

## Effects of THI changes on milk production and composition of three dairy cattle farms in Mugello from 2010 to 2018: a preliminary study

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Global warming is already affecting several areas and a further increase of 1.5°C is expected by 2050. Dairy cattle are particularly sensitive to high temperature. So, the aim of this study was to examine the effect of temperature-humidity index (THI) on milk traits, considering changes of climatic parameters in the different seasons from 2010 to 2018. The study was conducted in 3 farms located in a hilly-mountainous area of Tuscany, the Mugello, situated from 220 to 450 m above sea level. Data on average daily milk yield and composition were monthly collected in the 3 farms from 2010 to 2018, while climatic parameters were recorded by a climatic station located in the area of the farms. As regards the climatic parameters, no significant variations have been observed in the last decade. The THI calculated thanks to the recording of temperature and humidity of the weather station, during the warmest months, was high enough to cause heat stress. The milk quality traits declined when THI increased. In conclusion, there was not any evidence that global warming has been affecting Mugello, but, despite its altitude, high THI usually reached during spring and summer seasons are already high enough to cause heat stress and a further increase could worsen farm productivity.

**Keywords:** climate change, milk quality, heat stress, dairy cow

### 1 Introduction

According to the Intergovernmental Panel on Climate Change report on global warming (IPCC, 2018), an increase of 1.5°C in temperature is expected by 2050. Climate changes are not supposed to be globally uniform, but an increase in extreme weather events, including heatwaves, is expected. Global warming is rising concerns on sustainability of livestock productions, especially for dairy sector, which relies on animals that are highly susceptible to extreme temperatures. Body temperature of dairy animals ranges from 38.4 to 39.1°C, while their thermoneutral zone ranges from 16 to 25°C (Das et al., 2016). Animals start experiencing difficulties in dissipating heat load when temperature is approaching the upper limit of thermoneutral zone; when temperature exceeds 25°C, animals enter in heat stress. Heat stress depends on several factors, both related to the animal itself and to the external environment. The main environmental parameters involved are temperature and humidity, which are commonly combined to calculate an index known as temperature-humidity index (THI). The THI is used to evaluate the level of thermal stress for a given environment (Renaudeau et al., 2012). Heat stress has to do with adaption, resilience, and genetics. Moreover, animals living in higher latitudes are more affected by heat stress since they are less adapted to high temperatures than animals living at lower latitudes (Thornton et al., 2009). Therefore, in the next years, the global warming and the increased frequency of heatwaves (Zampieri et al., 2016) are expected to have an important impact on the dairy sector, especially in temperate

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countries (Gauly & Ammer, 2020, Silanikove & Koluman, 2015). Animals generally adopt several strategies to cope with heat stress such as the reduction of feed intake and increase of water intake, the alteration of some physiological functions such as reproductive and productive efficiency, and the change of respiration rate and sweating (Rojas-Downing et al., 2017). In presence of high temperatures, the reduction of feed intake in lactating cows at peak could lead to negative energy balance leading thus to a decline in milk production. A decrease in milk yield of 0.41 kg/cow/day was observed for each THI unit increase above THI of 69 (Spiers et al., 2004). Hot temperatures and high humidity rates also affect milk quality, determining a lowering in fat and protein contents when THI overcomes the value of 72. In temperate regions, heat stress is mainly experienced during summer, when THI is more likely to go beyond 72 (Das et al., 2016). The aim of this study was to carry out a preliminary investigation to evaluate the effects of THI on milk traits of dairy cattle in a hilly-mountainous area of Tuscany, the Mugello.

## 2 Material and methods

### 2.1 Farms and animals

Data from 3 dairy cattle farms from 2010 to 2018 were used in the present study. The farms were located in a mountainous-hilly area with an altitude ranging from 220 to 450 m above sea level. Two farms reared the Holstein Friesian breed, and one farm reared the Brown Swiss. Animals were kept in open barns with free access to an external paddock and they were milked twice a day.

### 2.2 Data collection

Average milk yield and fat and protein percentages were provided by the Regional Breeders Association of Tuscany (ARAT - Borgo San Lorenzo, Florence) with the consent of the breeders. Data were collected during routine monthly milk recording procedures carried out by ARAT in the farms registered to the herd book. The two Holstein Friesian farms had an average of 79 and 145 lactating cows, respectively, while the Brown Swiss farm had 89 lactating cows. Climatic parameters from 2010 to 2018 were recorded by a weather station located to an intermediate distance from the 3 farms and at a height of 320 m above sea level. The analyzed parameters were temperature (T, °C) and relative humidity (RH, %). Maximum diurnal THI was calculated according to Fabris et al. (2019):

$$\text{THI} = (1.8 \times T + 32) - ((0.55 - 0.55 \times (\text{RH}/100)) \times (1.8 \times T - 26)).$$

This value was matched to the average daily information on milk traits collected monthly in each farm.

### 2.3 Statistical analysis

The average maximum temperatures collected from 2010 to 2018 were plotted for each season (winter, spring, summer, autumn).

The general linear model procedure of SAS (SAS Institute Inc., Cary, NC, USA) was used to investigate the effects of THI on milk yield and composition, according to the following linear model:

$$y_{ijkl} = \mu + F_i + T_j + P_k + e_{ijkl},$$

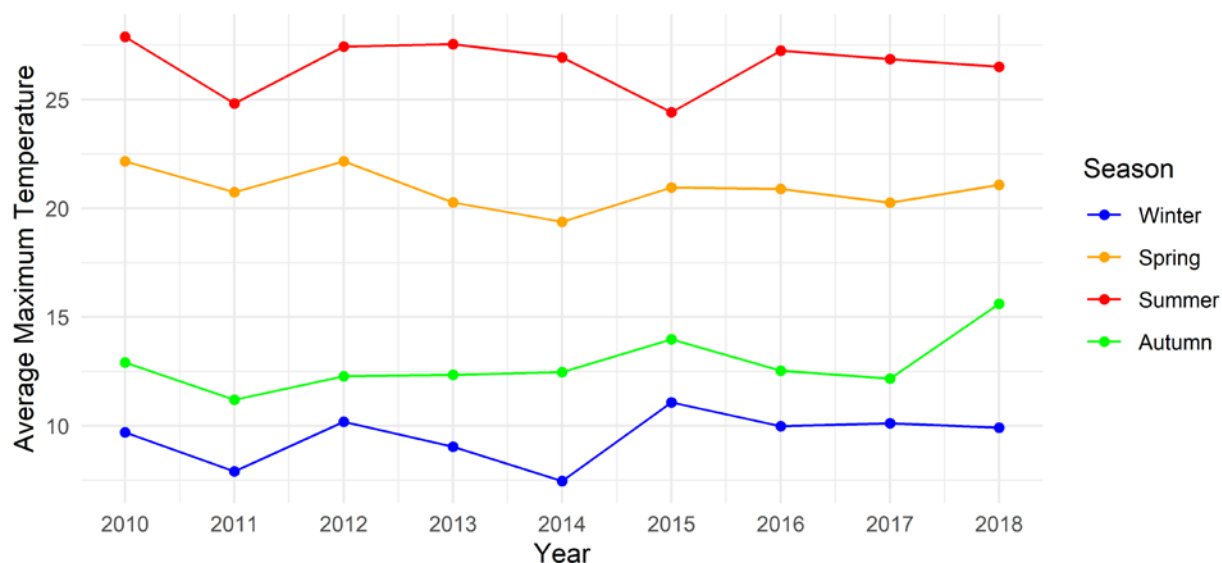
where  $y_{ijkl}$  is average daily milk yield, fat percentage or protein percentage;  $\mu$  is the overall mean;  $F_i$  is the fixed effect of the  $i$ th farm (3 levels);  $T_j$  is the fixed effect of the  $j$ th THI class (4 levels; 1: THI<64; 2: 64≤THI<72; 3: 72≤THI<79; 4: THI≥79);  $P_k$  is the fixed effect of the  $k$ th year (10 levels); and  $e_{ijkl}$  is the random residual. Least squares means were compared through multiple comparison Bonferroni *post-hoc* test.

Pearson's correlations between THI and milk traits were performed using *cor.test* function in R software (<https://www.r-project.org/>).

## 3 Results

The average maximum temperatures registered in the different seasons through the investigated period are reported in Figure 1. Fluctuations are present without a specific trend; during the summer season, 2011 and 2015 were the years with the lowest maximum temperatures. Since neither the temperature nor the humidity strongly varied over the studied years, the THI did not show significant fluctuations through the period, with an average value of 75.

Average, minimum and maximum seasonal THI scores recorded from 2010 to 2018 are summarized In Table 1. Days with THI > 79 occurred mainly in summer (22 days), in autumn (2 days) and spring (1), whereas winter, as expected, did not register any days with THI > 79.



**Figure 1** Average maximum temperatures (°C) in summer, spring, autumn and winter from 2010 to 2018

**Table 1** Average, minimum and maximum temperature-humidity index (THI) recorded in the different seasons from 2010 to 2018

Season	Average THI	Minimum THI	Maximum THI	n. days THI >79
Winter	33	10	51	0
Spring	53	31	79	1
Summer	75	62	93	22
Autumn	57	21	84	2

Table 2 reports descriptive statistics for THI and the investigated milk traits. In particular, THI, milk yield, fat percentage and protein percentage averaged  $53.76 \pm 18.04$ ,  $27.98 \pm 2.80$  kg/day,  $4.27 \pm 0.46\%$  and  $3.50 \pm 0.17\%$  respectively. No significant variations were observed for the investigated milk traits during the 9-year period considered. Least squares means of milk traits for the 4 classes of THI are reported in Figure 2. Milk yield did not differ significantly between the THI classes, whereas fat and protein percentages decreased significantly as THI increased. This result was confirmed by Pearson's correlations between milk contents and THI (Table 3); indeed, moderate and negative associations of THI with fat and protein were estimated (-0.28 and -0.34, respectively;  $P < 0.001$ ).

**Table 2** Descriptive statistics for temperature-humidity index (THI), milk yield, fat content and protein content

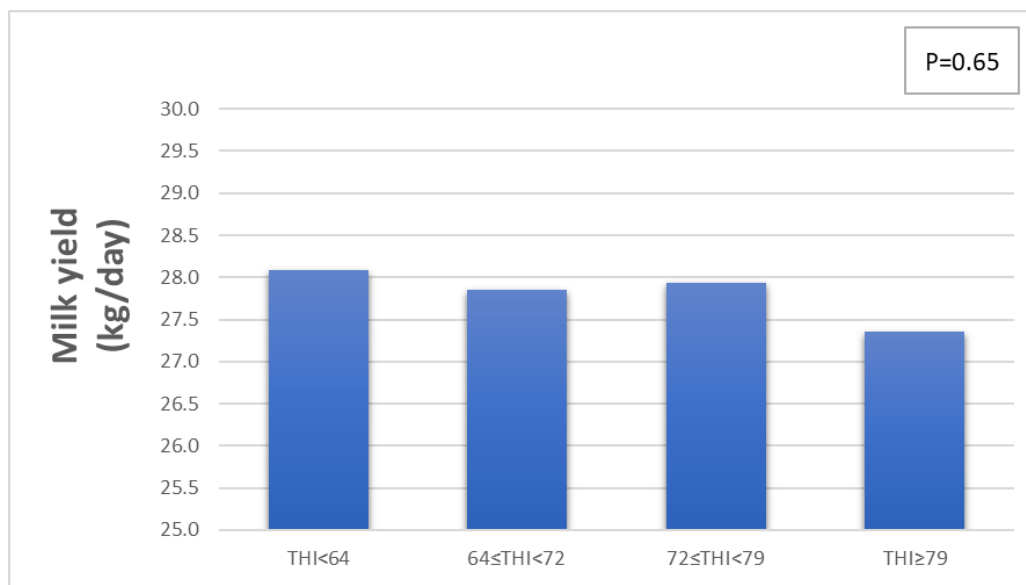
Item	n	Maximum	Minimum	Mean	SD
THI	273	93.31	10.28	53.76	18.04
Milk yield (kg/day)	291	37.04	21.83	27.98	2.80
Fat (%)	290	5.44	3.27	4.27	0.46
Protein (%)	290	3.91	3.11	3.50	0.17

SD – standard

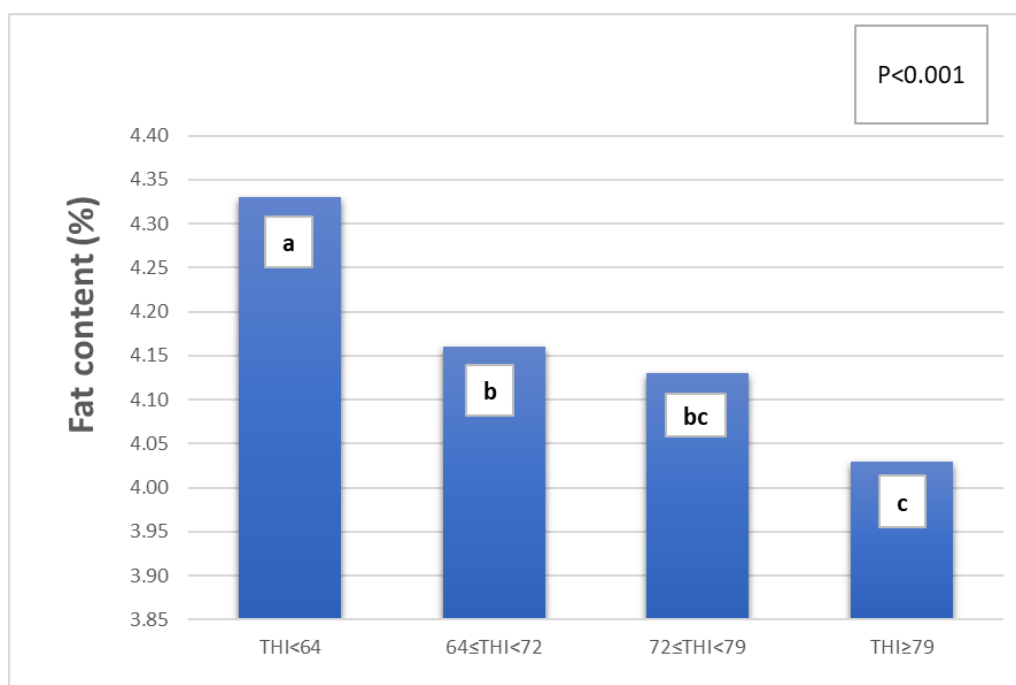
**Table 3** Pearson's correlations of temperature-humidity index with milk yield and composition traits

Trait	Correlation coefficient	P-value
Milk yield (kg/day)	-0.07	0.269
Fat (%)	-0.28	<0.001
Protein (%)	-0.34	<0.001

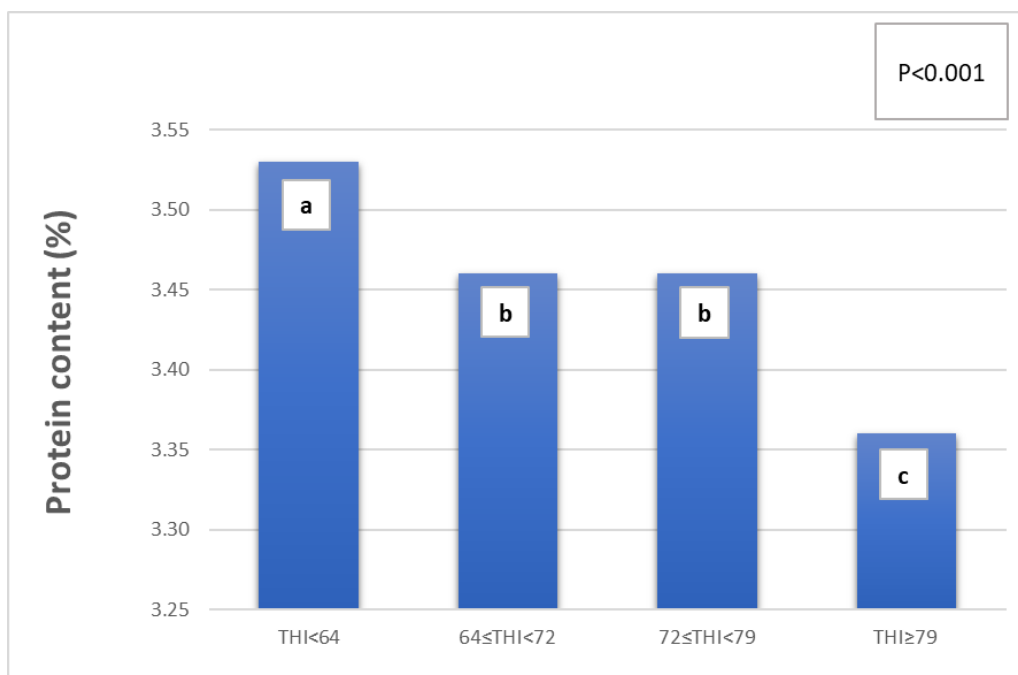
a)



b)



c)



**Figure 2** Least squares means of a) milk yield, b) fat content and c) protein content in different classes of temperature-humidity index (THI)

#### 4 Discussion

In Tuscany, annual and seasonal long-term trends of temperatures indicate a significant increase in average temperature for each season, with the major increase observed in summer (+1.5°C) (Bartolini et al., 2012). Such trend was not observed for our data even if the average maximum temperatures during the summer were stable over 25°C. However, these average values must not be misled as they resulted from an extreme variability of observations; it is noteworthy to point out that the THI reached high values in summer. Therefore, even in mountain-hilly areas livestock can suffer for hot periods and heatwaves.

The relationship between milk production and hot climate is widely known. Indeed the first coping strategy adopted by animals to deal with heat stress is to reduce dry matter intake, which accounts for 35% of the decrease in milk yield (Rhoads et al., 2009) and it increases the metabolic maintenance requirements of about 7 to 25% (Polsky & von Keyserlingk, 2017). Moreover, Hossein-Zadeh et al. (2013) assumed that heat stress could shift blood circulation favoring the irrigation of peripheral tissues for cooling, thus modifying nutrient metabolism and further decreasing milk production. The effect of heat stress, especially in summer, could be associated with fodder shortage which might be the main reason for reducing milk production (Javed et al., 2004). Glucose disposal was higher in heat-stressed than in thermal neutral environment dairy cows. Heat-stressed animals show decreased hepatic glucose synthesis, shift of glucose turnover and increased glucose required for energy. As a result, the need for glucose for the synthesis of lactose in the mammary gland decreases. Lactose production is the foremost osmoregulator which determine milk production, thus low glucose availability leads to decline milk yield (Baumgard and Rhoads, 2007). André et al. (2011) and Herbut et al. (2018) observed that, despite thermoneutral upper limit is at 25°C for dairy cattle (Das et al., 2016), a decrease in milk production of 1.5 kg occurred after the animal has experienced several hours of T between 20 and 25°C, followed by only few hours at thermoneutral zone. The milk depletion exacerbates as the length of hot periods increases. Hence, Herbut et al. (2018) identified the most challenging period in July and August, but milk decrease continued also in September. Secondly, after having experienced a long series of hot days, animals appear more sensible to heat stress, causing rapid and large drops in milking performance even at lower temperatures than their thermoneutral upper limit (Herbut et al., 2018).

The THI, taking into account both temperature and humidity, is the most used index to evaluate environmental conditions driving to heat stress (Bohmanova et al., 2007). The connection between THI and temperature can be appreciated from Table 1 which shows how the highest values of THI are in summer, the period characterized by the highest temperatures. Usually, THI scores are divided into four categories: thermal comfort, mild heat stress, moderate heat stress and severe heat stress. However, this clustering varies among studies (Polsky & von Keyserlingk, 2017). Most papers on this issue reported that as THI increases there was a decrease in both milk yield and fat and protein contents (Bouraoui et al., 2002; Bernabucci et al., 2015; Hill and Wall, 2015; Mohammed and Mahmoud, 2017). In our study, only fat and protein contents were affected by THI. Amamou et al. (2019), in agreement with the present work, reported a negative correlation of THI with protein and fat yields, with the highest correlations and the lowest individual variability during mild and severe heat stress conditions. Also, Bertocchi et al. (2014) reported a consistent decrease of fat and protein percentages as THI increased. High THI might irritate the neuroendocrine system, which in turn influences energy and water balance, hormonal equilibrium, and body temperature and thus disturbs milk quantity and quality.

## 5 Conclusions

The preliminary study on data recorded for about 10 years (2010-2018) in Mugello showed that average maximum temperatures did not change significantly over years. However, variations of THI that occurred between seasons, affected milk quality traits. A negative correlation between THI and fat and protein percentages were observed. Further analyses are needed to better understand the factors involved in modulating milk production under different climatic conditions, including lactation phase of animals, parity and age within parity as well as a more detailed study of climatic parameters recorded by in-farm meteorological stations.

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