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New Animal-Based Measures to Assess Welfare in Dromedary Camels

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Abstract

Reliable and measurable animal-based measures (ABMs) are essential for assessing animal welfare. This study aimed at proposing ABMs for dromedary camels identifying their possible associations with management. Data were collected at a permanent camel market; a total of 76 pens and 528 camels were evaluated. ABMs were collected for each welfare principle (i.e. Good feeding, Good housing, Good health, Appropriate behaviour), while resources or management-based measures were collected at three levels of investigations (Animal, Herd or Caretakers). Associations were calculated by Generalized Linear Models. Body Condition Score and Thirst index (ABMs of Good feeding) resulted negatively associated with short caretaker's experience, dirty bedding, limited shaded space, feeding and water space, and space allowance ($P<0.05$). Resting behaviours and Restricted movements (ABMs of Good housing) were associated with short caretaker's experience, dirty bedding and water, rationed water distribution, water points in the sun, and presence of hobbles ($P<0.05$). Disease, Injury, and Pain induced by management procedures (ABMs of Good health) were negatively associated with short caretaker's experience, presence of hobbles, limited space allowance and shaded space, dirty bedding, and feeding and watering practices (e.g. frequency of distribution, resource quality, location of the troughs) ($P<0.05$). Response to Approaching test and Aggressivity (ABMs of Appropriate behaviour) were negatively associated with limited space allowance, shaded, feeding and water space, and rationed water distribution ($P<0.05$). Overall, the proposed ABMs seems to be appropriate indicators of welfare consequences in camels being able to identify factors related to housing and management practices that may impair or improve camel welfare.

Introduction

Animal welfare measures how an animal is coping with the environment where it lives (Broom, 1996; OIE, 2008). Animal welfare assessment consequently has to be based on reliable, measurable, and valid indicators. Those measures may be animal-based (ABM) or resource and management-based indicators. Often ABMs reflect the consequences, positive or negative, of factors related to housing and management and are therefore treated as the outcome in the formal risk assessment analysis (EFSA, 2012c; a). In the last decade, scientists have emphasized the role of ABMs since they can better express how an animal is feeling both physically and psychologically providing an integrative and direct measurement of its welfare state (Broom, 1996; Main et al., 2007; Munoz et al., 2018). ABMs may indeed indicate not only impaired functioning associated with malnutrition, dehydration, movement difficulties, injury, and disease but also needs and affective states such as pain and fear (Broom, 1996; EFSA, 2012a). The ABMs selected to obtain an impression of the animal's quality of life as complete as possible should cover all dimensions of animal welfare, reflecting thus the multidimensional concept of welfare. According to the Welfare Quality® and AWIN projects, four main dimensions of welfare, called principles, should be monitored: Good feeding, Good housing, Good health, and Appropriate behaviour (Welfare Quality, 2009; AWIN, 2015). The ABMs, however, are required to be not only reliable but also feasible in order to make the on-farm assessment protocol both time- and resource-saving (Main et al.,

2007; EFSA, 2012c). A short-list of ABMs could be selected avoiding overlapping of information but covering the main factors capable of inducing concerns for the welfare of that particular animal (EFSA, 2012c). In this context, an important feature of ABMs is their “fitness for the purpose of the assessment”. The selected ABMs should be fit for that particular animal species and category at that time, for the skills of assessors, the conditions under which they are to be collected, ethics and financial constraints (Main et al., 2007; EFSA, 2012c).

The attention of the scientific world has therefore focused on the selection of ABMs according to the species and the farming systems. However, most of the research has been conducted in European countries for animals such as pigs, poultry, ewe, and dairy cattle (Main et al., 2007; EFSA, 2012b; Cook, 2017; Munoz et al., 2018; Tremolada et al., 2020). Among farm animals, the camel was rarely involved in studies related to welfare assessment (Pastrana et al., 2020; Zappaterra et al., 2021) and an *ad hoc* protocol for its welfare assessment has only recently been proposed (Padalino and Menchetti, 2021). This protocol includes a combination of animal-, resource- and management-based measures assessed at three levels of investigation: using a face-to-face interview with the caretaker (Caretaker level), checking the herd and the pen facilities (Herd level), and inspecting individual camel behaviour and health status (Animal level). These measures could be then scored and combined to produce overall assessment indices, and to classify the pens according to their camel welfare level (Menchetti et al., 2021). As far as we know, however, no specific ABMs have been selected for camels and their relationship with factors that may effect their welfare has not been investigated yet. These topics should be urgently addressed as important steps toward the identification of welfare concerns and standards for camels. With the intensification of camel production in many parts of the world (Bengoumi and Faye, 2002; Faye, 2014), indeed, the possible harms to the well-being of these animals in intensive farms or transport are increasing (Bauer and Havenstein, 2017; Pastrana et al., 2020).

Thus, hypothesizing that ABMs would be related to management, the aim of this study was to propose new ABMs for dromedary camels and to evaluate the possible associations between these ABMs, used as indicators of welfare consequences, and resource and management-related factors in camels kept in an intensive system.

Materials And Methods

General description of housing and animals

This study was conducted as part of a larger study aimed at applying a protocol for the welfare assessment of camels kept at the permanent camel market in Qatar. The research project was run with the permission of the Department for Agriculture Affairs & Fisheries of the Ministry of Municipality and Environment of the State of Qatar (protocol code 2404/2020). The study involved no invasive sampling methods and all data collection was performed without disturbing the animals. Oral owners' and caretakers' consents were received before the assessment.

Data were collected at the market in the morning (7:00-11:00 AM) from the 11th to the 18th of September 2019. The mean temperature and humidity were 42.3 °C (standard deviation (SD)=2.9°C) and 32.2% (SD=8.6%), respectively, while Temperature Humidity Index (THI) was 89 (SD=3). The Doha market is a permanent market where there are 92 pens; 76 out of 92 pens contained animals at the time of the study and were therefore involved in our data collection, with a total of 528 camels. Camels could have different owners and caretakers, they came from different geographical areas (i.e. Qatar, Sudan, Oman, Saudi Arabia, United Arab Emirates, Kuwait, Pakistan, and Somalia) and were kept at the market for different purposes (i.e. milk, meat, breeding, sales or racing).

Measures, data collection and handling

The assessment was conducted by five assessors with a solid scientific background in camel behaviour, health, and welfare using three different approaches (i.e. three levels of investigation, Caretaker, Herd and Animal Level). The Caretaker level consisted of a face-to-face interview with 49 caretakers who managed one or more pens at the market. Four of the 23 items of the questionnaire proposed by the protocol of Padalino and Menchetti (2021) were used in the present study. The Herd level consisted of a check of the general characteristics of the pens (n=76 pens) and all animals included therein (n=528 camels). Seventeen measures among those proposed by the protocol (Padalino and Menchetti, 2021) were selected for the present study. The Animal level consisted of a deeper inspection of 2 randomly selected animals within each pen, but in some pens, there was only one camel (n= 132 camels). The authors could perform the deeper inspection of a maximum of two camels per pen, due to constraints in animal ethics. Eleven measures among those proposed for the Animal level by the protocol (Padalino and Menchetti, 2021) were selected for the present study. Each level of investigation included both animal-based and management- or resource-based measures.

The animal-based measures treated as welfare consequences were all “direct” indicators (i.e. taken from the animal (EFSA, 2012c)) and they did not require further laboratory analysis. At least two indicators for each welfare principle (i.e. Good feeding, Good housing, Good health and Appropriate behaviour) were selected, as detailed in Table 1. Animal-based measures could be collected at both Herd and Animal level, according to the protocol of Padalino and Menchetti (2021). Some measures involved only the visual inspection of the animals (e.g. Body Condition Score (BCS), presence of disease or injuries) while others required behavioural observations (i.e. resting behaviour and aggressivity) or specific behavioural tests (i.e. Thirst Index and Approaching test). For the presence of disease, evident clinical signs, such as swollen joints or udder, lameness, discharge (i.e. nasal, ocular, vulvar), diarrhoea, alopecia, coughing and abnormal breathing, were noted down. For statistical purposes and due to the skewed data distribution, measures expressed as scores (i.e. BCS and Thirst Index), and a measure collected at Herd level (i.e. aggressivity) were categorized in 2 or 3 categories (Table 1). The other measures collected at the Herd level (i.e. Restricted movements and Pain induced by management procedures) were, instead, expressed as the proportion of animals in the pen. As the number of animals in the pen showed great variability (from 1 to 37 camels) and the proportion could be biased in uncrowded pens (e.g., 100% indicated only

one affected animal in pens holding 1 camel), each percentage was weighted for the maximum number of animals for which the criterion was satisfied.

The presence of stereotypies, initially selected as welfare consequence for Appropriate behaviour, was instead excluded from the analysis as no events were recorded.

Table 1. Animal-based measures treated as indicators of welfare consequences according to the welfare principle investigated, with information about their collection (level of observation and description) and data handling (categorization, coding and statistical model).

Welfare principle	Welfare consequences	Level of observation	Description	Categorization and coding	Statistical model
Good feeding	Body Condition Score (BCS)	Animal	Score on a 0-5 scale recorded by camel visual examination of the ribs, the ischial and coxal tuberosities, the hollow of the flank, and the recto-genital zone ¹	Low (BCS \leq 2), Normal (BCS=3), and High (BCS \geq 4) ⁵ coded as 1, 2, and 3, respectively	Ordinal logistic
	Thirst Index (TI)	Animal	Parameters recorded by TI (i.e. time the camel takes to approach a bucket with fresh and clean water, and volume of water drunk) scored and summed to produce a scale from 0 to 3 ² .	Low (0-1 scores) and High (2-3 scores) coded as 1 and 2, respectively	Binary logistic
Good housing	Resting behaviour	Animal	Resting behaviour (sternal or lateral decubitus) of the camel recorded during a 3-minutes period of continuous observation	No and Yes coded as 0 and 1, respectively	Binary logistic
	Restricted movements	Herd	Proportion of camels in the pen unable to move freely, and/or unable to walk comfortably, due to physical environment ³	Proportion of animals within the pen weighted for the maximum number of camels for which the criterion is satisfied	Tweedie with log link
Good health	Disease	Animal	Presence of a clinically detectable clinical sign in the camel	No and Yes coded as 0 and 1, respectively	Binary logistic
	Injury	Animal	Presence of an injury or skin wound in the camel	No and Yes coded as 0 and 1, respectively	Binary logistic
	Pain induced by	Herd	Proportion of camels in the pen	Proportion of animals within	Tweedie with log link

	management procedures		with cauterization and/or nosering and /or scars from hobbles	the pen weighted for the maximum number of camels for which the criterion is satisfied	
Appropriate behaviour	Approaching test (AT)	Animal	Behavioral responses of the camel during AT (an unfamiliar person approaches the camel slowly, one step at a time) classified as "Positive," "Neutral," or "Negative" ² .	Positive, Neutral and Negative responses coded as 1, 2, and 3, respectively	Multinomial cumulative logistic
	Aggressivity	Herd	Presence in the pen of one or more camels showing aggressive behaviours (attempt or bite, push or kick another camel) ² recorded during a 3-minutes period of continuous observation	No and Yes coded as 0 and 1, respectively	Binary logistic
	Stereotypies	Animal	Locomotor (pacing in a circle or head-shaking) or oral (self-biting, self-mutilation, bar-mouthing) stereotypies ⁴ of the camel recorded during a 3-minutes period of continuous observation	No and Yes coded as 0 and 1, respectively	Binary logistic

¹ Faye et al. (2001); ² Padalino and Menchetti (2021); ³ EFSA (2010); ⁴ Padalino et al. (2014); ⁵ Benaissa et al. (2015)

Management- and resource-based measures were treated as factors, because they could have the potential to influence welfare, and were instead collected at all three levels of investigation (Table 2). At the Caretaker level, information mainly related to management, such as the feeding, watering and health management practices, and the camels' productive purpose were obtained. The camels' productive purpose could indeed have influenced the approach of the caretaker and his management choices.

Furthermore, assuming that the experience of the caretakers could influence management choices and their ability in approaching/handling animals (des Roches et al., 2016; Diverio et al., 2016; Menchetti et al., 2020), a question related to the caretaker's experience was included as a possible factor. Caretakers' experience was later categorized into three categories (Table 2). Measures collected at the Herd level were mainly related to space allocation and housing facilities (i.e. space allowance, shade availability, number of water and feeding points, water and feeding space per animal, water and feed quality, cleanliness of bedding). Other management-based measures involved the observation of the camels within the pen and they could be collected both at Herd and Animal levels (i.e. the presence of tethered and hobbled animals). The measures could be expressed as categorical (e.g. Clean, Partially clean or Dirty; Sun or Shade; Presence/Absence of hobbles) or numerical (e.g. the number of feeding and water points, water temperature) variables. However, for statistical purposes, some numerical variables (e.g. space allowance, water and feeding space) were categorized by statistical binning using the tertiles as the threshold (Altman, 2014; Menchetti et al., 2021).

Moreover, some animal-based measures (i.e. age, presence of diseases or injuries) were also treated as factors since they could have influenced some welfare outcomes (Table 2).

Table 2. Measures included in the protocol of Padalino and Menchetti (2021) and in the present study treated as possible factors with the ability to impair or improve camel welfare. They were included in the models as predictors with their level of investigation and type of variable or their categories.

Measure	Level of investigation	Type of variable/Categories
Frequency of feed distribution	Caretaker	<i>Ad libitum</i>
		Rationed
Frequency of water distribution	Caretaker	<i>Ad libitum</i>
		Rationed
Productive purposes of camels	Caretaker	Meat
		Milk, breeding or race
		Both
Caretaker's experience in working with camels	Caretaker	>10 years (Well-experienced)
		6-10 years (Moderately experienced)
		0-5 years (Slightly experienced)
Space allowance	Herd	$\leq 19.0 \text{ m}^2/\text{camel}$ (Limited)
		19.1-40.0 m^2/camel (Regular)
		$>40.0 \text{ m}^2/\text{camel}$ (Ample)
Shaded space allowance	Herd	$\leq 2.50^2 \text{ m}^2/\text{camel}$ (Limited)
		2.51-7.00 m^2/camel (Regular)
		$>7.00 \text{ m}^2/\text{camel}$ (Ample)
Water space per animal	Herd	$\leq 0.060^2 \text{ m}^2/\text{camel}$ (Limited)
		0.061-0.160 m^2/camel (Regular)
		$>0.160 \text{ m}^2/\text{camel}$ (Ample)
Water quality ¹	Herd	Dirty (D)
		Partially clean or Clean (PC/C)
Water point location ¹	Herd	Sun
		Shade
Water temperature	Herd	Continuous variable
Feeding space per animal	Herd	$\leq 0.40^{\text{¥}} \text{ m}^2/\text{camel}$ (Limited)

		0.41-1.10 m ² /camel (Regular)
		>1.10 m ² /camel (Ample)
Feed quality ¹	Herd	Dirty (D)
		Partially clean or Clean (PC/C)
Feeding point location ¹	Herd	Sun
		Shade
Cleanliness of bedding	Herd	Dirty (D)
		Partially clean or Clean (PC/C)
Number of camels in the pen	Herd	Continuous variable
Tethering and hobbles	Animal or Herd	No /Yes or Continuous variable
Age ³	Animal	Continuous variable
Disease ^{3,4}	Animal or Herd	No /Yes or Continuous variable
Injury ^{3,4}	Animal or Herd	No /Yes or Continuous variable

¹ referred to a randomly selected trough (when more than one trough was present)

² or not available (i.e. 0 m²/camel)

³ animal-based measures

⁴ treated both as dependent and predictor variable

Statistical analysis

Descriptive statistics were used to present the collected measures using mean and standard deviation (SD), median (Mdn) and range or interquartile range (IQR), number and percentage. The observed distributions of categorical variables (except those obtained by statistical binning) were compared with the expected probability distributions (each assuming all categories equal) using the chi-square goodness of fit test.

Associations between ABMs and management or resource-related factors were evaluated by Generalized Linear Models (GLMs). Each ABM (Table 1) was included as a dependent variable while measures reported in Table 2 were included as predictors. When the dependent variable was evaluated at the Animal level and there was no multicollinearity, 'age of camel' was included in the GLMs as a covariate. Multicollinearity was verified by Chi-square or Kruskal-Wallis tests and it was found for the following variables: Number of camels in the pen, Space allowance, Feeding and water space per animal. 'Camel'

was included in the GLMs as ‘subject’ while ‘pen’ was included as within-subject variable (as two camels per pen were evaluated). Models selected for each variable, and codes used for each category are detailed in Table 1. The first category (i.e. 0) was set as the reference category. Results of GLMs were expressed as odds ratio (OR), 95% confidence interval (95%CI), and the P-value of Wald statistic. The estimated marginal means and standard errors were also reported for the results of interest.

Statistical analyses were performed using SPSS 25.0 (SPSS, an IBM Company, Chicago, IL) while GraphPad Prism, version 7.0 (GraphPad Software, San Diego, CA) was used for visualization. Statistical significance occurred when $P \leq 0.05$ but the trends towards significance ($P < 0.1$) were also reported and discussed.

Results

Descriptive statistics of measures and prevailing categories

The descriptive statistics of the measures collected at Caretaker level are shown in Table 3. Rationed feeding was mostly applied ($P < 0.001$) while water was rationed in about half of the pens ($P = 0.491$). The majority of the animals were kept for milk production, breeding or race ($P < 0.001$) and about half of the pens were managed by well-experienced caretakers ($P = 0.029$).

Table 3. Descriptive statistics and relative goodness of fit test of the measures collected at Caretaker level. Values are absolute (N) and relative (N%) frequency (n=76 pens).

Measure	Category	N	N %	P value ¹
Frequency of feed distribution	Ad libitum	15	19.7%	<0.001
	Rationed	61*	80.3%	
Frequency of water distribution	<i>Ad libitum</i>	35	46.1%	0.491
	Rationed	41	53.9%	
Productive purposes of camels	Meat	11	14.7%	<0.001
	Milk, breeding or race	40*	53.3%	
	Both	24	32.0%	
Caretaker's experience in working with camels	Well-experienced	36*	47.4%	0.029
	Moderately experienced	22	28.9%	
	Slightly experienced	18	23.7%	

¹ P value from chi-square goodness of fit test

* higher observed number respect to expected (all categories equal)

According to the descriptive statistics of the measures collected at Herd level (Tables 4 and 5), the median number of camels per pen was 5, but 25% of the pens included more than 8 camels. The space allowance ranged from 3 to 161 m²/animal (Mdn=24 m²/animal). Shelters were present in most of the pens (85.5%, P<0.001) but the shaded space allowance was less than 2.50 m²/animal in one-third of the pens. Median water and feeding space per animal were instead 0.1 and 0.65 m²/animal, respectively, but there were 7 pens without water points and 1 pen without feeding point. Moreover, both water (P<0.001) and feeding (P<0.001) points were mainly positioned in the sun and the water temperature was higher than 38.3°C in about 25% of the pens. Finally, in about a third of pens, water (P=0.001) and feed (P=0.066) were classified as dirty. In most of the pens, bedding was clean or partially clean (P=0.004). In half of the pens, the prevalence of disease ranged from 12.5 to 66.7%. A lower prevalence was found for injuries but a high percentage of camels showed signs of pain induced by management procedures. The proportion of camels with restricted movements and showing aggressive behaviours was very variable, ranging from 0 to 100%.

Table 4. Descriptive statistics and relative goodness of fit test of the measures collected at Herd level and evaluated as categorical variables. All measures were management- or resourced-based. Values are absolute (N) and relative (N%) frequency (n=76 pens).

Measure	Category	N	N %	P value ¹
Space allowance ³	Limited	26	34.2%	-
	Regular	25	32.9%	
	Ample	25	32.9%	
Shaded space allowance ³	Limited	23	30.3%	-
	Regular	27	35.5%	
	Ample	26	34.2%	
Water space per animal ³	Limited	22	28.9%	-
	Regular	27	35.5%	
	Ample	27	35.5%	
Water quality ²	Dirty	25	32.9%	0.001
	Partially clean or Clean	51*	67.1%	
Water point location ²	Sun	66*	95.7%	0.029
	Shade	3	4.3%	
Feeding space per animal ³	Limited	26	34.2%	-
	Regular	24	31.6%	
	Ample	26	34.2%	
Feed quality ²	Dirty	30	39.5%	0.066
	Partially clean or Clean	46	60.5%	
Feeding point location ²	Sun	62*	82.7%	0.029
	Shade	13	17.3%	
Cleanliness of bedding	Dirty	12	15.8%	0.004
	Partially clean or Clean	64*	84.2%	

¹ P value from chi-square goodness of fit test. Not calculated for categories obtained with statistical binning (-).

² referred to a randomly selected trough (when more than one trough was present)

³ chi-square goodness of fit test not performed as the measure had been categorized using statistical binning (equal percentile)

* higher observed number respect to expected (all categories equal)

Table 5. Descriptive statistics of the measures collected at Herd level and evaluated as numerical variables. The list includes both animal-based and management- or resourced-based measures. Values are median (Mdn), interquartile range (IQR), and range (minimum and maximum).

Measure	Median	IQR	Minimum	Maximum
Animals/pen (number)	5	3-8	1	37
Proportion of camels with a disease (%)	40.00	12.5-66.7	0.0	100.0
Proportion of camels with physical injuries (%)	0.0	0.0-7.3	0.0	100.0
Proportion of camels with restricted movements ¹ (%)	0.0	0.0-20.0	0.0	100.0
Proportion of camels with pain induced by management procedures ² (%)	58.3	25.0-100.0	0.0	100.0
Proportion of camels showing aggressive behaviours (%)	0.0	0.0-80.0	0.0	100.0
Water temperature (°C)	35.6	32.6-38.3	32.0	43.0

¹ camels unable to move freely, and/or unable to walk comfortably, due to physical environment

² cauterization and/or nosering and /or scars from hobbles

At Animal level (Table 6), more than 60% of the camels had a BCS <3 ($P<0.001$) and showed the worst scores for the Thirst Index ($P=0.001$). Only 5 camels were tethered but about 20% were hobbled ($P<0.001$). At Animal level, the prevalence of diseases and injuries was 38.6% ($P=0.009$) and 22.0% ($P<0.001$), respectively. About half of the animals examined showed resting behaviour ($P=0.296$) and a positive response to the approaching test ($P<0.001$). Furthermore, stereotypical behaviour was never noted ($P<0.001$).

Table 6. Descriptive statistics and relative goodness of fit test of the categorical measures collected at Animal level. Values are absolute (N) and relative (N%) frequency (n=132 camel).

Measure	Category	N	N %	P value ¹
Body Condition Score	Low	83*	62.9%	<0.001
	Normal	30	22.7%	
	High	19	14.4%	
Thirst Index	Low	47	35.9%	0.001
	High	84*	64.1%	
Tethering (presence)	No	127*	96.2%	<0.001
	Yes	5	3.8%	
Hobbles (presence)	No	105*	79.5%	<0.001
	Yes	27	20.5%	
Disease (presence)	No	81*	61.4%	0.009
	Yes	51	38.6%	
Injury (presence)	No	103*	78.0%	<0.001
	Yes	29	22.0%	
Stereotypies (presence)	No	132	100.0%	-
Resting behaviour (presence)	No	72	54.5%	0.296
	Yes	60	45.5%	
Approaching test (response)	Positive	62*	48.1%	0.001
	Neutral	38	29.5%	
	Negative	29	22.5%	

¹P value from chi-square goodness of fit test

* higher observed number respect to expected (all categories equal)

Associations between animal-based measures, as indicators of welfare consequences, and management or resource-based measures, as factors that may effect welfare

Good feeding (Figure 1a and 1b)

Camel's age, as a result of both univariable and multivariable models (for all: OR>1.00; P<0.001), was one of the factors positively associated with high BCS. BCS was also positively associated with the cleanliness of the bedding (81.0% of the camels living in pens with dirty bedding had Low BCS; P=0.028).

Finally, high BCS tended to be negatively associated with the presence of a disease ($P=0.059$) and limited feeding space (73.3% of camels with a Low BCS had a feeding space $<0.40 \text{ m}^2$; $P=0.089$; Tables 1SM).

Limited space allowance ($P<0.001$) and shaded space ($P=0.016$) were instead factors strongly associated with the highest (worst) Thirst Index. A high Thirst Index score was also positively associated with limited feeding ($P=0.032$) and water space ($P=0.006$). Conversely, a high Thirst Index was negatively associated with water temperature ($P=0.009$). Finally, the odds of having a high Thirst index score tended to increase as the number of camels per pen increased ($P=0.060$) and in pens managed by well-experienced caretakers ($P=0.099$; Tables 2SM).

Good housing (Figure 2a and 2b)

Resting behaviours were positively associated with water temperature ($P=0.007$) and rationed distribution of water ($P=0.041$) as well as with the longest experience of the caretakers ($P=0.007$). Resting behaviours also tended to be positively associated with dirty water ($P=0.065$), the presence of hobbles on the camel ($P=0.095$), and clean bedding ($P=0.054$); namely the odds of showing resting behaviour was 3 times higher among camels living in pens with clean bedding (Table 3SM).

The likelihood of having a greater proportion of animals showing restricted movements was higher in pens holding camels reared for milk, breeding or race ($5.3 \pm 2.1\%$; $P=0.001$) and dual-purpose ($2.6 \pm 1.4\%$; $P=0.038$) than in pens with camels reared for meat production ($0.5 \pm 0.3\%$). The proportion of camels unable to move freely were also positively associated with *ad libitum* distribution of water ($P=0.016$) while only a trend was found for water point positioned in the sun ($P=0.067$; Table 4SM).

Good health (Figure 3a, 3b and 4)

Regarding factors associated with the presence of disease, camels having a disease were 2.7 times more likely to live in pens with dirty bedding ($P=0.048$). The percentage of healthy camels was only 41.5% in pens with dirty beddings while it rose to 65.3% in pens with clean or partially clean bedding. The other factors associated with increased odds of being sick were the rationed distribution of water ($P=0.050$) and the slight experience of the caretaker ($P=0.025$). Indeed, nearly two-thirds of sick camels (64.7%) did not receive water *ad libitum* while more than half of sick camels (53.6%) were handled by slightly experienced caretakers. Finally, 'disease' was negatively associated with the presence of hobbles ($P=0.032$; Table 5SM).

Camels with injuries were 2.7 times more likely to have hobbles than those without injuries (prevalence of injury: 37.0% and 18.1% among camels with and without hobbles, respectively; $P=0.038$). The other factors associated with increased odds of having injuries were the age of camels ($P=0.007$) and moderate caretaker's experience ($P=0.042$; Table 6SM).

Protective factors for pain induced by management procedures were ample space allowance ($P=0.013$), ample shaded ($P=0.003$), feeding ($P<0.05$), and water spaces ($P<0.05$). For example, the estimated

proportions of animals showing signs of pain induced by management procedures were $21.3 \pm 3.9\%$ and $11.8 \pm 1.8\%$ in pen with regular and ample space allowance, respectively, while they were $23.1 \pm 3.6\%$ and $12.0 \pm 1.9\%$ in pens with regular and ample shaded space, respectively. The presence of pain induced by management procedures was also positively associated with dirty feed ($P=0.020$) and the placement under the sun of water points ($P=0.049$). Moreover, animals showing pain induced by management procedures increased as the proportion of hobbled animals increases ($P<0.001$). Finally, the presence of pain-induced tended to be positively associated with dirty water ($P=0.081$; Table 7SM).

Appropriate behaviour (Figure 5a, and 5b)

Regarding factors associated with the Approaching test, the likelihood of having negative responses reduced as camel age increased and this effect was significant both at the univariable and multivariable models (for all: $OR<1.00$; $P<0.05$). Moreover, the negative response to the Approaching test was positively associated with limited shaded space ($P=0.019$) when compared with ample space. Indeed, about 35.0% of camels with limited shaded space showed negative responses while only 33.0% showed a positive response. Conversely, a positive response was recorded in over 60% of the camels having ample shaded space. Finally, responses to the Approaching test tended to be affected by limited feeding space ($P=0.062$) and rationed distribution of water ($P=0.095$), namely 82.8% of camels showing a negative response were not fed *ad libitum* (Table 8SM).

The presence of aggressive animals was positively associated with the number of camels in the pen ($P=0.002$) and with limited space allowance ($P=0.029$). In 54.2% of the pens where there were aggressive animals, indeed, the space allowance was $\leq 19.0 \text{ m}^2/\text{animal}$. Similarly, the presence of aggressive animals was positively associated with limited feeding ($P=0.021$) and water space ($P=0.023$). About half of the pens keeping aggressive animals had a feeding space $\leq 0.40 \text{ m}^2/\text{camel}$ (50.0%) and a water space $\leq 0.06 \text{ m}^2/\text{camel}$ (45.8%; Table 9SM).

Figure 6 summarizes resource and management-related factors significantly associated with welfare outcomes of camels kept at the permanent market.

Discussion

This study proposed new ABMs for camels and evaluated their associations with resource and management-related factors in dromedary camels kept in a permanent market. Our methodological approach, although did not presume to define direct cause-effect relationships, could verify the validity of some ABMs as welfare indicators as well as identify relevant factors related to housing and management that were likely linked to camel welfare. Thus, our findings may be useful to recognize welfare issues and propose guidelines to safeguard welfare in camels kept in intensive systems.

The space allowance and the number of camels per pen stood out among the management factors affecting camel welfare, being associated with many of the proposed ABMs. In pens where space allowance was less than 19 m² per animal, indeed, camels had the worse Thirst index as well as the highest likelihood of showing pain induced by management procedures and aggressive behaviours. These associations may be linked to both logistic and social factors. First, water and feed supply in overcrowded pens are more demanding from a management point of view, and besides, require facility adjustments. The probability, therefore, that water and feed needs are not fulfilled in overcrowded pens could be greater. Second, camels in overcrowded pens have limited opportunity to walk freely and frequently experience unstable social relationships. In this context, natural behaviours are inhibited (Wang et al., 2016) and dynamic dominance hierarchies characterized by high levels of agonistic behaviours could increase (Fu et al., 2016; Eriksson et al., 2021). Under natural conditions, indeed, camels move over very large areas and are great walkers, practising “ambulatory grazing” (Faye, 2020). Camels, moreover, are herd animals but groups are, in general, stable and not large. They indeed comprised around 9 animals including one adult bull, adult females, sub-adults, and young (Wilson, 1990; Schulte and Klingel, 1991). The risk of not meeting these ethological needs in intensive systems and livestock markets increases dramatically and, therefore, preventive measures are necessary. Our results indicated that a minimum space allowance of 19 m² per camel could reduce the hazard of the negative welfare consequences. Caretakers, furthermore, should avoid the formation of too numerous herds, paying attention to their composition in terms of age, sex, and relationships between members in order to limit competitive hierarchies and negative social interactions. The effect of space allowance on camels’ welfare has been recently also evaluated by El Shoukary et al. (2020) and Zappaterra et al. (2021). Those authors showed that overcrowding had negative effects not only on behavior, increasing aggressions and stereotypies, but also on body conditions and reproductive performance of camels. Overcrowding is a recognized welfare concern for all the animals reared under intensive conditions (Nordquist et al., 2017). The adverse effect of limited space allowance on drinking and feeding behaviour, abnormal behaviours, and body lesions have been indeed shown in most livestock species (Salak-Johnson et al., 2012; Fu et al., 2016; Raspa et al., 2020; Eriksson et al., 2021).

Shaded space allowance was also associated with several proposed ABMs. Its link with the welfare criteria of absence of prolonged thirst, as evaluated by Thirst Index, is quite intuitive. However, our findings also showed that an ample shaded area was also associated with a reduction in the use of management procedures inducing pain (e.g. hobbles and nosering) and an improvement in the human-animal relationship. These findings may suggest that the presence of shade increased not only the thermal but also the social comfort of camels. It has recently been shown that camels have a preference for shade and express more behaviours indicating a quiet and positive state, such as recumbency and ruminating, in the shaded than sunny areas (Zappaterra et al., 2021). The opportunity to have positive experiences and express natural behaviours could have influenced their intra- and interspecies relationships resulting in an improvement of welfare outcomes. Moreover, if the shaded space is adequate for rearing density, camels could reduce competitive behaviour and peacefully share this resource. Our results seem also to support Mellor's concept, which emphasizes the role of positive

experiences in the animal welfare assessment (Mellor, 2016). According to Mellor, welfare cannot be only defined on the basis of the animals' responses to living in poor environments. It is also necessary to evaluate their opportunities to engage in behaviours they find rewarding, including thermal comfort, positive social interactions, resting and feeding behaviours (Mellor, 2016). Behavioural changes related to the presence of shaded areas have been shown both in intensive and extensive systems in several species, such as cattle, sheep, buffaloes, and horses, although previous studies mostly focused on the effect on productive traits (Schütz et al., 2010; Holcomb et al., 2015; Giro et al., 2019; De et al., 2020; Mishra, 2021). Our finding suggested that a shaded area of at least 7 m² per animal (our ample category) had beneficial effects on several aspects of the camel's welfare but further studies should define specific recommendations according to the environmental heat load.

Bedding may affect animal welfare (Welfare Quality, 2009; AWIN, 2015). In our study, it was indeed associated with ABMs of Good feeding, Good housing, and Good health. It is interesting to note that camels having a disease were about 3 times more likely to live in pens with dirty bedding confirming that keeping bedding clean is a good practice that should be recommended to prevent diseases also in camels (Schwartz and Dioli, 1992). The role of bedding management on animal welfare has already been emphasized in other species such as cattle and horses (Quigley et al., 2017; Siegers et al., 2018; Robles et al., 2020). However, the magnitude of welfare consequences for camels could be very affected by climatic conditions. Their faeces may indeed dry out quickly in the arid climate where they are usually raised (Padalino and Menchetti, 2021). Further studies, with longitudinal designs and in differentiated settings, could better define the role of bedding quality for camel welfare and validate additional indicators, possibly animal-based, to evaluate farm hygienic conditions. For instance, a score rating the cleanliness of some anatomical regions of camels (e.g. udder, legs, and flanks) rather than the bedding could be a more useful and direct welfare indicator. This type of score has already been proposed as welfare indicators for cattle resulting associated with several productive and pathological parameters such as milk somatic cell counts, mastitis, and enteritis (Faye and Barnouin, 1985; Ellis et al., 2007; Wolf et al., 2016; Molina et al., 2019).

Measures related to feeding and water management were other factors linked to many ABMs. In some cases, the link between these management factors and the ABMs was expected and easy to explain. Ample feeding and water spaces were, for example, associated with good body conditions and the absence of thirst. It is indeed logical to expect an increase in feeding and drinking activity as available spaces increase, particularly for those subordinate camels that may have more difficulty accessing resources due to their low social rank (Turner et al., 2000; DeVries et al., 2004). Ample feeding and water spaces were also associated with reduced risk of pain induced by management procedures and improved camel behaviour. This finding confirms that increasing space allowance at the feed and water places could reduce competition and aggressive interactions among camels. As widely demonstrated in other species (Turner et al., 2000; DeVries et al., 2004), indeed, competition for resources is a primary reason for aggressive interactions in animals reared in groups under intensive systems. Sometimes, however, the relationship between management factors and ABMs could be less easy to explain. A management

factor could just be a mediator or a confounder for other exposure variables; otherwise different factors may interact to produce different animal-based responses (EFSA, 2012c). We could also hypothesize that the behaviour of camels indirectly benefited from ample feeding and water spaces being mediated by the general improvement in body conditions. It has been shown, for example, that donkeys with a high BCS are friendlier with humans (Farhat et al., 2020). This hypothesis also supports the multidimensional concept of welfare in which biological functions, as indicated by BCS and Thirst Index, and affective state, as indicated by the absence of pain or fear, are connected and superimposed (Fraser, 2003). A feeding space $>1.10 \text{ m}^2/\text{camel}$ and a water space $>0.160 \text{ m}^2/\text{camel}$ may be suggested to obtain good welfare outcomes related to principles of Good feeding and health as well as of Appropriate behaviours. However, these thresholds were calculated based on our study population and require external validation (Menchetti et al., 2021).

Ad libitum distribution of water and the placement of the water points in the shade are good husbandry practices (Pritchard et al., 2005; Bergin and Nijman, 2019; Rodrigues et al., 2020). However, they were poorly followed in the market. The distribution of water was indeed rationed in about half of the pens and, for the most part, the water points were positioned in the sun. These factors were negatively associated with ABMs not only of Good housing but also of Good health. Water management is a well-known welfare issue for animals kept in several intensive and extensive contexts (Pritchard et al., 2005; Bergin and Nijman, 2019; Bekele et al., 2020; Rodrigues et al., 2020), but it may seem to be surprising for the camel due to its famous adaptability to resources scarcity. Thus, it is worthwhile noting that the odds of having a disease was 2 times higher in camels receiving rationed than *ad libitum* water suggesting that water supply is an aspect of camel welfare that cannot be overlooked (Menchetti et al., 2021; Padalino and Menchetti, 2021). It must also be taken into account that water needs in intensive systems are greater than in Bedouin ones (about 9 times higher to produce 1 litre of milk (Faye, 2013)). Our analyses also showed an inverse association between thirst and water temperature. In other words, non-thirsty camels were more likely to have hot water. This result was not expected and we can only speculate that the non-thirsty camels received water in overabundance and the excess water remaining in the trough increased its temperature over time. It, therefore, seems that the importance of having fresh water plays a secondary role compared to the benefits of *ad libitum* access.

Caretaker's experience and productive purpose of the camel resulted associated with the proposed ABMs. In particular, a long experience of caretakers seemed to be a protective factor for disease and injuries. This was expected since it has been already reported that the health of camels could benefit from staff training (Menchetti et al., 2021). Regarding the productive purpose of camels, we curiously found that camels reared for milk or breeding were more likely to show signs of restricted movements than camels intended for slaughter. Perhaps the use of hobbles or ropes was more frequent in camel reared for milk or breeding as they needed to be more frequently moved and handled notably at milking time. The positive association between the presence of hobbles and ABMs such as pain or injuries is also worth mentioning to highlight the role of the limited freedom of movement and practices used for restraint on camel welfare. Limited freedom of movement has been already indicated as a factor that may have negative

consequences from a social and metabolic point of view while the use of restraint tools is a direct cause of injuries, infections, and inflammations (Rayner et al., 2018; Farhat et al., 2020; Menchetti et al., 2021; Padalino and Menchetti, 2021). Therefore, when hobbles are considered unavoidable, it would be desirable to limit the use of inappropriate ropes, adopting also pain relief strategies, such as pads under the hobbles. Moreover, the camel's health status of camels wearing hobbles should be strictly monitored.

Finally, it is worth noting that the age of the camel was included in the applied statistical models as a covariate since it influenced several ABMs. For example, BCS increased as the camel's age increases, probably due to age-related changes in body composition (Kenyon et al., 2014; Ouchene-Khelifi and Ouchene, 2021). As expected, the likelihood of having injuries also increased with increasing camel's age while it appeared that aggressive behavioural responses to the human approach reduced over time. The accumulated familiarity with human contact and the taming could explain this last result (Waiblinger et al., 2006). The human-animal relationship could be indeed influenced by several factors but many of these are linked to the quality of past experiences. Habituation and early positive human contacts as well as the use of positive reinforcements are husbandry practices that could improve animal's perception of humans (Mota-Rojas et al., 2020) and should therefore be encouraged on camel farms. About a quarter of the camels at the market evaluated by the Approaching test showed negative responses to human contact. Farm animals showing human-direct aggression and problematic to handle not only may lose their commercial value and be repeatedly sold but could also be manipulated with techniques that can exacerbate the undesirable behaviours causing injuries and stress. Aggressive animals could eventually be suppressed (Burattini et al., 2020). Conversely, a good human-animal relationship has positive effects not only on the welfare of the animal but also on its productivity and product quality (Waiblinger et al., 2006; Mota-Rojas et al., 2020). Despite this key role in animal welfare (Waiblinger et al., 2006; Welfare Quality, 2009; EFSA, 2012c), the human-animal relationship is complicated to assess and cannot be measured directly (Waiblinger et al., 2006). It probably deserves more valorization in the camel protocol and the validation of additional ABMs for its assessment (Padalino and Menchetti, 2021).

Our findings need to be interpreted with caution due to several limitations of the study. The main limitations are probably linked to the cross-sectional approach. For example, our study did not take into account the magnitude of welfare consequences (duration x intensity (EFSA, 2012c)) and could not provide definite information about cause-and-effect relationships. As suggested by EFSA, the duration of the welfare consequences might not even be considered in risk analysis whether the applied welfare measures reflect a momentary situation (EFSA, 2012a). A major criticism could be to treat the duration of management factors as constant. Camels could indeed be frequently moved or sold and this made the exposure to management factors very dynamic. Moreover, the quantitative indications concerning for example space allowance cannot be generalized, because these numbers were strictly related to our study population and require external validations as well as adjustments based on the type of scenario. It is also worth highlighting that among the categorical variables, the ABMs related to presence of a disease were limited by the type of assessments, which allows only to record the presence of major clinical signs. This could be overcome probably including more specific ABMs, able to identify the type of disease according to their original causes, and including longitudinal evaluations. As suggested by Faye et al.

(1999), diseases can be classified into "immanent diseases", linked to the practices and conditions of the farms, and "transcendental diseases", coming from external causes (affecting all farming system independently of the practices and local environments, such as cases of Rift Valley Fever, MERS-Cov, anthrax, rabies, and brucellosis). This approach would clarify better the implications of the disease on camel welfare and how to prevent it. Finally, validation of the selected ABMs would require repeated measurements and the involvement of other researchers (EFSA, 2012c). Monitoring and surveillance systems inside the camels' pens/farms as well as a broad application of the welfare assessment protocol will help fill these gaps. Despite these limitations, the approach chosen in the selection of both animal-based and management-based measures complied with the feasibility features required for an on-farm welfare assessment (Main et al., 2007; EFSA, 2012a). These measures, moreover, seem "fit for purpose" (EFSA, 2012c) as identified several plausible welfare consequences as well as practicable corrective actions.

Overall, this study proposed new practical and feasible ABMs for dromedary camels kept under intensive management. They seemed to be appropriate indicators of welfare consequences in this species being able to identify factors related to housing and management practices that may impair or improve camel welfare. Our preliminary results need to be validated on a larger dataset, but they may be the first steps towards the development of welfare standards and guidelines for dromedary camels.

Declarations

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Conflicts of interest.

The authors declare no competing interests.

Availability of data and material

All data are included in the article/SupplementaryMaterial, further inquiries can be directed to the corresponding author.

Code availability (software application or custom code)

Not applicable.

Authors' contributions

Conceptualization: Laura Menchetti, Barbara Padalino; Methodology: Laura Menchetti, Barbara Padalino; Formal analysis and investigation: Laura Menchetti; Writing - original draft preparation: Laura Menchetti, Bernard Faye, Barbara Padalino; Writing - review and editing: Bernard Faye, Barbara Padalino; Funding acquisition Barbara Padalino; Supervision: Barbara Padalino

Ethics approval

The research project was approved by the Department for Agriculture Affairs & Fisheries of the Ministry of Municipality and Environment of the State of Qatar (Approval code 2404/2020).

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Figures

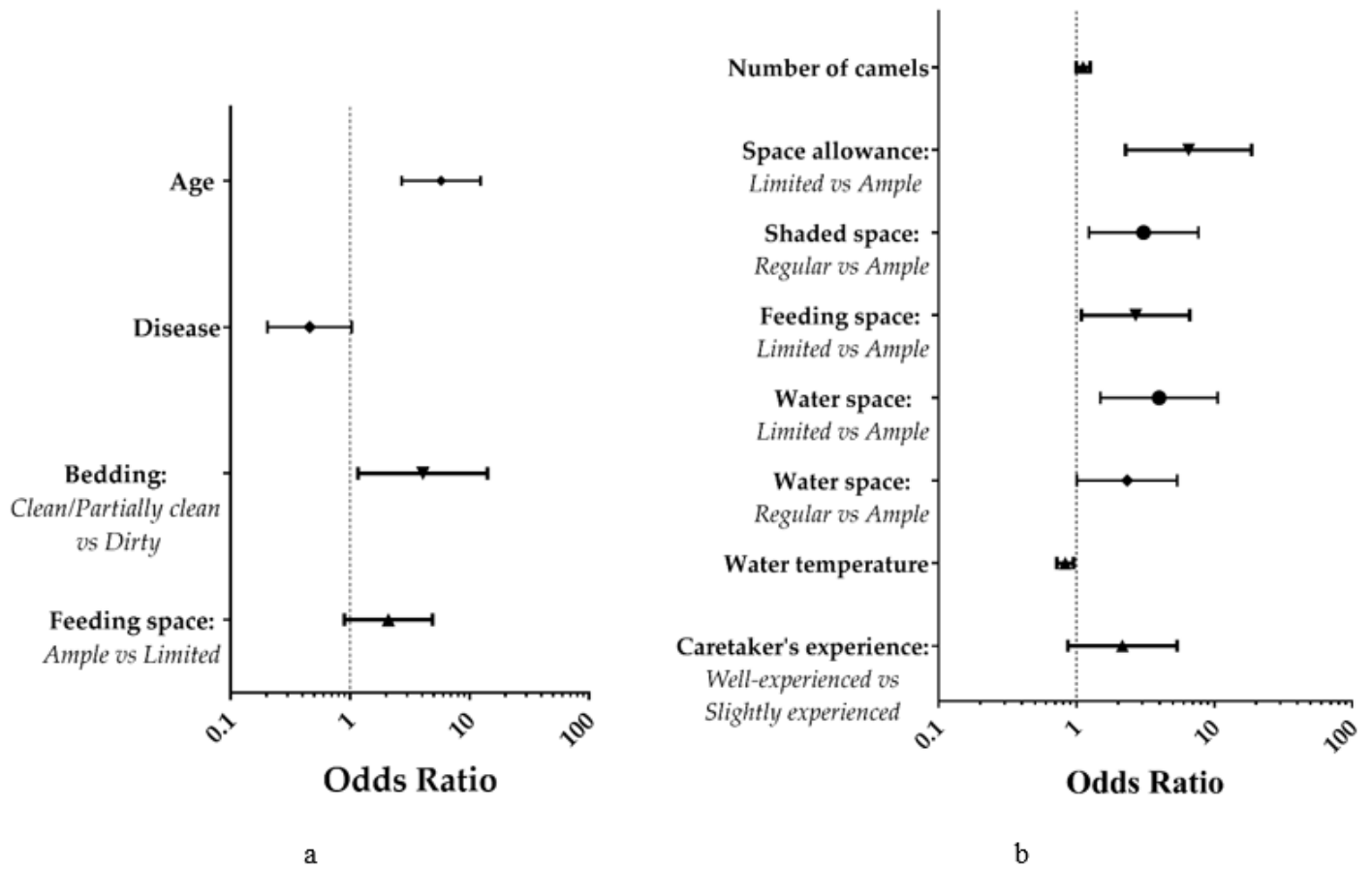
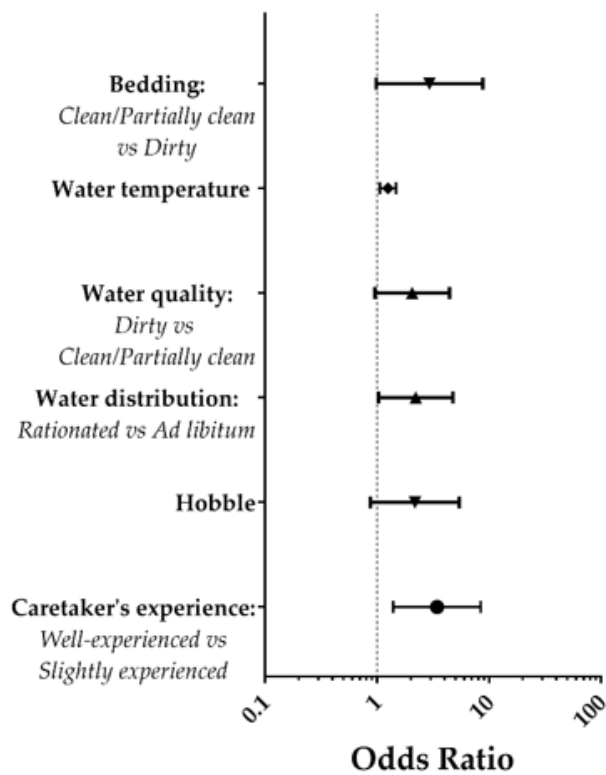
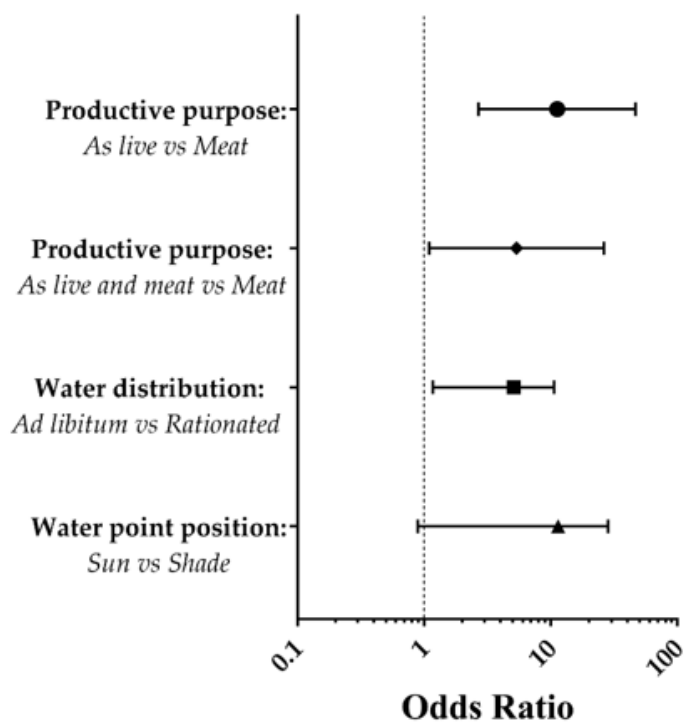


Figure 1

Forest plots displaying the associations between high Body Condition Score (Panel a) and Thirst Index (Panel b) assessed at Animal level and age, management- or resource-based measures in the pens of a camel market.



a



b

Figure 2

Forest plots displaying the associations between resting behaviours assessed at Animal level (Panel a) or restricted movement assessed at Herd level (Panel b) and management- or resource-based measures in the pens of a camel market.

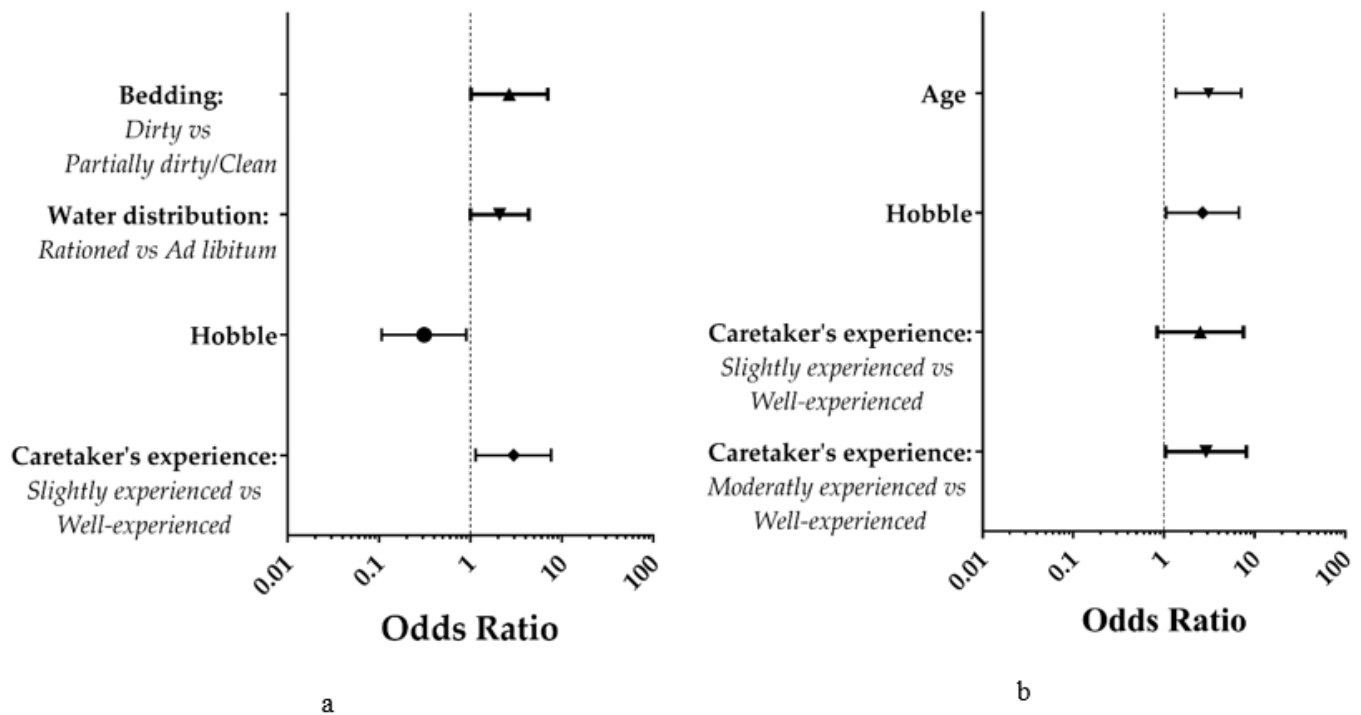


Figure 3

Forest plots displaying the associations between disease (Panel a) or injuries (Panel b) assessed in camels at Animal level and age, management- or resourced-based measures recorded in the pens of a camel market.

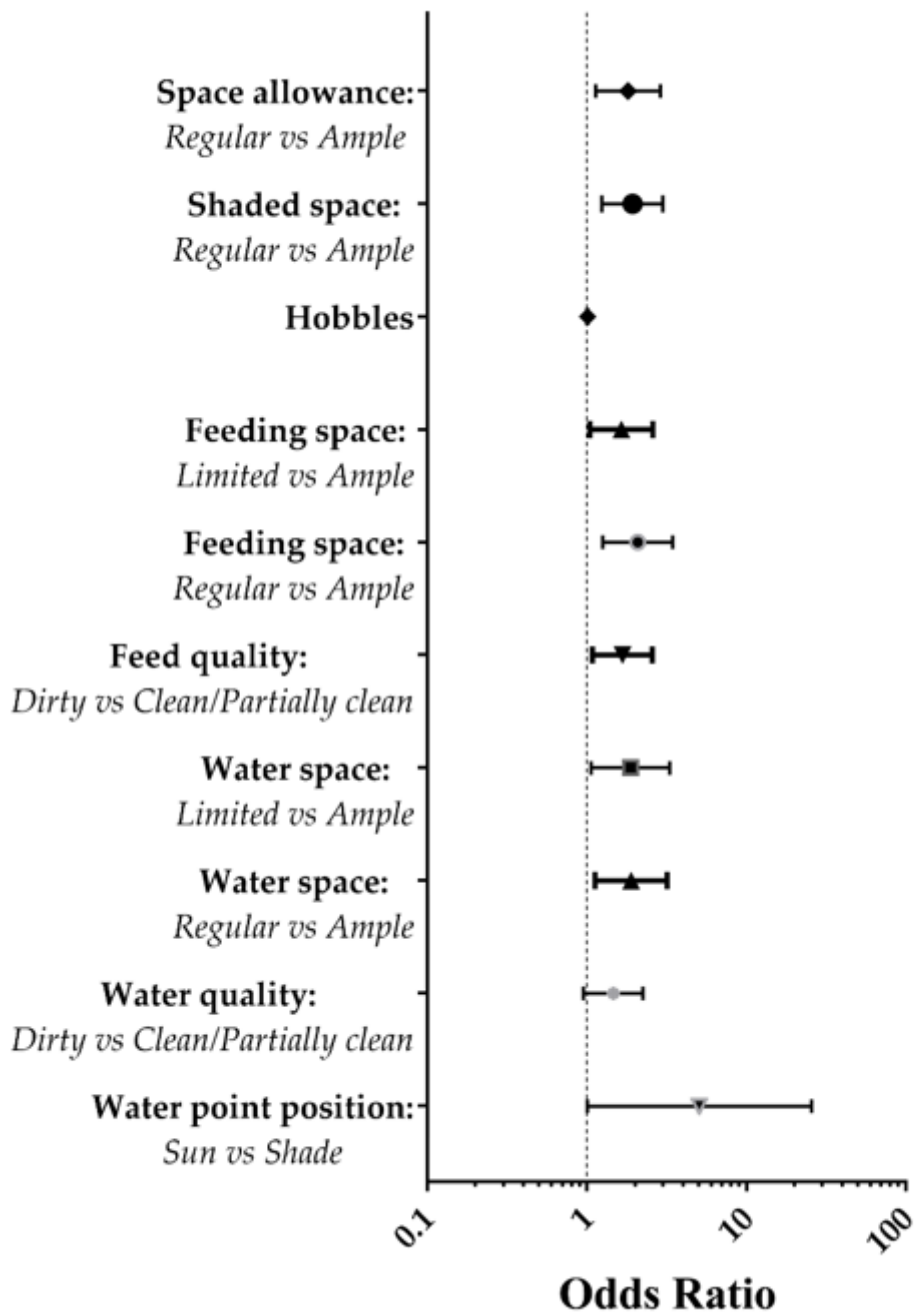


Figure 4

Forest plot displaying the associations between indicators of pain induced by management procedures and management- or resource-based measures in the pens of a dromedary camel market.

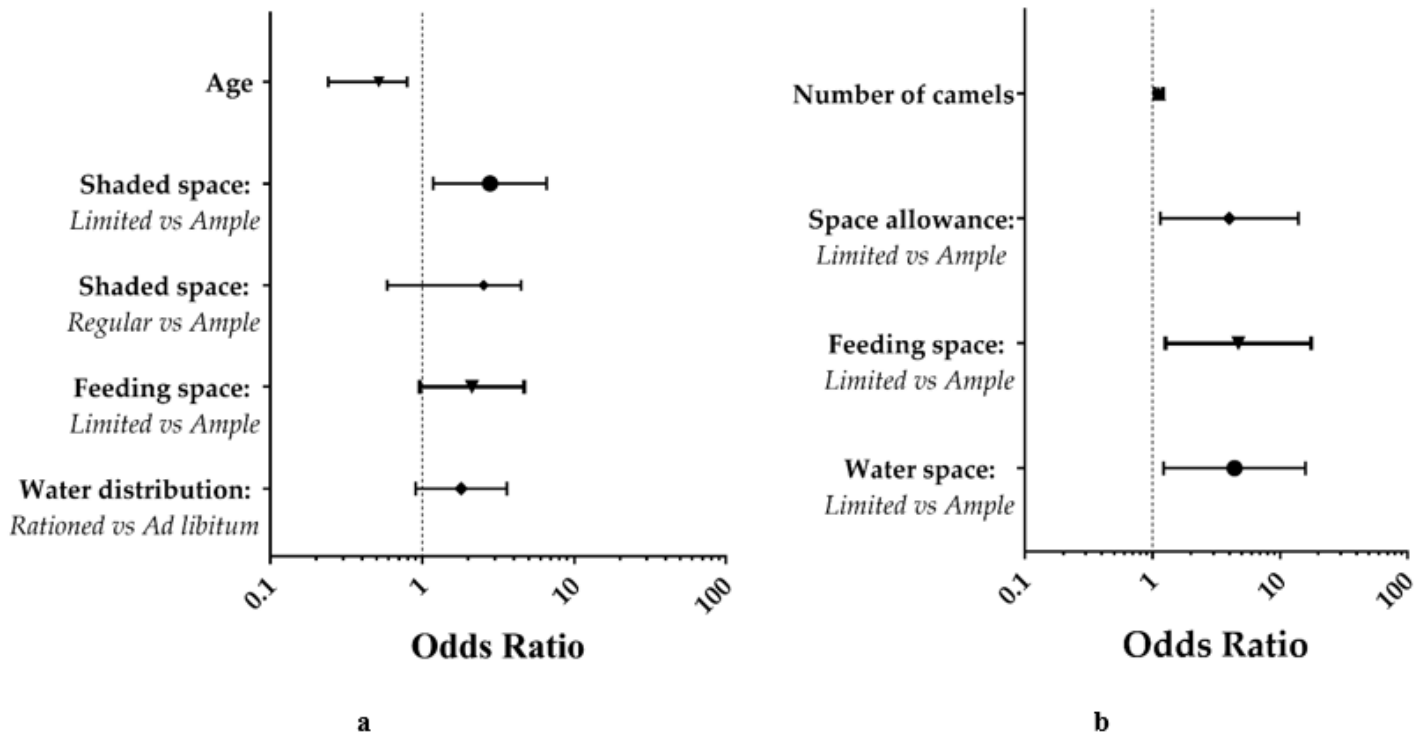


Figure 5

Forest plots displaying the associations between negative responses to the Approaching test of the camels assessed at Animal level (Panel a) or presence of aggressive camels in the pen (Panel b) and management- or resource-based measures in the pens of a camel market.

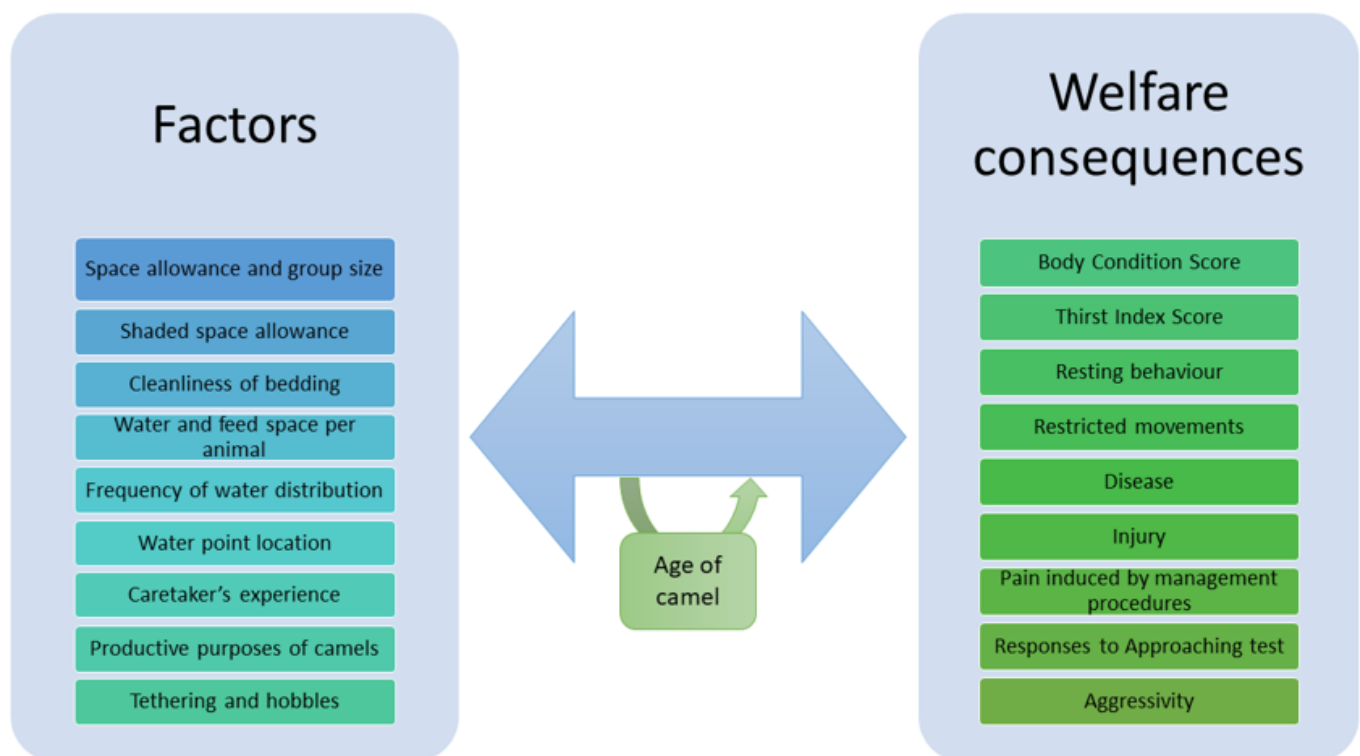


Figure 6

An overview of management- and resource-based measures, treated as factors that may have the potential to influence dromedary camel welfare, associated with the animal-based measures, treated as indicators of welfare consequences.

Supplementary Files

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