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Effect of diet composition on dry matter intake of dairy she-camels

F. Laameche[1,2] · A. Chehma[1] · B. Faye[3]

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Abstract

The present paper aims to propose an evaluation of the ingestibility and selectivity of food items, as well as the effect of different levels of energetic supplementation and concentrate feed ingredients, on camels dry matter intake (DMI). With this goal, an experiment on six dairy she-camels receiving every 14–15 days a progressive high level of concentrates was conducted. During experimental periods, DMI ranged from 1.30 to 1.96 kg DMI per 100 kg of body weight (BW) was used. In an effort to examine the feeding behavior, a sign of reduced appetite was observed. Based on the results, it can be unveiled that as soon as the concentrate intake (CI) reached a quantity of 3.3 kg DM/d, which represented 51% of the total DM intake, the camels did not appear to ingest more exceedingly and their eating activity occurred in a distributed manner during daytime. Besides, an amount of concentrate supplements, which can characterize a high selectivity to fermentable carbohydrates, fed camels consumed dates, as well. In addition, food items such as corn, soybean meal, and dates that are rich in simple nutrient improved DMI. However, the statistical analysis did not reveal any statistically significant negative effect of concentrates on hay ingestion used in the experimental diets. Therefore, the intake of concentrates did not substitute the ingested amount of hay. Furthermore, the immense incorporation of dates and the increase in energy density of diet (DER) negatively affected the ingestion of hay.

Keywords Appetite · Dairy she-camel · Energy density · Hay · Ingestibility · Selectivity

Introduction

Like all herbivores, the dromedary is sensitive to the quality of the food supply, and dry matter (DM) ingested may vary according to this criterion (Faye 1997). The ingestibility of an herbivore increases as well as its body weight (BW), rumen size, and their energy needs (production) (Jarrige 1988). It has been reported (Jouany 2000) that the total ingested quantities related to BW were significantly lower in dromedary camel than in cattle.

The main objective of sustainable dairy production, therefore, is to transform roughages into food of high nutritional value, as milk and meat are characterized. In order to achieve the same growth as cattle, it has been stated (Kamoun 2004a) that the limiting factor lies on a low-intake ability of camels. In this paper, we offer a study of the effect of dietary composition on dry matter intake (DMI) in dairy she-camel.

Materials and methods

Animals and management

This experimental study was carried out on a randomly selected sample consisted of six (6) healthy non-gravid dromedary she-camels with live BW averaged 418–446 kg and within 3rd and 4th parities. All experimental she-camels were followed-up at the medium-term of lactation (between 5 and 7 months). In this phase, only maintenance and lactation needs were considered. The maintenance requirements of dairy she-camels were evaluated based on the observed BW and estimated by the barymetric formula (Shwartz and Dioli 1992), as follows:

✉ F. Laameche
f.laameche@gmail.com

[1] Laboratory of Saharan Bio-resources Preservation and Valorization, University of Kasdi Merbah, 30000 Ouargla, Algeria

[2] Scientific and Technical Research Centre for Arid Areas (CRSTRA), 7000 Biskra, Algeria

[3] Agricultural Research Centre for International Development CIRAD-EMVT, TA 30/A, International campus de Baillarguet, 34398 Montpellier-Cedex, France

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$$BW(kg) = SH \times TG \times HG \times 50$$

SH height at withers (meter)
TG chest circumference (meter)
HG abdominal circumference at the peak of the hump (meter)

Additionally, the production requirements were determined by recording the quantities of milk produced daily. The referential requirements of dairy she-camels were evaluated using the estimates by different authors from the available literature as shown in Table 1 below.

Feeds and feeding

The feeding trials were intended to investigate the effect of diet composition on diet selection and feed intake capacity when roughages were fed ad libitum, within gradually an increase in concentrate supply and in its effect.

The feeding trials lasted 103 days within four consecutive periods. During the follow-up period, 5 different diets were distributed (noted R1 to R5). Each diet was offered to animal during a period of 2 weeks followed by a week of adaptation.

When diet changed, the energy and protein concentration was gradually increased. Thus, in each experimental period, the concentrates (corn, dates, and wheat bran and soybean meal) were increased from 2.39 to 6 kg per day, while the hay was decreased in proportion as given in Table 2.

Water and hay were distributed ad-libitum. In fact, the distributed quantities of hay were estimated based on data and observations about the adaptation period as reported by Kamoun (1995). The available refusals were weighed before each morning. In addition, daily intake was recorded on dry matter basis.

Data statistical analysis

The relationship between the intake (either total or that reported to metabolic weight $W^{0.75}$or both) and the different components of diets was examined using Pearson correlation test. The analysis of variance using the ANOVA procedure of XLSTAT 2009 software Version 10.7.01 (Addinsoft ©) made it possible to evaluate the effect of ration as a qualitative variation factor on all quantitative parameters (intake, weight, etc.).

Results and discussion

Dry matter intake

In all experimental diets, she-camels were offered water and oat hay (based roughage) ad-libitum. Reducing water intake decreases saliva production and thus, the food intake decreased immediately after watering restriction (Gahlot 2004). Table 3 reports the DMI related to BW and metabolic weight ($W^{0.75}$) of the different studied diets.

The quantity of DM ingested by camels is ranged from 1.30 to 1.96 kg per 100 kg of BW. To provide criticisms in detail, the offer of diets in DM and rationing for camels lack a system of expression of the intake capacity as in other domestic ruminants (Richard 1989).

For constant results, it is necessary to further to express the ingestibility of fodder with another unit rather than a kilogram of DM, which is the "fill unit" UE system for the prediction of the voluntary intake of forage (Jarrige 1988). Table 4 below compares the intake level used herein with other intake levels suggested by numerous authors in previous literature.

Expectedly, the camel ingestion capacity recorded is low. The highest values (1.96% BW) were observed with huge incorporation of concentrate (37/63 hay/concentrate ratio). Kamoun (2004b), however, recorded the same result. He reported that the highest value (2.1% BW) was found with a diet of 38/62 (hay/concentrate).

In this study, the intake capacity of experimented she-camels was ranged from 4.4 to 5 UEL (forage-based diet fill units for lactation). Besides, the real quality of the oat hay used according to Jarrige (1988), the late harvest, the yellowish color, and the encumbrance value of 1.45 UEL/kg DM), and

Table 1 Daily nutrient requirement for lactating she-camels

	UFL [1]	PDI [2] (g)	Ca (g)	P (g)	NaCl(g)
Maintenance needs (Wilson 1989) and (Faye 1997)					
	1.2[3]	80 + (0.45 × BW[4])	4[3]	2.5[3]	20[3]
Milk production needs (Soltner 1982), (Richard 1989), and (Faye 1997)					
1 l milk fat 4%	0.44	50	1.9	1.1	2.5

[1] UFL, forage unit for milk production
[2] PDI, protein digestible in the intestine
[3] Expressed by 100 kg of BW
[4] BW in kilograms

Table 2 Composition of different studied diets

Diets	kg of DM										
	Corn	Wheat bran	Dates	Soybean meal	Vitamin and mineral premix (VMP)	Ca-P	Salt	Concentrates	Hay	Total	Energy density of diet DER[1]
R1	0.87	0.96	0.48	0	0.055	0	0.036	2.39	3.05	5.44	0.91
R2	1.24	1.37	0.76	0	0.0789	0	0.051	3.49	2.96	6.45	1.17
R3	2.27	1.08	1.18	0.28	0.121	0.046	0.086	5.06	2.39	7.45	1.86
R4	2.41	1	1.1	0.4	0.156	0.047	0.089	5.21	3.1	8.31	1.56
R5	2.66	0.92	1.47	0.8	0.054	0.036	0.054	6	1.93	7.93	2.66

[1] DER = the energy density of diet is the ratio of the UF (forage unit) of diet to its UE (the INRA "fill unit" system for predicting the voluntary intake of forage), all reported to kg of DM (Jarrige 1988)

the characteristics of the studied camels (BW 425 kg, production of 3 to 4 l) were taken into account.

Due to the high incorporation of concentrates in R5 diet (a diet implemented by the farmer), the ingestion rate has been very high. In general, the roughage was offered usually in small quantities by the farmer, unlike in the experimental diets (R1 to R4) which make oat hay fully available to camels. Accordingly, the intake of roughage is high in the experimental diets compared to R5. When both roughages and concentrates were offered free-choice to animals, the total DMI was regarded as the animal's most favorable feed intake capacity (Farid et al. 2010).

As a whole, the variation in ingested DM depends on the quality of food offered and the intake level of concentrates supplied (Faye 1997). In a clinical survey study, findings have shown that the main factors of variation in fodder digestibility and the intake quantities received by dromedary she-camels are the same as those observed in other ruminants (Richard 1988). Likewise, camels are sensitive to forage and diet quality (Faye et al. 1995).

However, the practical intake of concentrates did not coincide exactly with the theoretical scientific recommendations in R2, R3, and R4 (Fig. 1) during this experimental study. Nevertheless, the refusal quantities of concentrated food were decreased from 0.3 kg of DM/day/camel in R2 to disappear at the end of the study.

Once the concentrates supply reached 3.3 kg of DM per camel or 51% of total DMI, the camels ingested more slowly with a very well distributed manner throughout the day. It has been reported (Jarrige 1988) that the speed and duration of ingestion is an adequate criterion for all farm animal's appetite. Anticipatively, it is worth noting that rejections did not only affect dates but also the rest of mixed concentrate. For that purpose, it was observed that she-camels initially ingest dates, then the rest of the concentrates, which can explain the phenomenon of selectivity of camels towards fermentable carbohydrates that would probably rebuild the reserves or meet the outset the ruminants' energy needs as Jarrige (1988) reported.

Indeed, the findings cited by Farid et al. (2010) indicated that the raised camels under this study had free choice to select their diets from both concentrates and roughages and as a result was capable to regulate their voluntary food intake predominantly through physiological mechanisms to satisfy energy requirements.

The correlations between DMI and different diets (Table 5) appear to be higher with total intake than with metabolic weight intake.

The intake of hay ranged from 3.1 kg to 1.93 kg DM/day/camel. Besides, an increasing proportion of hay in the diet is associated with a decrease in DMI. However, this effect is not significant. When fodder is richer in nitrogen, total consumption increases significantly in opposite to poor products, like straw, which is less ingested (Faye 1997).

In contrast, the concentrates increasingly integrated into the diet were associated with an increasing DMI. The

Table 3 DMI reported to BW and metabolic weight ($W^{0.75}$) of different studied diets

Diets	DMI of hay (g)/kg $W^{0.75}$	DMI of concentrates (g)/kg $W^{0.75}$	DMI of hay (%) of BW	DMI of diet (g)/kg $W^{0.75}$	DMI of diet (%) of BW
R1	33	26	0.73	59	1.30
R2	31.4	37	0.69	68	1.50
R3	25.1	53.2	0.55	78	1.72
R4	33.4	56	0.73	89	1.96
R5	20	62	0.43	82	1.78

Table 4 Levels of DMI by camels

Author	DMI			
Wilson (1984)	2.5 kg/100 kg BW			
Richard (1985)	2.3 an 3.4 kg /100 kg BW			
Djabre and Okacha (1999)	2–3 kg/100 kg BW			
Knoess et al. (1986)	20 kg DM/day			
Gihad et al. (1989), Richard (1989)	51 g/kg $W^{0.75}$			
Kareche (1990) in Titaouine (2006)	1.4 an 1.5 kg/100 kg BW			
Kamoun (1995)	1.6 kg/100 kg BW or 61 g/kg $W^{0.75}$			
Hashi et al. (1995)	0.92, 0.65, and 0.66 kg/100 kg BW of meadow hay, wheat straw, and oat hay respectively			
Faye (1997)	1.6 to 3.8 kg/100 kg BW			
Kamoun (2004b)	1.66 to 2.1 kg/100 kg BW			
Farid et al. (2010)	Roughages	Straw	Hay	Atriplex
* Concentrates distributed at 100%	Total DM* g/$kg^{0.73}$	78.9	83.9	96.4
** Concentrates distributed at 50%	Roughage* g/$kg^{0.73}$	16.1	22.5	33.4
	Roughage ** g/$kg^{0.73}$	56.16	64.18	99.98
Faye et al. (2018)	1.88 to 1.96 kg/100 kg BW			

concentrates contribute significantly ($p < 0.01$) to the increase in total DMI. Similarly, Farid et al. (2010) and Richard (1988) reported that a supply of concentrate for 20% of forage-based diet increase ingestion by 17–22%. Thus, food used in our experiment such as corn, soybean meal, and dates which are rich in simple nutrient increase DMI ($p < 0.01$) (Table 5).

The addition of vitamin and mineral premix (VMP) supplemented with Ca-P and salt ($P < 0.01$) had also a slightly significant effect ($P < 0.05$) on the total ingestion of DM. The mineral-vitamin supplementation (VMP, Ca-P, and Salt) promotes the DMI by ensuring a good nutritional balance to the rumen flora of camels.

In desert conditions, camels ingest frequently large amounts of halophytes and have a very high requirement of salt in their diet probably more than other herbivores (Farid et al. 2010). Accordingly, Chamberlain (1989) demonstrated previously the fact that camel requires six to eight times the amount of salt required by other livestock. Indeed, camels need about 140 g of salt per day even when they have no regular access to salted aliments (Faye et al. 2011). Moreover, nutritional deficiencies (mineral, in particular) and diseases have a negative influence on DMI by ruminants in general (Jarrige 1988) and by camels in particular (Faye et al. 2011).

Interactions between concentrates and roughage

The analysis of interactions between concentrates and roughage (Table 6) shows that there are no significant correlations. The ingestion of concentrates did not substitute the quantity of hay DMI by she-camels.

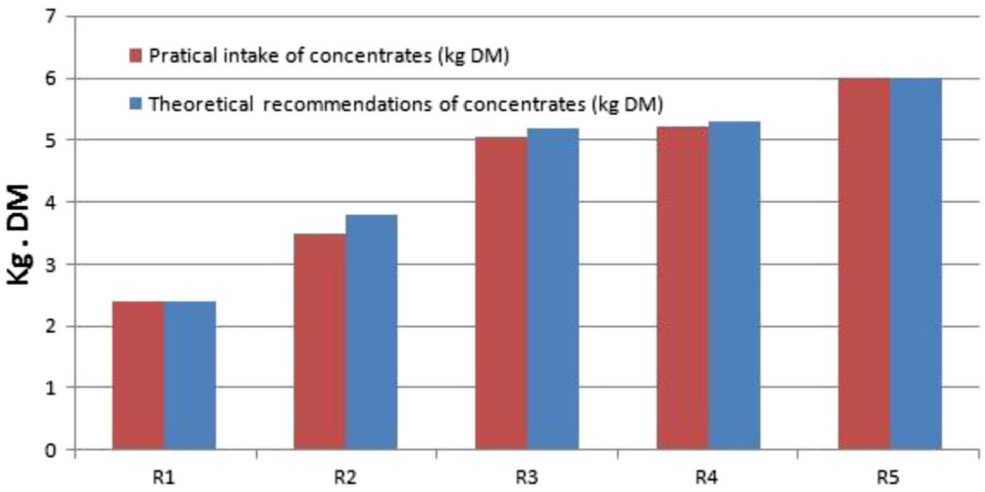

Fig. 1 Evolution of concentrated food refusals in experimental diets

Table 5 Correlations (r) between total ingestion; ingestion reported to metabolic weight with the various components of the studied diets

Components (kg DM)	Total ingestion of DM (kg)	Total ingestion of DM (g)/kg $W^{0.75}$
Corn	0.778 **	0.800 *
Wheat bran	− 0.085 NS	− 0.200 NS
Dates	0.778 **	0.600 NS
Soybean meal	0.654 **	0.738 *
Vitamin and mineral premix	0.556 *	0.400 NS
Ca-P	0.700 **	0.738 *
Salt	0.778 **	0.800 *
Mixed concentrates	0.833 **	0.800 *
Oat hay	0.000 NS	− 0.200 NS

NS $P > 0.05$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

The mineral-vitamin improvement has a marginally non-significant positive effect on the ingestion of hay.

Richard (1988), Kayouli et al. (1994), Dardillat et al. (1994), and Dulphy et al. (1994) agreed that the addition of concentrates has no negative effect on the digestion of roughage, which forms the basis of diet. The work of Kamoun (2004b) also reinforces our observations. The author in his study indicated that the concentrates did not replace the based studied forge (hay), but on the contrary, increases the ingestibility of those, which have a mediocre quality.

This result is explained by a higher rate of elimination of microbial digestion products (acids, ammonia) linked to a faster turnover of the liquid phase of the digesta and to a greater absorption pattern by the digestive tract (Faye et al. 1995). The bicarbonate and carbonate secretion via the forestomach mucosa contributes considerably to the homeostasis in the fermentative media and the digestive efficiency in microorganisms (Vallenas and Stevens 1971).

Indeed, the observation of feeding behavior indicates that she-camel consumes hay and concentrates in a balanced manner. For this reason, it is evident that the camels ingest the concentrates in a fractional way and do not further finish them immediately once their supply achieves a quantity of 3.3 kg of DM or 51% of ration DM.

On the contrary, in an ancient publication, Kamoun et al. (1989) indicated in his experiment that the rate of substituting the hay with concentrates was higher (0.6 kg DM hay with 1 kg DM concentrate). It was found (Farid et al. 2010), reflecting upon the concept of supplementary feeding, that percentages represent reduction of pasture intake when concentrate supplementation increases from about 28 to 63 g DM/day/$kg^{0.73}$ (metabolic size). Nevertheless, it was indicated in the same reference that roughage intake had not been affected in the atriplex fed camels when it amounted to 100 g DM/day/$kg^{0.73}$. But this could be due to the positive response of camels to atriplex feeding, which is attributed to high amounts of salts and high secretion of camel saliva. In this case, the latter confers protection to the mucosa of the digestive tract from mechanical injuries, fixes the plant tannins, and thereby protect their negative

Table 6 Interactions and correlations (r) between roughage and concentrates ingestion

	Roughage ingestion (kg DM)	Roughage ingestion (DM) (g)/kg $W^{0.75}$	Roughage ingestion (DM) (%) of BW
Concentrates ingestion (kg DM)	− 0.400 NS	− 0.400 NS	− 0.527 NS
Concentrates ingestion (DM) (g)/kg $W^{0.75}$	− 0.400 NS	− 0.400 NS	− 0.527 NS
Corn (kg DM)	− 0.183 NS	− 0.400 NS	− 0.527 NS
Wheat bran (kg DM)	− 0.031 NS	0.200 NS	0.105 NS
Dates (kg DM)	− 0.243 NS	− 0.600 NS	− 0.738 *
Soybean meal (kg DM)	− 0.072 NS	− 0.316 NS	− 0.444 NS
Vitamin and mineral premix (kg DM)	0.304 NS	0.400 NS	0.316 NS
Ca-P (kg DM)	0.110 NS	0.105 NS	0.000 NS
Salt (kg DM)	0.061 NS	0.000 NS	− 0.105 NS
Energy density of diet (DER)	− 0.600 NS	− 0.600 NS	− 0.738*

NS $P > 0.05$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

effects on protein metabolism in the rumen (Schmidt-Witty et al. 1994).

In previous experiments (Hoover 1986; Nsahlai and Umunna 1996; Faverdin 1999), in all roughage groups, liberal intake of corn grains especially when offered ad libitum might have increased rumen acidity and osmolality and intensified the effect of propionate in the liver and impair fiber digestion (long-term adjustment to liberal corn feeding was observed as of about day 30, and beyond where corn grains intake started to decrease, roughage and cottonseed meal intake increased and total DMI decreased (Farid et al. 2010)).

The increase in energetic density of diet, however, decreases the hay intake relatively to the BW ($p < 0.05$) (Table 6) and accordingly, the ingestion of dates negatively affects the hay ingestion ($p < 0.05$). It must be noted that this aliment is not adapted to the regime of dairy she-camels and thus, its incorporation must be perfectly controlled.

Conclusion

In order to adequately cover its needs, the she-camel should consume a large amount of DM, even though its appetite is limited and hardly exceeds 1.96% of its BW. Roughage should be distributed ad-libitum, as camels have an insufficient time access to feeding that decreases DMI since they take longer time to ingest compared to other domestic animals. Hence, the type of forage-based diet, the percentage of concentrates and their interactions have a significant influence on the ingestion capacity and selectivity of agri-food. According to its natural feeding behavior, the dromedary she-camels preferentially take food rich with salt or nitrogen or even both (particularly acacia-type legumes), which allows them to make better use of the ecosystems that are lack of the fodder resources, where they are used to be stabilized. However, in stabling with the lignified types of forages, the natural ability of the dromedary she-camels to select food is at a low level and consequently, leads to a reduction in the ingestion. Based on the foregoing results, it can be concluded that it is necessary to develop supplementations to overcome the most well-known mineral and vitamin deficiencies. With intensification, however, she-camels become more fertile and thus, can produce dairy food.

The findings are of direct practical relevance. Clearly, further research will be required to a new livestock situation, namely situation of ruminants with low ingestion capacity that is most difficult to handle and in-demand as well.

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Compliance with ethical standards

Human and animal rights and informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The manuscript does not contain clinical studies or patient data. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Conflict of interest The authors declare that they have no conflict of interest.

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