Received: 02 October 2023, Accepted: 23 October 2023

Journal of Advanced Veterinary Research
(2023) Volume 13, Issue 10, 1966-1970

Original Research

Effect of Climate Change on Productive Traits and Genetic Parameters for Friesian Cows in Egypt

Samah Z. Ebrahim[1*], Shereen K. Genena[1], Mohamed A. Mostafa[2]

[1]Department of Cattle Breeding Research, Animal Production Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.

[2]Department of Animal Production. Faculty of Agriculture, Mansoura University, Egypt.

***Correspondence**
Corresponding author: Samah Z. Ebrahim
E-mail address: ebrahim.samah@yahoo.com

Abstract

The database was obtained from 4560 records multiple records were collected from 2000 to 2022 For a total of 2560 records for Sakha station and 2000 records for El-Qardah station of the Ministry Agriculture and land reclamation in Egypt, meteorological data were obtained from the central laboratory of Agricultural climate. The data was divided into two periods, the period from 2000 to 2010 (P1) and the period from 2011 to 2022 (P2). Thermal Humidity Index (THI) and season effect on productive traits (LTMY, TMY, LP and DP) were varied from significant ($P<0.05$) to highly significant ($P<0.01$) for both groups, except for the effect of THI on the DMY in P2 and season effect on DMY in P1, which were non-significant. Climate change in the period from 2011 to 2022 witnessed a rise in atmospheric temperature (AT), which was followed by an increase in relative humidity (RH) and atmospheric pressure (AP), as well as an increase in the value of THI especially in the summer season, which is hotter than the rest of the seasons, this had a negative effect on the productive traits. Estimates of permanent environmental variance for the second period for most traits were lower than additive genetic variance, it may indicate that sensitivity to heat stress is not specific to the cow but is hereditary. Heritability estimates are low to moderate for most milk production traits, which indicate the possibility of genetic improvement by selecting the most valuable cows for heritability or genetic selection of cows with improving the herd management.

KEYWORDS
Climate change, Egypt, Genetic, Friesian, Productive traits.

INTRODUCTION

Recently, the world witnessed a thermal change in atmospheric temperature, humidity, and atmospheric pressure, and therefore it became necessary to study its effect on the productive traits and genetic parameters of farm animals. Egypt is one of the hottest countries in the world, and climate extremes are on the rise, which corresponds to the global warming. The impact of this on animal production is significant under Egyptian conditions.

Egypt is expected to experience a huge rise in temperatures within this century. However, higher temperatures will restrict ruminant production in particular due to their high internal heat production during the digestion of fibrous material by microorganisms. The end result will be decreased milk production. Thus, it is expected that the per capita share will decrease from 61 kg/year in 2011 to 26 kg/year in 2064 (Goma and Phillips, 2021).

The cause of global climate change in the first place is greenhouse gases emissions that lead to a rise in the temperature of the atmosphere. These effects primarily as a result of a combination of temperature and an increase in the concentration of carbon dioxide in the atmosphere, the variation in precipitation and relative humidity. Heat stress can cause significant losses in livestock production (Saricicek, 2022).

Cattle are already experiencing periods of heat stress during summer season. The expected rise in atmospheric temperature is attributed to the climate change that will affect livestock production by reducing growth and milk production as a result of appetite suppression and reduced pregnancy rate. In severe cases, these effects can lead to death (Goma and Phillips, 2021).

Kohli *et al.* (2014) reported that summer heat stress significantly reduced milk production in high milk production (HMP) cows. Heat stress can be reduced, if all dairies with crossbred cows implemented cattle housing modifications. Bouraoui *et al.* (2002) observed that heat stress in summer significantly reduces production of milk, milk fat and protein under Mediterranean climatic conditions. As THI values increase from 68 to 78, DMI decreased by 1.73 kg and milk protein reduction of 4 kg. Strategies are needed to reduce heat stress and optimal protection for the animal.

Researchers found a negative effect of THI or heat stress on milk production (Bouraoui *et al.*, 2002; Kohli *et al.*, 2014; Goma and Phillips, 2021). The aim of this study was to investigate the effect of climate change on productive traits and its effect on genetic parameters.

MATERIALS AND METHODS

Source of data

The current study was conducted on 4560 records of Sakha and Al-Qarda farms in Kafr El-Sheikh, affiliated to the Ministry of

ISSN: 2090-6277/2090-6269/

Agriculture and Land Reclamation, Animal Production Research Institute, Dokki-Giza, Egypt. For more than 22 years (from 2000 to 2022) data were collected for a total of 2560 records for Sakha station and 2000 records for El-Qardah station. Meteorological data were obtained from the central laboratory of agricultural climate. The data was divided into two parts, the first part covered the period from 2000 to 2010 (P1) and the second part for the periodfrom 2011 to 2022 (P2). Both periods were divided into four seasons (spring, summer, autumn and winter) and the productivity traits and genetic parameters of both were compared.

Herd management

The animals were fed under a routine system according to the level of production and the administrative system in the Sakha and El-Qardah farms. Animal nutrition was depended on concentrated feed with rice straw, in addition to Egyptian clover in winter. Rice straw was introduced at a rate of 4kg/cow. The concentrated mixture was given according to the weight, milk production and pregnancy status. Alfalfa hay was provided during the summer with concentrated feed. Artificial insemination of cows was done by using frozen semen. Pregnancy is diagnosed by rectal palpation. The cows were dried for approximately two months before the next calving.

Statistical analysis

The data was analyzed by using ANOVA and regression procedures in statistics (SAS, 2011, version 9.3). The effects of seasons and THI were determined as linear regression on milk yield traits (Lifetime milk yield (LTMY), Total milk yield (TMY), Daily milk yield (DMY), Lactation period (LP) and dry period (DP).
The statistical model used in this study:
$Y_{ijklm} = \mu_i + S_j + F_k + THI_L + e_{ijklm}$
where Y_{ijklm}= observation of the trait,
μ_i= the overall mean,
S_j= effect of season i(Winter, Autumn, Spring and Summer).
F_k= fixed effect of farm 1 (Sakha) and 2 (El- Karada).
THI_L= Temperature-humidity effect
e_{iklm}= random error.

Thermal Humidity Index (THI) was calculated according to this equation using average values of relative humidity (RH) and average temperature (°C) using the formula described by Hahn *et al.* (2009):
$THI= 0.8 \cdot T + [(T - 14.4) \cdot RH] / 100 + 46.4$.

Estimate heritability and variance component by using the MTDFREML program of Boldman *et al.* (1995). The model used in this study:
$y= X\beta +Qg+Za+Wpe+e$
Where:
y= a vector of productive traits (LTMY, TMY, DMY, LP and DP);
β= a vector of fixed effects (season, year of calving, parity and farm); a= additive genetic effect; pe= permanent environmental), W= matrix relating records to permanent environmental (pe) impacts; e= residual effects and X, Z are incidence matrices relating observations to various effects of matrices relating records to genetic and fixed impacts.

RESULTS AND DISCUSION

Mean values, standard error, standard deviation and effect of (THI) on productive traits during the experimental periods are shown in Tables 1 and 2. According to the results in this study, cows in winter had significantly higher (P<0.01) LTMY, TMY, DMY, LP and DP where reached 19294d, 4798kg, 21kg, 303d and 158d, respectively for P1, while they were 17048d, 2971kg, 19d, 309 and 101d, respectively for P2. The productive traits of the winter season increased for both periods compared to the summer, spring and winter seasons. This has been confirmed in Australian dairy cattle by Nguyen *et al.* (2016) who reported that the average monthly temperatures (THI) were the lowest in winter (June-August) and elevated in summer (December-February).

Table 1. Least squares mean and standard errors (SE) for productive traits in different seasons for P1 (period from 2000-2010).

Season	Traits	Mean	S E	S D
Spring	LTMY	16198	687.41	10102.78
	TMY	4524	119.8	1760.77
	DMY	18	0.13	1.9
	LP	304	7.61	111.91
	DP	110	4.19	61.54
Summer	LTMY	17828	699.31	11297.77
	TMY	4616	102.87	1661.99
	DMY	16	0.27	4.4
	LP	307	6.65	107.47
	DP	155	6.33	102.42
Autumn	LTMY	17360	662.36	11376.41
	TMY	4428	98.75	1696.03
	DMY	20	0.16	2.69
	LP	291	6.36	109.29
	DP	96	2.81	48.34
Winter	LTMY	19294	585.08	10031.99
	TMY	4798	156.92	2690.55
	DMY	21	0.53	9.07
	LP	303	6.48	111.06
	DP	158	5.55	95.24

LTMY: Lifetime milk yield; TMY: Total milk yield; DMY: Daily milk yield; LP: Lactation period; DP: dry period.

Mean values of temperature, humidity, atmospheric pressure and thermal humidity index (THI) values are shown in Table 4. With the effect of heat stress or high temperature in the second period, the values of the productive traits decreased compared to the first period (P1), except for LTMY, it was affected by heat stress in the second period (P2), and it was higher in the autumn season. Climate change had a noticeable effect on the decrease in the milk yield production, the thermal humidity index (THI) value increased in the second group during the winter season to 54.44, this led to a decrease in LTMY, TMY, and DMY by 11.64, 38.1, and 10.5%, respectively. Cows in summer had the lowest values for (17602d, 2907kg, 12kg and 99d) for LTMY, TMY, DMY and DP, respectively in second period (P2). The increased heat stress in the summer to 62.95 reduced the daily milk production from 16 kg to 12 kg, with a decrease rate of 25%, and with a decrease ratio of 1.27, 37.02 and 36.13% for LTMY, TMY and DP, respectively. These results are comparable to those found by Ouarfli and Chehma (2021), who reported that the daily milk yield decreased during summer heat stress. When the THI value increased to more than 84 in the summer, the daily milk production decreased from 22kg to 19kg. However, Ravagnolo and Misztal (2000) reported that the decrease in milk production was 0.2 kg when the THI value exceeded the average. In addition to Ali *et al.* (2023) who indicated that each point increase in THI resulted in decreased the value of milk production by 0.12 kg/cow/day.

The results in Table 3, showed thermal humidity index (THI) and season effect on productive traits (LTMY, TMY, LP and DP), which showed significant (P<0.05) and highly significant (P<0.01) changes for both periods, except for the effect of THI on DMY in P2, and season effect on DMY in P1, which were non-significant. The effect of parity showed significant and highly significant changes for all traits for both periods (p1 and p2), except for TMY, DMY and DP, it was non-significant for P2.

Table 2. Least squares mean and standard errors (SE) for productive traits in different seasons for P2 (period from 2011-2022).

Season	Traits	Mean	S E	SD
Spring	LTMY	16774	639.87	13097.83
	TMY	2926	63.29	1295.42
	DMY	16	0.13	2.66
	LP	308	5.34	109.39
	DP	101	2.58	52.74
Summer	LTMY	17602	596.28	12746.92
	TMY	2907	65.04	1390.31
	DMY	12	0.19	4.19
	LP	308	5.67	121.16
	DP	99	1.94	41.39
Autumn	LTMY	183112	630.5	12672.9
	TMY	2869	65.81	1322.68
	DMY	17	0.36	7.14
	LP	295	5.63	113.12
	DP	138	5.74	115.44
Winter	LTMY	17048	598.4	12637.45
	TMY	2971	62.08	1311.12
	DMY	19	0.15	3.13
	LP	309	5.31	112.07
	DP	101	1.83	38.69

LTMY: Lifetime milk yield; TMY: Total milk yield; DMY: Daily milk yield; LP: Lactation period; DP: dry period.

Figures 1 and 2, shows that analysis of the meteorological data for the period from 2011–2022 (P2) indicated that AT, RH, AP and THI increased (P<0.05) compared to P1 (2000-2011). Autumn, spring and winter seasons were characterized by a decrease in heat stress, compared to the most affected summer season. The temperature increased from an average of 32°C to 39°C in the summer season, from 23°C to 29°C in the autumn season, from 26°C to 32°C in the spring, and from 22°C to 25°C in the winter season, which lie behind the lack of heat stress conditions during the winter season.

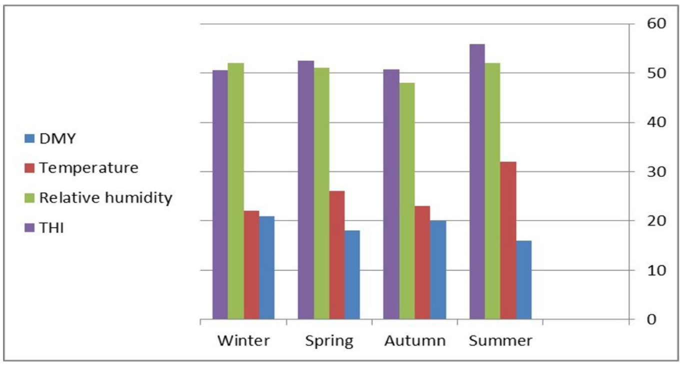

Figure 1. Average DMY, temperature (T), Relative humidity (RH) and temperature-humidity index (THI) during different seasons (The period from 2000-2010) for P1.

The values of THI were higher in both periods (P1, P2) in the summer month compared to autumn, spring and winter seasons. The values of THI were higher in the second period (P2), where the temperature, relative humidity and atmospheric pressure were higher. The increase in the values of THI for P2 compared to P1, as it reached 12.8, 9.2, 10.3, and 7.7% for summer, autumn, spring, and winter, respectively. These results agree with the findings of Nigm *et al*. (2015) who found noticeable change in the climate of the Delta region in Egypt, expressed in high temperature and humidity and (THI) values. This spike began in 2011 and went upwards until 2014, and this change negatively affects milk. These results corroborate with the findings of Konyves *et al.* (2017), who observed that summer heat stress negatively affects the milk yield and feed intake of dairy cows, heat stress reduced daily milk production by 1.32 kg or 9.46% by 0.92 kg or 9.62% and by 1.27 kg or 9.48% when the THI value was moved from 64 in the spring and from 66 in the fall and from 42.34 in winter periods to 79 in summer periods.

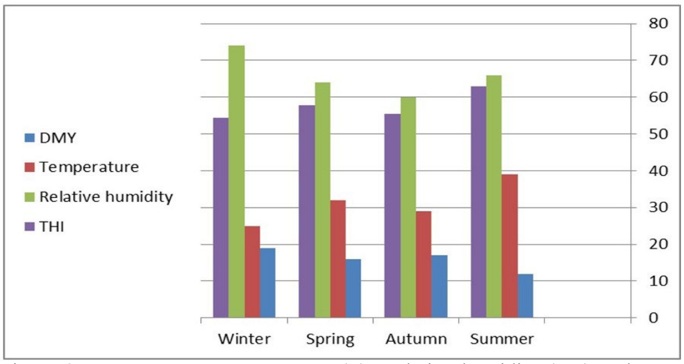

Figure 2. Average DMY, temperature (T), Relative humidity (RH) and temperature-humidity index (THI) during different seasons (The period from 2011-2022) for P2.

Table 3. Analysis variance for P1 and P2 under some environmental factors affecting studied traits.

Traits	F- Value and significance (P1: 2000-2010)		
	Season effect	Thermal Humidity Index (THI)	Parity
LTMY	0.88*	2.95**	1.44*
TMY	1.48*	4.12**	0.92*
DMY	0.45$^{n.s}$	1.25*	6.40**
LP	1.30*	2.73**	16.44**
DP	1.39*	3.55**	1.05*
	F- Value and significance (P2: 2011-2022)		
LTMY	1.55*	3.93*	3.49*
TMY	1.54*	3.44**	0.02$^{n.s}$
DMY	1.06*	0.44$^{n.s}$	0.08$^{n.s}$
LP	0.87*	16.44**	14.52*
DP	1.50*	3.20**	0.01$^{n.s}$

*: Significant (P<0.05); **: High significant (P<0.01); N.S: non- significant (P>0.05); LTMY: Lifetime milk yield; TMY: Total milk yield; DMY: Daily milk yield; LP: Lactation period; DP: dry period.

It could be concluded that the climate change in the period from 2011 to 2022 witnessed a rise in temperature (AT) and was followed by an increase in relative humidity (RH) and atmospheric pressure (AP), as well as an increase in the value of THI, this had a negative effect on the productive traits of Friesian cows in Egypt. This agrees with the findings of Bouraoui *et al*. (2002); Kohli *et al*. (2014); Nigm *et al*. (2015); Nguyen *et al*. (2016); Konyves *et al*. (2017); Goma and Phillips (2021) and Campos *et al*. 2022). These results are confirmed by the findings of Bouraoui *et al*. (2002), who recorded that summer heat stress reduced milk yield (DMI), altered the composition of milk as it affected the physiological functions of Holstein cows under Mediterranean climatic conditions.

Table 4. Means of Temperature, humidity, atmospheric pressure, and Thermal Humidity Index (THI) values for animals in different seasons.

Season	Temperature (AT) (ºC)	Relative humidity (RH) (%)	Atmospheric Pressure (AP) mbar	THI
(P1: 2000-2010)				
	Mean	Mean	Mean	Mean
Spring	26	51	984.42	52.52
Summer	32	52	1001.19	55.81
Autumn	23	48	1005.06	50.71
Winter	22	52	1014.87	50.53
(P2: 2011-2022)				
Spring	32	64	1019.15	57.92
Summer	39	66	1012.16	62.95
Autumn	29	60	1023.15	55.39
Winter	25	74	1025.15	54.44

Variance component and heritability estimates

Estimates of variance components and heritability are shown in Table 5. Estimates of the average LTMY, TMY, DMY, LP and DP heritability were 0.31, 0.42, 0.28, 0.35 and 0.13, respectively for P1, while they were 0.30, 0.41, 0.30, 0.32 and 0.15 respectively, for LTMY, TMY, DMY, LP and DP in P2, these results for the heritability tended to decrease a little with increasing THI. However, for LTMY, TMY and LP, this decrease in heritability occurred only with the highest THI values, DMY and DP were increased in heritability with increased THI in p2. Heritability for most productive traits tends to decrease slightly with increasing temperatures or THI, this is mostly due to the increased residual variance. This increase in the residual variance by itself is considered an indicator of stress. However, the available results in literature on heritability variation for all productive traits with THI are not diverged.

In this study, estimate of the heritability decreased with increased heat stress or temperature, this is compatible with the results of Brügemann *et al*. (2011) on Holstein cows for daily protein yield (PY), and Vinet *et al*. (2023) on cattle welfare for milk yield (MY), fat yield (FY), protein yield (PY), and somatic cell score (SCS). On the other hand, the heritability estimates of some traits increased with increasing temperatures, the same was determined by Campos *et al*. (2022). Heritability increased as THI increased above the milk production threshold (0.20 to 0.23) and protein yield (0.14 to 0.16). In addition, according to Dzivenu *et al*. (2022) on moderate heritability estimates for milk production at different levels of heat stress, the possibility of genetic improvement appears to produce milk for climatic conditions with high THI values.

It is likely that it decreased in the second period (P2) due to the impact of climate change or heat stress, which in turn had a direct impact on most of the productive characteristics, except for the characteristic of DMY and DP, which increased with the recent increase in temperatures. Productive traits with a high heritability equivalent are likely to adapt to future conditions faster than traits with low heritability. Results in the current study were similar to those recently reported by Hagiya *et al*., (2020), where Holstein cows in Japan heritability estimates and genetic variances decreased with increasing THI for test-day milk yield.

Ravagnolo and Misztal (2000) found that heritability estimates for protein yield increased as THI increased, while fat productivity heritability decreased slightly with increasing THI. Heritability estimates for milk yield showed a slight increase; in p1 the trends were quite general with the largest additive genetic variances, permanent environmental variance and phenotypic variance for the lowest heat stress or THI for all production traits. In contrast, in p2 a decrease in additive genetic variances, permanent environmental variance and phenotypic variance with increase of THI in this period. This is consistent with that found by Vinet *et al*. (2023) as cattle welfare genetic variance and permanent environmental variance decreased with increased THI. The residual variances also tended to decrease with increasing THI for LTMY, DMY, LP and DP, their values were 0.40, 0.35,0.79 and 0.41 respectively. In contrast LTMY increased with increasing THI, reaching 0.33 for p2, with reduced additive genetic variance and decreased heritability. Vinet *et al*. (2023) indicated that the phenotypic expression of the genetic potential can be hampered by the nuisance of environmental influences, especially high temperatures. Brügemann *et al*. (2011) recorded that additive genetic variation decreased with increased heat stress in terms of increasing THI. In addition, Dzivenu *et al*. (2022) in Tanzania reported that estimates of permanent environmental variances

Table 5. Estimate of variance components and heritability for productive traits in (P1 and P2) of Friesian cows in Egypt.

Estimate	(P1: 2000-2010)				
	LTMY	TMY	DMY	LP	DP
σ^2a	49499	5629	15.5	455	195.43
σ^2pe	38593	3501	13.86	343	441.19
σ^2e	72708	4370	24.32	508	874.38
σ^2p	160800	13500	53.68	1306	1511
h^2	0.31	0.42	0.28	0.35	0.13
C^2	0.23	0.2	0.25	0.25	0.29
e^2	0.46	0.25	0.44	0.39	0.58
(P2: 2011-2022)					
σ^2a	506.55	454.05	178.28	24.88	208.16
σ^2pe	503.07	282.04	212.98	77.47	206.95
σ^2e	678.72	374.94	206.42	378.53	292.28
σ^2p	1688.34	1111.03	597.67	480.89	707.39
h^2a	0.3	0.41	0.3	0.32	0.15
C^2	0.3	0.25	0.36	0.16	0.29
e^2	0.4	0.34	0.35	0.79	0.41

σ^2a: additive genetic direct variance; σ^2pe: permanent environmental variance; σ^2e: residual variance) σ^2p: phenotypic variance; h^2: heritability; c^2 : fraction phenotypic variance due to the permanent environmental; e^2: fraction phenotypic variance due to the residual effects; LTMY: Lifetime milk yield; TMY: Total milk yield; DMY: Daily milk yield; LP: Lactation period; DP: dry period.

were very small which indicates that the sensitivity of cows to heat stress is not specific to the cow, but it is genetic in origin.

Lee *et al.* (2019) found that in Holstein cattle in South Korea, THI values for milk production showed small variability in its genetic tolerance to heat. Covariance between additive genetic effects and heat tolerance was -0.33, which suggests that selecting animals with high milk productivity could be possible. Low values of additive genetic variance and heritability with increasing temperature and THI value for Holstein milk production, this was consistent with Bohlouli *et al.* (2013); Santana *et al.* 2015; Lee *et al.* (2019).

Estimate of variance component and heritability for productive traits under conditions of high temperatures and heat stress showed the presence of genetic variation among animals, which supports the possibility of selecting animals that are more adapted to environmental conditions and high temperatures. Estimates of permanent environmental variance for the second period for most traits were lower than additive genetic direct variance. This may indicate that sensitivity to heat stress is not specific to the cow, but it is hereditary. Heritability estimates are low to moderate for most milk production characteristics, this indicates the possibility of genetic improvement by selecting the most valuable cows for heritability or genetic selection of cows and improving herd management.

CONCLUSION

The value of THI calculated from the data of the central meteorological stations over a period of 23 years is useful for evaluating the effect of heat stress on the production of Friesian cows in Egypt, especially during the recent times of the highest temperature, humidity, and atmospheric pressure. The summer season is the hottest season of the year, which had a negative relationship with milk production and the heritability estimates. Whereas the rise in temperature and atmospheric pressure due to the phenomenon of global warming, negatively affects both milk production and its heritability values. Therefore, the use of environmental monitoring is an important tool to enable the stations to take corrective measures from. Moreover, good management strategies are needed to reduce heat stress and achieve optimal productivity and selection of cows with high genetic value.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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