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The Effect of Temperature and Humidity Related Factors on Milk Quality Traits of Nigerian Indigenous Breeds of Cattle

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Abstract
The study was conducted to evaluate the effect of Temperature- Humidity related factors on milk traits of some indigenous breeds of cattle in Nigeria. A total of eighty (80) lactating cows (20 each of Adamawa Gudali, Rahaji, Bokoloji and Bunaji) were used. Data on temperature and relative humidity were used to compute Temperature-Humidity Index (THI). Four levels of temperature were adopted; T26-30 °C, T31 °C, T36-40 °C and T>40 °C. Relative humidity groupings were; R<20%, R21-40%, R41-60%, 61-80% and R61-80%. The ranges of THI used were as follows; THI64, THI 72, THI 76 and THI 84. Data collected on milk traits were subjected to Analysis of Variance (ANOVA) using SAS software and means with significant differences were separated using Duncan Multiple Range Test. Temperature affected ($p<0.05$) the traits measured except milk protein, calcium, phosphorus, and iron contents ($p>0.05$). The highest recorded milk, fat and protein yields (1.73 kg, 0.05kg and 0.08kg) were in T26-30. The highest recorded values of fat, TSNF and Sodium (3.83%, 4.31% and 49.46 mg/L) were in T>40. Relative Humidity significantly affected ($p<0.05$) milk yield, milk protein, sodium, and iron. Milk yield was highest in RH61-80 (1.59 kg). Milk fat (3.80%) was highest in RH21-20 but reduced as relative humidity increased. THI significantly ($p<0.05$) affected some traits measured. Milk yield (1.83 and 1.70kg), fat yield (0.06 and o.06kg) and protein yield (0.09 and 0.08kg) were highest in THI 64 and 72. It is therefore concluded that Milk quantity was better in lower THI while milk quality was better with increased THI levels. It was concluded that THI should be considered when planning and implementing dairy improvement programmes in Nigeria.

Keywords:*Dairy, Milk, Quality, Temperature, Humidity, Production*

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I. Introduction

The impacts of climate change on Agriculture as a result of the rise in ambient temperature is becoming a concern globally, but tropical and developing countries are especially vulnerablebecause of the high population depending on agriculture, (Venkateswarlu, 2017; Nayak*et al*., 2018). According to the fifth IPCC assessment report (AR5) on climate change, the global surface temperature is expected to rise by 1-7^{0}C come 2100 (IPCC, 2013). Also, a report by climatologists and meteorologists in Europe has predicted a threat of increasing ambient temperature by as much as 2^{0}C by 2050 (Peltonen-Sainio*et al*., 2010; Trnka*et al*., 2011). Apart from the direct effect of climate change on livestock, some of the long-lasting indirect effects include a change in habitat and feeding systems, alteration of fodder quality and quantity, change in yields, quantity and type of product, increased competition for resources and modifications in the ecosystem (Howden *et al.*, 2008; Moore and Ghahramani, 2013; Kebede, 2016). Climate change has affected and is still affecting livestock production through competition for natural resources, quantity and quality of feeds, livestock diseases, heat stress and biodiversity losses while the demand for livestock products, especially milk is expected to increase by 100% by the middle of the 21st century (Garnett, 2009; Thornton *et al*., 2014).

Several indices of heat stress have been driven and reviewed from meteorological measurements by several scientists (Hahn *et al*., 2009; Herbut and Angrecka, 2012; Adedibu*et al*., 2015; Macciotta*et al*., 2016; Raymond, 2017) and these indices ranged from a simple measurement of ambient temperature to an index that takes into consideration the effects of air temperature, relative humidity, solar radiation and wind speed. Ambient temperature has been recognized as one of the current and future problems in the livestock industry (Mirani-Milani*et al*., 2015; Raymond, 2017). There has been a great deal of research and development on ways to reduce the heat challenge of animals subjected to a short or an extended period of high ambient temperature

(Renaudeau*et al*., 2012; Adedibu*et al*., 2015; Mirani-Milani*et al*., 2015; Raymond, 2017). Ambient temperature and humidity are some of the most influential environmental conditions that collectively impact heat stress, and they are often combined into one metric called the Temperature-Humidity Index (THI) (Dikmen and Hansen, 2009; Joksimovic-Todorovic*et al*., 2011; Atrian and Aghdam, 2012; Pragna*et al*., 2016). The THI has been used to integrate environmental temperature and relative humidity (Thatcher *et al*., 2010). It has also been considered to be a reliable indicator of heat stress in cattle (Dikmen and Hansen, 2009).

Efficient productive performance of lactating dairy cattle in tropical/ subtropical and arid environments throughout the world is impacted by a multiplicity of factors such as: the physical environment, social-economic status of producers, available nutrients, adaptability and genetic composition of cattle, intensive or extensive management systems and available reproductive technology (Vesna*et al*., 2011; Raymond, 2017; Nayak*et al*., 2018). Heat stress has been reported to be one of the major concerns that affect the production potential of dairy cattle in every part of the world (Pragna*et al*., 2016). During heat stress, a reduction in milk yield has been recorded to be up to 30-40% (Baumgard*et al*., 2004; Pragna*et al*., 2016). Even though these facts exist, there is a dearth of information on the effect of heat stress particularly as caused by Temperature-Humidity factors on the milk composition of the Nigerian indigenous cattle in Adamawa State. The aim of this paper, therefore, is to evaluate the effect of Temperature-Humidity factors on milk traits of indigenous breeds of cattle in Adamawa State.

II. Materials and Methods

Description of the Study Area and Experimental site

The study was conducted on fourpurposively selected herds in Local Government Areas in Adamawa State (Mubi, Hong, Gombi and Song). Adamawa State is located at an altitude of 200 to 300 meters above sea level, between latitude 9°20' and 9°33'N and longitude 12^{0} 30' and 12º50' E (Ovimaps, 2018). It has an average daily minimum and maximum temperatures of 23.2 and 35.2ºC respectively. The average annual rainfall is 718.1 millimetres and relative humidity is 44.2 %. It occupies an area of 39,742.12 square kilometres. The predominant climate is Sudan, the rainy season last for only three to four months (June-September) (Adebayo *et al*., 2020).

Experimental Animals and Management

Eighty (80) clinically healthy indigenous lactating cows made up of twenty (20) each of Adamawa Gudali (AG), Rahaji (RJ) also known as Red Bororo, Bokoloji (BK) also known as SokotoGudaliand Bunaji (BJ) also known as White Fulani of within their first and second parity in selected herdswere purposively selected from traditional herders were used for the experiment. For the purpose of this experiment, Adamawa Gudali (AG), Rahaji (RJ), Bokoloji (BK) and Bunaji (BJ) were the names used for the studied breeds. The experiment was conducted within the late dry season (February- April) of 2022. The animals used were in their first and second parities and early lactation stage (1-60 days).

Milk Collection

Milk samples from the experimental animals were collected using the traditional hand milking method as reported by (Bhakat*et al*., 2017) in triplicate (second week of each month) into 50 ml falcon tubes from twenty (20) each of Adamawa Gudali, Rahaji, Bokoloji and Bunaji cows and were taken to the Nutrition and Biochemistry Laboratory of the Department of Animal Production, Adamawa State University (ADSU), Mubi for milk composition analysis.

Milk Traits Measured/ Determined

1. *Daily milk yield (MY)*: The cows were hand milked early in the morning; three times during each of the experimental seasons and its equivalent was measured using a measuring cylinder calibrated in litres on the farm and later converted to obtain the equivalent kilogram.
2. *Milk Protein (P):*The total nitrogen was determined using Kjeldahl method and the nitrogen content was converted into equivalent protein content using N×6.38 as conversion factor (Karman and Van Boekel, 1986). It was recorded in percentage.
3. *Milk Fat (F):*The fat content was determined using Gerber method (Bradely*et al*., 1992).
4. *Fat yield (FY):*The fat yield was obtained by multiplying the per cent milk fat by the daily milk yield as reported by (Bradely*et al*., 1992).
5. *Protein yield (PY)***:** The protein yield was determined by multiplying the per cent milk protein by the daily milk yield as reported by (Bradely*et al*., 1992).
6. *Total Solid Non-Fat (TSNF) (%)* **=** this was gotten by taking the lactometer reading of milk. Then the figures for fat content of milk and the lactometer readings were imputed in the following formulae for calculating total solid and solid nonfat. TSNF:

Formulae;

TSFN (%) = $\frac{CLR+0.21F+0.14}{4}$

Where CLR= corrected lactometer reading.

F= Fat content in milk.

7. *Minerals (Ca, Phos, K and Fe):* For minerals analysis, the milk solid content was taken and digested using two volumes of concentrated nitric acid. After adding one volume of perchloric acid, the content was heated gently on a hot plate followed by vigorous heating till dryness (proximately 1-2ml). This digestion technique makes no attempt to dissolve any silicate-base materials that may be present in the sample. After cooling, the digested samples were quantitatively transferred to a flask and diluted to 100ml with deionized double distilled water and then filtered. Minerals (Ca, Phos, K and Fe) were estimated using an Atomic Absorption Spectrophotometer (210, Buck Scientist USA) (AOAC, 2000).

Environmental Factor Data Collection

Data on the ambient temperature and relative humidity of the experimental sites were collected using a digital thermometer and hygrometer that were mounted under the nearest tree any time thermoregulatory data were collected. The ambient temperature (T) was later grouped into four. The groupings were; 26 to 30 °C as (T26-30); 31 to 35 °C as (T31-35); 36 to 40 °C as (T36-40) and 40 °C and above as (T>40).

For the relative humidity, the collected relative humidity was grouped into five and its effect on milk traits was evaluated. Relative humidity groupings were; 20% as (R<20); 21to 40 % as (R21-40); 41 to 60 % as (R41-60); 61 to 80 % as (R61-80) and greater than 80 % as (>80).

The temperature-humidity index (THI) was calculated according to the equation reported by (Ravagnolo*et al*., 2000; Adedibu*et al*., 2015).

THI = (1.8 x T + 32) – [(0.55 – 0.0055 x RH) x (1.8 x T – 26)]

Where T = dry bulb temperature (°C) and RH = relative humidity (%).

Ranges for temperature humidity index (THI)

The ranges of THI used were as follows; THI over 64 as (THI64) (minimal heat stress); THI over 72 as (THI 72) (moderate heat stress); THI ≥ 76 as (THI 76) (maximal heat stress) and THI of 84 as (THI 84) or more, death occurs (West, 2003; Igono*et al*., 1992)

Statistical Analysis

The statistical model for the experiment is as given below;

$Y_{ij} = \mu + E_i + e_{ij}$

Where, μ = general mean, E_i = i^{th} fixed effect of environmental factor (E = 3) and e_{ij} = experimental error.

The data obtained on milk traits were subjected to analysis of variance (ANOVA) using General Linear Model of SAS (2002) while means with significant differences were compared using Duncan Multiple Range Test (Duncan, 1955). The degrees of relationship between all pairs of variables were computed for all the animals within each breed groups and as a pool using CORR procedure of the SAS (2002) statistical package. The formula used for correlation is

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

III. Results and Discussion

Effect of temperature on milk traits in the indigenous cattle of Nigeria

Table 1 shows the effect of temperature on milk traits in the indigenous cattle of Nigeria. Temperature affected ($p<0.05$) the traits measured except milk protein, calcium, phosphorus, and iron contents ($p>0.05$). The observed higher record of milk, fat and protein yields were obtained in T26-30 while the least of same traits were in T>40. The observed higher values of fat, TSNF and Sodium were seen in T>40 while the least of them were in T26- 30. This implies that protein yield, fat yield and milk yield reduced with increase in temperature while fat, TSNF and Sodium increased as temperature increased.

Table 1: AMBIENT TEMPERATURE ON MILK TRAITS OF SOME SELECTED INDIGENOUS BREEDS OF CATTLE IN NIGERIA

Traits	T26-30	CV	T31-35	CV	T35-40	CV	T>40	CV
Milk yield (Kg)	$1.73{\pm}0.10^{a}$	25.15	$1.44{\pm}0.07^{ab}$	26.01	$1.22{\pm}0.07^{bc}$	23.41	$0.97{\pm}0.18^{c}$	24.21
Milk fat (%)	$3.38{\pm}0.72^{b}$	12.27	$3.33{\pm}0.05^{b}$	10.72	$3.61{\pm}0.06^{ab}$	10.37	$3.83{\pm}0.07^{a}$	3.57
Milk protein (%)	4.81±0.08	10.21	4.62±0.07	10.75	4.90±0.06	7.97	4.97±0.01	0.52
Fat yield (Kg)	$0.05{\pm}0.00^{a}$	22.72	$0.05{\pm}0.00^{ab}$	27.09	$0.04{\pm}0.00^{ab}$	25.64	$0.03{\pm}0.00^{b}$	28.05
Protein yield (Kg)	$0.08{\pm}0.01^{a}$	14.85	$0.07{\pm}0.01^{ab}$	20.57	$0.06{\pm}0.00^{b}$	22.64	$0.05{\pm}0.01^{b}$	23.05
Total solid non-fat (%)	$3.95{\pm}0.10^{b}$	14.84	$4.23{\pm}0.04^{ab}$	7.56	$4.21{\pm}0.05^{ab}$	7.39	$4.31{\pm}0.19^{a}$	8.73
Calcium (mg/L)	632.78±8.24	7.48	598.46±10.96	12.95	619.80±23.44	21.73	677.27±15.46	4.56
Phosphorus (mg/L)	359.0.61	8.71	340.63± 11.22	23.30	379.55±4.25	6.43	380.77±2.80	1.49
Sodium (mg/L)	$40.41{\pm}0.06^{b}$	8.70	$45.16{\pm}1.17^{ab}$	18.40	$48.21{\pm}0.88^{a}$	10.49	$49.46{\pm}0.92^{a}$	3.74
Iron (mg/L)	1.74±0.11	24.09	1.71±0.12	27.00	2.26±0.09	23.67	2.27±0.17	14.81

[abc] means with different superscripts within the rows are significantly different at 5%; T26-30 = Temperature at 26-30 ^{0}C; T31-35 = Temperature at 30 – 35^{0}C; T30 - 40 = Temperature at 35- 40^{0}C; T>40 = Temperature at greater than 40^{0}C; CV = Coefficient of Variation. E

The negative impact of rise in temperature on milk quantity (milk yield, fat yield and protein yield) in this study concurred with the report of Srivastava, (2010) and Nayak*et al*., (2018) who reported a global decline in milk yield due to increased climate change. It was reported that elevated environmental temperature is one of the causes of hyperthermia or heat stress (Collier *et al*., 2006) which in return affects milk production (Prasad *et al*., 2012). More generally, they have predicted that the increase in global average surface temperature by year 2100 may be between 1.8°C and 4.0°C (IPCC, 2013). The reduction in milk as a result of increase in temperature also concur with the report of Ravagnolo and Mizstal (2000) who reported that reduced milk production is the first perceived consequence of heat stress. Pragna*et al.* (2016) noted that apart from milk production, heat stress can also reduce the quality of milk. They reported that for a high yielding cow, when the body temperature is higher than 39°C production of milk would significantly fall. Some researchers (West, 2003; Atrian and Aghdam, 2012; Prasad *et al*., 2012; Raymond, 2017) opined that at the temperature of 35°C, a quantity of milk decreased by 33%, and at the temperature of 40^{0}C, milk production reduced by 50%. Herbut and Angrecka (2012) also reported a decreased milk production five (5) days after the start of high temperatures and returned to normal four (4) days after the end of heat wave.

Contrary to the findings of this study, other researchers (Sacido*et al*., 2001; Seignalini*et al*., 2011) reported a decrease in fat content from 3.6% to 3.2% as the temperature increased beyond 30^{0}C. Kadzere*et al*. (2002) also reported a decrease in fat content by 39.7% as temperature exceeds 40^{0}C. The effect of high temperature was also reported to decrease by wind, but solar radiation increases the heat effect on metabolic processes (Silva *et al*., 2007; Mirani - Milani*et al*., 2015). Discrepancies between the findings of this study with other research could be attributed to differences in health, management and the physiological states of the cows used (Nickerson, 1999; Zeleke, 2007; Dandare*et al*., 2014; Oladapo and Ogunekunn, 2015).

Effect of Relative humidity on milk traits in the indigenous cattle of Nigeria

Relative humidity significantly affected ($p<0.05$) milk yield, milk protein, sodium, and iron (Table 2). Milk yield was higher in RH61-80 (1.59 kg) but least in in RH21-40. Milk fat was higher in RH21-20 but reduced as relative humidity increased. This implies that milk yield increased when relative humidity increased.

Table 2: Relative Humidity on Milk Traits of Some Selected Indigenous Breeds of Cattle in Nigeria

Traits	R<20	CV	R21-40	CV	R41-60	CV	R61-80	CV	R>80	CV
Milk yield (Kg)	1.51±0.12^ab	21.05	1.15±0.10^b	25.78	1.29±0.11^ab	24.49	1.59±0.08^a	25.65	1.51±0.17^ab	26.86
Milk fat (%)	3.49±0.76^b	9.62	3.80±0.04^a	5.28	3.44±009^b	12.07	3.29±0.05^b	10.79	3.36±0.24^b	17.72
Milk protein (%)	5.03±0.04^b	3.62	4.95±0.02^a	1.61	4.90±0.08^a	7.86	4.54±0.07^b	11.67	4.76±0.28^ab	14.28
Fat yield (Kg)	0.05±0.00	20.56	0.04±0.02	27.95	0.04±0.00	28.04	0.05±0.01	25.87	0.05±0.01	21.08
Protein yield (Kg)	0.08±0.00	22.56	0.06±0.01	25.71	0.06±0.00	24.51	0.07±0.01	27.94	0.07±0.01	21.08
Total solid non-fat	4.10±0.06	6.67	4.286± 0.07	7.65	3.99. 66±0.08	9.43	4.04±0.06	11.68	4.07±0.23	14.01
Calcium (mg/L)	581.09±22.97	17.23	638.97±35.17	24.61	610.13±12.52	9.40	619.20±8.91	10.58	649.68±11.76	4.43
Phosphorus (mg/L)	346.68±28.40	23.56	376.33±3.48	4.13	349.63±4.55	5.96	356.53±5.82	12.00	371.85±17.36	2.57
Sodium (mg/L)	47.51±0.83^a	7.67	48.46±0.70^a	6.42	41.67±0.88^b	9.68	44.23±1.22^ab	20.23	40.81±0.43^b	2.57
Iron (mg/L)	2.50±0.10^a	17.93	2.21±0.01^ab	19.18	1.20±0.05^c	20.58	1.80±0.11^b	24.19	2.10±0.26^ab	21.58

[abc] means with different superscripts within the rows are significantly different at 5%; R<20 = Relative Humidity at less than 20%; R21-40 = Relative Humidity at 21 – 40%; R41-60 = Relative Humidity at 41-60%; R61-80 = Relative Humidity at 61 -80%; R>80 = Relative Humidity at greater than 80%; CV = Coefficient of Variation.

The importance of relative humidity in the study of heat stress was demonstrated by a decline in milk production between 32 ^{0}C with 20% relative humidity (RH) and 32ºC with 45% RH (Johnson and Vanjonack, 1976). Heat stress in dairy cows is provoked by a great number of external or climatic factors such as temperature, relative humidity, solar radiation, air circulation and precipitation (Joksimovic-Todorovic*et al*., 2011; Nayak*et al*., 2018; Rashamol*et al*., 2018). Factors that can be used to measure heat stress in dairy cattle are temperature, relative humidity and Temperature- Humidity Index (Bryant *et al*., 2007; Adedibu*et al*., 2015) and these factors have been reported to negatively affect milk quality and quantity. Santana *et al*. (2016) opined that genotype and environmental interaction due to heat stress are more relevant for milk yield than fat and protein percentages. Fluctuations in the environmental conditions (climate, feeding and management) from year-to-year at the same tropical location can be important in determining the preferred breed of dairy cows that are more resistant to heat stress (Thatcher *et al*., 2010). Significant negative impacts of climate change have been recorded in the livestock, industry and was reported to reduce milk yield by 4.5 to 9% depending on the level and distribution of global warning (FAO, 2013; Nayak*et al*., 2018).

Effect of Temperature-Humidity Index on the milk traits of the indigenous breeds of cattle in Nigeria

The effect of THI scores on the milk traits of the indigenous breeds of cattle in Nigeria is shown in Table 3. THI significantly (p<0.05) affected traits measured except milk fat, calcium, phosphorus and iron (p>0.05). Milk yield, fat yield and protein yield were higher (p<0.05) in THI 64 and 72.

Table 3: Temperature-Humidity Index (THI) on Milk Traits of Some Selected Indigenous Breeds of Cattle in Nigeria

Traits	THI64	CV	THI72	CV	THI76	CV	THI84	CV
Milk yield (Kg)	1.83±0.09^a	20.67	1.70±0.11^a	21.61	1.30±0.06^b	27.56	1.05±0.09^b	29.73
Milk fat (%)	3.39±0.10	11.96	3.41±0.07	11.41	3.48±0.05	11.23	3.32±0.12	12.78
Milk protein (%)	4.73±0.11^ab	9.50	4.93±0.07^a	8.54	4.74±0.06^ab	9.56	4.51±0.06^b	12.48
Fat yield (Kg)	0.06±0.00^a	22.89	0.06±0.01^a	22.49	0.05±0.00^b	24.92	0.04±0.01^c	28.54
Protein yield (Kg)	0.09±0.01^a	23.48	0.08±0.02^a	23.07	0.06±0.01^b	24.17	0.05±0.01^b	25.90
Total solid non-fat (%)	3.90±0.16^b	16.10	4.01±0.08^b	10.79	4.12±0.04^ab	8.32	4.30±0.08^a	6.36
Calcium (mg/L)	634.14±15.79	9.96	608.89±14.10	12.68	613.06±13.61	17.34	627.53±21.11	12.13
Phosphorus (mg/L)	337.45±23.93	28.36	356.18±13.90	21.38	361.09±4.56	9.88	371.41±9.99	9.70
Sodium (mg/L)	41.21±1.38^c	13.35	42.67±0.72^bc	9.27	46.14±0.90^ab	15.18	48.18±2.85^a	21.37
Iron (mg/L)	1.76±0.17	26.17	2.11±0.12	18.56	1.77±0.10	27.90	2.13±0.22	21.52

[abc] means with different superscripts within the rows are significantly different at 5%; THI64 = Temperature – Humidity index at 64; THI72 = Temperature –Humidity index at 72; THI76 = Temperature –Humidity index at 76; THI84 = Temperature –Humidity index at 84; CV = Coefficient of Variation.

THI as a general index of heat stress considers the effect of ambient temperature and relative humidity in determining the comfort of dairy cows and livestock in general (Thom, 1959; Herbut*et al*., 2018). Heat stress has been reported to cause a major economic loss due to declined milk production and other reproductive performances (Aguilar *et al*., 2010; Nardone*et al*., 2010; Biffani*et al*., 2016; Macciotta*et al*., 2017; Raymond, 2017). The decrease in milk production because of increased values of THI in this study concurred with the reports of other researchers (Ravagnolo and Misztal, 2000; Bohmanova*et al*., 2007; Brouceck*et al*., 2009; Thatcher *et al*., 2010; Akyuz*et al*., 2010) that for low yielding cows, productivity reduces once THI reaches 74.

They also set THI of 74 as a critical threshold value above which the productivity properties of cows begin to change and a drop in productivity will be noticed.

Aside from reduced milk production, economic losses attributable to heat stress were estimated to be between $897 million and $1,500 million per year for the U.S dairy industry (St-Pierre *et al*., 2003; Aguilar *et al*., 2010) and this may likely increase (Intergovernmental Panel on Climate Change, IPCC, 2013). A reduction in milk quantity from 35.6 to 34.2kg/day was reported in Holstein-Friesian when THI exceeded 72 (Smith *et al*., 2013). Bernabucci*et al*. (2002) also reported a reduction in milk production of 10% in the summertime than in the springtime. However, newer studies show that THI of 68 is the lowest critical limit for occurrences of heat stress in livestock (Segnalini*et al*., 2011; Carter *et al*., 2011; Carabono*et al*., 2014) Milk yield was also reported to have been reduced by 0.4 when THI increased (Mizstal*et al*., 2006). Osei-Amponsah*et al*. (2020) reported a decrease of up to 14% in milk production as THI increased from low to high. Milk fat and protein also increased by 3% and 2%, respectively as THI increased. Contrary to the findings of this present study, Nasr *et al*. (2017) reported that daily milk traits (milk yield, fat, protein, fat yield, protein yield and lactose percentages) were higher under THI≤72 (31.91kg, 3.91%, 3.22% 418kg, 349kg and 4.20%) as compared with THI ≥83. Since heat stress is caused by a combination of factors, Bourauoi*et al*. (2002) suggested that the adverse effect of heat stress on milk production could be due to reduced nutrient intake and decline in nutrient uptake by the portal drained viscera of the lactating cow. Lee *et al*. (2019) and Osei-Amponsah*et al*. (2020) also found out that dairy cow performance was better in most of the measured milk traits at a low THI than at high THI. According to Broucek (2009), a THI of 72-78 is likely to cause a very serious risk to milk production, and when THI reaches 76-78, the highest milk production decrease occurs. These levels include mild stress (THI 72-79), moderate stress (THI 79-89) and heavy stress (THI>89). Herbut and Angrecka (2012) opined that an increase in THI by 8 units resulted in a decrease in milk production by 2.88kg (0.36kg/ THI unit). Differences between THI values used by different authors to assess the level of thermal stress could be attributed to different methods of calculating THI and specific shape, constructions of the building and geographical orientations (Mader*et al* 2006; Herbut and Angrecka, 2012). Contrary to the findings of this study, Brugemann*et al*. (2012) reported a decrease in fat percentage when THI increased above 67. In addition, it was suggested that an alternative to measuring heat tolerance in animals is to measure the change in milk production traits under a warm environmental conditions (Hammami*et al*., 2015; Nguyen *et al*., 2016; Carabano*et al*., 2017). In contrast with the findings of this study, fat was reported to decrease with increased THI (GhaviHossein-Zadeh*et al*., 2013). The reasons for the discrepancies between the findings of this study could be attributed to differences in breeds, experimental conditions and the seasons of experiments (Nguyen *et al*., 2016; Carabano*et al*., 2017).

Correlation between THI and Milk components

The correlation between the milk traits of indigenous cattle and the environmental factors is shown in Table 4. The correlation coefficient varied in direction ($p<0.05$: r = - 0.46 to 0.44). Positive correlation exists for temperature with fat (r = 0.30), TSNF (r = 0.25), sodium (r = 0.44) and iron (r = 0.25). On the other hand, negative relationship exists for temperature with milk yield (r = - 0.43), fat yield (r = - 0.35) and protein (r = - 0.38). Significant ($p<0.05$) negative relationship exists for relative humidity with fat (r = - 0.39), protein (r = - 0.40), sodium (r = - 0.25) and iron (r = - 0.26). THI related negatively ($p<0.05$) with milk yield (r = - 0.40), protein (r = - 0.27) and fat yield (r = - 0.40) but positively with sodium (r = 0.36).

Table 4: Correlation Coefficients for Milk and Environmental Factors in the Studied Breeds

	MY	F	P	FY	PY	TSNF	Ca	Phos	Na	Fe
Ambient Temperature	-0.43*	0.30*	0.16	-0.35*	-0.38*	0.25*	-0.08	0.09	0.44*	0.25*
Relative Humidity	0.21	-0.39*	-0.40*	0.11	0.11	-0.14	0.08	0.01	-0.25*	-0.26*
THI	-0.40*	-0.02	-.27*	-0.40*	-0.46*	0.21	-0.01	0.15	0.36*	0.06

MY=Milk yield; F = fat; P =Protein; FY= Fat yield; PY= protein yield; TSNF= Total solid not fat; Ca = Calcium; Phos= Phosphorus; Na = Sodium; Fe = Iron; THI=Temperature-Humidity index; *=significant at 5%.

Apart from affecting milk yield, environmental factors also affect milk composition and yield, especially in high-yielding dairy breeds (Gantner*et al*., 2011; Das *et al*., 2015). For instance, reduced milk yield and protein fraction has been reported in dairy cattle exposed to heat stress (Atrian and Aghdam, 2012; Bernabucci*et al*., 2014). A negative correlation also exists between increased THI and milk composition (Kadzere*et al*., 2002). When ambient temperature rises above the zone of thermal neutrality, it causes a change in milk composition (Kadzere*et al*., 2002). Mirani - Milani*et al*. (2015) also reported changes in milk compounds and climate indices under different climatic conditions. The authors reported that during the spring, a high correlation existed between the fat and protein concentrations versus climate indices. They also stated that in the summer periods, the same relationship decreased in comparison with the spring. Also, changes were reported in the quantity and quality of milk over time due to environmental and climate changes (Sharma *et al*., 1983; Mirani- Milani*et al*., 2015). Contrary to the findings of this study, Knapp and Grummer (1991) and Roman-Ponce *et al*. (1978) reported a non-significant relationship between fat reduction and heat stress. In addition, GhaviHossein – Zadeh*et al*. (2013) also reported a linear relationship between milk and fat yields, but in contrast to the finding of this study, reported a non-significant relationship between THI and fat percentage of milk. Other researchers (Collier *et al*., 2006; O'Brien, 2010; Nikkhah*et al*., 2011; Gauly*et al*., 2013; Mirani- Milani*et al*., 2015) concluded that there was a positive correlation between milk yield, protein and climatic indices but negative correlation exists between fat and climatic indices with protein being more sensitive to the negative effect of heat stress and climatic variability. Many authors (Bernabucci*et al*., 2014; Hammami*et al*., 2015; Nguyen *et al*., 2016) have reported an unfavourable genetic relationship between milk production and heat tolerance.

IV. Conclusion

Milk yield increased in a reduced ambient temperature and THI but reduced with increased relative humidity. Milk quantity was better with lower THI while milk quality was better with increased THI levels. The relationship between environmental factors and milk traits should be considered in planning a milk improvement program. Local breeds of dairy cattle in Nigeria have the potential for better milk production in both quality and quantity. However, there is a need to optimize the prevailing weather extremities by adopting better production management practices that augment the effect of high temperatures (through diet optimization, installation of ventilators and sprinklers in the barns and stable) to achieve better milk yield in such breeds.

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Conflict of interest:
Authors declare no conflict of interest regarding the manuscript.

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