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Assessing limitations in published camel feeding studies: implications for smart feeding practices in meat and milk production

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Rearing camels in intensive production systems started in the last 20 years. This led to a considerable change in camel feeding and nutrition including the use of new feeds (i.e. gains, agricultural by-products, supplements). Therefore, research was conducted to determine the effect of using these feeds in camel meat and milk production. The existing studies on camel feeding and nutrition are scattered and lack both an appraisal and comprehensive summary. This systematic review analyses the ability of published feeding and nutrition studies to guide researchers, extension workers, and farmers in formulating rations for smart feeding of camels. The Web of Science database was used to collect all published and peer-reviewed articles on the effects of feeding options on camel meat and milk production using the following Boolean: camel AND (milk OR growth OR meat). The first search yielded 2475 unique entries. Screening of the title shortlisted 278 relevant articles and the summary and full text assessment identified 41 relevant articles (27 fattening studies and 14 milk production studies) that were reviewed in depth. The experimental diets in only two studies (out of 41 studies) were formulated considering camel feeding standards. It is concluded that the published peer-reviewed literature in the field of camel nutrition is limited in both quantity and quality in informing the camel production sector to design rations for smart feeding for meat and milk production.

KEYWORDS
camelus, milk, meat, feeding, nutritional requirements

1 Introduction

The human population is expected to increase by 2.5 billion by 2050 with Africa and the Middle East accounting for 50% of this increase (Roser, 2018). Climate change is expected to increase drought and desertification in these areas, leading to a shift in livestock farming from cattle to camels (Watson et al., 2016). In fact, many reports have indicated that the camel will be one of the main livestock species for future meat and dairy production (Gagaoua and Bererhi, 2022).

Camel is a multipurpose animal used for draft power, transportation and production of milk, meat, wool, hair, and skin. In addition, it is used for racing and tourism (Gagaoua and Bererhi, 2022). The total population of camels around the world in 2022 was 42,313,000 head, with more than 70% of them (30,000,000 head) kept by farmers in the arid and semi-arid areas of the developing world (FAOSTAT, 2022). The leading countries in camel population are Chad, Chad, Somalia, Sudan, Kenya, and Saudi Arabia (FAOSTAT, 2022). The camel population is increasing at an annual growth rate of 2.1%, which is higher than ruminant species (Faye, 2016a). Camel has relatively high potential of meat (580–733 g/day) and milk production (2550–5400 kg milk/300 d) (Kadim et al., 2008). These figures were measured under an extensive production system and it is expected to increase when camel is reared under intensive production conditions (Kadim et al., 2008). Camel produce less NH_3 [by 10–15% (Smits et al., 2023)] and less CH_4 [by 56% (Dittmann et al., 2014)] compared to cattle. Furthermore, camels are able to convert low quality feed that other livestock species do not normally consume, such as prickly plants, into meat and milk (Ali et al., 2019).

Historically, camels have been associates with nomadic or semi-nomadic production systems, in which they depend entirely on natural pasture with little attention given to their feeds, feeding and nutrition (Hashi et al., 1984). These production systems underwent rapid changes and transformations to meet the increasing demand for camel meat and camel milk (Faye, 2016b). Rearing camels under intensive production systems started in the last 20 years (Nagy and Juhasz, 2016) and it was not associated with negative consequences such as the emergence of zoonotic diseases and antibiotic resistance (Nagy et al., 2022). Countries such as Tunisia, Saudi Arabia and the United Arab Emirates have adopted camel machine milking (Nagy and Juhasz, 2016). Camel producers in Australia, Europe, and the United States have also begun milking their camels by machine (Nagy et al., 2022). Emirates Industry for Camel Milk and Products established the first large-scale camel dairy farm with 6000+ she-camels (Nagy et al., 2012).

As a result of this change in the production system, camel producers introduced new feed resources (such as grains and agricultural by-products) into camel diets to improve meat and milk production. Therefore, research was conducted to determine the effect of using these feeds in camel meat and milk production.

The existing studies on camel nutrition are scattered and lack a comprehensive summary. Summarizing and analysing the robustness of the published studies on camel feeding and nutrition would enable researchers to steer their research in the field. Furthermore, it would determine if camel producers could rely on these studies to increase the efficiency of the camel in converting feed into meat and milk.

Thus, the objective of this review is to provide a thorough and inclusive overview of the existing research on camel nutrition, while evaluating the significance and reliability of these studies in order to inform the development of ration formulation strategies for intelligent feeding. The current review does not aim at recommending the best camel feeding and nutritional practices.

2 Implementation of the search strategy

The current review aims at answering the following question: "can the published research on camel nutrition inform farmers in the camel production sector to achieve smart feeding?". The review targeted peer reviewed papers reporting on investigating the effect of nutritional interventions on camel meat and milk production.

The Web of Science was used to collect the relevant studies. The search used the following generic Boolean, "camel AND (milk OR growth OR meat)".

A multistage screening was applied to the studies resulted from the search to determine which ones should be read in full. The criteria for including/excluding studies for the final analysis is presented in Table 1.

3 Systematic map of the review

A detailed systematic map of the current review is presented in Table 2. A total of 41 original research articles related to the question of the review resulted from the process of searching, screening and appraisal.

TABLE 1 Details of search technique and inclusion/exclusion criteria used to screen studies for relevance in the current review.

Criterion	Restriction
Search specifications	
Search database	Web of Science
Search Boolean	camel AND (milk OR growth OR meat)
Search field	Anywhere in the article.
Inclusion/exclusion	
Population	Camel
Language of study	English
Type of publication	Peer reviewed journal article.
Date of publication	Any study published before 2023
Geographical reference	No restrictions
Climatic conditions	No restrictions
Theme of study	The study should have at least one feeding trial

TABLE 2 A systematic map of the systematic review.

Stage	Action	N of records
Identification	Records identified through database searching	3067
	Records identified after duplicates were removed	2475
Screening	Records meeting inclusion criteria 1st pass (title)	278
	Records meeting inclusion criteria 2nd pass (abstract)	41
	Records meeting inclusion criteria 3rd pass (conclusion)	41
	Records meeting inclusion criteria 4th pass (full text)	41
Total		41

4 Results

4.1 Summary of literature

The screening process revealed that 41 studies determined the effect of nutritional interventions on growth (27 studies) and milk (14 studies) production of the camel (Tables 3, 4). The studies were conducted across the countries of the Middle East (Iran, Saudi Arabia, Oman, Egypt, Algeria, Tunisia), Africa (Kenya, Ethiopia, Mali), and south Asia (Pakistan, India). The milk production studies covered the scopes of the effect of non-conventional feeds (one study), nutrient supplementation (eight studies), water deprivation (three studies), and management system (two studies). The effect of nutrient supplementation, non-conventional feed, management system, enzyme addition, and probiotics, on camel meat production were investigated in six studies, five studies, seven studies, one study, one study, and six studies, respectively.

Four studies characterized fattening performance of camel calves. Only two studies (fattening studies) out of the total of 41 studies considered feeding standards of camel when the dietary treatments were designed.

4.2 Summary of calf fattening studies

Dry matter intake, blood serum profile, growth, and economics of fattening weaned camel calves was recorded by Nagpal et al., (2012). Growth performance of camel calves varied between breeds (Basmaeil et al., 2012).

Increasing the protein content of the diet from 9.5% to 12% did not affect dry matter intake and protein digestibility but improved digestible protein intake in camel calves (Nagpal, 2007). However, increasing that level from 18% to 22% improved fattening

TABLE 3 A summary of studies which determined the effect of nutrition on camel calve growth.

Theme	Location	Author	Year	Feeding standards	
				Reference	*Accessible*
Nutrient supplementation	Saudi Arabia	Alhidary et al.	2016	NA	NA
Non-conventional feed	Saudi Arabia	Faye et al.	2018	NA	NA
Management system	Pakistan	Faraz et al.	2020	NA	NA
Characterisation	Saudi Arabia	Basmaeil et al.	2012	NA	NA
Nutrient supplementation	Egypt	Mostafa et al.	2020	NA	NA
Probiotics	Egypt	Mohamed et al.	2009	NA	NA
Non-conventional feed	Pakistan	Faraz et al.	2021	NA	NA
Nutrient supplementation	Oman	Mahgoub et al.	2014	NA	NA
Non-conventional feed	Saudi Arabia	Al-Owaimer	2000	NA	NA
Enzyme addition	Egypt	Adel and EL-Metwaly	2012	NA	NA
Non-conventional feed	Pakistan	Nagpal et al.	2005	NA	NA
Probiotics	Saudi Arabia	Alhidary et al.	2018	NA	NA
Management system	India	Bhakati et al.	2015	NA	NA
Non-conventional feed	NA	Emmanuel et al.	2015	NA	NA
Characterisation	India	Nagpal et al.	2012	NA	NA
Management system	Oman	Mahgoub et al.	2014	NA	NA
Management system	India	Saini et al.	2014	(ICAR, 2013)	Yes

(Continued)

TABLE 3 Continued

Theme	Location	Author	Year	Feeding standards	
				Reference	*Accessible*
Nutrient supplementation	India	Nagpal	2007	(Wardeh, 1997)	Yes
Nutrient supplementation	Saudi Arabia	Abdoun et al.	2015	NA	NA
Characterisation	Pakistan	Faraz et al.	2019	NA	NA
Characterisation	Iran	Dadvar et al.	2019	NA	NA
Nutrient supplementation	NA	Faye et al.	1992	NA	NA
Water Deprivation	NA	Nagpal et al.	1993	NA	NA
Management system	Pakistan	Faraz	2020	NA	NA
Management system	Pakistan	Faraz et al.	2018	NA	NA
Nutrient supplementation	Tunisia	Hammadi et al.	2015	NA	NA
Management system	Pakistan	Faraz et al.	2017	NA	NA

NA, not available.

performance and fattening revenue when the energy content in the diets was the same (Faraz et al., 2021b). Increasing concentrate intake (from 0.5% live weight to either 2% live weight or 2.5% live weight) had no effect on the growth and carcass characteristics of camel calves (Mahgoub et al., 2014a). Supplementing grazing camel calves with free access to green alfalfa fodder improved weight gain (Faraz et al., 2020). Salicornia hay has been substituted for Rhodes grass in the diet of camel calves without adverse effects on fattening performance or carcass characteristics of camel calves (Al-Owaimer, 2000).

The time spent by camel calves grazing was relatively less in the dry season compared to the wet season, while *Opuntia ficusindicus* was the most commonly grazed plant species in both the dry and wet seasons (Chimsa et al., 2013). Cool temperature grazing improved the growth rate of camel calves (Bhakat et al., 2015).

Grazing camels on natural pasture requires energy and protein supplementation to achieve adequate growth (Nagpal et al., 2000). However, Mangrove leaves alone ensured sufficient growth (550 g/day) for the camel calves (Faye et al., 1992). An intensive management system (one kg of concentrate/head/day and chickpea

TABLE 4 A summary of studies determined the effect of nutrition on milk production of she-camel.

Theme	Country	Author	Year	Feeding standards	
				Reference	*Accessible*
Non-conventional feed	Saudi Arabia	Faye et al.	2013	NA	NA
Nutrient supplementation	Kenya	Dell'Orto et al.	2000	NA	NA
Nutrient supplementation	NA	Laameche et al.	2021	NA	NA
Nutrient supplementation	Saudi Arabia	Abdelrahman et al.	2022	NA	NA
Water Deprivation	Ethiopia	Faraz et al.	2004	NA	NA
Management system	Tunisia	Ayadi et al.	2018	NA	NA
Water Deprivation	Ethiopia	Bekele et al.	2011	NA	NA
Nutrient supplementation	Kenya	Onjoro et al.	2006	NA	NA
Nutrient supplementation	Saudi Arabia	AL-Dobaib and Kamel	2012	NA	NA
Water Deprivation	Pakistan	Faraz et al.	2021	NA	NA
Nutrient supplementation	Ethiopia	Dereje and Uden	2005	NA	NA
Nutrient supplementation	India	Nagpal and Patil	2012	NA	NA
Nutrient supplementation	Algeria	Cherifa et al.	2018	NA	NA
Management system	Mali	Jacks et al.	1999	NA	NA

NA, not available.

straw *ad libitum*) improved growth performance and reduced growth feeding costs of camel calves by 28% compared to both an extensive management system (10 h of grazing per day and household food waste) (Faraz, 2020) and the semi-intensive management system (8 h of grazing + chickpea straw *ad libitum*) (Faraz et al., 2018). Interestingly, another study reported that the growth performance of camel calves in the extensive management system (all-day grazing + kitchen leftovers) was better than that in the semi-intensive management system (fed gram residues *ad libitum* and 8 h of grazing) (Faraz et al., 2017). The growth of stall-fed camels was better than grazing camels (781 g/day vs 2 g/day, respectively) (Saini et al., 2014) with no health or management problems (Mahgoub et al., 2014b). Blocking complete feed improved nutrient uptake, nutrient digestibility, and growth in camel calves (Nagpal et al., 2005). Replacing commercial concentrate with date urea blocks did not affect growth performance of camel calves (Faye et al., 2018). The inclusion of urea at 1% in roughage based ration improved nutrients intake, digestibility, growth performance and feed conversion efficiency of growing camel calves (Emmanuel et al., 2015).

Supplementation with yeast cultures (5 g/kg feed) or chromium yeast (0.5% of the diet) improved growth performance of camel calves by 200g/day (Mohamed et al., 2009) and 88 g/day (Alhidary et al., 2018), respectively. Trace mineral rumen bolus supplementation improved growth performance of camel calves (Alhidary et al., 2016).

Neither Chromium (0.5 mg/kg DM) (Abdoun et al., 2015) nor zinc (5 g/kg DM) (Mohamed et al., 2009) supplementation improved nutrient uptake, nutrient digestibility, or growth performance in camel calves. The addition of *Azolla pinnata* to the diet (2% of the diet) improved growth performance of camel calves (Kumari et al., 2014). Addition of exogenous enzymes (ZADO®) from anaerobic bacteria at a rate of 40 g/h/d improved nutrient digestibility and body weight gain (by 290 g/day) and reduced total meat fat content in camel calves (Adèle and El-Metwaly, 2012).

Daily *ad libitum* watering of camel calves improved nitrogen balance and growth performance by 25 g/day compared to weekly watering (Nagpal et al., 1993).

4.3 Summary of milk production studies

It has been found that she-camels require a minimum of 60% dietary fibre, 0.78 French feed units/kg and 63 g/kg digested protein for optimum milk production (Laameche et al., 2021). Increasing protein and energy level in the camel diet was associated with an improvement in milk yield and composition. Supplementing she-camels fed on alfalfa with 4 kg/head of feed concentrate improved protein and mineral levels of milk (Abdelrahman et al., 2022). Increasing the energy content (total digestible nutrients) of diets for lactating camel (from 50% to 60%) improved milk yield without affecting milk composition (Nagpal and Patil, 2012). Increasing the amount of concentrate feed given to grazing camels from 1kg/head/day to 4 kg/head/day improved milk yield and composition (El-Hatmi et al., 2004). Supplementing browsing she-camel with 4 kg/day maize grain improved milk yield and fat content while 4 kg/day groundnut cake supplementation improved only fat content without affecting milk yield (Dereje and Udén, 2005). Supplementing she-camel fed mainly on faba bean and barley straw with 1 kg barley grain/day/head improved milk yield, protein content and fat content (Saini et al., 2010).

Fat and protein content in milk did not change when barley grains (3kg/head/day) were totally replaced by olive cake in the she-camel diet (Faye et al., 2013).

Shrub browsing and *Euphorbia tirucalli* improved milk fat compared to pasture grazing of the she-camel (Kashongwe et al., 2017). However, the same study reported that she-camels fed *E. tirucalli* had higher milk protein than shrub or pasture grazing (Kashongwe et al., 2017). The inclusion of *Atriplex* shrub at a level of 40% in Berseem hay-based diet in late pregnancy and post-partum improved the productive and reproductive performance (postpartum first estrus interval, number of services, conception, days open, pregnancy rate, duration of placental drop, and calving interval) of she-camels as well as the growth performance of their calves (Mostafa et al., 2016).

There was no influence of the management system (grazing vs. cultivated forage) on milk yield and composition of the she-camel (Cherifa et al., 2018). Stabling camels had higher milk yield with more protein and less fat compared to grazing camels (Ayadi et al., 2018).

Mineral supplementation studies reported mixed results. Zinc-methionine supplementation (50 mg/kg feed) improved reproductive traits (postpartum first estrus interval, number of services/conception, days open, pregnancy rate, duration of placental drop, and calving interval), milk yield, milk fat, milk ash, and milk total solids of she-camels (Mostafa et al., 2020). Ground bones mixed with locally available natural salt (200 g/day) did not improve milk yield, but improved growth of weaned calves (Kuria et al., 2004) while phosphorus and cobalt supplementation has been found to improve milk yield in lactating camels (Onjoro et al., 2006). However, this study did not mention the level of mineral supplementation. Supplementing grazing dairy camels with 200 g/day of a mineral salt (a mixture of phosphate, calcium, and sodium chloride) had no effect on milk yield and composition (Dell'Orto et al., 2000). Replacement of bone minerals with inorganic minerals decreased milk yield and growth of dairy calves (Kuria et al., 2011).

Sunflower oil supplementation at 4% diet did not affect feed intake, milk yield, or milk composition in the female camel (Al-Dobaib and Kamel, 2013).

More frequent watering improved milk yield and composition of she-camels. Camels that had access to water weekly had lower milk yield than camels that had access to water every 4 days or daily (Faraz et al., 2021a). Milk yield, lactose content, protein content and fat content of she-camels decreased linearly starting from day 7 (Bekele et al., 2011) or day 12 (Bekele and Dahlborn, 2004) of water deprivation.

5 Discussion

The change in the management system of the camel from the traditional system — based on grazing natural pasture — to stall feeding resulted in a significant change in camel diets. Researchers were interested in determining the effect of feeding interventions associated with this transition on production and health of camels in order to give the best nutritional recommendations. The goal of the current study is to summarize and appraise the robustness of nutritional and feeding studies and to determine whether these studies could inform smart camel ration formulation. Hence, recommending the best feeding practices for camels is not the interest of the current review.

The current study found that since 1992, only 41 articles examined the influence of feeding and nutritional interventions on camel production performance. This number is so little compared to studies published on other livestock species. Replacing the keyword “camel” by either “cattle”, sheep” or “goat” in the search Boolean resulted in 61 k studies, 35 k studies, and 22 k studies on cattle, sheep, and goat, respectively.

Two feeding standards which are currently published for camels are “Nutrient requirements of camel” (ICAR, 2013) and “The nutrient requirements of the dromedary camels” (Wardeh, 1997). A closer look at the articles identified by the current study found that the experimental diets of the experimental animals in 39 articles did not consider the nutritional requirements of camels. Although both standards are available in the public domain, only two studies out of the 41 published studies (namely (Saini et al., 2014) and (Nagpal, 2007)) formulated the experimental diets of their camels based on feeding standards. The formulation of the experimental diets in animal nutrition trials has large impact on the ultimate conclusions drawn. It is crucial to avoid both overfeeding or underfeeding the experimental animals, as doing so would introduce an additional confounding factor into the trial. This confounding effect, in turn, would have a detrimental impact on the overall validity and reliability of the experimental treatments, ultimately compromising the soundness of the trials conclusions. The majority of the published studies on camel feed and nutrition overlooked camel nutritional requirements when the feeding and nutritional interventions were designed. Accordingly, the reliability of the conclusions of the camel feeding and nutrition studies in informing camel nutritionists is very limited and more studies in the field are still urgently required.

Feed constitutes 60%-70% of the overall expenditure in livestock production (Becker, 2008; Makkar, 2018). The traditional extensive production system for camels is typically characterized by minimal or negligible feeding expenses, relying entirely on natural pasture grazing with little to no supplementation. The increasing demand for camel meat and milk fosters a rapid trend towards commercialization within the camel production sector to achieve the maximum production potential. This momentum is primarily fuelled by the intention to enhance the economic viability of camel production through increased productivity and reduced production costs. Both underfeeding and overfeeding result in increased feed conversion ratio of livestock by either decreasing nutrient utilization or increasing feed amount consumed per kg of growth (Doreau et al., 2003). The current review showed that available literature about camel nutrition is unable to inform ration formulation for smart camel production. Thus, formulating camel rations based on existing literature may pose challenges to camel production economics, potentially impeding the sector commercialization efforts.

Although the nutritional requirements of the camel have been assessed since 1997, our review showed that most camel feeding studies did not follow camel feeding standards when they formulated the experimental diets. This pinpoints the lack of awareness about the existing feeding standards among camel researchers, and consequently, camel producers. Thus, the current review would contribute to raising awareness of researchers of the nutritional requirements of camels. The researchers in turn would disseminate these feeding standards among farmers to achieve optimal meat and milk production from camels.

6 Conclusions

The number of peer-reviewed publications on camel nutrition is limited. Furthermore, these studies are unreliable for formulating rations for smart meat and milk production of camels.

The current review would encourage more research in the field of camel nutrition to enable the producers to feed camels to achieve optimal production and welfare.

Author contributions

AA: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. AS: Conceptualization, Writing – review & editing. MM: Writing – review & editing. MT: Writing – review & editing. MN: Writing – review & editing. CO: Writing – review & editing. JW: Conceptualization, Writing – review & editing. EB: Conceptualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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