Effect of THI, NDF and rumination in milk production in Holstein cows

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ABSTRACT

Objective: The aim of the present study was to evaluate the effect of the temperature-humidity index (THI), the content of neutral detergent fiber (NDF), and rumination rate (RR) on milk production in Holstein cows in a dairy farm located in Bajío de San José, Jalisco, Mexico.

Design/methodology/approach: The THI is an indicator of the effect of the environmental climate can have on milk production, and likewise the nutritional content of forage is affected by weather conditions, such as the NDF is related with rumination activity of cows; increasing THI has shown a direct effect on milk production in cows. The HealthyCow 24® CSR remote equipment was used (SCR Engineers Ltd., Netanya, Israel), to monitor rumination, from a total registry of 284 cows with 2, 3, and 4 lactations distributed between August and December 2020 period, analyzing the NDF content from total mixed portion and monitoring the THI.

Results: The results showed there was no effect of THI on milk production ($p>0.05$), despite having reached a THI score of 76, while NDF ($p<0.05$) and RR ($p<0.001$) affected milk production; an effect of THI on RR ($p>0.05$) was not found, and the NDF only had a trend ($p<0.1$).

Limitations on study/implications: There were no limitations for the study.

Findings/conclusions: According to the results obtained, the THI threshold should be reconsidered according to the resistance of the productively active cattle on dairy farms.

Keywords: Climate adaptation, degradability, heat stress.

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INTRODUCTION

The temperature-humidity index (THI) is an indicator of the effect that the environmental climate can have on milk production. Cowley *et al.* (2015) mention that the impact of the heat stress (CS) has two causes: reduction of consumption and metabolic and physiological effects. Because of the decrease in consumption, low milk production of

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between 25-40% has been seen (Tao *et al.*, 2018). Collier *et al.* (2012) indicated that the THI threshold should be reconsidered, because of multiple results where thresholds of CS have been found at a lower scale than a THI of 72.

Increasing the Neutral Detergent Fiber (NDF) has been seen to improve the digestion of some nutrients such as starch. Dann *et al.* (2015) found similar milk productions (51.6 *vs* 50.5 kg of milk) when increasing the NDF from non-forage sources (34.7 *vs* 38.0%), similar to what is reported by Ranathunga *et al.* (2018) who increased non-forage NDF and did not have an increase in milk production (+2.1%). Naderi *et al.* (2016) reported that by substituting 12% of the sources of non-fodder fiber in place of the corn silage there were higher milk productions even under conditions of CS (+6.27%). The physically effective NDF is the fraction of fiber that stimulates chewing and contributes to the floating bed of long particles in the rumen (White *et al.*, 2017). Milk production has been associated with the rumination time, which has been associated with cows of higher milk production having a higher consumption and therefore needing more rumination time (Stone *et al.*, 2017). Salfer *et al.* (2018) mention that, in general, consumption, rumination and ruminal pH follow a daily pattern that was minimally modified by the type of fiber and carbohydrates. The cows use more time in rumination throughout the entire day when there is a higher concentration of NDF. Byskov *et al.* (2015) found an increase of 22 min of rumination time for every kg of NDF of forage consumed.

The CSR Heatime® HR system, in addition to being commonly used for reproductive programs (Burnett *et al.*, 2017; LeRoy *et al.*, 2018), has proven to have high sensitivity to detect changes in the activity and the rumination before the evident clinical signs of a disease such as displacement of abomasum, as well as metabolic and digestive disorders; this results in the early identification of it (Stangaferro *et al.*, 2016). Due to the variability of response of milk production in the presence of changes in THI, NDF and rumination that have been found, the objective of this study was to evaluate the effect of THI, NDF and the rumination rate (RR) on milk production, as well as evaluating the effect of THI and NDF on the RR in Holstein cows in a stable located in Bajío de San José, Jalisco.

MATERIALS AND METHODS

Study area

The study was developed in a stable of the locality of Bajío de San Jose, municipality of Encarnación de Díaz, Jalisco, Mexico.

Distribution of cows for the study

To record the information, there were cows of second, third and fourth lactation that had normal births, and in addition the cows had to be in a range between 21 and 306 days in milking (DIM), in each period of reading. The DairyComp305® system (DC305; Valley Ag Software, Tulare, CA) was used to identify the number of lactation and the days in milking (DIM) of the animals in each registry date of milk production when it was done. Monitoring was carried out during the period from the month of August to

the month of December, 2020, adjusting the milk records based on the activities of the ranch to avoid interfering with the management, obtaining a total of 284 records of milk weighing distributed in the dates: August 06 and 28, September 16, October 06 and 21, November 13, and December 18 of the year 2020.

Monitoring of the Temperature-Humidity Index

To estimate the THI, first the temperature and the humidity were measured manually within the farmyards, with a digital thermometer with relative humidity sensor brand Radioshack®, model 80904, with electrical characteristics of the temperature sensor: 10 K (−2%) Ohms, 3435 K. The readings were carried out at 15:00 hours (Cerqueira *et al.*, 2016) in the same dates when the records of milk production were obtained. The equation of the Temperature and Humidity Index equation by Dikmen and Hansen (2009) was used.

$$THI = (1.8 * T + 32) - [(0.55 - 0.0055 * RH) * (1.8 * T - 26)]$$

Where T is the temperature expressed in Celsius degrees and RH is the Relative Humidity expressed in percentage; these records were noted in a database with an Excel ® spreadsheet.

Rumination activity

To monitor the rumination activity, the remote equipment HealthyCow 24® CSR (SCR Engineers Ltd., Netanya, Israel) was used. The SCR Company programmed the software of the HC24 system to automatically download a back-up in Excel® format of the rumination monitoring each day. Every day throughout the monitoring period, considering the rumination reading that closes at 23:00 hours, it was used as the rumination rate in 24 hours (RR) for the purpose of mathematical analysis (Stangaferro *et al.* 2016).

Milk production

The milk production for each cow was recorded manually and individually with the SCR Milking Control System (SCR Engineers Ltd., Netanya, Israel) in each of the dates mentioned before.

Sampling of total mixed portions

Samples were collected from the total mixed portions in the day of the record of milk production directly from the manger; five portions of approximately 500 g were taken along the manger in equidistant form from the recently served manger, and then, mixing the five portions and from there taking a single sample of 1 kg.

Bromatological analysis

The dry matter, protein, ethereal extract and ashes were determined according to the AOAC (1990) method; the neutral detergent fiber was determined with the technique by Van Soest *et al.* (1991).

Statistical analysis

For the analysis of the effects of the variables THI, rumination and NDF on milk production, a multiple linear regression model was used, where the dependent variable Y=milk production and the three independent variables, X_1=THI, X_2=NDF and X_3=Rumination, were considered under model 1:

Model 1: $Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_i$

Where, "β" 0=Factor of initial adjustment, "β" 1=Coefficient of the THI effect, "β" 2=Coefficient of the NDF effect, "β" 3=Coefficient of the Rumination effect.

The assumptions of the model were tested making adjustments to the dependency of errors through the Cochrane-Orcutt method.

For the analysis of the effects of the variables THI and NDF on the Rumination, a multiple linear regression model was used, where the dependent variable Y=Rumination and the two independent variables, X_1=THI and X_2=NDF were considered, under model 2:

Model 2: $Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon_i$

Where, "β" 0=Factor of initial adjustment, "β" 1=Coefficient of the THI effect, "β" 2=Coefficient of the NDF effect.

An adjustment to model 2 was conducted through the transformation of the dependent variable by the Box-Cox technique, with a transformation factor 2.476736, to fulfill the assumption of normality of residuals.

All the statistical analyses were carried out with the R-Studio version 2022.03.3 system.

RESULTS AND DISCUSSION

Temperature and Humidity Index

During the monitoring period, fluctuating values of THI were found between 68 and 76 (Figure 1). The average milk production found when the THI was 76 that was recorded twice under an average of 3.1 Kg milk/day compared to the average that was obtained when the THI was 68 in the date of August; although within the August period the average milk production decreased by 6.21%, by the months of September and October the productions were maintained compared to the end of August, without altering them, although the THI decreased to 72 and then increased again to 76 at the end of October ($p>0.05$).

Neutral Detergent Fiber

The percentage ranges of NDF in total mixed portions were between 25.2% and 35.6% (Figure 2), where a significant negative effect of the NDF content on milk production was found of up to −19.5% ($p<0.05$); the drastic increase of the NDF recorded in the month of November was because of an imbalance of ingredients found per week.

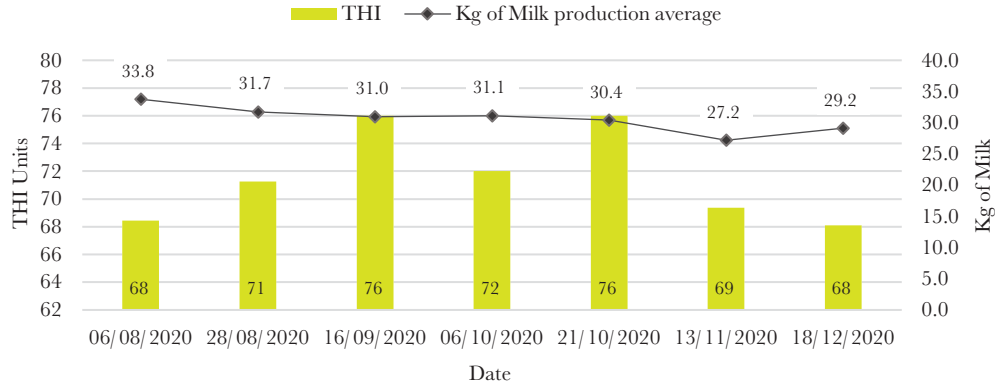

Figure 1. Variations of the Temperature and Humidity Index (THI) by date and average milk production (Kg), of cows with 2, 3 and 4 lactations, from August to December 2020, Bajío de San José, Jalisco.

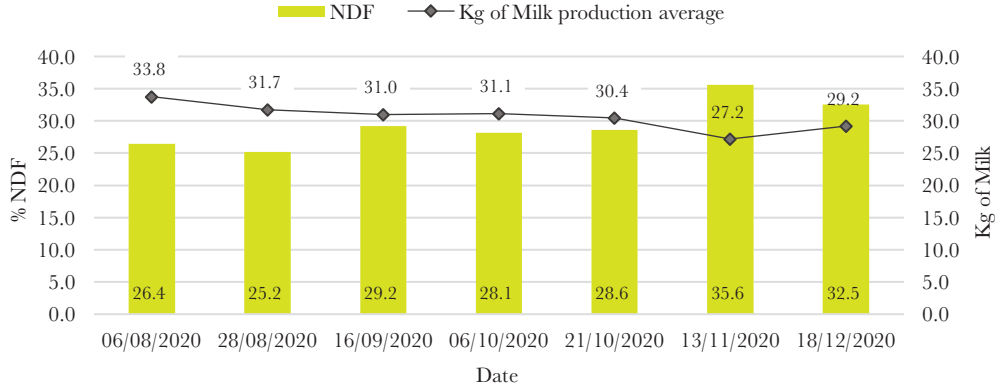

Figure 2. Variations of the content of Neutral Detergent Fiber (NDF) in the total mixed portions by date and average milk production (Kg) of cows with 2, 3 and 4 lactations, from August to December 2020, Bajío de San José, Jalisco.

Ruminant activity

The average RR of animals for each period had a range between 511 and 582/24 hr (Figure 3); the RR had a highly significant positive effect on milk production ($p<0.001$), although the RR was affected with lower significance due to the NDF ($p<0.10$) content, and the THI did not have a significant effect on the RR ($p>0.05$).

Temperature and Humidity Index

Results from this study indicate that milk production was maintained despite reaching THI of 76, compared to what was found by Cerqueira *et al.* (2016) and Perano *et al.* (2015) where production decreased when reaching a THI of 78 and 80.7, respectively, which in the case of Perano *et al.* (2015) found a decrease of milk production in heifers of up to 11.2% when reaching a THI of 80.7 if management to attenuate CS was not given. On the one hand, it is possible that the increase in THI in this study is due to an increase of food efficiency as mentioned by Hill and Wall (2017) when cows went through a medium CS, although Gao *et al.* (2017) reported that even if the apparent digestibility of

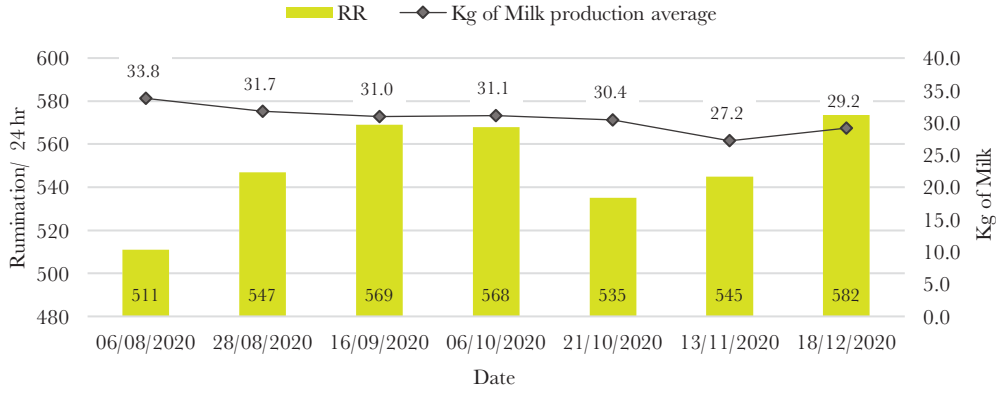

Figure 3. Variations of the average Ruminant Rate (RR) and the average milk production (Kg) of cows with 2, 3 and 4 lactations, from August to December 2020, Bajío de San José, Jalisco.

dry matter, organic matter, neutral detergent fiber, acid detergent fiber, raw protein, and ethereal extract increased when reaching a THI of 84.3, there was a decrease of 17% of milk production. On the other hand, it is necessary to consider that animals could modify the behavior to mitigate the effect of the increase in THI when it was ≥72, as was found by Hut *et al.* (2022), decreasing the time of lying down and increasing the time of standing without activity; above all, the possibility should be considered that the animals have a genetic tolerance to caloric stress (Jensen *et al.*, 2022).

Neutral Detergent Fiber

The negative effect of NDF on milk production dismisses the possibility that it could help to improve the digestibility of certain nutrients as mentioned by Dann *et al.* (2015); it is possible that the effect from factors such as plant maturity has been negative, as mentioned by Alstrup *et al.* (2016), which would be explained by the lack of digestibility of NDF suggested by Fustini *et al.* (2017) and Hristov *et al.* (2019), since it would have avoided the decrease in milk production when there was an increase of NDF, or else having used source of non-fodder NDF that could compensate the milk production, as done by Naderi *et al.* (2016) and Saylor *et al.* (2018).

Rumination

The positive effect of the RR on milk production is possibly more related to a higher consumption of the animal, as mentioned by Stone *et al.* (2017), and as a daily pattern of rumination that was minimally altered by the type of NDF (Salfer *et al.*, 2018), since the NDF content barely showed a significant trend ($p<0.1$) on the RR, different from what was found by Byskov *et al.* (2015).

In this study the RR was not affected by the THI, as was found by Müschner-Siemens *et al.* (2020) and Hut *et al.* (2021), where they report that rumination begins to decrease from a THI ≥52 and 72, respectively, depending on the type of climate that prevails in the region, which would be justified with a possible adaptation of the animal to the climate as suggested by Jensen *et al.* (2022).

CONCLUSIONS

Monitoring of rumination through automatized systems helps to evaluate punctually the factors that could impact milk production and the health of cows, since under the conditions of this study the NDF content did not have an effect on the RR. Although it did affect negatively the milk production, it is also clear that the resistance of the cattle in the presence of variations of THI in microenvironments should be reconsidered by regions, since the cattle could develop tolerance and that quality ought to be a filter for the selection of new replacements, since the livestock showed certain resistance maintaining productive stability.

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