Bulgarian Journal of Agricultural Science, 20 (No 4) 2014, 915-923
Agricultural Academy

EFFECTS OF FEEDING METHODS, SEASON AND PRODUCTION LEVEL ON LACTATION PERFORMANCE AND FEEDING BEHAVIOUR OF DAIRY COWS

M. BOGA[1*], M. GORGULU[2] and A. SAHIN[3]
[1] *Nigde University, Bor Vocational High School, 51700 Nigde, Turkey*
[2] *Cukurova University, Agriculture Faculty, Department of Animal Science, 01330 Adana, Turkey*
[3] *Ahi Evran University, Agriculture Faculty, Department of Animal Science, 40100 Kırsehir, Turkey*

Abstract

BOGA, M., M. GORGULU and A. SAHIN, 2014. Effects of feeding methods, season and production level on lactation performance and feeding behaviour of dairy cows. *Bulg. J. Agric. Sci.,* 20: 915-923

The present study was conducted to investigate the effects of feeding methods, season and production level on lactational performance and feeding behaviour of dairy cows. Twenty Holstein Friesian cows having 513 kg liveweight, 140 DIM, 25 kg milk/d for summer and the same number of cows having 543 kg live weight, 121 DIM, and 28 kg/d for winter were allocated 4 experimental groups consisting of 2 feeding methods (single feeding and choice feeding) and 2 production levels(low:~21 kg/d and high:~29 kg/d) combinations in a factorial arrangement. Single diet(TMR) was formulated with barley, corn, soybean meal, corn gluten meal, wheat bran and alfalfa hay grounded in 1.5-2 cm size with 60/40 concentrate/roughage ratio. These feed ingredients were offered to choice-fed cows ad libitum seperately and simultaneously. Choice-fed cows made diets containing less alfalfa hay and corn, and more barley than those fed single diet. High yielding cows preferred more barley than those of TMR compared to low yielding cows. Choice fed cows had lower dry matter intake and fat corrected milk than those fed with single diet. Nutrient intakes were lower for choice fed cows than those fed with TMR due to lower feed intake. Milk fat and milk urea level were lower for choice fed cows than those fed TMR. Milk protein contents were decreased as milk production increased. Season affected significantly milk yield, feed intake (as a percentage of body weight), milk yield & live weight changes and 4% FCM yield. These changes influenced the intakes of dry matter and nutrients, eating patterns and, consequently, the nutrient requirements of dairy cows in both production levels and seasons. The results revealed that choice fed cows changed their diet selection according to the changed season and milk yield but this did not affect milk yield positively.

Key words: feeding methods, milk production, eating patterns, heat stress

Introduction

Milk production of cow continues to increase after calving, with an increase in energy demand in early lactation. Adequate energy intake can prevent ketosis and hepatic lipidosis, allowing higher reproductive performance. Man made diets, ie, single diets (TMR) do not match always with the physiological requirements of dairy cows. Furthermore, microbial protein synthesis may not fulfil the essential amino acid requirements of dairy cow in early lactation since it depends on synchronization of available fermentable energy and degradable protein in the rumen (Hoover and Stokes, 1991). Diets or feeding methods allowing nutrient supply in a synchronized manner to ruminal microorganism may improve microbial growth in the rumen and also improve the utilization of dietary energy and/or protein in a harmony to get a reasonable performance.

It has been well studied that farm animals in choice feeding condition are able to select nutritionally balanced diet, corresponding to their physiological status, and consume high amount of concentrate without suffering any digestive problem by balancing fiber intake and creating of a synchronicity among feed ingredients in respect to energy and nitrogen supply to the rumen and/or host animal (Gorgulu et al., 1996; Fedele et al., 2002; Gorgulu et al., 2003; Yurtseven and Gorgulu, 2004; Gorgulu et al., 2008), except dairy cows.

Dairy cows, especially high yielding, are more sensitive to hot climate. Their feed intake and immunological function

* E-mail: mboga@nigde.edu.tr

will decrease when heat stress occurred (Kumar *et al.,* 2011) with changing their physiological status (Bernabucci et al., 2010; Farooq et al., 2010). These changes generally decrease milk production. However, some management techniques such as shading and cooling (West, 2003), night feeding (Ominski et al., 2002), concentrate feeding (Rhoads et al., 2009) and dietary bypass fat supplementation (Moallem et al., 2010) allow animal to optimize their nutrient utilization, microbial protein synthesis and improve animal performance during heat stress. However, there has been a lack of information on literature regarding "How does choice feeding help high yielding dairy cows' overcome the negative consequences of seasons (summer or winter)". Therefore, the present study aimed to monitor lactation performance and feeding behaviour of dairy cows subjected to different feeding methods in different milk production level and season.

Material and Method

The study was carried out to test the effects of feeding method, milk yield, milk composition and season on feeding activities of dairy cows. Therefore, two studies were carried out to point out the season (winter and summer) effects. Winter experiment was carried out in January, February and March. Summer experiment was carried out from June to July.

In each season, 20 Holstein Frisian dairy cows were allocated into four experimental groups with 5 replicates. Each cow was housed in a 3 m x 6 m sized pen having one trough automatic drinker for fresh water. The cows used in winter and summer seasons had 542 and 513 kg live weight, 2.6 and 2.9 body condition score, 3 and 2 lactation number, 120 and 140 DIM, respectively. The cows used in winter normally had higher milk yield than summer cows (33 kg vs 28 kg/d for high yielding and 24 kg vs 21 kg/d low yielding at the beginning of the study).

Cows were kept in 3x6 m individual pen with 3 m feed bunk and with closed roof. Feed troughs of animals in choice feeding groups were divided into six equal parts to offer feed ingredients separately but simultaneously. The study lasted totally 6 weeks; all cows were accustomed to experimental unit and high concentrate feed for the first two weeks. Normally, training period is required for choice-fed animals to habituate organoleptic properties and metabolic consequences of feed ingredients. Therefore, all feed ingredients wheat bran, alfalfa hay, soya bean meal, barley, corn and corn gluten meal were offered to choice fed cows *ad libitum* simultaneously at the beginning of experimental period together with the TMR groups. Each feed ingredient, except alfalfa hay, was mixed with limestone, salt and vitamin-mineral mixture as much as what present in the TMR in order to ensure the micronutrients intakes of choice does and, also, to prevent any possible effect of micronutrients on feed selection.

A computerized system was established to observe daily feeding pattern of cows in the study and 5 cows from TMR and 5 cows from choice fed groups (3 high yielding and 2 low yielding) were monitored in the system for 24 h during four weeks experimental period.

To record diurnal eating pattern of cows, a computerized recording system was developed and set up including 40 balances having 75 ± 0.02 kg capacities and connected a computer with serial multiplier. Data related to meal pattern were recorded with 5 electronic scales for 5 TMR cows and 6 scales for each cows in 5 choice-fed cows, total 30 scales connected computer via serial multiplier and special card designed having RS232 multiplier and data decoding and encoding capabilities (Figure 1). System recorded visit length (beginning date-time and ending date-time for visit) and meal size (beginning weight and ending weight) for each balance with getting stability after 5-10 seconds and 60 g feed consumed from the balance feeder for 24 h during 4 week study. Data were managed by a special program coded in Visual Basic that operating on a SQL database.

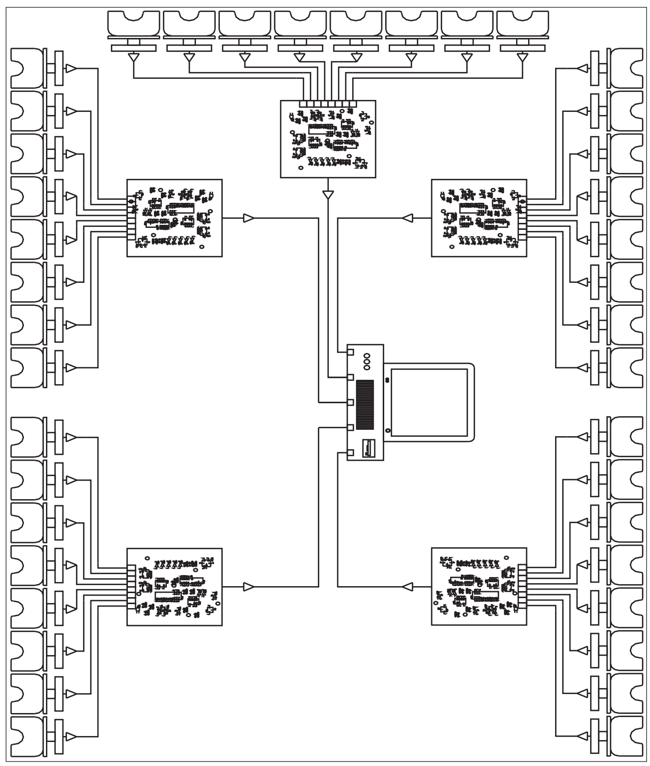

Fig. 1. Computerized feeding system including 8 communication and data processing cards with RS232 port and 40 scale feeders

Meal criteria was determined from data collected from the cows fed different feeding methods (Summer-TMR-Low yielding 2 cows: 8052 records, Summer-TMR-high yielding 3 cows: 15065 records, Summer-low yielding choice-fed 2 cows: 5817 records, Summer-high yielding choice fed 3 cows:11962 records, Winter-TMR-low yielding 2 cows: 5198 records, Winter -TMR-high yielding 3 cows: 8596 records, Winter-low yielding choice-fed 2 cows: 7209 records, Winter-high yielding choice fed 3 cows: 9086 records). Meal criteria were calculated as the point at which the probability density functions of the final two populations cross from the parameters of the two and three-population Gaussian models which minimizes the mis-assignment of intervals to the wrong populations (Tolkamp et al., 1998; Tolkamp and Kyriazakis, 1999; Yeates et al., 2001). The models were fitted using nonlinear curve fitting to the pooled and $\log_e$-transformed interval lengths (expressed in second) between feeding events.

The model consisting of two Gaussians each of which describes the frequency distribution of the $\log_e$-transformed lengths of a population of intervals follows as:

$$ylog(t)=p*(1/(\sigma1\sqrt{2\pi}))*\exp(-(\log(t)-\mu1)2/2\sigma12)+(1-p)*(1/(\sigma2\sqrt{2\pi}))*\exp(-(\log(t)-\mu2)2/2\sigma22)$$

to be used in estimation of meal criteria. Where ylog(t) is the probability density at log(t), p is proportion of intervals belonging to the first distribution, σ1 and σ2 are standard deviations of the first and second distribution, log(t) is natural logarithm of interval length (expressed in seconds), μ1 and μ2 are the mean log (interval length) of the first and second distribution. Models were fitted with a maximum likelihood procedure. Meal criteria (min) was calculated as 14.23 and 24.28 for low and high yielding TMR cows in winter, 10.44 and 14.00 for low and high yielding choice fed cows in winter, 17.56 and 8.46 for low and high yielding TMR cows in summer, 21.96 and 7.58 for low and high yielding choice fed cows in summer.

Chemical compositions of feed ingredients were determined according to the standard AOAC (1998). NDF and ADF were analyzed by using ANKOM fiber analyzer (Van Soest et al., 1991). Ingredient composition of single fed diet and its chemical content are given in Table 1.

Live weight change, milk yield and feed intake were determined weekly. Animals were milked at 05:00 in the morning and at 17:00 in the afternoon and milk samples were taken from morning and afternoon milk and analysed by Milkoscan FT-120 (Foss, DK) and composition was recalculated according to portion of morning and afternoon milk in total milk.

Table 1
Nutrient contents of feed ingredient used in winter-summer season (%)

Feed ingredients	DM	CP	ADF	NDF	Crude ash	Ether extract
Corn	87.65-89.89	8.88-6.96	3.58-3.12	10.61-6.34	3.01-2.36	1.56-1.41
Barley	90.65-90.61	12.11-11.14	6.10-7.26	17.16-19.02	4.60-5.29	1.36-0.65
Wheat bran	90.44-90.23	15.86-15.61	12.50-14.23	37.82-25.99	6.84-10.86	3.28-1.20
Soybean meal	90.06-91.31	42.89-40.34	7.38-6.75	10.28-11.49	7.88-8.16	1.51-1.20
Corn gluten meal	91.83-92.54	60.47-59.64	3.79-3.31	5.93-3.92	5.80-4.97	1.89-2.34
Alfalfa hay	91.83-93.24	13.12-11.60	46.79-39.28	54.87-45.25	6.70-7.63	0.87-0.80

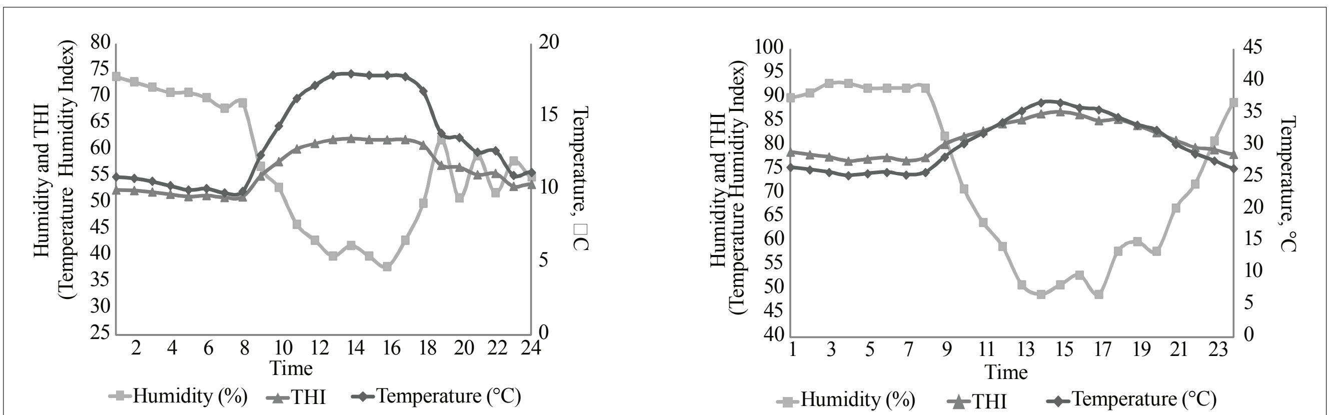

Fig. 2. Humidity and Temperature Humidity Index in experimental unit (winter, summer)

Rectal temperature was recorded using a digital thermometer by inserting 6-8 cm into the rectum. Respiration rate was determined visually by counting number of breaths per min. Heart rate below left elbow was also recorded by a stethoscope. Rectal temperature, heart and respiration rates were taken at 10:00 to 15:00 during the 10th day of adaptation, and on 3rd and 5th days of the data collection periods by trained person. Ambient temperature and relative humidity were recorded 24 h per day with 1 h interval by a data logger (Hobo H8 Family, Onset Computer Corporation's Boxcar) during the studies. Temperature-humidity index (Figure 2) was calculated by the equation as following:

THI=0.8 x Dry-Bulb Temp.°C+(Relative Humidity/100)x(Dry-Bulb Temp.°C-14.3)+46.3 (Lefcourt and Schmidtmann, 1989).

Data were analysed in 2x2x2 factorial arrangement to investigate the effects of season (winter, summer), feeding method (single feeding, choice feeding) and production level (low, high) on lactation performance and feeding behaviour of dairy cows by using GLM procedure of SPSS (Windows version of SPSS, release 13.0). Difference between the diets selected by the cows in different season was separated by t-test while the difference between TMR and the diets selected by cows was compared by using One-Sample t-test.

Results and Discussion

During experimental period, both in winter and summer, cows were monitored to obtain the data regarding lactation performance and feeding behaviour in order to understand the responses of low and high producing cows fed a single diet and offered feed ingredients in choice feeding. For obtaining data, our methodologies were familiar to what mention in the detailed review of Meier et al. (2012).

Table 2
The diets selected by dairy cows (as fed, %)

Feeding methods (FM)	Single feeding		Choice feeding				SEM	Effects (P<)		
Season (S)	Winter	Summer	Winter		Summer					
Production level (PL)			Low	High	Low	High		S	PL	SxPL
Corn	10.2		7.1	11.8	1.0**	2.0**	1.65	0.04	0.43	0.60
Barley	22.3		53.4**	42.0	37.5**	54.0**	3.79	0.81	0.75	0.10
Wheat bran	15.1		6.8*	11.2	28.8*	10.2	2.09	0.03	0.13	0.02
Soybean meal	9.3		0.9**	1.5**	2.6**	0.9**	0.36	0.49	0.52	0.15
Corn gluten meal	2.1		5.7	7.0	2.7	0.8	0.79	0.01	0.87	0.36
Alfalfa hay	40.0		26.1**	26.5**	27.4**	31.9**	1.00	0.13	0.27	0.34
Premix¥	1.1¥¥									
Nutrient composition (DM basis)										
	Winter	Summer	Low	High	Low	High	SEM	S	PL	SxPL
DM, %	90.8	91.7	90.8	90.7	91.3**	91.4**	0.05	0.00	0.99	0.21
ME, Mcal/kg	2.3	2.3	2.4**	2.4**	2.3*	2.4**	0.01	0.00	0.69	0.31
CP, %	16.5	15.2	15.4	16.3	14.6	12.3**	0.45	0.02	0.48	0.13
ADF,%	23.1	20.5	16.9**	17.2**	17.9**	18.1**	0.41	0.29	0.78	0.96
NDF, %	33.6	28.1	27.2**	27.8*	27.5	27.7	0.42	0.96	0.69	0.84
Crude ash,%	6.9	8.0	5.3**	5.3**	7.6	6.6**	0.11	0.00	0.06	0.03
Ether extract,%	1.5	0.9	1.4	1.5	0.9	0.8*	0.03	0.00	0.80	0.07

¥ All feed ingredients except alfalfa hay were supplemented with 0.75% salt, 0.88% limestone, and 0.17 % mineral-vitamin mixture providing 8.000.000 IU vitamin A ,1.000.000 IU vitamin D3, 30.000 mg vitamin E, 50.000 mg Mn, 50.000 mg Zn, 50.000 mg Fe, 10.000 mg Cu, 150 mg Co, 800 mg I and 150 mg Se per kg. Each supplement increased 1.67 times due to dilution of alfalfa preferences.
* Difference between TMR and the diets selected by cows are significantly important at P<0.05.
** Difference between TMR and the diets selected by cows are significantly important at P<0.01.

The obtained results are presented in Tables 2 and 3 and Figure 3.

Feeding behaviour

The diets selected by cows having different production levels in different seasons are presented in Table 2 while eating patterns are illustrated in Table 3. Also, time dependent dietary choices of choice fed cows are shown in Figure 3. In summer, choice fed cows decreased corn and corn gluten meal and increased wheat bran in their diet compared to winter ($P<0.05$). Above all, choice fed cows preferred less alfalfa hay compared to single fed cows; therefore, they need to decrease acidogenic effect of their selected diets by choosing wheat bran. Coppock and West (1986) found out that when forages and concentrates were fed separately, heat-stressed cows reduce fiber intake by reducing hay intake. Furthermore, nutrient contents of wheat bran are better than alfalfa hay (Table 1). Likewise, Kaya (2011) found out that Awassi lambs kept outdoor preferred more wheat bran in order to get rid of the negative consequences of heat stress. Choice fed cows decreased soya bean meal in their diet about ten times than those fed single diet, except low producing cows in summer (Table 2).

These cows decreased soya bean meal about 5 times compared to single fed cows. In winter, choice fed cows increased corn gluten meal about three times compared to single fed cows. But, in summer, high producing choice fed cows decreased corn gluten meal about three times compared to low producing choice fed cows (Table 3, Figure 3).

Choice fed cow's decreased corn (1.05-7.11%) in their diet in both season compared to single fed cows (10.20 %), except high producing cows (11.82 %) in winter. Choice fed cows increased barley (37.50-54.05 %) compared to single fed cows (22.30%). Low producing choice fed cows made a diet containing less barley (37.5 %) than high producing cows (54 %) in summer.

On the contrary, high producing choice fed cows made a diet containing less barley (42.0 %) than those of low producing cows (53.4 %) in winter. High preferences to barley instead of corn could be explained high need to readily available energy for rumen microorganism and/or host animal. Lower soya bean meal preferences may be related to avoid of high ruminal amonia level due to its high ruminal degradable protein content (Table 2).

The high yielding cows preferred less barley in winter but more barley in summer as they decreased feed intake in summer. High yielding cows made diets containing higher protein content than those of low yielding cows in winter, but they decreased protein content in their diet in summer. It is well known that excess protein intake may increase heat production in the body in summer. High producing cows in choice feeding made a diet including less crude protein content. Decrease in corn and corn gluten meal in summer in the diet selected by choice fed cows was compensated by barley and wheat bran consumption of these cows. High-energy contents of the diets selected by cows are a reflection of innate effort of cows to compensate reduction in feed intake as well.

In winter, low producing cows preferred dominantly alfalfa hay and corn while high producing cows preferred corn gluten meal and alfalfa hay. In summer, low producing cows dominantly preferred corn gluten meal and wheat bran while high producing cows preferred barley and corn gluten meal (Figure 3).

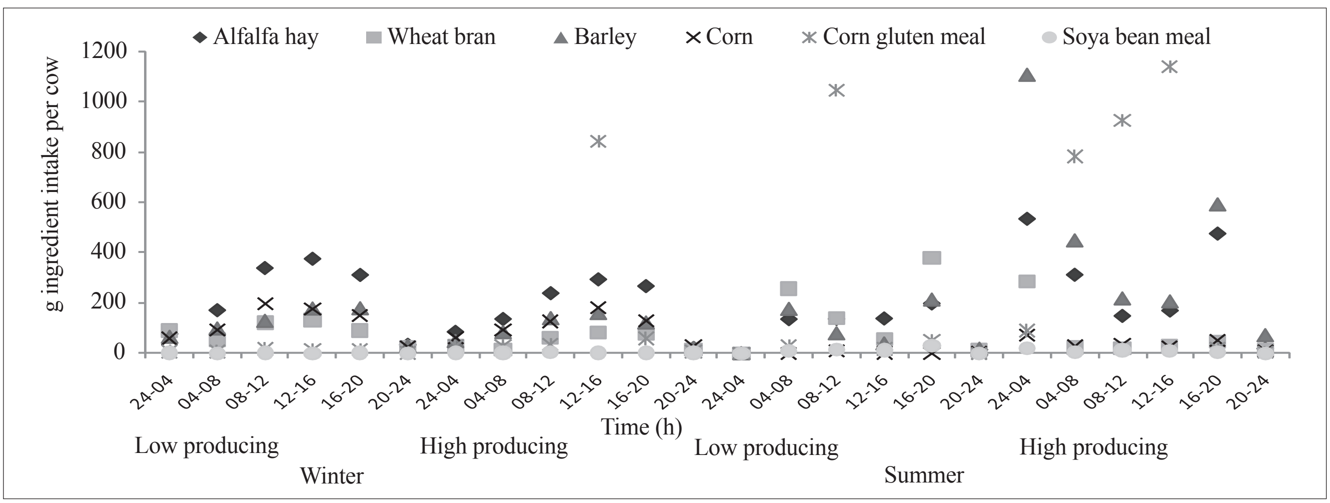

Fig. 3. Time dependent feed ingredient intake of choice fed cows in summer and winter

Table 3
The effects of season, feeding methods and production level on performance, milk composition, eating patterns and some physiological parameters of dairy cows.

Season(S)		Winter				Summer				SEM	P values						
Feeding Method (F)		Single Feeding		Choice Feeding		Single Feeding		Choice Feeding									
Production level (P)		Low	High	Low	High	Low	High	Low	High		S	F	P	S*F	S*P	F*P	S*F*P
Performance per cow	Live weight change, kg	27.5	20.2	24.4	25.9	3.2	7.7	-1.4	2.89	2.89	0.00	0.29	0.59	0.18	0.92	0.82	0.24
	Changes in milk yield, kg	-1.23	-2.29	-0.09	0.59	-4.64	-6.03	-6.56	-6.87	0.56	0.00	0.72	0.56	0.06	0.71	0.43	0.85
	Milk yield, kg/day	23.92	32.06	24.21	32.94	16.58	23.59	15.45	21.91	0.60	0.00	0.66	0.00	0.30	0.37	0.99	0.77
	Feed intake, %	4.08	4.22	3.75	3.99	3.06	3.36	2.87	2.97	0.05	0.00	0.00	0.02	0.97	0.94	0.76	0.38
	BCS	2.80	2.83	3.35	2.98	3.26	2.88	2.89	2.77	0.08	0.76	0.66	0.10	0.02	0.73	0.78	0.19
	4% FCM, kg/day	20.6	29.3	18.0	25.6	15.6	20.2	13.2	18.0	0.44	0.00	0.00	0.00	0.53	0.02	0.73	0.66
	Dry matter intake kg/day	19.8	23.3	20.0	21.3	14.8	15.0	12.7	13.0	0.34	0.00	0.01	0.02	0.29	0.05	0.35	0.32
	Feed intake/Milk yield	0.92	0.82	0.93	0.73	0.99	0.70	0.92	0.65	0.03	0.42	0.26	0.00	0.80	0.11	0.64	0.51
	ME intake, Mcal/day	49.5	58.1	53.8	57.0	36.7	37.1	32.3	33.5	0.20	0.00	0.39	0.03	0.06	0.08	0.43	0.29
	CP intake, kg/day	3.6	4.2	3.3	3.7	2.5	2.5	2.0	1.8	0.08	0.00	0.00	0.15	0.41	0.02	0.29	0.87
	ADF intake, kg/day	5.0	5.9	3.7	4.1	3.3	3.4	2.5	2.6	0.10	0.00	0.00	0.04	0.02	0.07	0.49	0.44
	NDF intake, kg/day	7.3	8.6	6.0	6.6	4.5	4.6	3.9	3.9	0.13	0.00	0.00	0.03	0.03	0.05	0.42	0.40
Milk composition, %	Fat	3.1	3.4	2.4	2.6	3.6	3.0	2.9	2.8	0.12	0.21	0.00	0.84	0.09	0.35	0.73	0.39
	Protein	3.4	3.2	3.5	3.1	3.3	2.9	3.4	2.8	0.05	0.02	0.86	0.00	0.15	0.95	0.31	0.66
	Lactose	4.6	4.7	4.7	4.9	4.6	4.7	4.6	4.8	0.03	0.25	0.05	0.02	0.77	0.49	0.46	0.80
	Casein	2.7	2.6	2.8	2.5	2.6	2.3	2.7	2.3	0.04	0.01	0.94	0.00	0.11	1.00	0.43	0.58
	Urea, mg/dL	49.1	56.5	41.7	44.7	50.8	53.1	46.4	41.5	1.90	0.98	0.01	0.51	0.28	0.79	0.34	0.81
Eating pattern per cow	Meal number	8.4	7.1	9.0	8.2	7.9	13.4	7.6	13.1	1.12	0.00	0.21	0.00	0.01	0.00	0.47	0.56
	Meal size, kg/meal	2.7	3.7	2.8	3.3	2.1	1.3	1.6	1.3	0.32	0.00	0.00	0.46	0.36	0.00	0.90	0.00
	Meal length, min	54.4	73.6	51.4	53.2	27.0	16.3	30.2	20.2	7.58	0.00	0.00	0.95	0.00	0.00	0.00	0.00
	Intermeal interval, min	110.7	123.6	90.4	95.1	142.0	91.8	134.2	79.4	15.30	0.02	0.00	0.00	0.01	0.00	0.26	0.76
	Total meal time, min	428.4	500.9	420.7	417.7	198.1	215.4	233.3	256.6	52.23	0.00	0.71	0.00	0.00	0.46	0.07	0.04
	Eating rate in meal, g/min	119.7	76.2	148.4	362.0	102.2	108.4	135.5	123.7	159.41	0.05	0.00	0.17	0.03	0.14	0.04	0.02
Physiologic responses	Respiration rate	38.1	36.6	39.3	37.8	106.5	94.5	98.6	90.3	1.83	0.00	0.41	0.05	0.22	0.14	0.75	0.75
	Heart rate	94.8	89.7	95.7	99.9	77.4	75.7	69.4	72.6	1.63	0.00	0.99	0.95	0.04	0.81	0.18	0.67
	Rectal temperature	38.3	38.0	38.2	38.3	39.3	39.5	39.3	39.9	0.07	0.00	0.19	0.21	0.70	0.02	0.12	0.96

S: Season, FM: Feeding methods, PL: Production level

Although the choice fed cows decreased ADF and NDF content of their diets (Table 2) by decreasing alfalfa hay preference, they did not suffer acidosis and did not show any sign of acidosis since these cows decreased their feed intake significantly in both seasons (P<0.01). The previous studies revealed that ruminants arrange their choice in order to optimize their rumen condition and minimize nutrient deficiency in the rumen (Forbes, 2001).

Irrespective to production level, cows increased meal size in winter but decreased meal size in summer (P<0.01, Table 3). Experimental cows had might tried to avoid extra heat load by decreasing meal size in summer. On the other hand, the reduced milk yield in summer cows also may have lowered the nutrient requirements of these cows during summer.

In summer, irrespective to production level, choice fed cows decreased eating rate (P<0.01), meal size and meal length compared to winter (P<0.01) (Table 2). The best known effect of heat stress is the reduced appetite (Silanikove, 2000) as shown in our study. Decrease in meal size in choice fed cow probably resulted from the diet selected with high energy content due to high preferences of barley and low preferences of alfalfa hay. These preferences may increase lactic acid production in rumen and low ruminal pH, besides causing energy satiety. The choice fed cows had higher eating rate than single fed cows in both season however the difference is more prominent in winter (P<0.01). Eating rate was the highest in high yielding choice fed cows in winter but the highest in low yielding choice fed cows in summer.

High yielding cows increased meal number in summer compared to winter (P<0.01), but low yielding cows did not change meal number according to season (P>0.05). Increased meal number in summer may be attributed to need to compensate decrease in meal size and meal length. Meal lengths were similar for low yielding cows in both feeding methods but high yielding single fed cows increased meal length in winter. However, in summer, only low yielding cows in both feeding system increased meal length compared to high yielding cows since the latter cows were more sensitive to heat stress (Tapki and Sahin, 2006).

Lactation performance

Cows markedly decreased feed intake and, consequently, consumed less nutrients (CP, ADF, NDF) in summer compared to winter (P<0.01). The cows in summer had 34% less feed intake, 31% less milk yield compared to the cows in winter. Reduced nutrient intake was accounted for 35% (Rhodas et al., 2009) and 50% (Wheelock et al., 2010) of heat stress-induced decrease in milk synthesis (Figure 2). In summer, the heart rate of experimental cows decreased in both feeding systems, especially in choice fed cows. Decrease in heart rate is a typical response of heat stress (Kadzere et al., 2002) whilst Serbester et al. (2005) did not observe any differences in heart rate due to heat stress in dairy cows. Summer season increased rectal temperature of cows about 1-1.9^{o}C (P<0.01), irrespective to feeding methods and production levels. Heat stressed dairy cows generally had higher rectal temperature (Serbester et al., 2005; Kadzare et al., 2002).

Experimental cows in both feeding methods increased respiration rate in summer compared to winter (P<0.01). It was expected an increase in respiration rate in summer for evaporative cooling. Even though season and production level interaction on respiration rate was insignificant; this rate was tended to lower in high producing cows. This may be attributed to the lowered feed intake and the decreased metabolism of these cows evidenced by the usage of body nutrient reserves (Table 3), as a result of heat stress in summer (Figure 2).

In hot environment, lactating cows reduce their metabolism, feed intake and milk production but increase respiratory rate and body temperature that result in production losses in summer (Armstrong, 1994). Higher producing cows are more sensitive to heat stress than lower producing cows (Bianca, 1965) since the upper critical temperature shifts downward milk production, feed intake and heat production (Barash et al., 2002). Summer season indirectly affects milk yield through an increase in body temperature and maintenance energy requirements, in turn causing a depression of dry matter intake (Kim et al., 2010). It is obvious that the decrease in DM intake affects milk yield and feed efficiency, negatively.

Choice-fed cows decreased feed intake compared to single-fed cows in both season (P<0.01). When compared with single fed high producing cows, those choice fed cows ate less dry matter, protein, ADF and NDF in summer (P<0.01) since these cows decreased FCM yield about 2 kg as well (P<0.01, Table 3). The decrease in feed intake as a percentage of body weight caused decrease in dry matter intake and, consequently, lower FCM yield. It can be expected that the changed nutrient requirements by lowered milk yield in summer, in turn, resulted in decrease in nutrient intakes as well since milk yield decreased about a 4-7 kg per cow from the beginning of study to the end during summer (Table 3).

Choice fed cows decreased their FCM yield due to a lower feed intake and alfalfa hay intake in comparison to single fed cows. This was evidenced the lower milk fat content of choice fed cows in Table 3. On the literature, there has been a close relationship between dietary roughage and milk fat content. Low roughage intake decreases milk fat content (Storry and Sutton, 1969). Also, it was mentioned that increasing the ratio of forage to concentrate to prevent depression of milk fat (Palmquist and Jenkins, 1980) due to decline in hay intake and subsequent shift in the acetate-to-propionate ratio (Galloway et al., 1993). Milk lactose content is basic osmotic material and determines milk volume (Mirzaei-Aghsaghali and Fathi, 2012). This explains why high yielding cows had high lactose content in their milk in the current study. As expected, high feed intake of high yielding cows maintains high amount of glycogenic material to be used for lactose synthesis in udder tissues. However, these cows produced milk containing less protein content in summer season ($P<0.05$), despite of being, more likely, dilution of milk to sustain a reasonable milk volume, ie. lactose. High producing cows in both feeding system decreased milk protein content in summer ($P<0.01$). Undegraded protein improves milk yield in hot climates (West, 1999). However, our experimental cows did not consume sufficient amount of undegradable protein source corn gluten meal in both feeding system in summer. This may explain why cows produced lower protein contained milk in summer. Both low and high yielding cows in choice feeding decreased milk urea content compared to single fed cows ($P<0.05$). This will be explained that the economic usage of blood urea, more likely, the penetration of urea from blood circulation to rumen to be used to ruminal microorganism to be used for microbial protein since the similar content of milk protein content were in both single and choice fed cows (Table 2). Also, the passage rate of ruminal digesta reduces in hot environment (in summer) (Christopherson and Kennedy, 1983). This may explain the economic usage of consumed nutrients on behalf of rumen microorganisms and host animal as well.

Conclusion

Choice fed cows changed their diet selection according to the changed season and milk yield but this did not affect milk yield positively since the priority of dairy cows is, more likely, to maintain their physiological comfort rather than increasing milk yield.

References

AOAC, 1998. Official Methods of Analysis: 16th Edition, 4th Revision. Washington, D.C.

Armstrong, D. V., 1994. Heat stress interaction with shade and cooling. *Journal of Dairy Science,* **77:**2044-2050.

Barash, H., N. Silanikave, A. Shaway and E. Ezra, 2002. Interrelationships amoung ambient temperature, day length, and milk yield dairy cows under a Mediterranian climate. *Journal of Dairy Science,* **84**: 2314-2320.

Bernabucci, U., N. Lacetera, L. H. Baumgard, R. P. Rhoads, B. Ronchi B. and A. Nardone, 2010. Metabolic and hormonal acclimation to heat stress in domestic ruminants. *Animal,* **4**: 1167-1183.

Bianca, W., 1965. Reviews of the progress of dairy science. Section A. Physiology. Cattle in hot environment. *Journal of Dairy Science*, **32**: 291-345.

Christopherson, R. J. and Kennedy. P. M., 1983. Effects of thermal environment on digestion in ruminants. *Canadian Journal of Animal Science*, **63**: 477.

Coppock, C. E. and J. W. West, 1986. Nutritional adjustments to reduce heat stress in lactating dairy cows. In: Proc. Georgia Nutr. Conf. Feed Industry. Atlanta. GA.Univ. Georgia, Athens. GA. pp. 19-26.

Farooq, U., H. A. Samad, F. Shehzad and A. Qayyum, 2010. Physiological responses of cattle to heat stress. *World Applied Science Journal*, **8**: 38-43.

Fedele, V., S. Claps, R. Rubino, M. Calandrelli and A. M. Pilla, 2002. Effect of Free Choice and Traditional Feeding Systems on Goat Feeding Behaviour and Intake. *Livestock Production Science*, **74**: 19-31.

Forbes, J. M., 2001. Consequences of Feeding For Future Feeding. *Comparative Biochemistry and Physiolology,* Part A, **128**: 463-470.

Galloway, D. L., A. L. Goetschl, L. A. Forster, A. R. Patil, W. Sun and Z. B. Johnson, 1993. Feed Intake and Digestibility by Cattle Consuming Bermudagrass or Orchardgrass Hay Supplemented with Soybean Hulls and (or) Corn. *Journal of Animal Science*, **71**: 3087-3095.

Görgülü, M., H. R. Kutlu, E. Demir, O. Öztürkcan and J. M. Forbes, 1996. Nutritional Consequences or Free Choice among Feed Ingredient by Awassi Lambs. *Small Ruminant Research,* **20**: 23-29.

Görgülü, M., N. Kılıçalp and H. R. Kutlu, 1998. Influence of Roughage/Concentrate Ratio on Milk Yield and Milk Composition of Dairy Cows in Hot Climates: Book of Abstract of the 49th Annual Meeting of the European Association for Animal Production, pp: 192, 24-27 August 1998, Warsaw, Poland.

Görgülü, M., O. Güney, O. Torun, O. Özuyanik and H. R. Kutlu, 2003. An Alternative Feeding System for Dairy Goats: Effects of Free-Choice Feeding on Milk Yield and Milk Composition of Lactating Suckling Damascus Goats. *Journal of Animal and Feed Science*, **12**: 35-46.

Görgülü, M., M. Boğa, A. Sahin, U. Serbester, H. R. Kutlu and S. Sahinler, 2008. Diet Selection and Eating Behaviour of Lactating Goats Subjected to Time Restricted Feeding in Choice and Single Feeding System. *Small Ruminant Research*, **78**: 41–47.

Hoover, C. W. and S. R. Stokes, 1991. Balancing Carbohydrates and Proteins for Optimum Rumen Microbial Yield. *Journal of Dairy Science*, **74:** 3630–3638.

Kadzere, C. T., M. R. Murphy, N. Silanikove and E. Maltz, 2002. Heat stress in lactating dairy cows. *Livestock Production Science*, **77**: 59–91.

Kaya, S., 2011. The effects of outdoor housing and cafeteria feeding on growth performance and feeding behavior of Awassi lambs kept in hot climate condition. *Journal of Animal and Veterinary Advances*, **10**: 2550-2556.

Kim, K. H., D. H. Kim, Y. K. Oh, S. S. Lee, H. J. Lee, D. W. Kim, Y. J. Seol and N. Kimura, 2011. Productivity and energy partition of late lactation dairy cows during heat exposure, *Animal Science Journal,* **81**: 58-62.

Kumar, S., K. Ajeet and K. Meena, 2011. Effects of Heat Stress in Tropical Livestock and Different Strategies for its Amelioration. *Journal of Stress Physiology and Biochemistry*, **7**: 45-54.

Lefcourt, A. M. and E. T. Schmidtmann, 1989. Body temperature of dry cows on pasture: environmental and behavioral effects. *Journal of Dairy Science*, **72**: 3040.

Meier, J. S., M. Kreuzer and S. Marquardt, 2012. Design and methodology of choice feeding experiments with ruminant livestock. *Applied Animal Behaviour Science*, **140**: 105–120.

Mirzaei-Aghsaghali, A. and H. Fathi, 2012. Lactose in ruminants feeding. A review. *Annals of Biological Research,* **3**: 645-650.

Moallem, U., G. Altmark, H. Lehrer and A. Arieli, 2010. Performance of high-yielding dairy cows supplemented with fat or concentrate under hot and humid climates. *Journal of Dairy Science*, **93**: 3192-3202.

Ominski, K. H., A. D. Kennedy, K. M. Wittenberg and S. A. Moshtaghi Nia, 2002. Physiological and production responses to feeding schedule in lactating dairy cows exposed to short-term, moderate heat stress. *Journal of Dairy Science*, **85**: 730-737.

Palmquist, D. L. and T. C. Jenkins, 1980. Fat in lactation rations. *Journal of Dairy Science*, **63**: 1-14.

Rhoads, M. L., R. P. Rhoads, M. J. VanBaale, R. J. Collier, S. R. Sanders, W. J. Weber, B. A. Crooker and L. H. Baumgard, 2009. Effects of heat stress and plane nutrition on lactating Holstain Cows: Production, metabolism and aspects of circulating somatotropin. *Journal of Dairy Science*, **92**: 1986-1997.

Serbester, U., M. Görgülü, H. R. Kutlu, S. Yurtseven, A. Arieli and Z. M. Kowalski, 2005. The effects of sprinkler + fan, fish meal or dietary fat on milk yield and milk composition of dairy cows in mid lactation during summer. *Journal of Animal and Feed Science*, **14**: 639-653.

Silanikove, N., 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock Production Science*, **67**: 1-18.

Storry, J. E. and J. D. Sutton, 1969. The effect of change from low -roughage to high-roughage diets on rumen fermentation, blood composition and milk fat secretion in the cow. *British Journal of Nutrition*, **23**: 511-521.

Tapki, I. and A. Şahin, 2006. Comparison of the thermoregulatory behaviours of low and high producing dairy cows in a hot environment. *Applied Animal Behaviour Science*, **99**: 1-11.

Tolkamp, B. J., R. J. Dewhurst, N. C. Friggens, I. Kyriazakis, R. F. Veerkamp and J. D. Oldham, 1998. Diet Choice by Dairy Cows: Selection of Feed Protein Content During the First Half of Lactation. *Journal of Dairy Science*, **81**: 2657-2669.

Tolkamp, B. J. and I. Kyriazakis, 1999. To split behaviour into bouts, log-transform the intervals. *Animal Behaviour*, **57**: 807-817.

Van Soest, P. J., J. B. Robertson and B. A. Lewis, 1991. Methods of Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccarides in Relation to Animal Nutrition. *Journal of .Dairy Science*, **74**: 3583-3597

West, J. W., 1999. Nutritional Strategies for Managing the Heat-Stressed Dairy Cows. *Journal of Animal Science*, **77**: 21-35.

West, J. W., 2003. Effects of Heat-Stress on Production in Dairy Cattle. *Journal of Dairy Science,* **86**: 2131-2144.

Wheelock, J. B., R. P. Rhoads, M. J. VanBaale, S. R. Sanders and L. H. Baumgard, 2010. Effects of heat stress on energetic metabolism in lactating Holstein cows. *Journal of Dairy Science*, **93**: 644-655.

Yeates, M. P., B. J. Tolkamp, D. J. Allcroft and I. Kyriazakis, 2009. The use of mixed distribution models to determine bout criteria for analysis of animal behaviour. *Journal of Theoretical Biology,* **213**: 413-25.

Yurtseven, S. and M. Görgülü, 2004. Effects of Grain Sources and Feeding Methods, Free-Choice vs Total Mixed Ration, on Milk Yield and Composition of German Fawn × Hair Crossbred Goats in Mid Lactation. *Journal of Animal and Feed Sciences*, **13**: 417-428.

Received November, 2, 2013; accepted for printing June, 2, 2014.