Pakistan J. Zool., pp 1-9, 2023. DOI: https://dx.doi.org/10.17582/journal.pjz/20220809010838

Effect of Rumen-Protected Niacin and Vitamin C Supplements on Productive Performance of Lactating Friesian Cows under Heat Stress Condition

Nabil Eweedah[1]*, Atef Salem[1], Hamed Gaafar[2], Ahmed Shams[2], Abdel-Aziz Mahmoud[3], Reda Mesbah[2] and I. Aljadba[1]

[1]*Animal Production Department, Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh 33516, Egypt.*
[2]*Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt.*
[3]*Dairy Science Department, Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh 33516, Egypt.*

Article Information
Received 09 August 2022
Revised 05 December 2022
Accepted 29 December 2022
Available online 24 May 2023 (early access)

Authors' Contribution
NE, AT, HG and AAM presented the concept. All authors performed formal analysis and investigation. RM, IA, NE, HG and AAM wrote the manuscript. AT, IA, NE, HG and AAM planned methodology. AAM and IA arranged funds for the study.

Key words
Dairy cows, Heat stress, Rumen-protected niacin, Vitamin C, Rumen activity, Economic evaluation

ABSTRACT

Niacin (vitamin B3) is known for its effect on mammalian vasodilatation and its function in lipid metabolism. It reduces the impact of heat at the cellular level and enhancing the body's evaporative heat loss, both serve to reduce heat stress. Niacin (6 g/cow/day) may be beneficial since it lowers skin temperature and improves milk production. The aim of this study was to see how rumen protected niacin and vitamin C improved the performance of lactating Friesian cows that had been subjected to heat stress during the summer. Twenty-four multiparous cows were divided up into four groups of six each and given a basal diet. The first diet, which contained 10 g/head/day of either rumen-protected niacin (RPN, G2) or vitamin C (VC, G3), was designated as the control (G1). The fourth group offered 5 g RPN + 5 g VC/head/day (G4). Temperature-humidity index ranged from 78.49 to 83.57. The control group had the lowest digestibility coefficient of nutrients, feeding values and feed intake (P<0.05), while G4 had the greatest values. Ruminal pH value and ammonia nitrogen (NH_3-N) level in G1 were substantially higher (P<0.05) compared with other groups. Concentration of total volatile fatty acids was highest in G4 and lowest in G1 (P <0.05). Glucose, protein and globulin concentrations were significantly increased (P<0.05) as a result of the supplements, but albumin to globulin ratio, urea-N, creatinine concentrations as well as and alanine aminotransaminase and aspartate aminotransaminase activities were lowered (P<0.05). Additionally, G4 had the highest productivities for all milk constituents. Feed conversion increased significantly (P <0.05) with rumen-protected niacin and vitamin C supplementation. G4 had the highest total and net outputs as well as the highest economic efficiency, which was followed by G2 and G3 and then G1. The current study suggest that vitamin C or niacin or both, may have a protective effect against heat stress in lactating Friesian cows during the summer, increase the efficiency of feed conversion as well as digestibility, feed intake, rumen fermentation, milk yield and composition.

INTRODUCTION

Heat stress (HS) is one of the most serious concerns at dairy farms under tropical climates. In Egypt, the hot season lasts for a long time with powerful energy radiant and high relative humidity (Abd El-Hafeez *et al.*, 2020).

* Corresponding author: OWO_Health@kfs.edu.eg; nabeweda@yahoo.com
0030-9923/2023/0001-0001 $ 9.00/0

As a consequence, the HS is a long-term affliction. Evenings are usually without relief from the heat that caused a significant heat surges and humidity damage performance even more. HS reduces feed intake, decreasing milk production (Ghosh *et al.*, 2017). However, according to Gaafar *et al.* (2011), lactation period, milk yield, and milk composition are significantly reduced in Egyptian Friesian cows from June to October. To reduce the HS and achieve optimal animal performance, management and feeding systems are required. Temperature humidity index (THI) is a common index for measuring dairy cows' HS degree. The HS is detectable in animals with a THI of 72 or above. Measured stress levels varied from low (72-79), moderate (80-89), and severe (90-100) (Armstrong, 1994; Smith *et al.*, 2006).

Numerous researches showed that niacin supplements increases milk production (St-Pierre *et al.*, 2003; Zimbelman *et al.*, 2013). Niacin supplementation increased the amount of milk fat (Schwab *et al.*, 2005). Panda *et al.* (2017) stated that 12 g of niacin per day could improve milk production by 1 pound. Adding 14 g/head/day of niacin to Holstein cows increased milk yield, total solids (TS) content and energy-corrected milk yield (Karkoodi and Tamizrad, 2009). However, no significant variations in milk protein, lactose, or SNF (solids not fat) levels were seen in Holstein cows given a niacin supplement (Ghorbani *et al.*, 2008).

HS occurs when a dairy cow that is lactating cannot effectively remove heat due to the high air temperature. The formation of oxygen-derived free radicals is increased during heat stress, which may have a number of negative impacts, including an increased prevalence of some diseases and problems with reproduction in lactating cows (Miller and Brezezinska-Slebodzinska, 1993; Lykkesfeldt and Svendsen, 2007). HS reduced the plasma vitamin C (VC) concentration in dairy cows and regulated high ambient temperature decreased plasma vitamin C (VC) concentration by 50% (Padilla *et al.*, 2006). The findings of Padilla *et al.* (2006) demonstrating that lactating cows' plasma VC content was significantly lower in the summer than in the autumn were further supported by Tanaka *et al.* (2008) results. Supplementing with VC has been observed to enhance the efficiency of heat-stressed poultry and weaned piglets (McKee and Harrison, 1995; De-Rodas *et al.*, 1998; Sahin *et al.*, 2003), suggesting that VC supplementation is potentially beneficial to animals undergoing HS. The goal of this study was to see how rumen protected niacin and VC improved the performance of lactating Friesian cows that had been subjected to HS during the summer.

MATERIALS AND METHODS

Temperature humidity index (THI)

The THI was calculated using Kibler's (1964) formula: THI= (0.8T) + H (T-14.4) + 46.4. Where T is the surrounding temperature and H is the relative humidity.

Experimental animals and rations

Twenty-four multiparous nursing Friesian cows weighing an average of 500±25 kg were categorized into four equivalent groups (6 cows each) based on live body weight, milk supply, and the number of lactation seasons after the peak of lactation (60 days). All cows were fed a basic diet consists of 50% of concentrate feed mixture, 30% of corn silage, 20% rice straw on dry matter basis. Cows in G1 served as control without any supplementation. At the same time, G2 received 10 g/head/day rumen-protected niacin (RPN) and G3 received 10 g/head/day VC, whereas G4 received 5 g/head/day RPN + 5 g/head/day VC (70±2% niacin, ANEVIS, Quali TechInc, United States, is rumen-protected niacin (35% active vitamin C, AVITASA, Spain). The CFM (concentrate feed mixture) contained undecorticated cotton seed cake (32%), yellow maize (22%), wheat bran (24%), linseed cake (5%), rice bran (11%), limestone (2%), molasses (3%), and common salt (1%). Components and chemical analysis of different dietary treatments are shown in Table I.

Table I. Components and chemical analysis of basal diet used in feeding cows.

Item	Basal diet
Components (DM basis, %)	
Concentrate feed mixture	50
Corn silage	30
Rice straw	20
Chemical analysis (DM basis, %)	
Dry matter	55.01
Organic matter	90.37
Crude protein	11.50
Crude fiber	19.03
Ether extract	2.59
Nitrogen free extract	57.25
Ash	9.30
Neutral detergent fiber	45.56
Acid detergent fiber	27.19
Acid detergent lignin	3.61

DM, dry matter.

Management procedure

According to NRC's (2001) feeding allowances for dairy cows, each animal was fed individually to meet their recommended dietary requirements. Then, based on each animal's average body weight and milk production, feed intake was adjusted each week. CFM, corn silage and rice straw were supplied twice daily. RPN and VC were added to the concentrate feed combination during morning feeding. All day fresh water was available for the animals.

Digestibility trials

To determine the digestibility and feeding values of the experimental diets, four digestibility trials were carried out with three cows from each group throughout the feeding period. Each digestibility trial had a preliminary phase of 15 days and a collecting period of 7 days. As a natural indicator, acid-insoluble ash was used (Van keulen and Young, 1977). Feces were collected from each cow's rectum twice daily with a 12 h interval. During the collection period feed ingredients and feces samples were chemically analysed using AOAC (1995). According to the Schneider and Flat (1975) equation, nutrient digestibility was estimated as follows:

$$\text{DM digestibility (\%)} = 100 - \left[100 \times \frac{\text{\% of AIA in feed}}{\text{\% of AIA in feces}}\right]$$

$$\text{Nutrient digestibility (\%)} = 100 - \left[100 \times \frac{\text{\% of AIA in feed}}{\text{\% of AIA in feces}}\right] \times \left[\frac{\text{\% of nutrients in feces}}{\text{\% of nutrients in feed}}\right]$$

Where, AIA is acid-insoluble ash.

Digestible crude protein and the total digestible nutrients were calculated using the conventional McDonald *et al*. (1995) formula.

Rumen liquor samples

Three hours after morning feeding, using a stomach tube, cows' rumen samples were collected. and the draw pulse power of an automatic milking machine. Two layers of cheese cloth were used to strain each sample (Van Soest *et al*., 1991). Rumen pH measured using a digital pH metre Orian 680 immediately. According to the AOAC (1995) method, ammonia nitrogen was assessed using a saturated solution of magnesium oxide. Warner (1964) proposed a method for measuring total volatile fatty acids using steam distillation.

Blood samples

Three hours after morning feeding, blood samples from the cows' jugular veins were taken, and they were then allowed to clot for 30 to 60 min to obtain the serum. The obtained serum was centrifuged at 4,000 rpm for 15 min before being placed in a deep freezer until analysis. By use of commercial diagnostic kits, serum's proteins, albumin, globulin, glucose, urea nitrogen, creatinine, AST, and ALT were determined.

Milk yield and composition

Individual daily milk yields were recorded and corrected for milk with 4% fat using the Gaines (1928) formula as follows: 4% FCM =0.4 x milk yield (kg) +15 x fat yield (kg). Weekly milk samples from consecutive morning and evening milking were collected throughout the trial and mixed in proportion to milk yield. Using a Milkoscan, model 133 B, milk samples were analysed for protein, fat, lactose, total solids (TS) and solids not fat (SNF). Ash was determined by the difference.

Feed conversion

The feed conversion was calculated for each cow in the term of DM, TDN, CP, and DCP required for kg of 4% fat corrected milk (FCM).

DM (kg/kg 4% FCM) = DMI/4% FCM yield
TDN (kg/kg 4% FCM) = TDNI/4% FCM yield
CP (g/kg 4% FCM) = CPI/4% FCM yield
DCP (g/kg 4% FCM) = DCPI/4% FCM yield

Economic efficiency

Economic metrics including feed cost per kg 4% FCM, price of 4% FCM yield and net output were calculated using 2018 prices.

Statistical analysis

One-way ANOVA was used to analyse the data using the General Linear Models (GLM) method, and the following model was developed (IBM SPSS, 2020) for the user's guide:

$$Yij = \mu + xi + e\ ij$$

Where Yij is observation, µ is mean, xi is treatment effect, and eij is experimental error.

Duncan's test was used to measure the degree of significance between treatment means using the SPSS software (P<0.05).

RESULTS

Environmental conditions

Average monthly maximum, lowest environmental temperatures and relative humidity used to compute THI is shown in Table II. Average THI values ranged from 70.88 to 75.82 at night and between 86.10 and 91.59 during the day. suggesting that animals done at day under severe stress during August and September and under moderate stress during July and October and under mild stress at night during July, August and September, but not experiencing HS at night during October. The mean THI values revealed that animals experiencing moderate HS during July, August and September and mild HS during October. These higher THI values demonstrate that the majority of dairy cattle are subject to the adverse effects of HS.

Nutrient's digestion and feeding values

Feeding values and digestibility for different dietary treatments are shown in Table III. The addition of RPN (G2) or VC (G3) and their combination in G4 resulted in significantly increased (P<0.05) digestibility, total digestible nutrients (TDN) and digistible crude protein (DCP) values compared to control (G1). Additionally, when rumen-protected niacin and vitamin C were supplied simultaneously in G4 as compared to individually in G2 and G3, all nutrient digestibilities and feeding values were significantly greater (P< 0.05).

Table II. Maximum and minimum of ambient temperature (AT), relative humidity (RH) and temperature humidity index (THI) during experimental period.

Items		July	August	September	October
AT	Max.	33.7	34.6	34.6	31.5
	Min.	27.3	28.2	27.1	24.6
	Mean	30.45	31.4	30.85	28.05
RH	Max.	84.2	85.3	86.7	84.8
	Min.	51.1	49.7	47.7	47.1
	Mean	67.65	67.50	67.20	65.95
THI	Max.	89.61	91.31	91.59	86.10
	Min.	74.83	75.82	74.14	70.88
	Mean	82.22	83.57	82.87	78.49

Table III. Values of nutrient digestion and feeding for different dietary treatments.

Item	Experimental treatments				SEM	P value
	G1	G2	G3	G4		
Digestion coefficients %						
DM	65.08^c	66.98^b	66.79^b	67.72^a	0.30	0.000
OM	66.62^c	68.76^b	68.52^b	69.93^a	0.36	0.000
CP	62.45^c	64.49^b	64.08^b	65.30^a	0.32	0.000
CF	59.53^c	61.60^b	61.22^b	62.74^a	0.36	0.000
EE	76.13^c	78.58^b	78.25^b	80.34^a	0.50	0.004
NFE	69.24^c	71.40^b	71.25^b	72.63^a	0.38	0.000
Feeding values %						
TDN	62.58^c	64.59^b	64.37^b	65.71^a	0.34	0.000
DCP	7.18^c	7.42^b	7.37^b	7.51^a	0.04	0.000

a, b, c values in the same row with different superscripts are significantly different (*P*<0.05). DM, dry matter; OM, organic matter; CP, crude protien; CF, crude fiber, EE, ether extract; NFE, nitrogen-free extract; TDN, total digestible nutrients; DCP, digistiblecrude protien.

Feed intake

Table IV shows the average daily feed intake for the different dietary treatments. Daily intake of corn silage, concentrate feed mixture and rice straw increased at G1 to 18.33, 9.44 and 3.82 kg, respectively. This increase served to meet the requirement that was due to the increases in milk production. Between the various groups, there were significant differences (P<0.05) in the intake of TDN, DCP, DM and CP. G1 had the lowest intake followed by G2 and G3, while G4 had the highest intake.

Rumen fermentation activity

Rumen fermentation activity for cows in different dietary treatments is presented in Table IV. In comparison to control G1, the ruminal pH value of G4 supplemented with RPN and VC was significantly lower (P <0.05) (6.23 vs. 6.50). As compared to G1 and G4, the rumen pH values in G2 and G3 showed a not insignificant difference between the two groups. With RPN and/or VC additives, ruminal NH3-N concentration declined significantly (P <0.05). G1's rumen liquor had a significantly higher concentration of NH_3-N than G2, G3, or G4's produced (P<0.05). Ruminal total VFA concentration demonstrated an inverse relationship with pH value, with G4 being the highest (P<0.05) TVFA concentration, followed by G2 and G3 while, G1 had the lowest concentration.

Table IV. Feed intake, rumen activity, and biochemical of blood serum of dairy Friesian cows in various group treatments.

Item	Experimental treatments				SEM	P value
	G1	G2	G3	G4		
Feed intake (kg/day, on DM basis)						
As fed basis						
CFM	8.15	8.43	8.35	8.60		
Corn silage	4.89	5.05	4.99	5.25		
Rice straw	3. 26	3.37	3.33	3.44		
Total DM	16.30^c	16.85^b	16.67^b	17.29^a	0.10	0.001
TDN	10.20^c	10.88^b	10.73^b	11.36^a	0.12	0.000
CP	1.87^c	1.94^b	1.92^b	1.99^a	0.01	0.001
DCP	1.17^c	1.25^b	1.23^b	1. 30^a	0.01	0.000
Rumen fermentation parameters						
pH value	6.50^a	6.33^{ab}	6.30^{ab}	6.23^b	0.04	0.152
NH_3-N (mg/100 ml)	13.90^a	12.39^b	12.47^b	12.69^b	0.20	0.002
TVFA's (meq/100 ml)	10.58^c	12.46^b	12.45^b	13.75^a	0.35	0.000
Blood serum biochemical						
Total protein (g/dl)	6.95^b	7.51^a	7.50^a	7.68^a	0.08	0.005
Albumin (g/dl)	3.47	3.42	3.46	3.36	0.04	0.825
Globulin (g/dl)	3.48^b	4.09^a	4.04^a	4.32^a	0.09	0.002
Albumin: Globulin ratio	1.01^a	0.85^b	0.87^b	0.78^b	0.03	0.013
Glucose (mg/dl)	60.00^b	67.89^a	68.89^a	70.67^a	1.45	0.039
Urea-N (mg/dl)	40.33^a	34.89^b	34.44^b	34.00^b	0.99	0.071
Creatinine (mg/dl)	1.07^a	0.97^b	0.94^b	0.96^b	0.02	0.045
AST (u/l)	62.44^a	57.56^b	56.67^b	57.11^b	0.84	0.045
ALT (u/l)	33.11^a	30.00^b	30.44^b	28.22^b	0.67	0.071

a, b, c values in the same row with different superscripts are significantly different (*P*<0.05). See Table III for explanation of all abbreviations used.

Blood serum metabolites

Blood serum biochemical of dairy Frisian cows supplemented with RPN and / or VC are shown in Table IV. With RPN and/or VC supplementation, the globulin, protein and glucose content were increased significantly (P<0.05). Supplementing with RPN, VC, or a mix of both led to significant (P0<.05) decreases in albumin to globulin ratio, urea-N and creatinine concentrations, as well as AST and ALT activity. While serum albumin concentrations were nearly similar in all groups.

Milk yield, milk composition and constituents

Table V shows the milk yield, milk constituent yield, and milk composition for the experimental groups. The highest yield of actual and 4% FCM was recorded by group 4 (P <0.05), followed by groups 2 and 3, and the lowest yield was recorded by group 1. When compared to G1, the actual milk yield in G2, G3, and G4 increased by 5.96, 4.70, and 10.09%, respectively. 8.14, 6.27, and 14.29 % were the comparable figures for 4% FCM.

Table V. Milk yield, milk composition, and constituent's yield for various dietary treatments.

Item	Experimental treatments				SEM	P value
	G1	G2	G3	G4		
Milk yield (kg/day)						
Actual milk	15.95^c	16.90^b	16.70^b	17.56^a	0.13	0.000
4% FCM	15.47^c	16.73^b	16.44^b	17.68^a	0.16	0.000
Milk composition %						
Fat	3.80^c	3.93^b	3.90^b	4.05^a	0.02	0.000
Protein	3.03^c	3.12^b	3.10^b	3.20^a	0.02	0.000
Lactose	4.88	4.92	4.90	4.94	0.01	0.258
SNF	8.64^c	8.76^{ab}	8.74^{bc}	8.86^a	0.02	0.001
TS	12.44^c	12.69^b	12.63^b	12.91^a	0.03	0.000
Ash	0.73	0.72	0.73	0.72	0.004	0.660
Constituent's yield (kg/day)						
Fat	0.61^c	0.66^b	0.65^b	0.71^a	0.007	0.000
Protein	0.48^c	0.53^b	0.52^b	0.56^a	0.006	0.000
Lactose	0.78^c	0.83^b	0.82^b	0.87^a	0.007	0.000
SNF	1.38^c	1.48^b	1.46^b	1.56^a	0.013	0.000
TS	1.98^c	2.14^b	2.11^b	2.27^a	0.020	0.000
Ash	0.116^b	0.122^{ab}	0.122^{ab}	0.126^a	0.001	0.013

a, b, c values in the same row with different superscripts are significantly different (*P*<0.05). FCM, fat corrected milk; SNF, solids not fat; TS, total solids.

Table V shows measurement of milk composition revealing that G4 cows' milk had the greatest percentages of protein, solids not fat, and total solids and fat, whereas G2 and G3 cows had the lowest percentages (P 0<.05). However, supplementing with RPN and/or VC had a negligible (P>0.05) effect on the percentages of lactose and ash and was exactly similar among groups. At the main time, the yield of milk constituents revealed are confirmed with milk yield and G4 recorded significantly (P0.05) the highest milk yield, followed by G2 and G3, while G1 had the lowest yield.

Feed conversion

The effects of RPN and VC supplementation on feed conversion are shown in Table VI. With supplementation RPN and VC, the conversion of CP and DM significantly improved (P <0.05), G4 recording the lowest (P <0.05) amounts of DM and CP required per kg of 4% FCM, followed by G2 and G3. G1 had the greatest amounts. However, addition of RPN and VC had no appreciable (P>0.05) impact on conversion of TDN and DCP, and the amounts of DCP and DCP required per kg of 4% FCM were nearly the same among all groups, with only a negligible (P>0.05) variation.

Economic efficiency

All economic factors varied significantly (P<0.05) among the different dietary treatments (Table VI). G2 and G4 followed G3 being the lowest average daily feed cost. G1 had the highest daily feed cost. In contrast, G2 significantly recorded (P<0.05) the highest feed cost per kg of 4% FCM, followed by G1 and G3, while G4 had the lowest value. However, G4 significantly (P 0.05) revealed the highest output of 4% FCM and net output, as well as improvements in output and net output, with G2 and G3 followed, while G1 had the lowest values. The average daily 4% FCM output for G2, G3, and G4 increased by 8.60, 6.79, and 14.29 % in comparison to G1, respectively. The comparable numbers for net output were 6.89, 9.59, and 19.05%, respectively.

DISCUSSION

These high THI levels show that the majority of dairy cattle are susceptible to the detrimental effects of heat stress. For Holstein cattle, 25°C is the highest critical temperature (Berman, 2010). From May to September, Tunisia suffers heat stress for four to five months, with THI values exceeding 72, according to Ben-Salem and Bouraoui (2009). 25°C was the highest temperature for lactating cows, and relative humidity levels of more than 80% were observed have an indirect impact on the maximum critical temperature (Kume *et al*., 1998). Friesian cows in Egypt had severe heat stress from June to October, THI values ranging from 76.7 to 80.4 (Gaafar *et al*., 2011). This resulted in a 30% reduction in the average daily milk yield.

The THI is a common method for determining the degree of HS in dairy cows. At a THI of 72 and higher, animals start to show symptoms of HS. Stress levels were

Table VI. Feed and economic efficiency for various dietary treatments.

Item	Experimental treatments				SEM	P value
	G1	G2	G3	G4		
Feed conversion						
DM	1.054[a]	1.003[bc]	1.008[b]	0.978[c]	0.010	0.004
TDN	0.660	0.648	0.649	0.643	0.004	0.390
CP	0.121[a]	0.115[bc]	0.116[b]	0.113[c]	0.001	0.004
DCP	0.076	0.074	0.074	0.074	0.0005	0.249
Economic efficiency						
Feed cost (LE/day)	56.79[c]	62.56[a]	59.21[b]	62.45[a]	0.74	0.000
Feed cost (LE/ kg FCM)	3.67[ab]	3.72[a]	3.58[bc]	3.53[c]	0.03	0.023
Output of 4% FCM (LE)	108.29[c]	117.60[b]	115.64[b]	123.76[a]	1.68	0.000
Output improvement %	00[c]	8.60[b]	6.79[b]	14.29[a]	1.54	0.000
Net output (LE)	51.50[c]	55.04[b]	56.43[b]	61.30[a]	1.12	0.000
Net output improvement %	00[c]	6.89[b]	9.59[b]	19.05[a]	2.06	0.000

a, b, c values in the same row with different superscripts are significantly different (P<0.05). Prices of CFM = 4800 LE, corn silage = 680 LE, rice straw = 620, 4% FCM = 7 LE (2018). For abbreviations see Table IV.

classified as mild (72 to 79), moderate (80 to 89), and severe (90 or higher) (Armstrong, 1994; Smith *et al*., 2006).

Growing-fattening calves supplemented with niacin (Mostafa *et al*., 2015), had a significant (P < 0.05) increase in DM and OM digestion coefficients and feeding values (TDN, DCP and DE). Furthermore, according to Luo *et al*. (2019), niacin supplement increased the apparent digestibility of all nutrients in male Chinese Jinjiang cattle (P < 0.05). VC supplementation in laying hens increased (P 0.05) the nutrients' digestibility, according to Sahin *et al*. (2003).

When an animal is exposed to HS, which is described as the state in which the body's physiological processes are activated to maintain the body's thermal homeostasis, this negatively affects a number of variables, including DM intake (Marai and Habeeb, 2010). According to Tag El-Din *et al*. (2008), adding VC to the meal greatly improved the amount of feed that local laying hens consumed. The average daily feed intake of growing children dramatically increased with VC supplementation, according to Abd El-Monem and Kandeil (2011). According to Havlin *et al*. (2017), supplementing dairy cows with niacin significantly increased their daily DM intake from 19.3 to 21.5 kg compared to control.

The study's pH values are within the range suitable for rumen fermentation, and this range's pH has the following impacts on the rumen: All rumen microorganisms grow in a pH range of 6.2 to 7.0, which is neutral to slightly acidic. At ph values below 6.2 and 5.4, which result in the death of fiber-digesting bacteria and the growth of lactic acid bacteria, acidosis occurs (Barber *et al*., 2010). Niacin supplementation has increased the synthesis of microbial proteins (Flachowsky, 1993). Additionally, Niacin supplementation improved rumen fermentation in buffaloes, according to Kumar and Dass (2005), who also found that it increased protein synthesis and decreased ammonia-N concentration.

In contrast to control group, Soliman *et al*. (2020) found that feeding dairy cows' juice from fruits and vegetables that contains active substances such ascorbic acid significantly cut the level of ruminal ammonia-N. Niacin supplementation also caused an increase in ruminal VFA (Doreau and Ottou, 1996). Kumar and Dass (2005) observed a significantly increases (P<0.01) in TVFA concentration when adult buffaloes with rumen fistulas were administered niacin. In comparison to the control, vitamin C nominally increased VFA by 10%, according to Tagliapietra *et al*. (2013).

All serum biochemical concentrations are within the range that is considered normal for cattle (UCDAVIS, 2011). Sayed-Ahmed *et al*. (2018) reported that growing rabbits' aspirate amino transferase (ALT, AST) as well as urea, albumin and protein concentrations significantly increased (P<0.05) after ingesting supplemental ascorbic acid. Additionally, Tag El-Din *et al*. (2008) found that supplementing dietary folic acid and VC significantly increased the blood albumin, globulin and protein concentrations in laying hens (P<0.05) compared with control group. Niacin supplementation led to a significantly increased glucose concentration in the blood of Holstein cows (Karkoodi and Tamizrad, 2009). According to Mostafa *et al*. (2015), rations supplemented with niacin resulted in significantly higher total protein concentrations in the blood serum of Friesian calves.

Minor *et al*. (1998) found that niacin supplementation increased the production of fat-corrected milk with relation to milk yield and composition (FCM, 3.5 %). Additionally, Karkoodi and Tamizrad (2009) reported that cows supplemented with 14 g of niacin per day had significantly higher milk yield and fat-corrected milk. The increase in serum oxytocin level may be responsible for the increases milk production and VC content together. Vitamin C acts as a cofactor in a variety processes, including the peptidyl-gylcine alpha-amidating monooxygenase enzyme's role in promoting oxytocin hormone's synthesis (Epipper *et al*., 1993). Ogweje *et al*. (2019) stated that the increases in blood oxytocin levels may have had an impact on the increase in milk VC supply. Because its function as cofactors for the enzymes required to synthesis amino acids necessary for milk production, water soluble vitamins improve milk yield. Its action as a cofactor to the enzyme peptidyl-gylcine alpha-amidating monooxygenase increasing synthesis the hormone oxytocin is one of the many reactions that Vit C, a water-soluble vitamin, cofactors (Epipper *et al*., 1993). The mother's state of health affects how much milk she can produce. According to studies, stressors can reduce milk synthesis, this increases dopamine and adrenaline levels, which inhibits lactational hormones and reduces milk production by increasing the quantity of reactive oxygen groups in the body (Hassioutou and Geddes, 2012). Inadequate milk let down or supply (hypogalactia) is still being observed as a serious and commonly lactation problem that causes maternal nutrition cessation (Odom *et al*., 2013). Schwab *et al*. (2005) found that niacin increased the amount of milk fat. Niacin supplementation at 14 g/head/day for Holstein cows increased the percentages of protein, solids not fat and total solids in milk (Karkoodi and Tamizrad, 2009). Ghorbani *et al*. (2008) found that Holstein cows given niacin supplements did not exhibit any detectable differences in the amount of lactose in their milk.

The findings of Abou-Elenin *et al*. (2016), who noticed a significant (P<0.05) improvement in feed conversion in buffalo calves as a result of niacin supplementation. For children fed diets supplemented with ascorbic acid, Abd El-Monem and Kandeil (2011) observed that feed conversion increased significantly (P<0.05) during the experimental periods.

The economic findings of our study concur with those of Mostafa *et al*. (2015), who worked with Friesian calves, and Abou-Elenin *et al*. (2016), who found that niacin supplementation increased economic efficiency in buffalo calves. According to Abd El-Monem and Kandeil (2011), the group receiving the ascorbic acid-supplemented diet had the best margin.

CONCLUSION

The findings of this study demonstrated that supplementation rumen protected niacin or vitamin C alone or in combination enhanced feed intake, digestibility, rumen activity, milk yield and composition, feed and economic efficiency in lactating Friesian cows during the summer season when they had exposed to heat stress.

ACKNOWLEDGEMENT

Authors are grateful to the members of Animal Production Department for their support during the study.

Funding

No funding is received for this study.

IRB approval and ethical statement

All experimental procedures were approved by the ethical committee of the Faculty of Agriculture, Kafrelsheikh University, Egypt.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Abd El-Hafeez, A.M., Amin, A.M.S., Ramadan, M.H., Helal, A. and Mohamed, M.Y., 2020. The most applicable physical properties of cervical mucus correlated with high pregnancy rate in Egyptian cows under heat stress conditions. *Adv. Anim. Vet. Sci*., **8**: 122-131. https://doi.org/10.17582/journal.aavs/2020/8.s2.122.131

Abd El-Monem, U.M. and. Kandel, M.A., 2011. Effects of chromium picolinate and ascorbic acid supplementation on growth performance, carcass traits, blood constituents and picture of growing kids under the summer conditions. *BS Vet. Med. J*., 21: 15-21. https://doi.org/10.21608/jvmr.2011.77656

Abou-Elenin, Ebtehag, I.M., Abdou, A.A., Riad, W.A. and Mostafa, M.R.M., 2016. Effect of dietary niacin and/or thiamin supplementations on growth and fattening performance of buffalo calves. *Egypt. J. Nutr. Feeds*, **19**: 415-425. https://doi.org/10.21608/ejnf.2016.74975

AOAC, 1995. *Official methods of analysis*, 16th Ed. Association of Official Analytical Chemists, Washington, DC, USA.

Armstrong, D.V., 1994. Heat stress interaction with shade and cooling. *J. Dairy Sci*., **77**: 2044-2050. https://doi.org/10.3168/jds.S0022-0302(94)77149-6

Barber, D., Anstis, A. and Posada, V., 2010. *Managing for healthy rumen function.* Nutrition Plus, The State of Queensland, DEEDI.

Ben Salem, M. and Bouraoui, R., 2009. Heat stress in Tunisia: Effects on dairy cows and potential means of alleviating it. *South Afr. J. Anim. Sci*., **39**: 256-259. https://doi.org/10.4314/sajas.v39i1.61164

Berman, A., 2010. Forced heat loss from body surface reduces heat flow to body surface. *J. Dairy Sci.,* **93**: 242–248.

Castillo-Gonzáleza, A.R., Burrola-Barrazab, M.E., Domínguez-Viverosb, J. and Chávez-Martínez, A., 2014. Rumen microorganisms and fermentation. *Arch. Med. Vet*., **46**: 349-361. https://doi.org/10.4067/S0301-732X2014000300003

De-Rodas, B.Z., Maxwell, C.V., Davis, M.E., Mandali, S., Broekman, E. and Stoecker, B.J., 1998. L-ascorbyl-2-polyphosphate as a vitamin C source for segregated and conventionally weaned pigs. *J. Anim. Sci*., **76**: 1636-1643. https://doi.org/10.2527/1998.7661636x

Doreau, M. and Ottou, J.F., 1996. Influence of niacin supplementation on In-vivo digestibility and ruminal digestion in dairy cows. *J. Dairy Sci*., **79**: 2247-2254. https://doi.org/10.3168/jds.S0022-0302(96)76601-8

Epipper, B.A., Milgram, S.L., Husten, J.E., Yun, H.Y. and Mains, R.E., 1993. Peptidylglycine α-amidating monooxygenase: A much functional protein with catalytic processing and routing domains. *Protein Sci*., **2**: 489-497. https://doi.org/10.1002/pro.5560020401

Flachowsky, G., 1993. Niacin in dairy and beef cattle nutrition. *Arch. Anim. Nutr*., **43**: 195-213. https://doi.org/10.1080/17450399309386036

Gaafar, H.M.A., El-Gendy, M.E., Bassiouni, M.I., Shamiah, S.M., Halawa, A.A. and Abu El-Hamd, M.A., 2011. Effect of heat stress on performance of dairy Friesian cows 1- milk production and composition. *Researcher*, **3**: 85-93.

Gaines, W.L., 1928. The energy basis of measuring milk yield in dairy cows. *Illinois Agric. Exp. Stat. Bull*., **308**. University of Illinois, Urbana.

Ghorbani, B., Vahdani, N. and Zerehdaran, S., 2008. Effects of niacin on milk production and blood parameters in early lactation of dairy cows. *Pak. J. biol. Sci*., **11**: 1582-1587. https://doi.org/10.3923/pjbs.2008.1582.1587

Ghosh, C.P., Keesh, S.S., Tudu, N.K. and Datta, S., 2017. Heat stress in dairy animals, its impact and remedies: A review. *Int. J. Pure appl. Biosci*., **5**: 953-965. https://doi.org/10.18782/2320-7051.2577

Hassioutou, F. and Geddes, D., 2012. Anatomy of the human mammary gland: Current status of knowledge. *Clin. Anat*., **26**: 29-48. https://doi.org/10.1002/ca.22165

Havlin, J.M., Robinson, P.H. and Garrett, J.E., 2017. Niacin feeding to fresh dairy cows: Immediate effects on health and milk production. *Anim.Prod/Sci*., **57**: 1069–1078.

IBM SPSS Statistics, 2020. *Statistical package for the social sciences*. Release 27, SPSS INC, Chicago, USA.

Karkoodi, K. and Tamizrad, K., 2009. Effect of niacin supplementation on performance and blood parameters of Holstein cows. *S. Afr. J. Anim. Sci*., **39**: 349-354. https://doi.org/10.4314/sajas.v39i4.51128

Kibler, H.H., 1964. Environmental physiology and shelter engineering. LXVII. Thermal effects of various temperature-humidity combinations on Holstein cattle as measured by eight physiological responses. *Res. Bull. Missouri Agric. Exp. Stat*. **862**.

Kumar, R.D. and Dass, R.S., 2005. Effect of niacin supplementation on rumen metabolites in Murrah buffaloes (*Bubalus bubalis*). *Asian Austral. J. Anim. Sci*., **18**: 38–41. https://doi.org/10.5713/ajas.2005.38

Kume, S., Tohamat, T. and Kobavashi, N., 1998. Effect of restricted feed intake of dams and heat stress on mineral status of newborn calves. *J. Dairy Sci.,* **81**: 1581-1590.

Luo, D., Gao, Y., Lu, Y., Zhang, Q., Qu, M., Xiong, X., Xu, L., Zhao, X., Pan, K. and Ouyang, K., 2019. Niacin supplementation improves growth performance and nutrient utilisation in Chinese Jinjiang cattle. *Ital. J. Anim. Sci*., **18**: 57-62. https://doi.org/10.1080/1828051X.2018.1480426

Lykkesfeldt, J. and Svendsen, O., 2007. Oxidants and antioxidants in disease: Oxidative stress in farm animals. *Vet. J*., **173**: 502–511. https://doi.org/10.1016/j.tvjl.2006.06.005

Marai, I.F.M. and Habeeb, A.A.M., 2010. Buffalo›s biological functions as affected by heat stress-A review. *J. Livest. Sci.,* **127**: 89- 109.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. and Morgan, C.A., 1995. *Animal nutrition*. 5th Ed., Copyright licensing LTD., London.

McKee, J.S. and Harrison, P.C., 1995. Effects of supplemental ascorbic acid on the performance of broiler chickens exposed to multiple concurrent stressors. *Poult. Sci*., **74**: 1772–1785. https://doi.org/10.3382/ps.0741772

Miller, J.K. and Brezezinska-Slebodzinska, E., 1993. Oxidative stress, antioxidants and animal function. *J. Dairy Sci*., **76**: 2812–2823. https://doi.org/10.3168/jds.S0022-0302(93)77620-1

Minor, D.J., Trower, S.L., Strang, B.D., Shaver, R.D.

and Grummer, R.R., 1998. Effects of nonfiber carbohydrate and niacin on periparturient metabolic status and lactation of dairy cows. *J. Dairy Sci.,* **81**: 189-200.

Mostafa, M.R.M., Abou-Elenin, Ebtehag, I.M., Abdou, A.A. and Riad, W.A., 2015. Effect of thiamin or niacin supplementation into the rations of growing fattening calves on their productive performance. *Egypt. J. Nutr. Feeds*, **18**: 373- 382. https://doi.org/10.21608/ejnf.2015.105823

NRC, 2001. *Nutrient requirements of dairy cattle*. 7th revised ed. National Research Council, National Academy Press, Washington, D.C., USA.

Odom, E.C., Li, R. and Scanlon, K.S., 2013. Reasons for earlier than desired cessation of breastfeeding. *Paediatrics*, **131**: 726-732. https://doi.org/10.1542/peds.2012-1295

Ogweje, A.E., Bako, I.G. and Akor-Dewu, M.B., 2019. Evaluation of milk yield and some lactogenic hormones in lactating Wistar rats after treatment with ascorbic acid and α-tocopherol. *J. Afr. Assoc. Physiol. Sci*., **7**: 38-43.

Padilla, L., Matsui, T., Kamiya, Y., Kamiya, M., Tanaka, M. and Yano, H., 2006. Heat stress decreases plasma vitamin C concentration in lactating cows. *Livest. Sci*., **101**: 300–304. https://doi.org/10.1016/j.livprodsci.2005.12.002

Panda, S., Panda, N., Panigrahy, K.K., Gupta, S.K., Mishra, S.P. and Laishram, M., 2017. Role of niacin supplementation in dairy cattle: A review. *Asian J. Dairy Fd. Res*., **36**: 93-99. https://doi.org/10.18805/ajdfr.v36i02.7949

Sahin, K., Onderci, M., Sahin, N., Gursu, M.F., and Kucuk, O., 2003. Dietary vitamin C and folic acid supplementation ameliorates the detrimental effects of heat stress in Japanese quail. *J. Nutr*., **133**: 1882–1886. https://doi.org/10.1093/jn/133.6.1882

Sayed-Ahmed, I.E., Abd El-Monem, U.M., Al-Sagheer, A.A. and Khalil, B.A. 2018. Effect of ascorbic acid supplementation on performance of growing rabbits under Egyptian conditions. *Zagazig J. Agric. Res.,* **45**: 263-273.

Schneider, B.H. and Flat, W.P., 1975. *The evaluation of feeds through digestibility experiments*. The University of Georgia Press, Athens. pp. 423.

Schwab, M.A., Kolker, S., Van Den Heuvel, L.P., Sauer, S., Wolf, N.I., Rating, D., Hoffmann, G.F., Smeitink, J.A. and Okun, J.G., 2005. Optimized spectrophotometric assay for the completely activated pyruvate dehydrogenase complex in fibroblasts. *Clin. Chem*., **51**: 151–160. https://doi.org/10.1373/clinchem.2004.033852

Smith, T.R., Crouch, J., Riley, T., Pogue, D., Williams, R.J., Chapa, A., Willard, S. and Herndon, C., 2006. Evaporative tunnel cooling of dairy cows in the southeast. I: Effect on body temperature and respiration rate. II: Impact on lactation performance. *J. Dairy Sci*., **89**: 3904-3923. https://doi.org/10.3168/jds.S0022-0302(06)72433-X

Soliman, S.M., Hassan, A.A., Bassuony, Neamat I. and El-Morsy, A.M., 2020. Effect of biological extract supplementation on milk yield and rumen fermentation in dairy cows. *Int. J. Dairy Sci*., **15**: 88-98. https://doi.org/10.3923/ijds.2020.88.98

St-Pierre, N., Cobanov, B. and Schnitkey, G., 2003. Economic losses from heat stress by US livestock industries. *J. Dairy Sci*., **86**: E52-E77. https://doi.org/10.3168/jds.S0022-0302(03)74040-5

Tag El-Din, T.E.H., Hassan, R.H., El-Samra, Abo-Egla and Hanaa, A.B., 2008. Effects of vitamin C and/or folic acid supplementations in alleviating the negative effects of heat stress in local laying hens. *Egyptian J. Anim. Prod.,* **45** (Suppl. Issue): 333-346.

Tagliapietra, F., Cattani, M., Hansen, H.H. and Bittante, G., 2013. High doses of vitamin E and vitamin C influence in vitro rumen microbial activity. *Anim. Feed Sci. Technol*., **183**: 210-214. https://doi.org/10.1016/j.anifeedsci.2013.05.010

Tanaka, M., Kamiya, Y., Suzuki, T., Kamiya, M. and Nakai, Y., 2008. Relationship between milk production and plasma concentrations of oxidative stress markers during hot season in primiparous cows. *Anim. Sci. J*., **79**: 481–486. https://doi.org/10.1111/j.1740-0929.2008.00553.x

UCDAVIS, 2011. *Clinical chemistry reference intervals*. Veterinary Medical Teaching Hospital. University of California, Davis, USA.

Van Keulen, J. and Young, B.A., 1977. Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. *J. Anim. Sci*., **44**: 282-287. https://doi.org/10.2527/jas1977.442282x

Van Soest, P.J.; Robertson, J.B. and Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci*., **74**: 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Warner, A.C.I., 1964. Production of volatile fatty acids in the rumen, methods of measurement. *Nutr. Abst. Rev*., **34**: 339.

Zimbelman, R.B., Collier, R.J. and Bilby, T.R., 2013. Effects of utilizing rumen-protected niacin on core body temperature as well as milk production and composition in lactating dairy cows during heat stress. *Anim. Feed Sci. Technol*., **180**: 26-33. https://doi.org/10.1016/j.anifeedsci.2013.01.005