Egyptian Journal of Veterinary Sciences
https://ejvs.journals.ekb.eg/

Effects of Consuming Different Quality Diets and Animal Sex on Digestion and Energy Usage in Dromedary Camels, Using Heart Rate as an Indicator for Energy Expenditure

Mostafa Abdel Hamid[1], Ahmed R. Askar[1*], Mahmoud M. Khorshed[2], Ehab Y. Eid[1], Nasr E. El-Bordeny[2] and Afaf A. El Shereef[1]

[1]*Animal and Poultry Nutrition Department, Desert Research Center, Cairo, Egypt.*

[2]*Animal Production Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.*

Abstract

THIRTY-two adult dromedary camels, half males and half females, were employed to study the effects of feed quality and sex on digestion and energy utilization. Animals of each sex were randomly divided into two feeding treatments, including different concentrate-to-roughage ratios of 65:35% (high concentrate) or 35:65% (low concentrate) of concentrate feed and alfalfa hay, respectively. Animals were individually housed in two sets of 16 each, with 4 animals per treatment and sex for each set. Each set consisted of 21 days for adoption, 7 days for collection, and 2 days for gas exchange. Animals were fitted with a face mask facilitating open-circuit respiration for measuring O_2 consumption, while heart rate (HR) monitors were simultaneously measured to determine the individual energy expenditure (EE)/HR ratio. Although a comparable total intake was found between feeding treatments, animals fed a high-concentrate diet had higher nutrient digestibility, except for fiber digestibility, with males digesting nutrients more efficiently than females. However, EE was greater for a low- vs. high-concentrate level, regardless of animal sex. This resulted in a greater energy balance for the high- vs. low-concentrate diet. Similar values for EE were observed between both sexes, with a greater digestible energy intake for males vs. females that was reflected in a greater energy balance, respectively. The EE/HR ratio was consistent across feeding treatments and sexes, with no interaction between them, which is considered a solid indicator for validating HR as a predictor of EE in dromedary camels.

Keywords: Feeding quality, Camel sex, Digestion, Heart rate, Energy expenditure.

Introduction

In light of climate change, camels, as drought-resistant animal species, play a vital role in ensuring food security, particularly in arid regions [1]. They are exceptionally adapted to desertification and limited natural resources, making them a critical source of income for those who live in dry environments [2, 3, 4]. They are regarded to be the most productive animal in such tough environments [2, 5].

Camels are most common in East Africa, where dry environments severely limit the ability to raise other livestock species. Even though vegetation is limited and dispersed in arid regions, most camels depend on grazing natural rangelands, which are the most affordable source of feed, to match their nutrient requirements [6]. Camels' ability to go up to a week without water and travel up to 24-50 km daily in search of feed [7, 4] provides them a clear advantage as one of the most drought-resistant species. Many pastoralists, notably in Africa, have shifted their livestock production systems away from cattle and toward camels as a climate-resilient alternative that helps ensure the livelihoods of poor and marginal farmers. In spite of these advantages, camels have received comparatively little scientific attention relative to sheep, goats, and cattle.

Although increasing the concentrate level in the diet may increase feed costs [8], it can influence diet composition [9] and digestibility [10, 6]. A high concentrate diet was expected to have a significant

*Corresponding authors: Ahmed R. Askar, E-mail: ahmed_askar@yahoo.com, Tel.: 00201069898566
(Received 07 August 2025, accepted 24 September 2025)
DOI: 10.21608/EJVS.2025.411821.3028

negative effect on fiber digestibility [10, 4]. This was likely attributed to the fact that it had a negative effect on rumen pH [11], which alters rumen fermentation [12], reducing the activity of cellulolytic bacteria [13,14] and protozoa [15,16], and rumen residence time [17]. High-fiber diets, on the other hand, promote microbial fermentation with a diverse community of fibrous microorganisms, in which the rumen plays a vital role in the fermentation of lignocellulose materials, resulting in improved fibrous component degradation and efficient utilization [14, 11].

However, environmental conditions [18, 19, 20], feed intake level [21, 22, 8], animal activity [23, 24, 4], season, and production level may affect energy expenditure (EE) of animals [25]. The EE has been measured under controlled or confined [26] respiratory chamber conditions, although these conditions may not accurately represent those of grazing animals. Heart rate (HR) has been effectively employed as a potential means of assessing EE in unrestrained animals, which has been applied with sheep [27, 28, 6], goats [29, 28, 6], and cattle [30, 31], and this technique relies on the ratio between EE and HR [32]. In camels, HR was previously used to assess dynamic response for physical activity [33]. However, the effect of concentrate-roughage-ratio and sex on digestibility and energy usage was investigated in this study, considering the feasibility of using HR as an indicator for EE in camels.

Material and Methods

The study was carried out at the “National Campaign for the Promotion of Camel Productivity” farm, Ras-Sudr Research Station, which belongs to the Desert Research Center (DRC), Egypt. It is about 200 kilometers from Cairo, Egypt, at coordinates 29, 35, 30 N and 32, 42, 20 E, on the western coastline road to the South Sinai Governorate. It is called a desert environment with a virtually complete absence of precipitation throughout the year.

Animals and treatments

Thirty-two adult dromedary camels, with equal numbers of males and females, with average body weights of 471.9 ± 9.41 kg for males and 508.4 ± 5.77 kg for females, were employed in two phases to investigate the effects of diet quality and sex on digestion, HR, EE, and the relation between both of them when they were fed 150% of their maintenance requirements [5]. Camels were individually housed in 3x3 m² pens with sand floors. Animals of each sex were randomly assigned to one of two feeding treatments. The feeding treatments included different concentrate-to-roughage ratios of 65:35% (high concentrate, HC) and 35:65% (low concentrate, LC) of concentrate feed and alfalfa hay, respectively. The proximate analysis of alfalfa hay and concentrate feed is presented in Table 1.

Experimental procedures

The study lasted two months, from August to October 2021, and consisted of two sets. Each set consisted of 21 days for adoption, 7 days for collection, and 2 days for gas exchange and heart rate measurements. Animals were located in the individual pens in two sets of 16 each, with 4 animals per treatment and sex for each set. Individual animals received the diet, as prescribed, in two meals at 08:00 and 16:00 h, with free access to water. Feed intake was measured daily. Animals in each treatment were fitted with fecal bags and allowed to adjust to the new setting before fecal matter collection began for the following seven-day measurement period. Feed and orts were sampled to get a proportional composite sample for each animal for a seven-day period. Offered feeds, refusals , and feces were recorded regularly on a daily basis. A subset of each camel was taken to form a unique composite sample. All samples were air-dried at 65°C and preserved for further analysis. The acid-insoluble ash was adjusted for its fecal recovery and used to determine the digestibility [6].

Energy expenditure

As stated by [32] for small ruminants and Askar et al. [5] for camels, animals were outfitted with a face mask that allowed open-circuit respiration for monitoring oxygen consumption. The individual EE/HR ratio was determined by taking simultaneous readings from the RCX3 HR (Polar Electro Oy, Kempele, Finland). Furthermore, the HR was thought to be individually collected at 1-minute intervals for at least 24 hours, with the individual EE:HR ratio being used to compute the daily EE. The Polar software was used to analyze the collected data.

Weather data

Outside ambient temperature (T °C) and relative humidity (RH) were measured daily (RC-4HA Temperature and Humidity Data Logger) and employed to compute the temperature humidity index (THI) as follows: (0.8 x T) + [(RH/100) x (T - 14.4)] + 46.4 [34].

Analytical procedures

Feeds, orts, and feces samples were proximately analyzed [35], including fiber fraction analysis. The gross energy (GE) was measured using a bomb calorimeter (IKA, model C 200, Germany). The metabolizable energy (ME) was calculated as 82% of digestible energy (DE) [25]. The gross energy (GE) was measured using a bomb calorimeter (IKA, model C 200, Germany), with benzoic acid as the standard.

The metabolizable energy (ME) represented 82% of digestible energy (DE) [25].

Statistical analysis

Data were analyzed using the GLM procedure [36], considering the effects of feeding treatments, sex, and their interaction. The least significant difference with a protected F-test was used to determine differences between means. Differences between means are significant when the P-value is below 0.05 and considered tendency when P-value is between 0.05 and 0.10.

Results

The mean temperature was 26°C (Figure 1), while those of RH and THI were 31.0% and 63.0 respectively (Figure 2).

The effects of concentrate-to-roughage ratio and camel sex on nutrients intake and digestibility are summarized in Tables 2 and 3. The data showed no differences in BW between camels fed the HC or LC diets (Table 2). Similarly, there were no differences in total dry matter (DM) intake between the two diets, whether calculated in g/day or g/kg $BW^{0.75}$. However, significant differences in concentrate or forage intake were typically found between camels fed the HC and LC diets.

However, it was clearly shown that females weighed more than males, which was reflected in a consistently higher ($P<0.01$) feed intake (g/day, Table 2) for females compared to males regardless of the concentrate level. This difference between both sexes disappeared when it was calculated based on BW (g/kg $BW^{0.75}$, Table 2). However, no significant interactions were found for nutrient intakes between feeding treatment and sex (Table 3).

Camels on HC or LC diets had similar total DM intake (g/kg $BW^{0.75}$) but significantly different intakes of organic matter (OM), crude protein (CP), or fiber fraction ($P<0.05$) (Table 3). Animals fed an HC diet had higher DM, OM, and CP digestibility but lower fiber fraction digestibility, most likely because of the low fiber content of the concentrate. However, significant differences in digestibility were noted between the sexes, with males digesting nutrients more efficiently than females.

A significant interaction between concentrate level and sex regarding the digestibility of DM, OM ($P<0.05$), and CP ($P<0.10$) was observed, indicating a similar digestibility between males and females when fed an LC diet, while a greater digestibility was observed for males vs. females when fed an HC diet, indicating that males digested more efficiently than females when they fed an HC diet. However, no significant interactions were observed between feeding treatment and animal sex regarding CP, NDF, and ADF digestibility.

The effects of concentrate-to-roughage ratio and camel sex on energy utilization are presented in Table 4. In line with the DM intake (g/kg $BW^{0.75}$), a similar GE (kJ/kg $BW^{0.75}$) was observed across feeding treatments or camel sexes. However, a higher DE was observed for an HC vs. LC level and for males vs. females (kJ/kg $BW^{0.75}$ or %, $P < 0.01$). A similar pattern was demonstrated for ME intake (kJ/kg $BW^{0.75}$, $P<0.01$).

The EE/HR ratio was consistent across feeding treatments and camel sex, with no significant interaction between them. Heart rate and EE were affected ($P<0.01$) by feed quality regardless of animal sex, which was greater for LC vs. HC levels, reflecting in a greater energy balance (EB) for the HC vs. LC diet. However, similar values for HR or EE were observed between camel sexes, with a greater DE intake for males vs. females reflected in a higher EB, respectively.

Discussion

Camels exhibit remarkable adaptability to different feeding schedules and to both HC and LC diets due to the unique composition of their digestive system. They are very efficient at breaking down the fiber in low-quality feed items such as dry grasses and leaves because of the specific microbes present in their segmented stomach [14, 11]. Camels also can adapt to HC diets with high levels of grains and energy because they are better than other ruminants at absorbing carbohydrates and avoiding digestive disorders such as acidosis [16, 20]. Camels with this nutritional flexibility are more productive in various contexts because they can make use of available feed in challenging circumstances [20, 4].

Although total DM intake was nearly similar for both feeding treatments (Table 3), camels fed an HC diet had higher DM, OM, and CP digestibility but lower fiber digestibility, most likely attributable to the low fiber content of the concentrate. This is mostly due to the inclusion of non-structural carbohydrates in concentrates that promotes rapid fermentation and elevates nutrient digestibility [37, 4]. The current findings are in line with the findings of Thiakunu et al.[38], who reported that HC diets contain higher levels of DE and protein that enhance nutrient digestibility and feed utilization. However, an HC level was projected to have a significant negative effect on fiber digestibility [10], regardless of animal sex (Table 3). This was probably due to the alteration in rumen fermentation [12], which influenced the rumination and rumen residence time [17]. The detrimental impact of concentrate on fiber digestibility in camels was clearly reported [20], and it may be related to its negative effect on rumen pH [11], which reduced the activity of cellulolytic bacteria [13,14] and protozoa in camel calves [15,16] In this context, increasing the concentrate level could also increase the gastrointestinal tract passage rate. This could be connected to a reduction in ruminal digestibility, particularly fiber digestibility [39], as presented in Table 3. In contrast, high-fiber (LC) diets promote microbial fermentation in the rumen, with a diverse community of fibrous microorganisms in which the rumen plays a critical role in the fermentation of lignocellulose materials, leading to improved degradation of fibrous components and their efficient utilization [14, 11].

However, results in Table 3 showed that male camels exhibit higher digestibility than females, implying that males digest nutrients better than females. This difference can be attributed to variations in digestive system anatomy and metabolic rates. Male camels have been found to possess anatomical advantages in their digestive systems, such as larger rumen capacity and more efficient gastrointestinal tract structures, which enhance nutrient absorption [40]. In general, males' metabolic rates are higher, leading to increased nutrient utilization efficiency [41]. Studies indicate that male camels may select higher-quality forage, which contributes to better digestibility metrics [42]. For instance, when fed barley grains, male camels demonstrated superior digestibility across various nutrients compared to other feed types [41], indicating that the nutritional composition of feed significantly impacts digestibility. Conversely, while male camels show higher digestibility, female camels may have adaptations that allow them to maintain energy balance (EB) during reproduction and lactation, which could influence their overall nutrient absorption efficiency. This highlights the complexity of camel nutrition and the need for tailored feeding strategies based on sex and physiological status.

Energy utilization

Animal and diet

There are many factors affecting the energy requirement for maintenance, as part of the total EE, such as acclimatization [18,19], intake level [21,43,44,22,8], feed quality [45], and animal activity [23,24,46,4]. In this study, the type of diet has a clear effect on EE, regardless of animal sex, with several options existing. Forage diets demand more energy for mastication than concentrate diets, which presumably contributes to the difference in EE at high vs. low forage meals [47, 29]. Hence, the majority of high-forage diet digestion probably occurred in the rumen, with small intestine digestion focusing on microbial protein. In contrast, small intestine digestion may have been significantly larger with the HC diets, given a significant ruminal escape of grain protein and energy. Furthermore, EE by splanchnic tissues relative to ME is greater for forage than for concentrate-based diets [48], which could be partly explained by the effects of the physical nature of the diet on gut mass and energy use. Findings are confirmed in which the relationship between EE and ME intake showed a better state for an HC vs. LC diet (72.3 vs. 81.5% of ME intake, Table 4) and are in line with the increased forage consumption for those fed an LC vs. HC diet (Table 2). In this context, a favorable correlation between the forage consumption level and EE was reported in camels [4] and small ruminants [29]. The sites of digestion and the pattern of nutrient release could also have played a significant role. Alfalfa is known to be abundant in protein that is rapidly degraded or digested in the rumen, and potentially digestible cell walls of legumes have high ruminal digestion rates [49]. Askar et al. [4] reported that replacing forage with concentrate in dromedary camels increased ME intake and retained energy, which was consistent with current energy usage data findings (Table 4), which indicated that an HC diet increased ME intake and improved EB when compared to an LC diet. Replacing forage with concentrate may increase feeding costs [8, 5], but it may improve digestibility [6, 10] and feed efficiency [50, 4]. However, greater DE and ME for males vs. females (Table 4) led to a better relationship between EE and ME intake (74.4 vs. 79.3% of ME intake) and a greater EB (120.1 vs. 91.8 kJ/kg $BW^{0.75}$) for males vs. females, respectively.

Heart rate and EE:HR

Camel HR has been effectively employed as a dynamic response indicator for physical activity [33], which is reflected in EE [46]. Additionally, HR has been widely utilized as an indication for the EE in sheep and goats [24, 28, 6], cattle [31], and recently camels [5, 4], by monitoring O_2 consumption and HR simultaneously. However, a similar EE/ HR ratio was reported in this study across two feeding treatments and animal sex, with an overall mean of 6.61 kJ/ kg $BW^{0.75}$/ heart beat/ min (Table 4), which is similar to that observed in goats and sheep fed alfalfa (6.73 kJ/ (kg $BW^{0.75}$/ day)/ heart beat/ min, [28] and in goats fed different concentrate-roughage ratios [29], but higher than in goats and sheep fed *Atriplex* (6.27 kJ/ (kg $BW^{0.75}$/ day)/ heart beat/ min, [28] or sheep fed an HC or LC diet (5.12 kJ/ (kg $BW^{0.75}$/ day)/ heart beat/ min, [51]) and lower than that observed in cattle (7.13 kJ/ (kg $BW^{0.75}$/ day)/ heart beat/ min, [30]). Reasons for differences in EE:HR among animal species are not clear, but it is possible that delivery of oxygen by the heart varies among ruminant species [29]. However, a similar EE/HR ratio was reported between goats and sheep when determined in the same experiment [52, 28]. However, a consistent EE/HR ratio over the course of the day (Table 4) is a solid indicator for validating HR as a predictor of EE in dromedary camels. Puchala et al. [29] found that it would seem desirable to monitor EE:HR over an extended period of time, such as a full day, in order to make the most accurate prediction of EE from HR.

Conclusion

Camels fed an HC level had greater DM, OM, CP and energy digestibility, but lower fiber digestibility, with males digesting nutrients more efficiently than females. Energy expenditure was affected by feeding quality, but not by animal sex. The EE/HR ratio was similar across feeding quality and animal sex, with no interaction found between them, which is regarded as a solid indicator for validating HR as a predictor of EE in dromedary camels.

Acknowledgments

The authors thank the Ras-Sudr Research Station, Desert Research Center, Egypt, and the camel farm technical team for their assistance in completing this work.

Funding statement

This research work was financed by the Academy of Scientific Research and Technology (ASRT), Egypt, through “The National Campaign for the Promotion of Camel Productivity”.

Declaration of Conflict of Interest

The authors have declared that they have no conflict of interest.

Ethical approval

This study follows the ethics guidelines of the Animal and Poultry Production Division, Desert Research Center, Egypt (ethics approval number: 28022024).

TABLE 1. The chemical composition of concentrate feed and alfalfa hay, based on a dry matter (DM) basis.

Ingredients	*Concentrate feed	Alfalfa hay
Dry matter, g/ kg fresh matter	946	938
Gross energy, MJ/ kg DM	17.7	14.3
Chemical composition, g/ kg DM		
Organic matter	874	809
Crude protein	156	141
Neutral detergent fiber	342	464
Acid detergent fiber	125	252
Acid detergent lignin	37.1	59.1

*The concentrate consisted of 55% corn, 15% soybean meal, 10% cottonseed meal, 15% wheat bran, 2.5% limestone, 1.5% salt, 0.5% sodium bicarbonate, 0.1% yeast, 0.1% antitoxins, and 0.3% premix.

TABLE 2. Body weight and dry matter intake for camels fed a different concentrate-to roughage ratio in the diet

	Concentrate level			Sex			Concentrate level X Sex					Significant		
	Low	High	SEM	Female	Male	SEM	Low		High		SEM	Treat	Sex	T*S
							Female	Male	Female	Male				
Body weight														
Kg	502	500	10.1	529^{a}	472^{b}	10.1	530	473	528	471	14.3	ns	***	ns
$kg^{0.75}$	106	106	1.6	110^{a}	101^{b}	1.6	110	101	110	101	2.3	ns	***	ns
Dry matter intake														
Concentrate														
g/ day	1667^{b}	3052^{a}	41.7	2463^{a}	2257^{b}	41.7	1739	1595	3186	2918	60.0	***	***	ns
g/ kg $BW^{0.75}$	15.7^{b}	28.9^{a}	0.11	22.34	22.30	0.11	15.8	15.7	29.0	28.9	0.16	***	ns	ns
Forage														
g/ day	3048^{a}	1626^{b}	54.9	2436^{a}	2238^{b}	54.9	3178	2919	1693	1558	77.7	***	**	ns
g/ kg $BW^{0.75}$	28.8^{a}	15.4^{b}	0.19	22.10	22.06	0.19	28.8	28.8	15.4	15.4	0.27	***	ns	ns
Total														
g/ day	4715	4678	91.9	4898^{a}	4495^{b}	91.9	4916	4514	4879	4476	129.9	ns	***	ns
g/ kg $BW^{0.75}$	44.5	44.3	0.27	44.41	44.39	0.27	44.5	44.5	44.3	44.3	0.38	ns	ns	ns

^{a,b} Means having different superscripts within the same row differed significantly ($P<0.05$). ns = Non-significant; ** = $P < 0.01$; *** = $P < 0.001$. SEM = Standard error of means.

TABLE 3. Intake and digestibility for camels fed a different concentrate-to-roughage ratio in the diet

	Concentrarte level		SEM	Sex		SEM	Concentrarte level X Sex				SEM	Significant		
	Low	High		Female	Male		Low		High			Treat	Sex	T*S
							Female	Male	Female	Male				
Dry matter														
Intake, g/ day	4715	4678	91.9	4898^{a}	4495^{b}	91.9	4916	4514	4879	4476	129.9	ns	***	ns
Intake, g/ kg BW$^{0.75}$	44.5	44.3	0.27	44.41	44.39	0.27	44.5	44.5	44.3	44.3	0.38	ns	ns	ns
Digestion, %	67.4^{b}	72.2^{a}	0.41	68.5^{b}	71.1^{a}	0.41	66.9^{c}	67.8^{c}	70.0^{b}	74.3^{a}	0.59	***	***	***
organic matter														
Intake, g/ day	4199	4120	88.9	4339^{a}	3981^{b}	88.9	4379	4020	4298	3943	125.7	ns	***	ns
Intake, g/ kg BW$^{0.75}$	39.6^{a}	39.0^{b}	0.31	39.3	39.3	0.31	39.6	39.6	39.0	39.0	0.45	t 0.06	ns	ns
Digestion, %	73.9^{b}	78.3^{a}	0.72	74.3^{b}	77.9^{a}	0.71	72.9^{c}	74.9^{bc}	75.7^{b}	80.9^{a}	1.02	***	***	*
Crude Protein														
Intake, g/ day	658	667	12.9	691^{a}	634^{b}	12.9	686	630	695	638	20.1	ns	***	ns
Intake, g/ kg BW$^{0.75}$	6.21^{b}	6.31^{a}	0.037	6.26	6.26	0.037	6.21	6.21	6.32	6.31	0.053	*	ns	ns
Digestion, %	72.3^{b}	76.6^{a}	1.40	72.3^{b}	76.6^{a}	1.40	71.4^{b}	73.2^{b}	73.1^{b}	80.1^{a}	1.97	**	**	t
Neutral detergent fiber														
Intake, g/ day	2456^{a}	2032^{b}	46.1	2340^{a}	2148^{b}	46.1	2561	2351	2119	1945	65.2	***	***	ns
Intake, g/ kg BW$^{0.75}$	23.2^{a}	19.2^{b}	0.14	21.2	21.2	0.14	23.2	23.2	19.2	19.3	0.20	***	ns	ns
Digestion, %	65.8^{a}	61.0^{b}	0.65	61.4^{b}	65.3^{a}	0.65	64.1	67.5	58.8	63.1	0.92	***	***	ns
Acid detergent fiber														
Intake, g/ day	57.2^{a}	46.8^{b}	0.76	50.2^{b}	53.8^{a}	0.76	1482	1361	1142	1049	37.4	***	***	ns
Intake, g/ kg BW$^{0.75}$	13.4^{a}	10.4^{b}	0.08	11.9	11.9	0.08	13.4	13.4	10.4	10.4	0.12	***	ns	ns
Digestion, %	57.2^{a}	46.8^{a}	0.76	50.2^{b}	53.8^{a}	0.76	55.5	58.9	44.9	48.7	1.08	***	**	ns

^{a,b,c} Means having different superscripts within the same row differed significantly (P<0.05). ns = Non-significant; t=P<0.10; * = P < 0.05; ** = P < 0.01; *** = P < 0.001. SEM = Standard error of means.

TABLE 4. Energy utilization for camels fed a different concentrate-to-roughage ratio in the diet

	Conentrate level			Sex			Concentrate level X Sex					Significant		
	Low	High	SEM	Female	Male	SEM	Low		High		SEM	Treat	Sex	T*S
							Female	Male	Female	Male				
Gross Energy														
MJ/ day	78.7	77.6	1.53	81.5^a	74.8^b	1.53	82.0	75.3	81.0	74.3	2.16	ns	***	ns
kJ/ kg BW$^{0.75}$	743	735	4.5	739	739	4.5	743	743	735	735	6.4	ns	ns	ns
Digestible energy														
MJ/ day	57.3^b	60.4^a	1.16	59.8	57.8	1.16	58.7	55.9	61.0	59.8	1.64	*	ns	ns
kJ/ kg BW$^{0.75}$	541^b	573^a	6.0	542^b	571^a	6.0	532	551	554	591	8.6	***	***	ns
%	72.9^b	77.9^a	0.80	73.5^b	77.3^a	0.80	71.6	74.2	75.3	80.5	1.13	***	***	ns
Metabolizable energy														
MJ/ day	47.0^b	49.5^a	0.95	49.1	47.4	0.95	48.1	45.9	50.0	49.0	1.35	*	ns	ns
kJ/ kg BW$^{0.75}$	444^b	470^a	5.0	445^b	468^a	5.0	436	452	454	485	7.0	***	***	ns
Heart rate,														
Beat/ min	54.2^a	51.0^b	0.521	52.9	52.3	0.521	54.4	53.9	51.3	50.6	0.736	***	ns	ns
Energy expenditure,														
EE/ HR ratio	6.69	6.66	0.115	6.69	6.66	0.115	6.75	6.62	6.63	6.70	0.162	ns	ns	ns
kJ/ kg BW$^{0.75}$	362^a	340^b	6.33	353	348	6.33	367	357	340	339	8.95	**	ns	ns
Energy balance,														
kJ/ kg BW$^{0.75}$	81.8^b	130.1^a	6.91	91.8^b	120.1^a	6.91	69.1	94.5	114.5	145.6	9.77	**	**	ns

[a,b,c] Means having different superscripts within the same row differed significantly (P<0.05). ns = Non-significant; t=P<0.10; * = P < 0.05; ** = P < 0.01; *** = P < 0.001. SEM = Standard error of means.

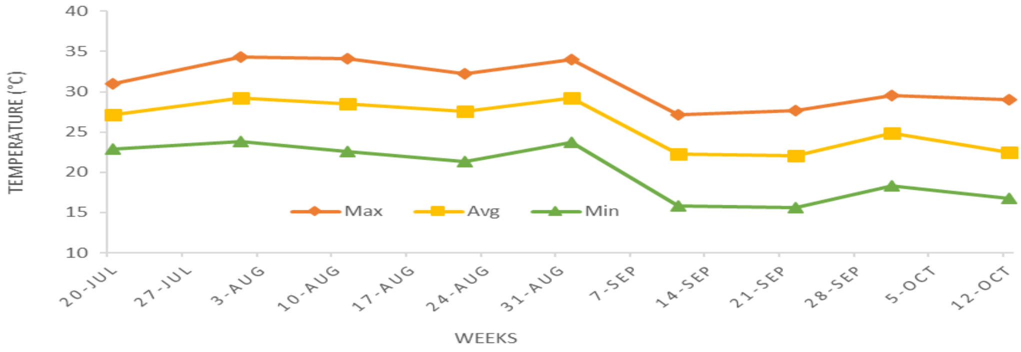

Fig. 1. Mean temperature, relative humidity, and temperature–humidity index (THI) in 1-week periods throughout the experimental period that camels were exposed to July–October, 2021.

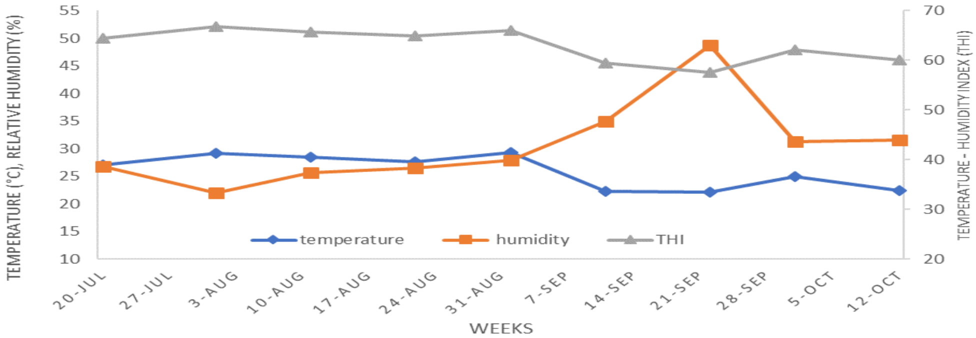

Fig. 2. Mean temperature, relative humidity and temperature–humidity index (THI) in 1-week periods throughout the experimental period that were exposed to July – October, 2021.

References

1. Kandil, H.M., Wassif, I.M., Rabee, A., Khidr, R.E., Shoukry, M.M. and Askar, A.R. Camel, the animal of food security and climate change. *Egyptian J. Camel Sci.*, **1**(1), 1–8 (2023).
2. Farah, Z., Mollet, M., Younan, M. and Dahir, R. Camel dairy in Somalia: Limiting factors and development potential. *Livestock Science*, **110**(1-2), 187-191 (2007).
3. Salamula, J.B., Egeru, A., Asiimwe, R., Aleper, D.K. and Namaalwa, J.J. Socio-economic determinants of pastoralists' choice of camel production in Karamoja sub-region, Uganda. *Pastoralism*, **7**(1), 26 (2017).
4. Askar, A.R., Saber, A.R. Allam, S., Kewan, K.Z., Bakr, M.H., Fayed, F., Kandil, H.M., Abo Ragab, S., Hussien, B.A., Abou El Ezz, S.S. and Shoukry, M.M. Effects of concentrate supplement on camel performance, forage utilization, and energy usage in arid-area rangelands. *BMC Veterinary Research.*, **21**(1), 387 (2025b).
5. Askar, A.R., Masoud, A., El-Bordeny, N.E., Kewan, K.Z., Abd El-Galil, E.R.I., Abou El-Ezz, S.S. and Shoukry, M.M. Grazing camels under semi-extensive production system: selectivity, feed intake capacity, digestion and energy expenditure. *BMC Veterinary Research*, **20**(1), 364 (2024).
6. Askar, A.R., Salama, R., El-Shaer, H.M. and Raef, O. Effects of supplementary feeding level on digestion and energy utilization by sheep and goats grazing arid-area rangelands. *Anim. Feed Sci. Technol.*, **271**, 114695 (2021).
7. Wardeh MF. Foraging behavior and the nutritive value of diets selected by the dromedary camels. *Camel Newsletter.*, **15**, 19–27 (1998).
8. Askar, A.R., Salama, R., El-Shaer, H.M., Safwat, M.A., Poraei, M., Nassar, M.S., and Raef, O. Evaluation of the use of arid-area rangelands by grazing sheep: Effect of season and supplementary feeding. *Small Ruminant Research*, **121**(2-3), 262-270 (2014).
9. Goetsch, A.L. and Gipson, T.A. Review: use of a web-based nutrient requirement calculation system to assess potential influences of various factors on nutrient needs of goats while grazing. *Prof Anim Sci.*, **30**(2), 192-214 (2014).
10. Garcés-Yépez, P., Kunkle, W.E., Bates, D.B., Moore, J.E., Thatcher, W.W. and Sollenberger, L.E. Effects of supplemental energy source and amount on forage intake and performance by steers and intake and diet digestibility by sheep. *J. Anim. Sci.*, **75**(7), 1918–1925 (1997).

11. Rabee, A.E., and Askar, A.R. Composition of the rumen archaeal community of growing camels fed different concentrate levels. *International Microbiology,* **28** (Suppl 1), 53-62 (2025).

12. Dijkstra, J., Boer, H., Van Bruchem, J., Bruining, M., and Tamminga, S. Absorption of volatile fatty acids from the rumen of lactating dairy cows as influenced by volatile fatty acid concentration, pH and rumen liquid volume. *British Journal of Nutrition,* **69**(2), 385-396 (1993).

13. Mann, S.O. and Ørskov, E.R. The effect of feeding whole or pelleted barley to lambs on their rumen bacterial populations and pH. *Proc. Nutr. Soc.,* **34**(2), 63A-64A (1975).

14. Askar, A.R., Allam, M.A., Kewan, K.Z., Darwesh, R., Lamara, M., Sabra, E.A., Allam, S. and Rabee, A.E. Effect of concentrates level on digestibility, ruminal fermentation, and bacterial community in growing camels. *Animal Biotechnology,* **1**(1), 1-8 (2023).

15. Gharechahi, J., Sarikhan, S., Han, J.L., Ding, X.Z. and Salekdeh, G.H. Functional and phylogenetic analyses of camel rumen microbiota associated with different lignocellulosic substrates. *NPJ Biofilms Microbiomes,* **8**(1), 46 (2022).

16. Ghanem, M.M., Abdelraof, Y.M., Abdelghany, H.A., Eman, A.E.E., Askar, A.R. and Eissa, A.A. Clinical, haematobiochemical, ultrasonographical, and ruminal alterations in induced lactic acidosis with therapeutic evaluation in camels in South Sinai. *Advances in Animal and Veterinary Science,* **10**(5), 1066-1075 (2022).

17. Hashi, M.A., Kamoun, M. and Cianci, D. Feed and Water Requirements of the Camel. *CIHEAM – Options Mediterranean's,* **13**, 71–80 (1995).

18. Helal, A., Youssef, K.M., El-Shaer, H.M., Gipson, T.A., Goetsch, A.L., and Askar, A.R. Effects of acclimatization on energy expenditure by different goat genotypes. *Livestock Science,* **127**(1), 67-75 (2010).

19. Patra, A.K., Puchala, R., Animut, G., Gipson, T.A., Sahlu, T. and Goetsch, A.L. Effects of acclimatization on energy expenditure by meat goats. *Small Rumin. Res.,* **81**(1), 42–54 (2009).

20. Askar, A.R., Darwesh, R., Allam, S., Abdul Aziz, G.M., El Shereef, A.A., Eid, E.Y., Kandil, H.M., Abou El Ezz, S.S, and Shoukry, M.M. Performance of 1-year-old camel calves fed a basal ration of alfalfa hay supplemented with different levels of concentrate. *BMC Veterinary Research,* **21**(1), 36 (2025).

21. Asmare, A., Puchala, R., Merkel, R.C., Sahlu, T. and Goetsch, A.L. Changes in energy expenditure by meat goats with varying levels of feed intake near maintenance and below. *J. Appl. Anim. Res.,* **29**(2), 81–89 (2006).

22. Helal, A., Puchala, R., Detweiler, G.D., Gipson, T.A., Sahlu, T and Goetsch, A.L. Effects of restricted feed intake on energy expenditure by different goat breeds. *J. Anim. Sci.,* **89**(12), 4175 – 4187 (2011).

23. Beker, A., Gipson, T.A., Puchala, R., Askar, A., Tesfai, K., Detweiler, G., Asmare, A. and Goetsch, A.L. Effects of stocking rate, breed, and stage of production on intake, digestion, energy expenditure and activity of meat goat does on pasture. *J. Appl. Anim. Res.,* **36**(2), 159-174 (2009).

24. Beker, A., Gipson, T.A., Puchala, R., Askar, A.R., Tesfai, K., Detweiler, G.D., Asmare, A. and Goetsch, A.L. Energy expenditure and activity of different types of small ruminants grazing varying pastures in the summer. *J. Appl. Anim. Res.,* **37**(1), 1–14 (2010).

25. NRC. National Research Council (US). Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids. *Committee on Nutrient Requirements of Small Ruminants.,* pp.308 (2007).

26. Brouwer, E. Report of subcommittee on constants and factors. *Proceedings of the 3rd Symposium on Energy Metabolism.* Academic Press, London, pp. 441-443 (1965).

27. Barkai, D. Landau, S., Brosh, A., Baram, H. and Molle, G. Estimation of energy intake from heart rate and energy expenditure in sheep under confinement or grazing condition. *Livest. Prod. Sci.,* **73**(2-3), 237–246 (2002).

28. Askar, A.R., Nassar, M.S., Badawy, H.S., Eid, E.Y., Guada, J.A. and Farid, M.F.A. Recovered energy and efficiency of digestion in sheep and goats fed *Atriplex nummularia* compared to alfalfa hay. *Livest. Sci.,* **194**, 1–6 (2016).

29. Puchala, R., Tovar-Luna, I., Goetsch, A.L., Sahlu, T., Carstens, G.E. and Freetly, H.C. The relationship between heart rate and energy expenditure in Alpine, Angora, Boer and Spanish goat wethers consuming different quality diets at level of intake near maintenance or fasting. *Small Rumin. Res.,* **70**(2-3), 183–193 (2007).

30. Brosh, A., Aharoni, Y., Degen, A.A., Wright, D. and Young, B. Estimation of energy expenditure from heart rate measurements in cattle maintained under different conditions. *J. Anim. Sci.,* **76**(12), 3054–3064 (1998a).

31. Brosh, A., Aharoni, Y. and Holzer, Z. Energy expenditure estimation from heart rate: validation by long-term energy balance measurement in cows. *Livest. Prod. Sci.,* **77**(2-3), 287-299 (2002).

32. Askar, A.R. Effects of long-term restricted feeding on digestion and energy utilization in Balady than Shami goats. *Livest. Sci.,* **185**, 61–67 (2016).

33. Bosona T., Gebresenbet G. and Bulitta F. S. Modeling the dynamic response of camels' heart rate to physical activities. *Livest. Sci.,* **142**(1), 138–146 (2011).

34. Amundson, J.L., Mader, T.L., Rasby, R.J. and Hu, Q.S. Environmental effects on pregnancy rate in beef cattle. *Journal of animal science,* **84**(12), 3415-3420 (2006).

35. AOAC. Official Methods of Analysis of AOAC International, 18th ed., AOAC Gaithersburg, MD, USA. (2005).

36. SAS. Statistical Analysis Systems Institute Inc. Release 8.1, Cary, NC, USA, (2000).

37. Tafaj, M., Kolaneci, V., Junck, B., Maulbetsch, A., Steingass, H. and Drochner, W. Influence of fiber content and concentrate level on chewing activity, ruminal digestion, digesta passage rate and nutrient digestibility in dairy cows in late lactation. *Asian-Australasian Journal of Animal Sciences,* **18**(8), 1116–1124 (2005).

38. Thiakunu, F.K., Njehia, B.K., Nguhiu, P.N. and Arimi, J.M. Camel herd structure and performance in isiolo and Marsabit counties, Kenya. *Journal of Agricultural Science.*, **16**(1), 1-75 (2024).

39. Askar, A.R., Guada, J.A., Gonzalez, J.M., de Vega, A. and Fondevila, M. Rumen digestion and microbial protein synthesis in growing lambs fed high-concentrate diets: effect of cereal processing and animal age. *Anim Feed Sci Technol.*, **142**(3-4), 292–305 (2008).

40. Qureshi, A.S., Rehan, S., Usman, M., Hayat, K., Umar, Z., and Sarfraz, A. Quantitative Evaluation of Age-Related Anatomical Characteristics of Selected Digestive Organs of Dromedary Camel. *Pakistan Veterinary Journal*, **40**(2), 175-180 (2020).

41. Mahmoud, A. and El-Bana, H. Evaluation of olive and palm byproducts in feeding camels. *Pakistan J Nutr.*, **12** (9), 879-885 (2013).

42. Khattab, I.M., Abdel-Wahed, A.M., Anele, U.Y., Sallam, S.M. and El-Zaiat, H.M. Comparative digestibility and rumen fermentation of camels and sheep fed different forage sources. *Anim Biotechnol*., **34**(3), 609–618. (2021).

43. Asmare, A., Puchala, R., Tesfai, K., Detweiler, G.D., Dawson, L.J., Askar, A.R., Sahlu, T., Wang, Z. and Goetsch, A.L. Effects of small ruminant type and restricted protein intake on metabolism. *Small Rumin. Res.*, **98**(1-3), 111-114 (2011).

44. Asmare, A., Puchala, R., Tesfai, K., Detweiler, G.D., Dawson, L.J., Askar, A.R., Sahlu, T. and Goetsch, A.L. Effects of small ruminant type and level of intake on metabolism. *Small Rumin. Res.*, **102**(2-3), 186–190 (2012).

45. El-Meccawi, S., Kam, M., Brosh, A., and Degen, A. A. Heat production and energy balance of sheep and goats fed sole diets of Acacia saligna and Medicago sativa. *Small Ruminant Research*, **75**(2-3), 199-203 (2008).

46. Goetsch, A.L, Gipson, T.A., Askar, A.R. and Puchala, R. Invited review: feeding behavior of goats. *J. Anim. Sci.*, **88**(1), 361-373 (2010).

47. Webster, A.J.F. Energy costs of digestion and metabolism in the gut. *Digestive Physiology and Metabolism in Ruminants.* AVI Publishing, Westport, CT., pp. 469−484 (1980).

48. Goetsch AL. Splanchnic tissue energy use in ruminants that consume forage-based diets ad libitum. *J Anim Sci.*, **76**(10), 2737–2746 (1998).

49. Galyean, M.L., and Goetsch, A.L. Utilization of forage fiber by ruminants. *Forage cell wall structure and digestibility,* pp. 33-71 (1993).

50. Fajardo, N.M., Poli, C.H.E.C., Bremm, C., Tontini, J. F., Castilhos, Z.M.S., McManus, C.M., Sarout, B.N.M., Castro, J.M. and Monteiro, A.L.G. Effect of concentrate supplementation on performance and ingestive behaviour of lambs grazing tropical Aruana grass (*Panicum maximum*). *Anim. Prod. Sci.*, **56**(10), 1693-1699 (2015).

51. Arieli, A., Kalouti, A., Aharoni, Y. and Brosh, A. Assessment of energy expenditure by daily heart rate measurement – validation with energy accretion in sheep. *Livest. Prod. Sci.*, **78**(2), 99–105 (2002).

52. Animut, G., Goetsch, A.L., Aiken, G.E., Puchala, R., Detweiler, G., Krehbiel, C.R., Merkel, R.C., Sahlu, T., Dawson, L.J., Johnson, Z.B. and Gipson, T.A. Grazing behavior and energy expenditure by sheep and goats co-grazing grass/forb pastures at three stocking rates. *Small Rumin. Res.*, **59**(2-3), 191–201 (2005).

تأثير جودة الغذاء وجنس الحيوان على الهضم واستخدامات الطاقة في الإبل، باستخدام معدل ضربات القلب كمؤشر للطاقة المفقودة

مصطفى عبدالحميد[1] ، أحمد رجب عسكر[1] ، محمود خورشيد[2]، ايهاب يحيى عيد[1] ، نصر البردينى[2] و عفاف الشريف[1]

[1] قسم تغذية الحيوان والدواجن، مركز بحوث الصحراء، القاهرة، مصر.

[2] قسم الإنتاج الحيواني، كلية الزراعة، جامعة عين شمس، القاهرة، مصر.

الملخص

تم استخدام اثنين وثلاثين من الجمال البالغة العربية أحادية السنام، نصفهم من الذكور والنصف الآخر من الإناث، لدراسة تأثير جودة الغذاء والجنس على الهضم واستخدامات الطاقة. تم تقسيم الحيوانات من كل جنس عشوائيًا إلى مجموعتين غذائيتين تحتويان على نسب مختلفة من المركز إلى الخشن، الأولى بنسبة 65 : 35% (مستوى مركز عالى)، والثانية بنسبة 35 : 65% (مستوى مركز منخفض), على التوالى. تم وُضع الحيوانات في حظائر فردية وقسمت على مجموعتين، كل مجموعة تضم 16 جملاً، بحيث تحتوي كل مجموعة على 4 جمال لكل جنس ومعامله غذائية. شملت التجربه 21 يومًا للتعود، و7 أيام لجمع العينات، ويومين لقياس تبادل الغازات. تم تزويد الإبل بأقنعة وجه لقياس استهلاك الأوكسجين باستخدام نظام التنفس الدائري المفتوح، كما تم تركيب أجهزة لقياس معدل ضربات القلب بالتزامن مع تقدير الفاقد من الطاقة لكل حيوان. على الرغم من تشابه كمية الغذاء المأكول بين الإبل المغذاة على المعاملات الغذائية المختلفة، أظهرت الإبل التي تناولت مستوى المركز العالي قدرة أعلى على هضم المادة الجافة والمادة العضوية، باستثناء الألياف، كما أظهر الذكور كفاءة هضمية أعلى مقارنة بالإناث. ومع ذلك، كان كل من معدل ضربات القلب والطاقة المفقودة أعلى في الإبل المغذاة على مستوى المركز المنخفض، بغض النظر عن جنس الحيوان، مما أدى إلى تحقيق توازن طاقه أقل. وبالرغم من تقارب الطاقة المأكولة بين الجنسين، إلا أن الذكور أظهروا مدخولًا أعلى من الطاقة القابلة للهضم، ما انعكس في توازن طاقه أكبر مقارنة بالإناث. ولم يُظهر معدل EE/HR أي اختلاف يُذكر بين جودة الغذاء أو الجنس، مما يؤكد فعاليته كمؤشر موثوق به لقياس الطاقة المفقودة في الإبل العربية أحادية السنام.

الكلمات الدالة: جودة الغذاء، جنس الإبل، الهضم، معدل ضربات القلب، استهلاك الطاقة.