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The interest of a mountain dairy cow breed to cope with Mediterranean summer heat stress

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Abstract. The Tarentaise cow, a rustic breed from the norther part of the French Alps, is well adapted to the mountain harsh conditions, in particular during the summer season due to its ability to use efficiently the highland pastures. The Tunisian farmers also consider that the Tarentaise cows are well adapted to the Mediterranean climate. The aim of this work was to quantify the effect of summer heat stress on milk yield and quality of Tarentaise cows in comparison to Holstein cows. A dataset was collected for 441 Tarentaise and 560 Holstein cows reared in 21 farms in Tunisia from 2009 to 2014. This data comprising 16,400 monthly individual records of milk yield, fat, protein, urea and somatic cell count was merged with meteorological data from 5 public stations relative to the 21 farms. The temperature-humidity index (THI) calculated as a combination of ambient temperature (T_a) and relative humidity (RH) was used to characterize heat stress. Tarentaise and Holstein cows produced 11.4 and 14.8 kg/d of milk respectively. When THI increased from an average value of 53.7 in winter to 75.4 in summer, the Holstein and Tarentaise cows decreased their production by 0.93 and 0.15 kg/d respectively. Milk fat, protein and urea content decreased similarly in both breeds (-0.22 g/kg, -0.14 g/kg and -14 mg/L respectively) and milk somatic cell count increased for Holstein cows (+352,000 /mL) while it decreased slightly for Tarentaise cows (-160,000 /mL). The Tarentaise cows seem to be more resistant to heat stress than Holstein cows, especially when THI is over 78.

Keywords. Tarentaise cow – Heat stress – Temperature-humidity index – Milk yield – Milk composition.

L'intérêt d'une race bovine laitière de montagne pour faire face aux conditions de stress thermique méditerranéen

Résumé. La race Tarentaise, originaire des Alpes françaises, est particulièrement adaptée aux conditions montagneuses, précisément pendant la saison estivale. Cette race rustique est aussi appréciée des éleveurs tunisiens qui la considèrent comme bien adaptée au climat méditerranéen. L'objectif de cette étude était de quantifier l'effet du stress thermique sur les performances de production de la race Tarentaise en comparaison avec la race Holstein. Une base de données contenant 16 400 contrôles laitiers individuels de 441 Tarentaise et 560 Holstein élevées dans 21 exploitations en Tunisie, a été collectée entre 2009 et 2014 puis fusionnée avec les données météorologiques de 5 stations publiques. A partir des températures ambiantes et des humidités relatives, un index humidité-température (THI) a été calculé afin de comparer entre les deux races son effet sur la production laitière, le taux butyreux (TB), le taux protéique (TP), l'urée et le comptage des cellules somatiques (CCS). Les vaches Tarentaise et Holstein ont produit respectivement 11,4 et 14,8 kg/j de lait. Quand le THI passe d'une valeur moyenne de 53,7 en hiver à 75,4 en été, la production laitière de la Holstein et la Tarentaise baissent respectivement de 0,93 et 0,15 kg/j. Le TB, le TP et l'urée ont aussi chuté pour les deux races (-0,22 g/kg, -0,14 g/kg et -14 mg/L, respectivement) alors que le CCS a augmenté pour les Holstein (+352 000 /mL) et a baissé légèrement pour les Tarentaise (-160 000 /mL). La Tarentaise semble mieux résister au stress thermique que la Holstein, notamment quand le THI est supérieur à 78.

Mots-clés. Vache Tarentaise – Stress thermique – Index température-humidité – Production laitière – Composition du lait.

I – Introduction

High temperatures associated with elevated relative humidity are the principal origin of heat stress. This may prompt physiological dysfunction that negatively affects animal's production capacity. A temperature-humidity index (THI) was established to allow modeling the impact of heat stress on production traits of dairy cattle (Johnson, 1985). According to Johnson (1985) and Du Preez *et al.* (1990), the milk production is not affected when the THI is between 35 and 72. Moreover, under Mediterranean climatic conditions of Tunisia, Bouraoui *et al.* (2002) reported that milk yield began to decline when THI reached 68; and as the THI values increased from 68 to 78 during the summer period, heat stress reduced daily cow's milk yield by 21%. Some observations (Nickerson, 1987; Du Preez *et al.*, 1990) have suggested that heat stress is often associated with changes in milk composition and milk somatic cell count (SCC). On the other hand, the effect of heat stress is increased for high producing cows, as Holstein cows. According to Smith *et al.* (2013), selecting most suitable cattle for heat stress tolerance can be reached by discovering differences between dairy breeds. In Tunisia, Tarentaise cow, a mountain breed originating from the French Alps, was imported to achieve self-sufficiency in meat and milk. Dairy producers consider that Tarentaise cows are well suited to the Mediterranean climate of Tunisia. The aim of the present study is to compare the milk yield and composition of Tarentaise and Holstein cows under the climatic conditions of Tunisia.

II – Materials and methods

A dataset, provided by the genetic improvement direction of Sidi Thabet (Tunisia), contained individual data of 441 Tarentaise and 560 Holstein cows from 21 farms, obtained monthly between 2009 and 2014. This dataset included 16,400 individual records of milk yield, fat, protein, urea and somatic cell count. A meteorological dataset comprising monthly records of ambient temperature (T_a , in °C) and relative humidity (RH, in %) was obtained from 5 public weather stations in Tunisia, relative to the 21 herds over the five years. The THI index was calculated using equation as follows: $THI = 1.8 \times T_a - [1 - RH] \times [T_a - 14.3] + 32$ (Kibler 1964).

The THI was merged with production traits by assigning each dairy control of each farmer to the monthly weather records from the nearest weather station. Dairy cows were considered under hot climatic condition when THI is over 72. Later, Silanikove's (2000) classification of THI was used where heat stress is categorized as: without effect, light, moderate and extreme. The corresponding THI thresholds were: $THI < 70$, $70 \leq THI < 75$, $75 \leq THI < 78$ and $THI \geq 78$. The aim of this classification was to have a better visualisation of the effect of heat stress on production traits of Tarentaise and Holstein cows. Days in milk classes (DIM) were established according to the following thresholds: <120, 120-179, 180-300, and >300. Additionally, parity of all cows was classified into 4 ranges corresponding to the rank of lactation: first, second, third and "four and more".

The final data were analysed using Proc Mixed of SAS (version 9.4; SAS Institute, 2013). The effects of heat stress, breed and the interaction (THI×breed) on milk yield, milk components and SCC (expressed in \log_{10}/mL) were tested using the following model: $Y_{ijklmn} = \mu + t_i + b_j + tb_{ij} + f_k + d_l + p_m + c(f)_n + e_{ijklmn}$ where Y_{ijklmn} is a measurement of milk yield, fat, protein, urea or SCC; μ is the population mean; t is the fixed effect for numeral THI (or in classes for the second milk yield analyse) i ; b is the fixed effect for breed j ; tb is the interaction THI×breed ij ; f is the fixed effect for farmer k ; d is the fixed effect for DIM class l ; p is the fixed effect for parity class m ; $c(f)$ is the random effect for cow nested within the farmer (f) n ; and e_{ijklmn} is the residual error.

III – Results and discussion

The milk traits of both breeds were significantly affected by heat stress (Table 1). As expected, the average milk yield was higher for Holstein than for Tarentaise cows (+3.4 kg/d, $P < 0.001$). Moreover,

there is a significant interaction between THI and breed for milk yield. As THI increased from 53.7 in winter (mean value of the coolest months where $T_a = 11.8^\circ\text{C}$ and $\text{RH} = 76\%$) to 75.4 in summer ($T_a = 27.0^\circ\text{C}$ and $\text{RH} = 59.8\%$), Holstein milk yield decreased by 0.93 kg/d (-6%) while Tarentaise milk yield decreased by 0.15 kg/d (-1%). The decline in milk yield under heat stress conditions was also highlighted in earlier studies, confirming that exposure of dairy cows to high values of THI causes a reduction in milk yield from 10 to 34% (Du Preez *et al.*, 1990; Itoh *et al.*, 1998). Smith *et al.* (2013) found that when THI exceeds 72, Holstein milk yield decreased from 35.6 to 34.2 kg/d (-3.9%).

Table 1. Effects of breed and temperature-humidity index (THI) on milk yield and milk composition

	Holstein	Tarentaise	THI	Breed	THI × breed
Milk yield (kg/d)	14.8	11.4	***	***	***
Fat (g/kg)	38.2	37.2	***	NS	NS
Protein (g/kg)	31.8	32.6	***	NS	NS
Urea (mg/L)	212	213	***	NS	NS
SCC (\log_{10}/mL)	5.47	5.42	NS	***	***

NS (non-significant) $P > 0.05$; *** $P < 0.001$.

The effect of heat stress on milk yield is not linear but it increases with high THI (Silanikove, 2000; Smith *et al.*, 2013). The 4 ranges Silanikove's classification gave an appropriate visualisation of the non-linear effect of THI (Fig. 1). The decline in milk yield for the Holstein cows started as THI changed from 'without effect' range to 'light' range. Moreover, this decline in milk yield was more rapid for Holstein cows than Tarentaise between the ranges 'moderate' and 'extreme' (-0.82 vs. -0.13 kg/d).

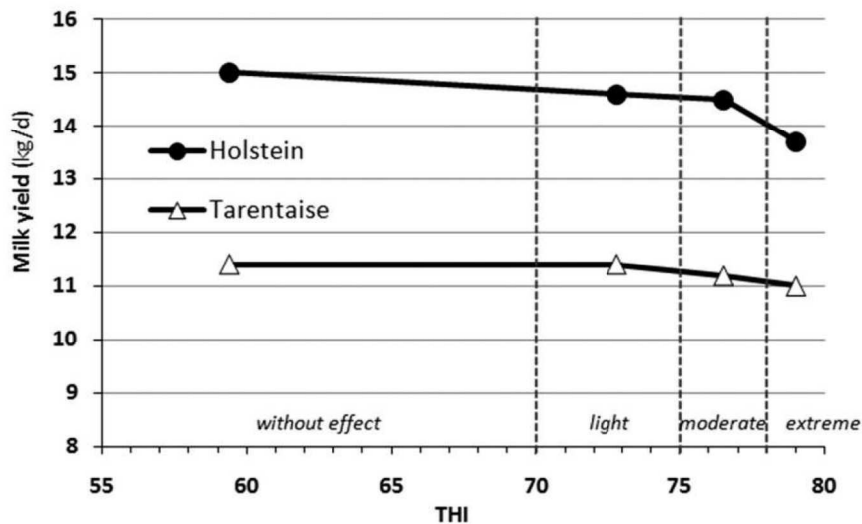


Fig. 1. Average milk yield by breed and Silanikove's ranges of temperature-humidity index (THI).

There was no difference between the two breeds regarding the milk composition. However, THI affected milk fat, protein and urea contents in both Holstein and Tarentaise cows (Table 1). Temperature-humidity index decreased milk fat content (-0.22 g/kg), which agrees with the reduction from 3.79 to 3.65% when THI rose from 65.6 to 83.9 in summer (Rejeb Bellil, 2014). Conversely, other studies carried on Holstein cows reported that heat stress either increased ($\text{THI} > 68$; Bouraoui

et al., 2002) or did not have an effect on milk fat (THI>72.4; Wheelock *et al.*, 2010). Milk protein percentage also decreased with THI (-0.14 g/kg) between winter and summer. These results are in agreement with those reported by Barash *et al.* (2001). In addition, concentration of urea in milk decreased by 14 mg/L between winter and summer season. However, Hojman *et al.* (2004) reported higher milk urea concentration during the summer months and a lowest concentration in November (181 vs.118 mg/L). These authors suggested that it was probably due to changes in the nutritional content of the cow's diet.

The SCC of the milk reflected the interaction between breed and THI ($P<0.001$). On average, Holstein had higher SCC than Tarentaise cows ($P<0.001$). During heat stress, the SCC from Holstein cows increased by 352,000 /mL while the SCC from Tarentaise cows decreased by 160,000 /mL. This result is counter to the common idea that elevated THI is often associated with greater SCC. Hammami *et al.* (2013) explained the higher SCC in milk observed in heat stress by the depressive immune function during the hot season.

IV – Conclusions

According to the current results, heat stress decreased milk yield and induced changes in milk composition for both breeds. However, Tarentaise cows seem to be more resistant than Holstein cows, especially when THI is over 78 as very often in the summer climatic conditions of Tunisia. The next step of this study is to quantify the metabolic and physiologic responses of Tarentaise cows under heat stress conditions.

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