showing that the Holstein of this study produced more milk per day (30.19 and 27.58 kg/day by TOFFANIN et al., 2015 and COSTA et al., 2018, respectively) with lowest SCS (TOFFANIN at al., 2015) reported mean SCS of 4.62). The greatest and lowest values of CV were obtained for SCS (68.10%) and lactose (5.19%), respectively.

The value found in this study for mean SCS is below of the levels of SCS recommended by countries such as France, Australia, Canada, the United States of America and New Zealand that also use production systems with high technological level.

SCC in milk besides being a tool to identify subclinical mastitis, is highly important for the dairy industry because milk with high value of SCC is directly associated with decreased production of dairy products by reducing shelf-life (ANDRADE et al., 2007), changes in milk composition which may result in decreased cheese yield, reduction of the shelf-life of pasteurized milk, and others (Le ROUX et al., 2003).

Lactose is the main carbohydrate in milk and presents strong positive correlation (0.979) with milk yield as has been reported for Holstein cows (MIGLIOR et al., 2007). In this study, the lactose percentage was 4.56 ± 0.23% (Table 1) representing 38.03% of the total solids and 52.05% of the solids non-fat in the milk. The value found for lactose in our study was close to five percent and it was very close to those values found by others authors that ranged from 4.28 (GONZALEZ et al., 2009) to 4.76 (COSTA et al., 2018).These findings showed as the lactose concentration in milk can vary in different locations.

In Brazil, the variation in lactose content in milk has been considered a problem for the dairy industry and that is related to heterogeneity in the management conditions, feeding of dairy herds and health of the mammary glands (ALLESIO et al., 2016). However in developed regions, lactose levels found are more constant due to fewer problems of mammary glands and, consequently somatic cell counts are lower, in addition the cows are fed with appropriate nutrition (JENKINS & McGUIRE, 2006).The lower the amount of lactose in milk will lower the income of dairy products in the industry (LEITNER et al., 2011), so this component has become increasingly important in the dairy industries (COSTA et al., 2018).

The distribution of milk samples for somatic cell counts in classes of SCS estimated in this study showed that 68.03% of the samples of milk produced in specialized cows, in the Agreste of Pernambuco, are up to score four that corresponds to a total of somatic cells of 200 to 399 cells x 1000 / mL (Table 2).

Table 2. Classes of somatic cell scores, variation of individual somatic cell count (SCCI), number of observations (N), absolute and cumulative percentages (%)

SCS*	Variation of SCCI**	N	Absolute %	Cumulative %
0	0-24	501	10.92	10.92
1	25-49	543	11.84	22.76
2	50-99	692	14.24	37.85
3	100-199	752	16.40	54.25
4	200-399	632	13.78	68.03
5	400-799	483	10.32	78.56
6	802-1591	389	8.48	87.04
7	1,600-3,193	258	5.26	92.67
8	3,207-6,391	214	4.66	97.33
9	6,403-9,999	122	2.66	100.00
Total	-	4,586	100.00	-

*(SCS= log2 (SCC / 100,000) + 3), ** (x 1,000 cells / mL).

Costa et al. (2018) found for 60.82% of Holstein cows reared in the North of Italy a mean SCS of 2.91. In countries with specialized dairy cattle, ranchers and dairy farmers work on the search for milk produced with a percentage

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above 80% for somatic cell count up to score three, reflecting good care and attention of producers regarding the prevention of mammary gland health and dairy companies to establish milk payment programs for quality focusing on the SCS standard (RIBAS, et al, 2014).

The number of samples found with three score was about 54.25% (Table 2), even if according to the parameters and international standards for milk quality still demonstrates the importance of promoting policies to encourage the improvement of milk quality. In addition to the SCC, some countries use other nutritional components present in milk to subsidize milk producers. Most milk marketing orders in France, Australia, New Zealand, Canada and the United States countries, have employed a multiple component pricing system that pays producers on the basis of protein, fat and other dairy solids contents of milk (RIBAS et al., 2004).

Pearson correlation coefficients of each milk component with SCS are shown in Table 3. Fat, protein, total solids and solids-non-fat percentages showed a positive correlation with SCS while lactose percentage and milk yield showed a moderate and low negatives correlations with SCS. Researchers working in the Center-South of Brazil also found positive correlations for the effect of SCS on the milk protein content of Holstein cows (CUNHA et al., 2008; MOSCON et al., 2011), while Rangel et al. (2009) found for lactose and total milk solids percentages positive and negative correlation with SCS, respectively.

Table 3. Pearson's correlation coefficients between somatic cell score (SCS) and milk composition and milk yield

Parametres	Correlations
Fat (%)	0.036*
Protein (%)	0.282*
Lactose (%)	-0.411*
Total solids (%)	0.045*
Not-fat-solids (%)	0.032*
Milk yield (kg / cow / day)	-0.118*

* (P <0.05).

It has been reported that high SCC (> 200,000 cells/mL) might cause changes in milk composition than samples with low SCC (≤200,000 cells/ml) (SANTOS et al., 2003). According to Alessio et al. (2016) the lactose content in milk is influenced by somatic cell count, as well as others factors such as parity, and season, but is not related to milk yield, fat and protein levels in milk. Malek dos Reis et al. (2013) reported that somatic cell count was negatively associated with reduced lactose in milk from Gir cows observing that lactose content was higher in health quarters than in quarters with high SCC. Berglund et al. (2007) evaluating quarter milking for improved detection of increased SCC observed that an increased from 31,000 to 450,000 somatic cells mL^{-1} reduced the lactose content from 4.86 to 4.69% and suggested that the deviations in lactose content may be a useful tool for detection of moderately increased SCC. Ogola et al. (2007) also found lower

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value (4.3%) for lactose content in samples from zebu cows with higher SCC (>750.000 cells/mL).
Figure 1 shows the relationships between SCS ranging from zero to nine with the respective adjusted means for milk yield (kg / cow / day) and percentage of lactose. There was a statistically significant difference (P<0.05) between SCS and mean milk yield (kg / cow / day) and lactose content, decreasing from 25.6% to 9.7%, respectively, in the largest SCS , which presented high somatic cell count (9 = 6400 cells x 1000 / mL).When SCS ranged from zero to nine, milk production (kg / cow / day) decreased from 34.43 to 25.62 (kg / cow / day), similar behavior was found to the 4.65% to 4.20% when SCS increased from 0 to 9, respectively. lactose content that decreased from In previous study, has been demonstrated that lactose is related to milk production (SHAHBAZKIA et al., 2010) and these two traits are negatively influenced by SCC. However, when occur an increased concentration of somatic cells in milk it causes a decrease in lactose in milk (e.g. MALEK DOS REIS et al. 2013; ALESSIO et al., 2016) because this will be a substrate for mastitis pathogens (BLUM et al., 2008).
A similar behavior to the results found in this work for milk yield, and increased SCS, have been reported in several studies (MAGALHÃES et al., 2006; NORO et al., 2006; ANDRADE et al., 2007; CUNHA et al., 2008). These authors also used Holstein cows in their researches in the Center-South of Brazil, observing losses of milk productivity as a result of the SCS increased.

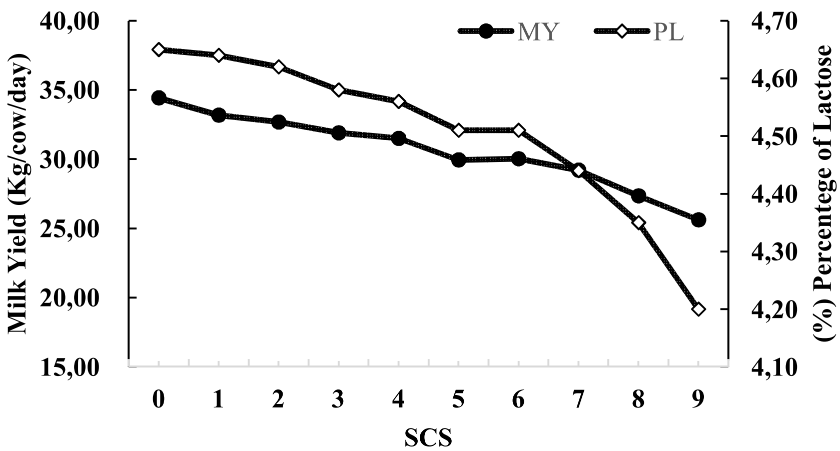

Figure1. Relationship between somatic cell score (SCS) and milk yield (MY) and lactose percentage (PL)

Where the percentage of fat increased from 3.08% to 3.38%; this same behavior of increasing tendency also occurred for the percentage of protein increasing from 2.99% to 3.53% (Figure 2). There was a statistically significant difference (P<0.05) between SCS and percentages of fat and protein, increasing by 9.74% and 19.06%, respectively, in the highest SCS 9 (6,400 cells x 1000 / mL). The highest fat percentage was 3.38% and the 3.56% protein percentage was obtained for the lowest SCS 0 (0 to 24 cells x 1000 / mL).

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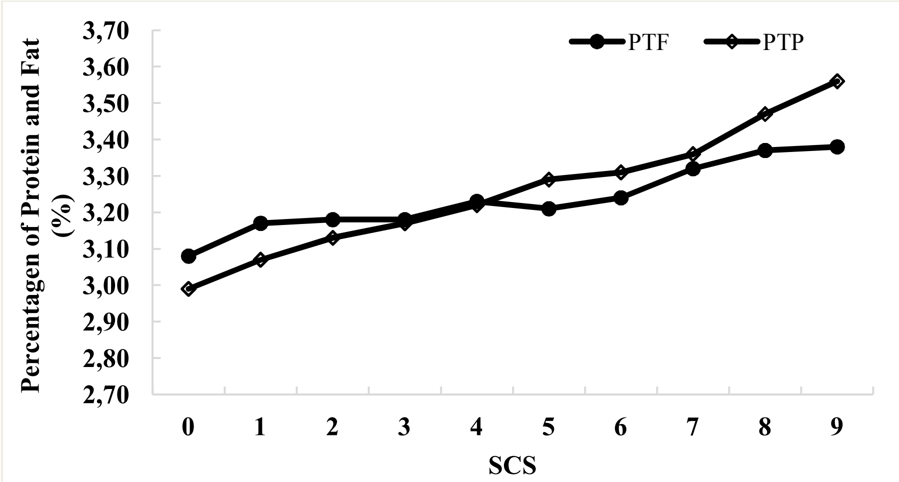

Figure 2. Relationship between somatic cell score (SCS) and protein (PTP) and fat percentages (PTF)

Total solids ranged from 11.70% to 12.18%, and for SCS nine there was a decrease in the percentage of total solids to 12.13% (Figure 3). The same behavior was observed for the contents of solids-not-fat which increased from 8.62% to 8.80%, and for SCS nine there was also a decrease in the percentage of solids-not-fat which dropped to 8.75%.There was a significant statistical difference (P<0.05), in a smaller magnitude in relation to the other variables, between SCS and percentages for total solids and solids-not-fat, which increased by 4.10% and 2.20%, respectively, in the higher SCS (8, between 3,207 and 6,391 cells x 1000 / mL). The highest percentage of total solids was 12.18% and 8.80% protein percentage was obtained for the lowest SCS (8; 3,207 to 6,391 cells x 1000 / mL).

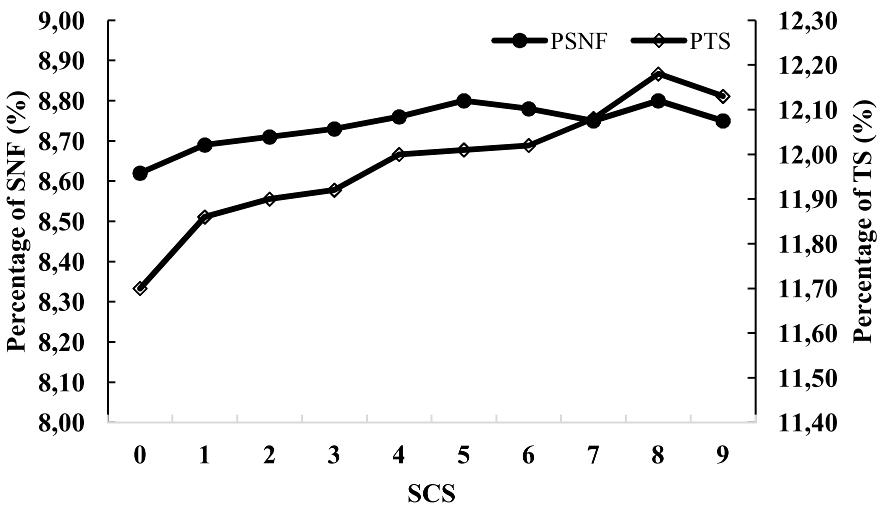

Figure 3.Relation between somatic cell score (SCS) and total solids (PTS) and solids-non-fat percentages (PSNF)

It was observed that the increase in somatic cell score influenced negatively milk yield and composition in Holstein cows reared in the semi-arid climate in Brazil. This can be justified by reduced production of milk due to infections of the mammary gland (subclinical mastitis). Despite the observed increase in fat, protein and total solids contents, this fact was not favorable for milk quality, since this may be due to the decrease in milk production when the somatic cell count increased.

Taking together all above information provide by this study, was suggested the significant effect of the somatic cell score on milk yield and composition showed us that the farmers need improving their managing practices to prevention and control of clinical and subclinical mastitis, as well as monitoring of milk productivity and quality.

The results found with this study demonstrated that Holstein cows even being reared in a region that present elevated temperature was as productive as those reared in others region with weather more recommended for breed type.

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