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Mademoiselle AMAMOU Hajer,

Titulaire d'un diplôme national d'ingénieur, spécialité sciences agricoles,

présentera en vue de l'obtention du grade et du diplôme de

DOCTEUR EN SCIENCES AGRONOMIQUES ET INGENIERIE BIOLOGIQUE,

le 25 août 2020, à 9h00 précises, en visioconférence :

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Cette dissertation originale a pour titre :

« Effects of climate change on dairy farming systems: evaluation and impacts of heat stress on dairy cows in Tunisia ».

Le jury est composé comme suit :

Président : Prof. J. BINDELLE, Professeur ordinaire,
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Abstract

The main objective of the research carried out within the framework of this thesis was to assess the risks related to climate change (CC), in particular heat stress (HS) in dairy cattle in Tunisia, and to identify measures or indicators that could reveal the tolerance of dairy cows to HS.

In the first study, an enquiry was conducted among 566 dairy farmers throughout Tunisia. The objective was to focus on Tunisian dairy farmers' perceptions of the risks and the actions taken to cope with changes attributable to CC. A total of 70 diagnostic variables relating to farm characteristics, resources, management, performances and profit, in addition to CC risk perception and adaptation strategies, were used and analysed. A typology based on multivariate statistical analysis was carried out using variables related to the land, feed resources, labour and infrastructure. Four groups of dairy systems were identified. The largest proportions of farmers around 70% belonged to the landless dairy systems (Clusters 1 and 2), whereas the minority of farmers belonged to medium-sized (18%, Cluster 3) and large-sized (12%, Cluster 4) farm systems that specialized in milk production. The analyse of results showed that almost all the farmers in all the clusters perceived that the greatest impact of CC would be on cow performance and forage production. The study of the attitudes of the farmers towards adaptation to CC reveals that they sought, as a priority, to modify and adapt their current livestock housing infrastructure. Other identified strategies were related to the storage of forage reserves, the purchase of fodder and the promotion of irrigated areas. Although the CC-related concerns varied among the farming clusters, dairy farmers focus on short-term environmental modifications rather than longer-term actions to address CC effects.

In the second study, the aspects of vulnerability to HS for dairy cattle farming systems in Tunisia was investigated for dressing adequate actions to combat CC effects. In order to do so, historical milk test-day records from official milk recording collected during 7 years were merged with historical temperature and humidity data provided by public weather stations. The results showed that dairy farms in Tunisia are exposed annually for 4 to 5 months with temperature-humidity index (THI) values above 72. Overall, the statistical models used in this study have shown that the tipping points (thresholds) of the THI at which milk yield started to decline ranged between 65 and 67. The largest milk decline per unit of THI above threshold values was 0.135±0.01 kg for multiparous cows. The milk losses estimated only during the 3 months of the summer period were 110 and 142 kg/cow in north and south, respectively. Individual cow response to heat load were estimated using random regression model and been considered as key measures of dairy farming system sensitivity assessment to HS. The results reveal the high sensitivity of Tunisian Holstein cows to HS especially in dairy farms characterized by large herd size and high level of milk production.

In the third study, an on-farm experimental protocol was set up on 4 commercial dairy farms during summer (HS) and autumn (thermo-neutral) periods using direct physiological, on-barn temperature and relative humidity, milk yield and milk composition measurements. This study aimed to investigate the effects of HS on physiological and production parameters of dairy cows. When the THI went from an average value of 54 in autumn to 77 in summer, respiration rate (RR) and skin temperature (ST) increased by 2.3- and 1.3-fold higher, whereas milk yield per milking decreased by 24%. The results showed a linear relationship between THI and all physiological traits and an increases in RR (+2 breaths/min), ST (+0.5°C) and rectal temperature (RT) (+0.04°C) per increase in one THI unit. Inversely, milk, fat and protein yields showed a drop of 0.13 kg, 0.4 g and 0.3 g per milking per increase in one THI unit, respectively. Methodology of cluster analysis allowed to classify dairy cows into two clusters where 82% of cows belonged to Cluster 1 of heat-sensitive, whereas only 18% of cows belonged to Cluster 2 of heat-tolerant. The reaction norm models conducted to quantify the individual responses of cows across the trajectory of THI during the HS period revealed that heat-tolerant cows tended to have higher RR, ST, and RT and lower to almost no decrease in milk yield compared to heat-sensitive cows. The results also suggested that RR could be used as a reliable indicator for thermo-tolerance.

In conclusion, this thesis shows that the CC-related concerns were linked to economic rather than climatic factors and adaptation strategies were focused on short-term environmental modifications to address CC effects in the Tunisian dairy farms. Moreover, dairy farms especially those characterized by large herd size and high level of milk production are highly sensitive to HS in Tunisia. At the individual scale, the RR might be used as an indicator for thermo-tolerance in order to assess HS and predict the thermal status in dairy cows. Only a small proportion (18%) of dairy cows were identified as heat-tolerant in our experiment.

Overall, this thesis demonstrated that HS is a current problem in Tunisian dairy farms. Moreover, considering the CC, the severity and duration of HS will increase in the future, which would consequently lead to worsening economic losses. Our results highlight the need to implement immediate and proper management strategies to alleviate HS impacts, as well as future developments in animal breeding and dairy system sustainability to address the CC-related risks.