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Camel herds' reproductive performance in Algeria: Objectives and thresholds in extreme arid conditions

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ABSTRACT

A survey was carried out for evaluating camel herd's fertility and fecundity under Algerian extreme arid conditions. Progeny History Testing data obtained from 14 camel herds (78 females and 20 males) were analyzed and compared with standard objectives and thresholds. The age at first rut, the first oestrus, first male and female mating (months ± SD) were 37.2 ± 16.29, 31.07 ± 8.97, 42.6 ± 14.28 and 35.52 ± 8.55, respectively. The birth conception interval, open days, age at first calving and calving interval were 40.35 ± 9.41 months, 340 ± 203 days, 51.05 ± 9.59 months and 22.32 ± 5.63 months. The mean male to female ratio was 1:40. Pregnancy diagnosis was performed 21.81 ± 16.4 (days) post-mating and the duration of pregnancy was on average 12.80 ± 0.30 months. The mean herd's annual fertility was 56.2 ± 6.6%; the mean culling age of males per herd was 15.30 ± 2.47 years whereas females were culled at 23.31 ± 5.64 years with a mean number of 5.23 ± 2.91 lactations. The observed reproductive traits were acceptable when compared to the fixed objectives for pastoral livestock. However, all the considered herds showed annual fertility out of threshold. The lack of significant strategy to improve age at first calving, calving interval and reasoned use of dromedary bulls, is likely to affect fertility and productivity of Algerian camel herds. Such negative trend could hamper the genetic improvement of autochthonous camel ecotypes and compromise the camel sector and the ecosystemic services provided by local cameleers.

1. Introduction

The dromedary camel (DC) species (*Camelus dromedarius*) represents an exceptional biological model of the Saharan ecosystems, likely to enhance the least productive parts of the planet. However, its reproductive efficiency under extreme arid conditions is said to be low due to low external input and traditional livestock management, precarious production conditions and low genetic potential of indigenous camel populations. The high incidence of genital abnormalities and of early embryonic deaths, the short male breeding season, infertility and low libido of bulls are other factors that could affect the herd's fertility (Tibary and Anouassi, 1997; Al-Qarawi, 2005; Monaco et al., 2015; Padalino et al., 2015; Gherissi et al., 2020). In front to this situation and the lack of specialized state health services for camelids, coupled with the difficulties for veterinarians to reach remote areas lead to the occurrence of the repeat breeding syndrome and to a high increase of culling rate. In addition, the lack of proper training for pregnancy diagnosis leads also to a high incidence of fetal wastage due to slaughtering of pregnant females (Ali et al., 2018; Gherissi et al., 2017). In Algerian pastoral conditions, obtaining data and establishing an accurate breeding statement about camel herds' is often limited by several factors: nomadism, pastures in remote areas and non-cooperative breeders. The greatest limitation for measuring herd fertility statue and annual numerical productivity is the high mobility of camel herds in wide pastoral areas (80% of the country's surface) and the lack of specific and reliable identification

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and traceability system; it is also difficult to record herd's and individual's major events in a dedicated herd notebook or similar documentation because of pastoralists' illiteracy. In a more global way and by referring to official statistics, the breeding level of the national camel herd was stable for several years displaying the highest percentage increase (247%) among the North-African countries and reaching 381.882 heads (FAOSTAT, 2017).

In order to better understand herd management and dromedary camel production in Algerian pastoral conditions, the present study aimed at answering the following questions: are satisfying reproductive performances achieved in Algerian camel pastoral herds? How Algerian camel herds could be ranked if evaluated through specific breeding objectives and thresholds?

Answering these questions would help to detect criticisms and risk factors: the productivity of camel herds, the breeders' income and thus the sustainability of DC breeding under Algerian pastoral systems could then be improved by targeted interventions.

2. Materials and methods

2.1. Study region

A survey was conducted between February 2013 and August 2014 at El Oued region, in the extreme arid region of South-East Algeria (Lat: 33°5′ - Long: 6°11′, average annual temperature: 25 °C, mean annual precipitation: 80 mm).

2.2. Animals and data collection

Reproductive parameters of male and female DC were collected using the "Progeny History Testing" (PHT) technique carried out through participatory appraisal (Catley, 2002; Keskes et al., 2013) according to terms and conditions of application as recommended by different international organisms namely; Food and Agriculture Organization, International Livestock Research Institute and International Institute for the Environment Development (Catley, 2002; Attamimi, 2011).

After an initial data collection and survey, 14 camel herds from the pastoral semi-nomadic and transhumant system were included in the study. Data were collected on 98 camels aged from 2 to over 20 years: 5 heifers, 5 primiparous, 68 multiparous and 20 camel bulls. Most of the considered animals were born in the herd; PHT survey was validated, according to Kaufmann (2005), excluding incongruent declarations before data processing and analysis.

2.3. Evaluation of reproductive traits and determination of objectives and thresholds

Retrospective and/or prospective (expected event eg. next calving or first calving after positive pregnancy diagnosis) parameters related to the reproductive history were obtained for primiparous and multiparous female camelsand for DC bulls. The breeding objectives and thresholds were set accounting the DC physiological reproductive patterns, as reported from other authors, and considering the environmental factors (wet and dry seasons) under extensive livestock system in Algeria (Table 1).

The considered parameters included:

Age at first female oestrus AFO (months): dromedary camel females reach puberty at 2–3 years of age (Zarrouk et al., 2003) but they are usually not bred until a more advanced age (see below). Accordingly, the age objective for the first heat expression has been set at 24–36 months and the threshold at >42 months.

Age at first mating AFMf (and Birth to conception Interval BCI) of female camel (months); in order to avoid dystocia due to feto-pelvic disproportion, usually matings are allowed when the females reach about 70% of their adult body weight (Tibary and Anouassi, 1997; Hammadi et al., 2004). Depending on the genetic potential, diet and husbandry conditions, this generally occurs at 36–48 months, but it is also a decision of the herdsman to allow mating at a younger age (Zarrouk et al., 2003). Therefore, 24–36 months was fixed as AFM and 36–48 months was defined as the objective for BCI. The retained thresholds for AFM and BCI were >48 months and >54 months, respectively.

Age at first calving AFC (months): since the pregnancy in dromedary camel lasts about 13 months (Skidome, 2011), the objective of this parameter should be 48–54 months. However, abortion seems to be frequent in primiparous, hence the threshold has been set at ≥60 months (Kaufmann, 2005; Tibary et al., 2005).

Calving-oestrus interval COI (months): following delivery, the first postpartum oestrus, in pastoral condition, has been reported to occur from 14 to 42 days (Elias et al., 1984). Derar et al. (2014) reported that she-camels could be mated between the 5th and 6th week postpartum with satisfactory conception rates. When calving occurs in the middle or at the end of the breeding season the COI could be extended to the next breeding season. Considering these aspects, the COI objective was set at 2 to 6 months and the threshold at ≥9 months.

Open days OD (days): in well-fed dromedaries, ovarian activity is evident in 70–80% of animals by 30 days postpartum and conception rate is normal at 45 days (Tibary and Anouassi, 1997; Derar et al., 2014). However, if nutrition is suboptimal it can take as long as 8–10 months for the follicular activity to resume (Skidmore et al., 1996b). Considering these aspects, the OD period for female camels that conceive within the same season of parturition is between 2 and 6 months. If the dam is mated during the next breeding season, the open days period could last, instead, from 7 to 12 months. Accordingly, the objective for this parameter was set at ≤180 days and the threshold at >360 days.

Calving Interval CI (months): it depends on the postpartum anoestrus as well as on the first mating after calving and on female fertility. Considering the pregnancy length (13 months), in case first postpartum mating occur within the same calving season, the calving interval would be from 14 to 18 months. If calving occurs in the middle or at the end of the breeding season, the CI would be 21 to 24 months. In this regard, a calving interval of 2 years has been reported as the most common for dromedary camels (Kaufmann, 2005). The CI objective has therefore been set at ≤18 months and its threshold at >24 months.

The **annual herd fertility AF** (pregnancy rate): it has been calculated as the number of pregnant females divided by the number of mated females within a year. According to Faye (2018), herds that aim at increasing the camel numerical productivity should have a fertility range between 70 and 95%. Due to the environmental conditions of Algerian pastures, the objective for this parameter was set at >85% and the minimum threshold at <75%.

Mating-pregnancy diagnosis MPD: to determine the pregnancy status after mating, it is suitable to identify which females are reactive (erectile and cocking tail) through a male parade. The suitable time to practice it would be 21 days after mating. At this stage, non-pregnant female camels could be in oestrus because of the lifespan of the cyclic *corpus luteum* at about 12–14 days. Therefore, they can be mated again at the time of the check after the previous mating (Skidmore et al 1996b). The defined objective and threshold of MPD were 21 and 30 days, respectively.

Pregnancy length PL (months): the retained objective and threshold for this parameter were 12.5 months and >13.5 months, respectively (Gherissi et al., 2017).

Culling age of females CAf (years): for the female camel, the body condition begins to deteriorate from the age of 17 years old and without adequate supplementary feeding the reproductive career it is almost concluded (Hammadi et al., 2004; Gherissi

Table 1
Objectives and thresholds of the reproductive traits for male and female camels from arid South-East Algeria.

Variable	Unit	Abbreviation	Objective	Threshold
Females				
Age at first oestrus	Months	**AFO**	24–36	>42
Age at first mating	Months	**AFM**	24–36	>48
Birth to conception interval	Months	**BCI**	36–48	>54
Age first calving	Months	**AFC**	48–54	>60
Calving to oestrus interval	Months	**COI**	2–6	>9
Open days	Days	**OD**	≤ 180	>360
Calving interval	Months	**CI**	≤ 18	>24
Annual fertility*	%	**AF**	>85	<75
Mating-pregnancy diagnosis	Days	**MPD**	21	30
Pregnancy length*	Months	**PL**	12.5	13.5
Culling age*	Years	**CA**	15–17	>17
Calving number	Integer	**CN**	5	7 > n > 3
Culled females per year*	%	**CFY**	<5	>30
Males				
Age at first rut	Months	**AFR**	24	>36
Age at first mating	Months	**AFMm**	36	>48
Number of mating/pregnancy	Integer	**NMP**	1–2	>4
Mating time	Minutes	**MT**	10	>20
Ratio male/female		**RMF**	1:30	>1:60
Age at culling	Months	**CAm**	13	>15

* Descriptive statistics for herd reproductive traits (n = 14). Refer to Tables 2 and 3 for animals out of threshold and results section for normality statistics.

et al., 2018b). Therefore, we admitted 17 years old as objective to cull female camel and >17 years as the threshold.

Calving number CN: this parameter depends on the age at first calving, calving interval, annual fertility and culling age of the female camel. Faye (1997) reported that CN per female camel throughout her reproductive life is between 3 and 7. In addition, the objective of this parameter was stated according to the maximal adult productive potential, which is expressed between 5th and 6th lactation (Musaad et al., 2013). An average lactation rank out of retained threshold would be likely to decrease herd production. The objective was set at 5 calvings per female camel and the threshold at 7 > n > 3.

The number of **culled females per year CFY** (%): the rates of reform for infertility chosen as herd objective and threshold are <5% and >30%, respectively (Tibary and Anouassi, 1997).

Age at first rut AFR and **age at first mating AFMm of male camel** (months); objectives = 24 months and 36 months, respectively. Depending on several factors (breed, breeding system, nutrition) camel bulls reach puberty and lose the prepuce adherence at around three years of age (Al-Qarawi et al., 2000; El-Harairy and Attia, 2010; Gherissi et al., 2014). Full maturity is reached, however, at 7 years of age (Al-Qarawi et al., 2000). Considering these aspects the thresholds of AFR and AFM were stated at >36 months and >48 months, respectively (Table 1).

The **number of mating for pregnancy per female NMP** and **Mating Time MT**: objectives were set at 1–2 and 10 min, respectively, thresholds were set at >4 and >20 min, respectively. The reported objectives and thresholds were set according to the description of Tibary and Anouassi (1997) and Padalino et al. (2015) about the sexual behaviour of the one-humped male camel.

The **male to female ratio** during the rutting season **RMF**: Burgmeister (1975) reported that a good dromedary bull, at the peak of the breeding season, could successfully mate three females per day either 50 to 70 females per breeding season. Excessive breeding with a high number of females and within a short rutting season is, however, a common cause of herd infertility (Al-Qarawi, 2005; Padalino et al., 2015). The recommended ratio is 1 male for 20–25 females and the threshold is >1 male to 60 females (Marai et al., 2009). Accordingly, the objective and threshold of the RMF were set at 1:30 and >1:60.

Culling age of males CAm: the breeding career of the male camel can continue up to 20 years of age. However, an arbitrary age of 13 years is to be considered as an objective since from this age there will be pronounced testicular parenchyma degenerative changes (Al-Qarawi et al., 2001), which may significantly reduce herd pregnancy rate (Al-Qarawi et al., 2002). Moreover, if a bull is kept within the same herd for a too long time, it increases the risk of consanguinity and the incidence of congenital defects (Burgemeister, 1975). The CAm objective was set at 13 years and the thresholds at >15 years

2.4. Statistical analysis

Statistical analyses were performed using the software SPSS® Statistics 20 (IBM Corp, Armonk, NY). For the continuous variables (reproductive traits), the normality assumption was checked using the Shapiro-Wilk test. Descriptive results were given as Mean ± SEM (Standard Error of Mean), the maximum, the minimum, the median and the variance. In addition, male and female camels were ranked according to nominal reproductive traits, and histograms were obtained for each parameter to show classes proportions.

3. Results

3.1. Female camel reproductive traits

Descriptive statistics of female camel's reproductive traits, the objectives and the percentages of animals out of the described thresholds are reported in Table 2.

3.1.1. Age at first oestrus

The mean birth-to-first oestrus interval was 31.07 ± 8.97 months. Data from this parameter were normally distributed (S/W. 4.16. df = 73, P = 0,077); a proportion corresponding to 28.21% of animals aged 30–36 months at first oestrus, 20.51% of animals aged 24–30 months and 16.67% showed the first oestrus at 36–42 months. The proportion of she-camels within AFO objective was 23.07% whereas those out of the threshold was 11.53% (Fig. 1).

3.1.2. Age at first mating

The mean AFMf was 35.52 ± 8.55 months (S/W. 0.949. df = 73, P = 0.05). A proportion of 6.41% and 52.56% of females had been

Table 2
Descriptive statistics, objectives and thresholds of female camel's reproductive traits in South-East Algeria (14 camel herds).

Variable	Unit	Abb	N	Mean	SD	Median	Min	Max	Objective	Threshold	(%) Out of Threshold
Age at first oestrus	Months	**AFO**	78	31.07	8.97	32	15	51	24–36	>42	11.53
Age at first mating	Months	**AFM**	78	35.52	8.55	35	17	64	24–36	>48	6.40
Birth-conception interval	Months	**BCI**	78	40.35	9.41	38	21	66	36–48	>54	6.85
Age first calving	Months	**AFC**	73	51.05	9.59	50	33	79	48–54	>60	13.70
Calving- oestrus interval	Months	**COI**	73	10.3	5.77	10	1	38	2–6	>9	72.60
Days open	Days	**OD**	73	340	203	360	30	1140	<180	>360	34.25
Calving interval	Months	**CI**	73	22.32	5.63	22	13	50	12–18	>24	40
Annual fertility*	%	**AF**	14*	56.2	6.6	51	38	67	>85	<75	100
Mating-pregn. diagn.	Days	**MPD**	14*	21.81	16.41		7	90	21	30	–
Pregnancy length*	Months	**PL**	14*	12.8	0.3		12	13.5	12.5	13.5	–
Calving number	Integer	**CN**	73	5.23	2.91	5	0	11	5	7 > n > 3	33.33
Culling age*	Years	**CA**	14*	23.31	5.64		10	30	15–17	>17	–
Culled females per year*	%	**CFY**	14*	4.42	3.12		0	11	<5	>30	0

Refer to Fig. 1 a to h for animals out of threshold and resultssection for normality statistics.
* Descriptive statistics for herd rerproductive traits (n = 14).

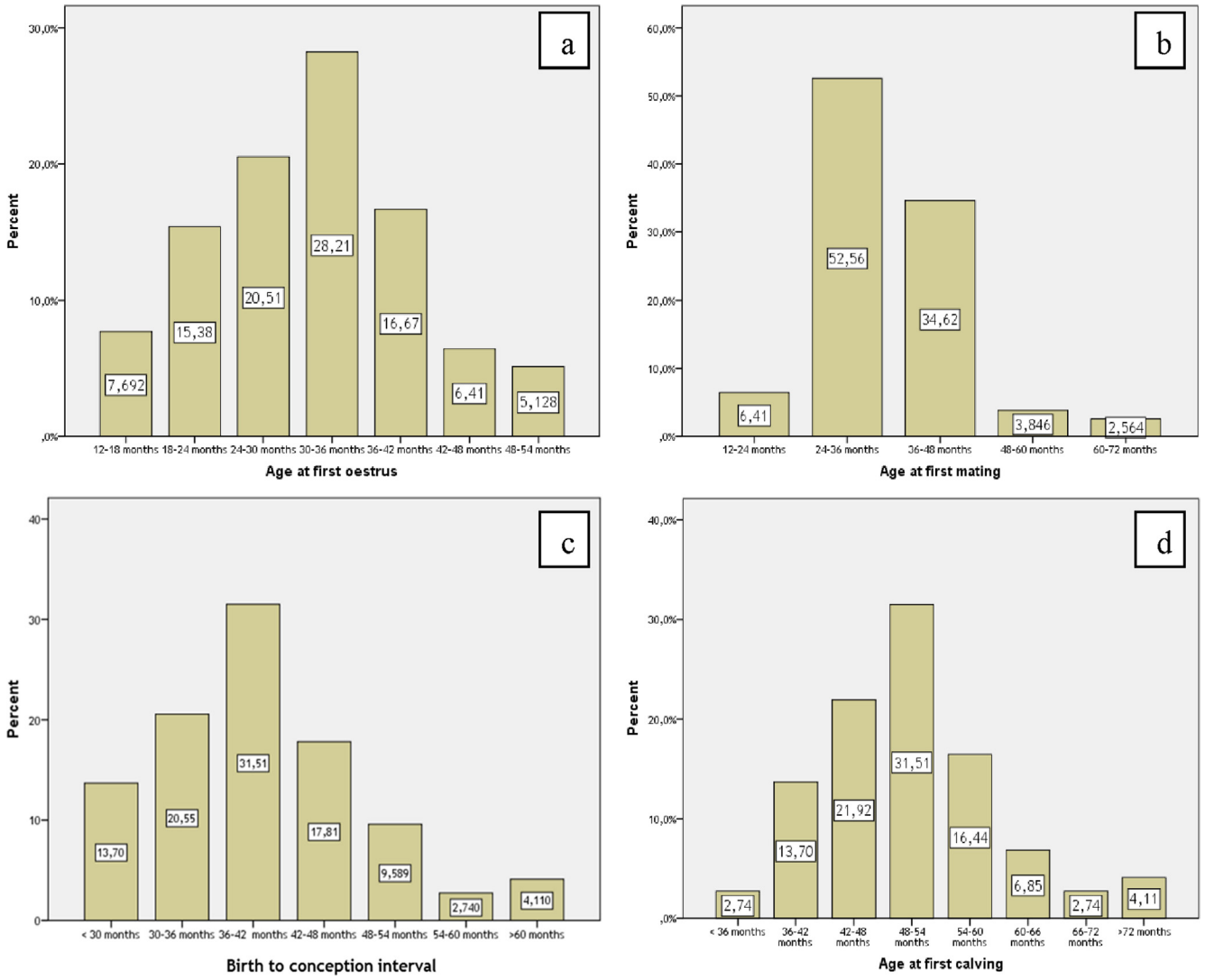

Fig. 1. Percentage of different classes of dromedary females (n = 78) belonging to 14 herds located in El Oued region (South-East Algeria) distinguished according to reproductive performances: a- age at first oestrus (AFO), b- age at first mating (AFMf), c- birth to conception interval (BCI), d- age at first calving (AFC), e- calving to oestrus interval (COI), f- open days (OD), g- calving interval (CI), h- calving number (CN).

bred for the first time when they were aged 12–24 monthsand 24–36 months, respectively. This corresponded to 58.97% of animals within the objective of AFMf. The proportion of those aged 36–48 months at first mating was 34.62%. A limited percentage of6.4%exceeds thresholds (3.84% for 48–60 months and 2.56% for 60–72; Fig. 1).

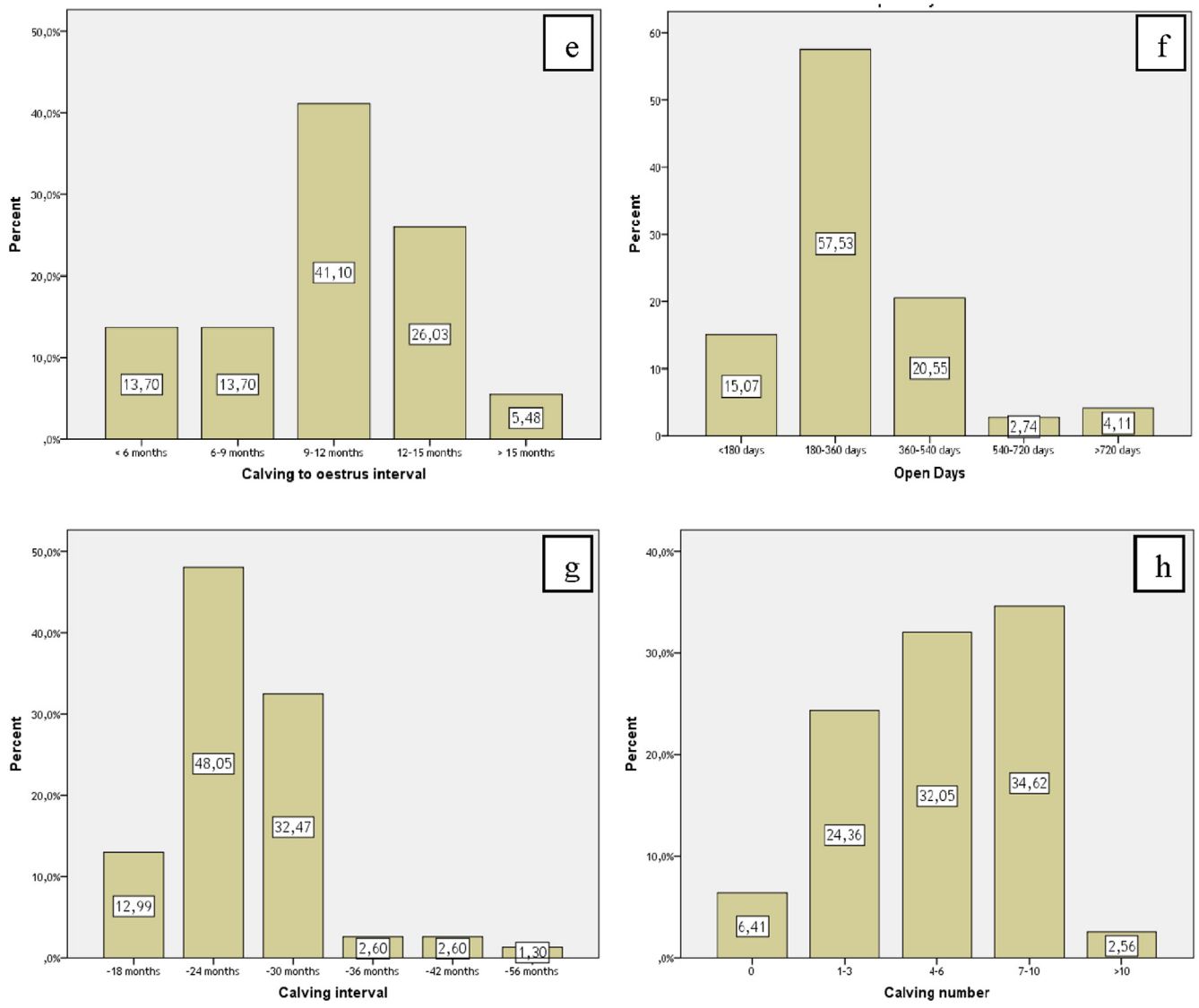

Fig. 1 (*continued*)

3.1.3. Birth to conception interval

The mean BCI was 40.35 ± 9.41 months, with minimal and maximal scores of 35 and 66 months, respectively. The median for this parameter was 38 months and the highest (31.51%) animal class was recorded in the interval 36–42 months (S/W. 0.883. df = 73, P = 0.04). The proportion of female camels who were pregnant at an age lower than or equal to 48 months (83.57%) was higher compared to those older than 42 months of age (16.43%) (Fig. 1).

3.1.4. Age at first calving

The average AFC was 51.05 ± 9.59 months (S/W. 0.965. df = 73, P = 0.04) (Table 2). The most important proportions (31.51% and 21.92%) were recorded for females aged at first calving 48 to 54 months and 42 to 48 months, respectively (Fig. 1). However, the female camels who calved for the first time before reaching 42 months and after 48 months of age was 16.44% and 61.63%, respectively.

3.1.5. Calving to oestrus interval

The average COI was 10.30 ± 5.77 months (S/W. 0.829. df = 73, P = 0.000). The proportion of female camels showing normal cyclicity before 6 months postpartum was 13.7% whereas most of the animals exhibited oestrus between 9 and 12 months postpartum (41.10%) followed by those with a COI of 12 to 15 months (26.03%). A very small number of animals exhibited oestrus after 15 months postpartum (Fig. 1).

3.1.6. Open days

The average mean of open days was 340 ± 203 days (11.38 ± 6.78 months) (S/W. 0.739. df = 73, P = 0.000) (Table 2). The animals were not distributed normally according to their OD, with the highest proportion of female camels under 180–360 days class (57.53%). The proportion of those exceeding 360 days after calving to conceive was 27.4% (Fig. 1).

3.1.7. Pregnancy diagnosis

All camel herders used the traditional method for PD (tail cocking of the pregnant female when approached by the breeding male) and performed this test, after mating, at 21.81 ± 16.41 days (S/W. 0.925. df = 73, P = 0.000), on average. A proportion corresponding to 51.6% of herders practice it between 7 and 15 days postmating. The average gestation length was 12.80 ± 0.30 months.

3.1.8. Calving interval

The average CI was 22.32 ± 5.63 months (S/W. 0.829. df = 73, P = 0.000). Most of the females had a CI of 18–24 months (48.05%) and 24–30 months (32.47%). Female camels with CI < than 18 months were 12.9%. (Fig. 1).

3.1.9. Annual fertility

The mean fertilityper year, observed within the 14 herds, ranged from 38 to 67%, with an average of 56.2 ± 6.6% (Table 2). The median showed that 50% of AF rates were ≤51%.

3.1.10. Age and rate of culled females

The average rate of females reformed per year/herd was 4.42 ± 3.1%; females were culled at an average age of 23.31 ± 5.64 years (S/W. 0871. df = 73, P = 0.022) and after 5.23 ± 2.91 lactations (S/W. 0.962. df = 73, P = 0.028). A higher culling rate was found for those animals with 4 to 10 calving (66.67%) (Fig. 1).

3.2. Male camel reproductive traits

Descriptive statistics, objectives and thresholds of male bull camel's reproductive traits belonging to 14 camel herds in the South-Eastern Algeria are reported in Table 3.

3.2.1. Age at first rut

The average age at first rut was 37.2 ± 16.92 months. The distribution of animals as related with this parameter was not normal (W/S 0.238, df = 20, P = 0.04). A considerable proportion of the studied males (40%) expressed rutting behaviour, for the first time, at 4 years of age (Fig. 2).

3.2.2. Age at first mating

The average AFMm of the male camels was 42.6 ± 14.28 months (Fig. 2). The rate of males that copulated for the first time at 48 months of age was 35%, which decreased mainly from 60 months old. The rate of those who mated at 48 and 36 months of age was 20 and 25%, respectively (W/S 0.117, df = 20, P = 0.102).

3.2.3. Ratio male/female

The RMF ranged from 1:20 to 1:100 with an average of 1 camel bull for 40.16 ± 24.01 females (W/S 0.421, df = 20, P = 0.01). A proportion corresponding to 45% of breeders maintain a male/female ratio from 1:21 to 1:40 whereas 30% of herders used 1 male for 40 to 60 females. The 1: 10–20 and 1: 61–100 ratios were less frequently observed (15% and 10%, respectively) (Fig. 2).

3.2.4. Culling age of the male camel

Camel bulls were kept in the herd, as a stud, until a mean age of 15.30 ± 2.47 years (Fig. 2) with the highest rate (60%) recorded for animals from 13 to 15 years (W/S 0.366, df = 20, P = 0.01).

3.2.5. Number and duration of mating per obtained pregnancy

The average NMP was 2.09 ± 1.03. The average time required for mating was 17.50 ± 6.48 min.

4. Discussion

The present survey evaluated dromedary camel reproductive performances in pastoral herds of South-East Algeria and compared them to objectives and thresholds, taking into account reproductive physiology as well as the particularities of local traditional husbandry. The obtained data shed light on some reproductive constraints responsible for the reduced productivity and productive life.

The reproductive standard objectives fulfil the physiological particularities of the camel species. Even, the strategies to achieve them are different and depend closely on the species' genetics interaction with environmental factors. So, the complexity to admit these objectives in the pastoral environment is related to the great variability from one year to the other of the environmental factors such as the precipitation level, photoperiod, temperature humidity index and availability of forage. Therefore, parameters such as the length of the breeding season, calving distribution on the year-round, growth on the pre-pubertal stage and body reserves level, depend on them. In addition, camel pastoral livestock systems have been evolved for several years, particularly in relation to the socio-economic aspects of the pastoral community, the level of inputs and the vocation of the animals (Gherissi et al., 2019).

The mean age at first oestrus (AFO), birth to conception interval (BCI) and age to first calving (AFC) run within the reported objective ranges (Table 2). The proportion of female camels with previous performances that do not exceed the respective thresholds was 88.46%, 93.15% and 86.31%, respectively. The breeding parameters of the female camels at heifer stage (AFO, AFM) were consistent with previous findings indicating that she-camels in extensive livestock system are often bred when they are aged between 3 and 4 years (Moslah and Megdiche, 1989; Mayouf et al., 2014; Gherissi et al., 2018b; Ali et al., 2018). In the same context, the Lahlou-Kassi et al. (1989) investigation in Moroccan camels, reported that 55% of primiparous females were mated at 3 years old, 30% were mated at 4 years of age and only 15% were mated at 2 years of age. In general, young camels reach puberty after the second year of age but they are generally not mated until the age of three years (Tura et al., 2010).

The age at first calving (AFC) ranged between 33 and 79 months, which corresponds to the range (36 to 71 months) indicated by Tibary et al. (2005) but lower than that recorded by Kaufmann (2005). This parameter is in accordance with that reported by Mayouf et al. (2014) in Algeria, by Abdussamad et al. (2011) in Nigeria, by Moslah and Megdiche (1989) in Tunisia and by Keskes et al. (2013) in Ethiopia. Tura et al. (2010) observed an age at first calving of 60 months in Kenya. The delayed puberty (determined by the expression of the first oestrus) and first calving

Table 3
Descriptive statistics, objectives and thresholds of male camel's reproductive traits in South-East Algeria (n° 14 camel herds).

Variable	Unit	Abb	N	Mean	SD	Median	Min	Max	Objective	Threshold	(%) Out of Threshold
Age at first rut	Months	**AFR**	20	37.2	16.92	42	12	72	24	>36	50
Age at first mating	Months	**AFMm**	20	42.6	14.28	48	24	72	36	>48	25
Ratio male/female		**RMF**	14*	1:40	24,01	1:52	1:20	1:100	1:30	>1:60	10
Mating/pregnancy	Integer	**NMP**	20	2,09	1,03	2	1	5	1–2	>4	–
Mating time	Minutes	**TM**	20	17,50	6,48	15	10	30	10	>20	–
Age at culling	Years	**CAm**	14*	15,30	2,473	15	12	20	13	>15	30

Refer to Fig. 2 a to d for animals out of threshold and results section for normality statistics.
* Descriptive statistics for herd reproductive traits (n = 14).

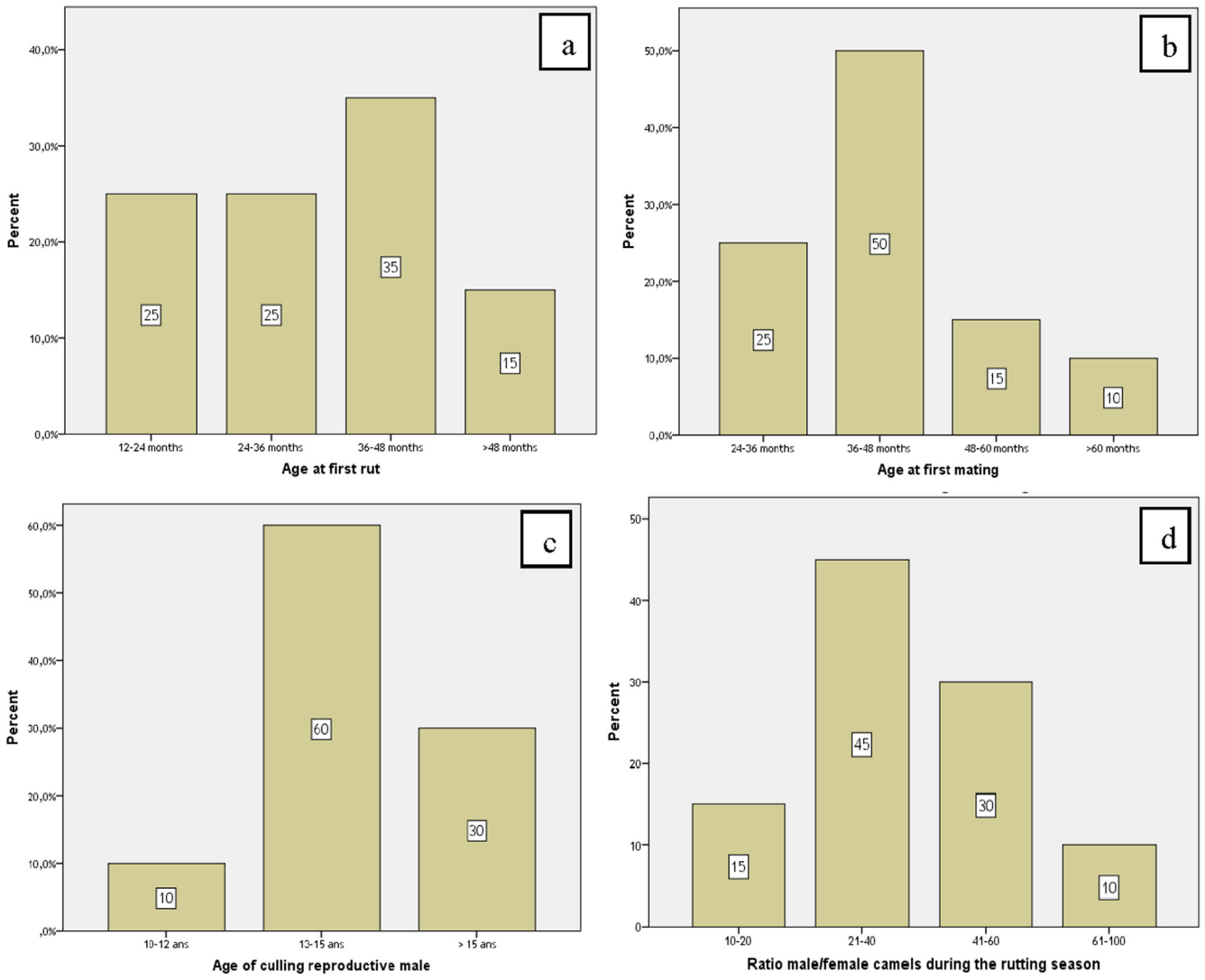

Fig. 2. Percentages of different classes of male dromedary camels, (n = 20) belonging to 14 herds located in El Oued region (South-East Algeria), according to reproductive performances: a- age at first rut, b- age at first mating, c- age of culling reproductive male, d- ratio male/female camels.

age would result from genetic factors (breed fertility), health, food availability, nutritional quality and management conditions. Indeed, these factors influence the level of weaning and post-weaning growth and thus the age at first mating and calving (Hammadi et al., 2004; Swelum et al., 2018).

The observed delay of the age at first calving is responsible for a decrease in the average yield per lifetime, a perturbation in the renewal rate of pastoral herds and supply of semi-intensive herds for fattening and camel meat production and slow down the genetic improvement by increasing generation interval. Conversely, early breeding and calving age may have the drawbacks of a lack of conformation in adulthood with increased risk of dystocia and of low milk yield, as well as to a longer inter-calving interval (by increased open days).

The mean calving to oestrus intervals (COI), open days (OD), calving interval (CI) and pregnancy length (PL) were 11.38 ± 6.78 months, 340 ± 203 days, 22.32 ± 5.63 months and 12.80 ± 0.30 m onths, respectively, resulting similar to those reported by Tibary et al. (2005) and Ali et al. (2018). The large variability of these reproductive parameters suggests the implication of several other factors such as nutritional level, breed differences and health (Tibary et al., 2005).

The OD and CI medians showed that 50% of the intervals were greater than 360 days and 22 months, respectively. The average COI, OD and CI exceeded standard objectives ($\leq$6 months, $\leq$180 days and $\leq$18 months). Therefore, 72%, 27.4% and 40% of the studied camels had COI, OD and CI greater than alarm thresholds (>9 months, >360 days and >24 months, respectively). In extensive breeding systems, several authors stated that the CI ranged between 2 and 3 years, which is close to our results (Khorchani, 1993; Faye, 1997; Kaufmann, 2005). Comparable results were also reported by Hammadi et al. (2004) who recorded a CI of 682 ± 137 days (~23 months) between two subsequent calving with a difference ranging from 386 to 1089 days.

Accurate reproductive management could reduce the level of herd infertility and the CI (the minimum for this study was 13 months and ~13% female camels had CI < 18 months) by acting on Waiting Period (WP: the time between calving and first mating) and Reproduction Period (RP: the time between first mating to conception). The WP may be shortened through the accurate management of breeding, of partum and peripartum period (improved monitoring and balanced nutrition) as well as by good production management practices (inputs and calves weaning) (Tibary et al., 2005; Nagy et al., 2015; Bakheit et al., 2016). Calving during the

beginning of the breeding season coincides with rainfalls and higher food availability, which promotes early resumption of ovarian activity with mating and pregnancies within the same season (Vyas and Sahani, 2000). In this context, synchronization protocols and fixed time mating would be an easy and on-field reliable strategy that may help planning parturition (and thus calving assistance and post-partum check) and thus facilitate herd management practices such as dam vaccinations, calf check, post-partum check, etc. (Quzyet al., 2013; Manjunatha et al., 2018). Regular checks of post-partum animals for diagnosing a nd treating post-partum related diseases (including mastitis) and calf mortalities are also recommended (Skidmore et al., 1996a; Ali et al., 2018; Gherissi et al., 2018b). Interventions on RP are implemented by regular monitoring of animal food intake (Mostafa et al., 2016), good herd management (male to female ratio and culling of old, unfertile animals) as well by diagnosing and treating female genital diseases (metritis, ovarian bursae disease) as well as with controlled breeding and with regular check of breeding males fertility (Tibary et al 2005; Ali et al., 2010; Monaco et al., 2013). In addition, photoperiodic control of ovarian cycles (Melatonin implant) and use of reproductive biotechnologies could be useful in overcoming long-term unproductive periods and short breeding season, help planning parturition, improve low reproductive performances of camel bulls, overcome long-term pregnancy and decrease the generation interval for accelerated genetic progress (Vettical et al., 2016; El Allali et al., 2018; Swelum et al., 2018; El-Maaty et al., 2019). The PL was within the range reported by most authors (Hammadi et al., 2004; Gherissi et al., 2017).

The recorded annual fertility was 56% (ranging from 38 to 67%); even though more than 50% of herds had AF $\geq$ 51%, all the considered herds were lower than 75% threshold. This parameter explains in part the substantial rate of CI out of threshold (40%). The herd annual fertility ranges corroborate those of 12 to 85% reported by Tibary et al. (2005) and 8 to 86% observed by Kaufmann (2005). In addition, the mean AF was close to that reported in Moroccan camel herds by Srairi et al. (2018), which performed considerably poorly, compared to the proposed objectives and alarm thresholds of the species. The most common components of poor fertility are increased early pregnancy loss and abortion, which may be as high as 40% (Tibary et al., 2005). In this context, the infectious agents causing abortion storms and significantly affecting herd productivity are rarely identified and, in such conditions, it is also hard to set up vaccination campaigns.

Bakheit et al. (2016) observed pregnancy rates of 88.9% and 33.3% in semi-intensive and traditional systems, respectively. The mean AF of Saudi camels reported by Ali et al. (2018) was 82.64 ± 0.35%, rather higher compared with proportions of 45%, 40% and 50% recorded in Egypt (Zeidan, 1999). Factors such as herd size and composition, camel bull experience, housing systems and genital disorders and genital tract contamination during natural mating influenced significantly the herd fecundity level (Tibary and Anouassi, 1997; Ali et al., 2018). According to the birth rate of the studied females, associated with the high CI, the numerical productivity of the camel herds would be very low. Indeed, Faye (2018) reported standard pregnancy and calving rates within a year of 90% and 80–90% to achieve the herd growth rate of 3.9% over 10 years (with abortion rate of 10% and mortality rate in animals aged 0–1 year < 20%).

The mean culling age of female camels was 23.31 ± 5.64 years, during which they gave birth on average 5.23 ± 2.91 times. These results reveal the low frequency of primiparous and nulliparous in the pyramidal age class of these animals. Based on the average of AFC (51.05 ± 9.59 months) and CI (22.32 ± 5.63 months) per animal as well as AF (56%) and CA (23.31 ± 5.64 years) per herd, it can be assumed that, in the considered population, the average number of calving (and lactations) for each female reproductive life is about 6. Higher values, however, were observed in a small number of animals: 2.56% of females with CN > 10. The average number of calving could be considered acceptable since the maximal adult productive potential is expressed between the 5th and the 6th lactation (Musaad et al., 2013). However, Ali et al. (2018) recorded higher scores in Saudi Arabia female camels (reproductive life of 20 ± 4.5 years, and mean CN of 9 ± 2.7). It seems that female camels aged more than 17 years have lower body condition scores and hardly could continue their reproductive life without improved feeding (Hammadi et al., 2004; Gherissi et al., 2018b).

The mean AFR and AFMm were 37 ± 16.92 and 42.6 ± 14.28 m onths, respectively. These results were higher than standard objectives (24 months and 36 months, respectively) and close to threshold values (>36 and >48 months, respectively). Only 35% and 45% of all camel bulls had an AFR and AFMm lower than thresholds. Our results were lower than those observed by Mehari et al. (2013) in Ethiopian extensive camel herds, and corroborate the experimental findings describing the various aspects related to puberty (behavioural, morphological, hormonal and reproductive data) reported Abd and Ibrahim (2014), Gherissi et al. (2016, 2018a) and Aubè et al. (2017). Most authors implicate live weight, the nutritional value of the diet, calving conditions and month of birth, herd management (male ratio: female, weaning, welfare, displacement ...), neonatal complication and health status of camel calves as the main factors influencing age at which they reach puberty (Hammadi et al., 2004; Kaufmann, 2000; Al-Saiady et al., 2013, 2015). El-Hassanein (2017) reported that full reproductive ability in the dromedary species is reached at 6–7 years of age.

The ratio of male camel bull to breeding female camels varied from 1:20 to 1:100 with an average of 1: 40.16 ± 24.01. Estimates of this parameter under traditional livestock conditions were strongly different from one country to another with a ratio varying from 1:5–7 (Watson, 1969), to 1:10–30 females (Keskes et al., 2013) and 1:50–80 (Abdussamad et al., 2011). According to Al-Qarawi (2005) and Ali et al. (2018), herds with RMF 1: <25 have an overall pregnancy rate of 95.29% whereas lower RMF reduced annual fertility since higher numbers of matings per day per bull reduce the sperm quality (Al-Qarawi, 2005). The management of bulls, before and during the breeding season (flushing before the breeding season, supplementation with concentrated for compensating the low food intake), is one of the most critical aspects that herd manager must control for increasing the number of pregnant females at the end of the breeding season (Al-Qarawi, 2005).

The average time required for mating (standing over the female stage) was in agreement with the mating times recorded by Padalino et al. (2015) and Abdulmohsen et al. (2018). It should be noted that excess workloads in a dromedary bull may also result in a lack of libido (Padalino et al., 2015) or in ejaculation failures (Al-Qarawi et al., 2001). The age to cull breeding male camels was on average of 15.30 ± 2.47 years, which seems an acceptable breeding career duration, able to prevent over-use of males within the herd, and its replacement before the physiological decrease of its reproductive potential.

Under traditional pastoral management of camel herds at the South Eastern Algeria, the dromedary exhibits low reproductive performance mainly characterized by delayed puberty and first calving, prolonged inter-calving interval and reduced annual fertility rate. The reproductive traits showed prominent levels out of thresholds suggesting serious management difficulties in camel herds. In order to pursue a more efficient breeding, it is recommended to improve the livestock system conditions and to monitor reproductive processes and their limiting factors (abortion, reproductive diseases and calf mortality). Training of camel herders and improvement of external services about diseases diagnosis, vaccination and antiparasite treatments, food supplementation,

reduction of calf mortality and use of reproductive biotechnologies as well as the preservation of camel pastoral environment will certainly contribute to the upgrading of the camel sector in Algeria.

Authors' contributions

GDE:study conception and design, data collection and analysis, manuscript preparation. MD: study conception and design, manuscript preparation and critical revision. BZ and BFA: study conception and design. GSSB and CE: critical revision of the final manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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