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1 **Mismothering and remedying the mother-young relationship in stabled**
2 **dromedary camels**

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27 **1. Introduction**

28 Camel husbandry is currently evolving from a pastoral towards to an intensive
29 system, due to a selection process for the use of this species in meat and milk
30 production (Faye, 2016). Captivity in intensive systems affects locomotion and social
31 activities, limits the expression of various behavioural needs and causes the
32 expression of abnormal behaviours in male camels (Padalino et al., 2014); indoor
33 living conditions could also affect female behaviour especially around parturition.
34 Giving birth and providing maternal care during the early postpartum period are an
35 essential and critical part of animal breeding management. Ruminants usually isolate
36 from the herd when ready to give birth, an adaptive process that allow the females to
37 give birth in a calm environment away from threats and social disturbances. In normal
38 parturition, the mother turns toward her neonate soon after giving birth and interacts
39 closely with it. Normal maternal responsiveness is characterized by sniffing, nursing
40 and vocalizing activities (sheep and goats: Poindron et al., 2007; cattle: Rørvang et
41 al., 2018, camels: Hammadi et al., 2021). Licking the neonate is also common except
42 in camels (Hammadi et al., 2021). Mutual mother-young recognition develops at an
43 early stage and ensures selective suckling and care of the newborn; this satisfies
44 basic requirements such as food, warmth, and protection for its welfare and ensures
45 that the mother does not misspend time and energy in alien young. Consequently, it
46 is acknowledged that the survival of the young ruminant relies, by in large, on
47 appropriate care and selective mother–young bonding (Nowak et al., 2000; Dwyer
48 and Lawrence, 2005).

49 Studies in cattle have shown that intensive management systems, involving
50 restricted space and high stocking densities, increase the risk of behavioural
51 disturbances and mismothering during the peripartum period, with failure to provide
52 adequate amount of colostrum to the neonate (Rørvang et al., 2018). Should a
53 newborn calf be abandoned by its mother, even temporarily, nutritional and
54 behavioural needs are not met, and its survival is at risk (Vogels et al., 2013). While
55 inadequate maternal care and rejection behaviours have been well investigated in
56 cattle, sheep, goats, and mares (Poindron et al., 2007; Žurek and Danek, 2012;
57 Kohari and Takakura, 2017), this aspect has never, to date, been investigated in
58 dromedary camels. Research is needed to understand camel postpartum behaviour
59 and the reasons leading to the potential rejection of newborns. Should this happen, it
60 is important to develop practical solution to remedy mismothering. Like other
61 ruminants, newborn camels are agammaglobulinemic, so colostrum is the main
62 source of food and early protective antibodies (Salhi et al., 2014). Any delay in
63 colostrum ingestion due to inadequate maternal care may be fatal. One potential
64 solution is to confine rejecting mothers in a pen and force them to maintain proximity
65 with their offspring repetitively. This has proven being efficient in sheep for re-
66 establishing proper mother-young relationships (Alexander and Bradley, 1985).
67 Other procedures to remedy altered maternal behaviour in ruminants have been
68 described. In a study by Levey et al. (1992), primiparous ewes prevented from
69 becoming maternal at birth using an epidural anaesthetic block, oxytocin treatment
70 was also effective in inducing full maternal responsiveness. In Tunisian traditional
71 system, the camel breeders restrain the mismothering dam with her neonate far from
72 the rest of the herd. Then, they obstruct the vulva after putting small stones into the
73 vagina and partially block the normal respiration. Even if she-camel accepts her

74 newborn after 3 to 4 hours, these practices are contrasts with ethics and animal
75 welfare. Dioli (2012) described rather unusual technique by the Somali and
76 neighboring ethnic groups to treat camel's newborn rejection. This technique
77 included isolating the newly partum camel and her calf than mimicking the behaviour
78 and sound of predators usually at sunset or early night. Soon after she camel reacts
79 to protect the calf, the impersonate retreats. Few nights with this deceit are sufficient
80 to establish maternal-young bond (Dioli, 2012).

81 Alterations in maternal responsiveness are triggered by stress, because the
82 process of parturition itself is stressful or because the environment does not comply
83 with the behavioural needs of the individual. Behavioural and physiological responses
84 observed in disturbed animals reflect their emotional reactivity (Deiss et al., 2009).
85 Cortisol, which is considered as an indicator of stress, is also used to predict the time
86 of parturition in female dromedary camels (Abd-El-Rahman et al., 2017).

87 Foetal cortisol and thyroid hormones play an important role in the maturation
88 and development of the young (Liggins, 1994). The decrease of the prepartum cortisol
89 surge in sheep for example reveals a dual mechanism. Firstly, late pregnancy is
90 associated with a rise in cortisol levels being the highest in the last 1–2 days of uterine
91 life, as it is the activation of the hypothalamic-pituitary-adrenal function that is
92 responsible for the birth process (Challis and Brooks, 1989). Secondly, the decline in
93 cortisol concurs with periods during which thyroid hormones increase as thermal
94 efficiency improves and rectal temperature stabilizes (Chniter et al., 2016).

95 During parturition cortisol levels increase from basal levels at around $21.9 \pm$
96 1.0 ng/ml to more than 121.6 ± 5.4 ng/ml (Mohamed, 2006). This suggests that

cortisol may also be used as an indicator of postpartum stress and could be linked to the expression of proper or inadequate maternal responsiveness.

The purpose of this study was twofold. First, we described mismothering behaviours in a herd of stabled dromedary camels, assessed its importance, and identified the causes of calf rejection. Plasma cortisol was also used as a physiological index that would relate to mismothering. Second, we designed a suitable method to try and solve this issue, based on restrain, forced body contact while bottle-feeding the neonate, and food-reward when the mother displayed signs of acceptance.

2. Material and methods

2.1. Animals and housing

The study was conducted at the experimental station of the “Institut des Régions Arides de Médenine”, located in southeastern Tunisia (33° 30 ' N, 10° 40 ' E), with a typical Mediterranean climate. The work was conducted during two consecutive calving seasons (1st season: November 2016-March 2017 and 2nd season: November 2017- April 2018) on respectively 36 (10 primiparas and 26 multiparas) pregnant dromedary females (weighing 440.0 ± 38.0 kg, aged 12.7 ± 5.7 years) and 9 (3 primiparas and 6 multiparas) pregnant dromedary females (weighing 446.0 ± 73.0 kg, aged 14.0 ± 6.2 years). During these two seasons, a total of 6 she-camels showed signs of calf rejection (mother moving more than 2 m away from her newborn just after giving birth) and were assigned to the group of mismothering dams (rejecting group). Whenever a rejection case was recorded, the first following calving with a successful mother-young relationship was also recorded to serve as a control (accepting group). The two mothers group had the same housing conditions.

Subsequently, after the first hour *postpartum*, the mothers accepting their neonates were moved to a maternity enclosure (15 m²), while those rejecting their calves were moved to a confinement enclosure (15 m²) located 200 m from the rest of the herd, to remediate the dam-young bond. The calving pen, feeding and management procedures of the same experimental herd were described previously by Hammadi et al. (2021).

2.2. Behavioural measurements

Digital infrared video cameras (DAHUA - HAC-HDW1220M) were mounted above the calving pen and used to determine calving behaviours from the appearance of the amniotic sac to the total expulsion of the calf. A qualified person was present during the parturition process to detect and describe the incidence of potential complication (dystocia, uterine prolapse, retained placenta, inappropriate maternal behaviour...) and/or disturbance occurred (presence of alien calves...). Maternal behaviours during the 1st hour post-calving (sniffing duration and number of low and high-pitched grunts) were measured in the accepting and rejecting groups using a camcorder (Sony® X60). During the first three days *postpartum*, maternal behaviour was videotaped for the rejecting group in the confinement enclosure over a 30 min period after 1 h, 6 h, 12 h, 24 h, 48 h, 72 h of confinement, however at 7 d *postpartum*, maternal behaviour was recorded for accepting and rejecting groups. An ethogram was defined to code and measure behaviour traits using the focal-animal sampling method (Altmann,1974) (Table1).

Insert Table 1 here

2.3. Cortisol analysis

145 Once the amniotic sac was visible, a blood sample was taken from the jugular
146 vein into heparinized plain tubes (5 mL). Samples were centrifuged at 3,000 rpm for
147 15 min at 4°C, and stored at –20°C until hormonal analysis. The concentration of
148 cortisol was determined by enzyme immunoassay using an “in home-kit” (validated
149 by Chacón et al., 2004). Each sample was determined in duplicate from 50 µl of
150 plasma. The mean of the duplicate was used as the result and expressed in µg/ml.
151 Inter- and intra-assay coefficients of variation were 3.5–6.0% and 3.9–9.9%,
152 respectively.

153 *2.4. Remedying the mother-young relationship*

154 *2.4.1. Confinement of mothers rejecting their calves*

155 To ensure adoption of abandoned calves, each dam showing mismothering
156 behaviour was isolated with her neonate in an individual enclosure away from the
157 herd and restrained. Because rejecting she-camels can be quite aggressive (Photos
158 1A, 1B and 1C), we used a multiple procedure to prevent any injury to the young and
159 consisting of:

- 160 • Restraining the mother with a 1.5 m of a strong rope in her front leg.
- 161 • Using a muzzle mouth guard on the mother to prevent her from biting the
162 newborn and take it off only in her feeding times. At this time, a qualified
163 person surveyed the mother to prevent her from attacking the newborn when
164 approached.
- 165 • Tying the mother's front and back legs together with a 1 m rope to prevent her
166 from kicking the newborn.
- 167 • Hanging up a thin rope onto the hoofs of the mother once she expressed
168 aggression, and removing it when she showed some nursing behaviour.

- Encouraging the calf to suckle at the udder.
- Providing an extra amount of concentrate food whenever nursing behaviour was observed.

2.4.2. Oxytocin treatment, milking and newborn feeding

Once the mother was moved into the confinement enclosure, 5 IU of synthetic oxytocin (Biocytocine, Laboratoires Biové, Arques, France) were injected into the jugular vein. A qualified person collected an amount of 300 ml of colostrum from the dam and ensured her newborn was fed using a baby bottle held on the surface of the udder and keeping the body contact between the two animals (Photo 1D). This intervention was repeated three times per day (8:00, 12:00 and 16:00) until the mother stopped being aggressive and accepted her neonate.

2.5. Statistical analyses

Boris software 6.3.1 (Friard and Gamba, 2016) was used to analyze behavioural data. Statistical analyses were performed with GraphPad Prism 7.00 for Windows (2016). Test of normality (Shapiro-Wilk test) was performed and showed a non-normal distribution. Consequently, comparison between the two mothers group on maternal expression during calving (change in birth site, head-turning, changing posture, tail raising, posture during newborn expulsion and newborn attack), and maternal behaviours (sniffing duration and number and low and high-pitched grunts) during the 1st hour and the 7th day *postpartum* were performed using the Mann-Whitney test. Overall, the effect of time (1 h, 6 h, 12 h, 24 h, 48 h, 72 h of confinement and 7 d *postpartum*) on maternal behaviors was performed by Kruskal-Wallis test with Dunn's correction for multiple comparisons. *P*-values less than 0.05

193 were considered as statistically significant. Results are presented in terms of median
194 and lower and upper quartiles [LQ-HQ].

195 The unpaired *t* test was used to compare plasma cortisol levels during
196 parturition between accepting and rejecting mothers. Results are presented as
197 means \pm standard errors (SEM) and *P*-values less than 0.05 were considered as
198 statistically significant.

199

200 **3. Results**

201 *3.1. Calving behaviour and cortisol levels in mothers accepting or rejecting their* 202 *newborns*

203 *3.1.1. Calving behaviours*

204 The proportion of females rejecting their newborns was 5/36 during the 1st and
205 1/9 females for the 2nd calving seasons, representing 13.3% of the herd. The duration
206 of parturition was longer in the mothers rejecting their calves compared to those
207 accepting them (Mann-Whitney *U* = 7; *P* = 0.04). Compared to the accepting
208 mothers, those which rejected their neonates spent more time in standing position
209 during calving (Mann-Whitney *U* = 4; *P* = 0.01), but there was no significant
210 differences in the time spent lying (Fig. 1).

211 During parturition, mothers rejecting their calves changed their birth place
212 (Mann-Whitney *U* = 1; *P* = 0.003) and turned the head towards their abdomen more
213 frequently (Mann-Whitney *U* = 3; *P* = 0.007) than those accepting their calves. There
214 was no difference between the two groups in changing posture and tail raising
215 behaviour (Fig. 1). Five out six rejecting females adopted the standing position during

216 the expulsion process and two kicked strongly backwards with their hind legs while
217 this behaviour was never observed in mothers accepting their neonates.

218 **Insert Fig. 1 here**

219 3.1.2. Plasma cortisol level

220 Mothers abandoning their newborns had higher plasma concentrations of
221 cortisol at parturition than those accepting their newborns (47.7 ± 2.0 vs. 29.5 ± 3.0
222 ng/ml; respectively, $P < 0.01$).

223 3.1.3. Causes of newborn rejection

224 In our study, the main reasons for abandonment were problems during
225 parturition and the presence of an alien calf (Table 2). The main cause of rejection
226 was found in the birth process (three occurrences). Two females had a long duration
227 of parturition compared to normal calving associated with more discomfort and pain,
228 suggesting dystocia. The third case of mother rejection was associated with dystocia
229 and uterine prolapse in which the uterus protrudes out of the vagina. It required the
230 intervention of the institutional veterinarian who replaced the uterus into its normal
231 position and provided appropriate medical treatment. Only one rejection event was
232 observed in the presence of an alien calf in the calving pen, in which the she-camel
233 displayed maternal response prior to parturition and adopted the alien calf, which
234 lead the mother to reject her own neonate. We hypothesize that the presence of the
235 alien calf is the responsible of this mismothering case. The last case concerned a
236 repeated rejecter, a female that never accepted her newborn in eight successive
237 parturitions. No particular sign of complication during calving was witnessed in this
238 dam.

239 **Insert Table 2 here**

240 *3.2. Maternal behaviour*

241 *3.2.1. Behaviour during the first hour postpartum*

242 Just after giving birth, the accepting mothers stayed close to their neonates
243 and provided care by protecting them between their front legs. During the first hour
244 *postpartum*, mothers rejecting their neonates exhibited less sniffing (both duration
245 and number), emitted less low and high-pitched grunts than those accepting their
246 neonates, and failed to show proper maternal care (Table 3). In addition, they were
247 indifferent to and moved away from their progeny. The mother who suffered from
248 dystocia and uterus prolapse was unable to get up and remained near her calf
249 without any responsiveness.

250 **Insert Table 3 here**

251 *3.2.2. Behavioural progress in mothers rejecting newborns*

252 In the confinement enclosure, the calves approached to suckle their mothers,
253 but they displayed attack behaviours in response and refused to nurse (Photos 1A,
254 1B and 1C). The number of these behaviours was the highest in the first 6 h before
255 declining significantly (Kruskal-Wallis = 32.4; $P < 0.0001$) after one day and
256 disappearing almost completely after 3 days of confinement (Fig. 2A). The reverse is
257 observed in the sniffing activity, which was limited in the first day. Then, both the
258 duration (Kruskal-Wallis = 21.7; $P = 0.001$; Fig. 2B) and the number of sniffing bouts
259 (Kruskal-Wallis = 22.0; $P = 0.001$; Fig. 2C) increased significantly in the following
260 days.

261 The number of high-pitched grunt was high during the first hour of confinement,
262 dropped after 12 hours and then remained at a low level (Kruskal-Wallis = 29.4; $P <$

0.0001; Fig. 3A). By contrast, the number of low-pitched grunt started low (Kruskal-Wallis = 21.4; $P=0.001$; Fig. 3B) and increased progressively over the first 3 days of confinement before declining significantly on the 7th day.

Insert Figures 2 and 3 here

Progressively, mothers accepted the presence of their newborns without any aggressive reactions. The next step was acceptance of the calf's attempts to make body contact without paying any particular attention to it or exhibiting any maternal care. This was facilitated by the human positioning the calf into normal suckling posture when giving colostrum and milk through a bottle (Photo 1D and 1E). The final step was total acceptance of the rejected calf with remediation of the mother- young relationship and complete restoration of maternal behaviour (Photos 1F and 1G).

Insert Photos 1 here

3.2.3. Maternal behavioural in mothers accepting and rejecting newborns at the 7th day postpartum

After returning to the herd, and at day 7 *postpartum* rejecting mothers exhibited more low-pitched grunts (Mann-Whitney $U = 0$; $P = 0.001$) and sniffing bouts (Mann-Whitney $U = 2$; $P = 0.005$) compared to the accepting mothers. However, there was no difference in the high-pitched grunts ($P = 0.45$) and in sniffing duration ($P = 0.13$) between the two mother's group (Fig. 4).

Insert Figure 4 here

4. Discussion

Newborn camel rejection by mothers had never been described before the present work. Despite the limited sample size, and the lack of comparison with other

286 methods to remediate mismothering, this study provides an applied technique to
287 reduce mismothering and to remediate this problem of rejection in the camel.

288 Aberrant maternal behaviour was related to birth difficulties with dystocia and
289 uterine prolapse in three cases, rejection of the neonate in two occurrences, while
290 acceptance of an alien calf prior to giving birth was observed only once. It is a
291 phenomenon that should not be neglected since it affected 13% of the herd. This
292 aberrant behaviour is reversible and mothers needed 3 days of restrain and human
293 assistance to maintain contact with the calf and restore signs of acceptance. One
294 striking element is that mismothering was displayed by multiparous camels, while in
295 domestic ungulates such behaviour characterizes inexperienced primiparous mothers
296 (Dweyer and Smith, 2008; McDonnell, 2012; Lv et al., 2015). Ihuthia (2010) reported
297 rather frequent newborn abandon by multiparous camels. He reported that up to
298 27.5% of abandon cases were registered in experienced camels. Some mares,
299 almost always primiparous, react to their neonate with fear behavior as they react to
300 objects which they have not been exposed. Positive reinforcement is effective in
301 helping a horse overcome fear of her newborn (McDonnell, 2012). In sheep and
302 horses, there is some speculation that in addition to environmental factors, maternal
303 rejection might also have a genetic background and may make an animal more likely
304 to reject the offspring repeatedly (Juarbe-Diaz et al., 1998; Grandinson, 2005).

305 However, hormonal failure during post-partum could also explain repeated calf
306 rejection in our camels. In fact, it has been reported that in ewes, females with better
307 maternal behavior have a higher level of oxytocin and noradrenaline than
308 mismothering ones (Wang et al., 2021).

309 In our study, the duration of parturition was longer in dromedary females that rejected
310 their calves compared to those accepting them. That parturition is a source of

311 discomfort is unquestionable and maybe even more in mammals giving birth to a
312 reduced number of newborns, especially singletons because of their size. Parturient
313 cows become quite agitated immediately before parturition, and in sheep the
314 incidence of prolonged and difficult parturition is threefold higher in single-bearing
315 ewes (Grommer et al., 1985; Von Keyserlingk and Weary, 2007). This can impair the
316 mother's motivation to care for her offspring (Nowak et al., 2000). Prolonged and
317 difficult parturition, assigned to pain and discomfort, is associated with reduced
318 mothering behaviour in ewes and mares, and contributes to increase newborn
319 rejection (Dwyer et al., 2003; Żurek and Danek, 2012).

320 Three typical signs of uneasiness were observed in camels: head-turning
321 towards the abdomen, regular changes of birth site, and standing position. Close to
322 parturition, females start to behave unusually, and restlessness is part of it. In some
323 species like cattle, restlessness is associated with frequent orientation of the head
324 towards the abdomen and reflects imminent calving (Barrier et al., 2012). It is
325 considered as a sign of disturbance since this behaviour is observed more frequently
326 in mothers needing assistance (Mainau et al., 2010). In this regard, camels are very
327 similar to cattle. Isolation seeking and selecting a birth site is another general trend in
328 domestic ungulates (Jensen, 2017), a behaviour that cannot be achieved under
329 intensive conditions. The constraints imposed on stabled camels may disturb the
330 future mother in her choice of birthplace, prolong labor, and impair the behavioural
331 changes necessary for the onset of maternal motivation as already described in
332 stabled animals (Grandinson, 2005; Nowak and Poindron, 2006). It has been shown
333 in sheep reared under intensive conditions, that should cubicles be provided for
334 isolation, periparturient ewes use them actively, and when doing so they spend less
335 time moving around and are less likely to be separated from their lambs (Gonyou and

336 Stookey, 1985). In our experiment, she-camels that displayed mismothering changed
337 birth site more frequently than those that accepted their calves. Likewise, studies in
338 sheep have shown that twin-bearing ewes are more likely to desert one of their lambs
339 if they have been moved away from the birth site (Nowak, 1996). Selecting and
340 staying on the birth site is crucial for the development of mother-young interaction
341 and bonding. Adequate space and facilities with minimal provocation of protective
342 behavior are recommended until protectiveness period naturally diminish.
343 Restlessness was also associated in she-camels with more frequent standing
344 posture during the expulsion process, and sometimes kicking. This reflects intense
345 discomfort as reported in cows (Norman and Youngquist, 2016) or in primiparous
346 she-camels (Hammadi et al., 2021). In addition, rejecting mothers preferred the
347 standing position during calving, which is not the normal posture adopted by
348 dromedary camels as documented recently by Hammadi et al. (2021). Lateral
349 recumbency is in fact a general trend in domestic ungulates. Whether birth difficulties
350 were directly responsible for increased locomotion and aberrant postures or due to
351 the emotional reactivity of some females that were stressed by the indoor rearing
352 conditions is unknown and should deserve further attention.

353 In any case, plasma cortisol concentration was shown to be higher in she-
354 camels that expressed mismothering. In ungulates, cortisol levels typically increase
355 with labor and rise during expulsion of the fetus (Nagel et al., 2019). Agarwal et al.
356 (1992) reported a periparturient concentration around 25 - 30 ng/ml in camels which
357 is considered to be important. While high concentrations around calving may arise
358 from the need for glucocorticoids increased to induce lactation, the metabolic
359 clearance rate reduced by estrogens and the onset of parturition triggered by fetal

360 maturation, abnormal parturition exacerbates such response (Sathya et al., 2007).
361 Our results confirmed these findings and show that cortisol, birth difficulties and
362 mismothering were related.

363 Under overcrowded conditions, stealing other neonates is common in
364 domestic ungulates and has deleterious consequences with mothers accepting alien
365 young but rejecting their own (Owens and Edey, 1985). It is particularly the case
366 when two females give birth at the same time because the amniotic fluids are
367 attractive around birth, determine the choice of birth site once spilt on the ground,
368 and trigger maternal licking (Nowak and Poindron, 2006; Poindron et al., 2007). This
369 was observed only once in our she-camels. We cannot conclude whether the scarcity
370 of such behaviour was due to the fact that camels, unlike other ruminants, do not lick
371 their young after giving birth (Hammadi et al., 2021) or because calving was
372 scattered over several months, making stealing of newborns unlikely to happen.

373 In Maghrebi dromedary camels, an intense period of behavioural interactions
374 between the mother and her newborn usually takes place after birth during which
375 sniffing and low-pitched grunt characterize maternal responsiveness (Hammadi et al.,
376 2021). It is believed that such behaviours are important for promoting bond formation
377 between the mother and her newborn like in sheep and goats (Grandinson, 2005;
378 Nowak and Poindron, 2006; Poindron et al. 2007). During the first *postpartum* hour,
379 she-camels displaying birth difficulties failed to show proper maternal care and
380 rejected their young. Unlike those that accepted their neonates, mothers attacked
381 and bit their own if they approached to suckle, hardly smelt them, and emitted high-
382 pitched grunt. Newborn rejection is also observed in horses but with a different
383 reaction comparatively to camels, in which mares going to their newborns and attack,

384 squeal, bite, and kick them, leading to injuring them (Zurek and Danek, 2012).
385 Rejection behaviours in other ungulates like sheep are less severe with head
386 threatening, butting and pushing. Care must be taken in camels to protect the calf by
387 restraining the mother's movement as bites and kicks might be fatal. Calf rejection
388 must be dealt with immediately after being witnessed to have the best chance of
389 solving the issue.

390 In the present work, the first step to remedy mismothering was to isolate the
391 mother and her abandoned calf in a small yard. The second was to restrain agitation
392 by putting a muzzle on the mother's nose and tying up her legs. Biting and kicking
393 were prevented while the female could still walk around freely. The third stage was to
394 provide colostrum to the calf by milking the mother after an intravenous injection of
395 oxytocin and bottle-feeding the neonate. Finally, human assistance helped the calf to
396 find the teats, maintain contact with the mother, and suckle without being rejected. All
397 these steps were performed by a qualified person who provoked proximal inter-
398 individual interactions. By doing so, aggressive behaviours and high-pitched grunt
399 vanished after 2 days of confinement while sniffing and low-pitched grunt were
400 restored. The she-camel began to accept the newborn showing that the mother-
401 young relationship became satisfactory, and that in all likelihood a bonding process
402 was taking place.

403 The mechanisms restoring maternal acceptance are unknown but our
404 methods combined two main factors. The first is the use of restraint, a method known
405 to induce fostering in sheep (Alexander and Bradley, 1985) since it prevents
406 aggression, promotes close contact, and facilitates nursing. Proximal contact
407 facilitates perception of body odors, and olfactory communication is crucial for the

establishment of a bond between mother and offspring in sheep and goats (Nowak and Poindron, 2006; Poindron et al., 2006). Restoring maternal responsiveness with the use of restraint takes several days in sheep and only two days in horses (Juarbe-Diaz et al., 1998). Camels fit within that timeframe. The second factor could be oxytocin. Oxytocin has been shown to induce maternal behaviour in a number of mammals including ruminants (Kendrick, 2000). It stimulates physical proximity between the mother and young, minimizes rejection of newborns and facilitate nursing (Keverne and Kendrick, 1992). Oxytocin has also been found to reduce aggression towards offspring and to decrease the level of fearfulness. The injection of exogenous Biocytocine® prior to milking, milking itself and nursing - which are known to trigger the release of central oxytocin - might have facilitated the onset of maternal responsiveness in rejecting she-camels.

5. Conclusion

In conclusion, breeders of stabled dromedary camels should be able to deal with mismothering immediately after calving. Reserving a special calving pen may be essential for each periparturient mother to avoid newborn rejection and calf stealing by alien females. An isolated confinement enclosure is necessary to remediate the mother-young relationship and encourage maternal care. Our study showed that dromedary females that rejected their newborns needed 3 days of restrain and human assistance to accept their calves correctly. This work describes some aspects relating to abnormal maternal behaviour but does not cover all of the issues. There are still many aspects to be clarified. One striking element is that mismothering was displayed by multiparous camels, while in domestic ungulates such behaviour characterizes inexperienced primiparous mothers. In sheep and horses, there is

432 some speculation that in addition to environmental factors, maternal rejection might
433 also have a genetic background and may make an animal more likely to reject the
434 offspring (Juarbe-Diaz et al., 1998; Grandinson, 2005). The factors involved in this
435 phenomenon are yet to be identified. No doubt there is great scope for future
436 research in maternal behaviour in the camel.

437 **Declaration of interest**

438 The authors declare that they have no conflicts of interest.

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446 Zaragoza, Spain” for their help in the cortisol analyses.

447 **Ethics statement**

448 The experimental conditions of the present work complied with the European
449 Directive 2010/63/EU on the protection of animals used for scientific purposes.

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570 **Fig. 1.** Parturition, lying and standing duration (A), number of changing posture,
571 changing place; head turning towards abdomen and tail raising (B) during the calving
572 process in dromedary mothers accepting (accepting group) and rejecting (rejecting
573 group) their calves. Data are expressed as medians and 1st and 3rd quartiles. a-b:
574 for each parameter, difference between groups is significant at $P = 0.05$.

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577 **Fig. 2.** Evolution of newborn, number of attack (A), and duration (B) and number (C)
578 of sniffing in dromedary females that rejected their calves during the confinement
579 period and at day 7 *postpartum*. Data are expressed as medians and 1st and
580 3rd quartiles. a-b-c: $P < 0.05$.

581

582 **Fig. 3.** Evolution of number of high (A) and low-pitched grunts (B) in the rejecting
583 group during the confinement period and at day 7 *postpartum*. Data are expressed as
584 medians and 1st and 3rd quartiles. a-b: $P < 0.05$.

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587 **Fig. 4.** Difference between the accepting and rejecting groups in low-pitched grunt
588 (A), high-pitched grunt (B), number of sniffing (C) and sniffing duration (D) at day 7
589 *postpartum*. Data are expressed as medians and 1st and 3rd quartiles. a-b: for each
590 parameter, difference between groups is significant at $P = 0.05$.

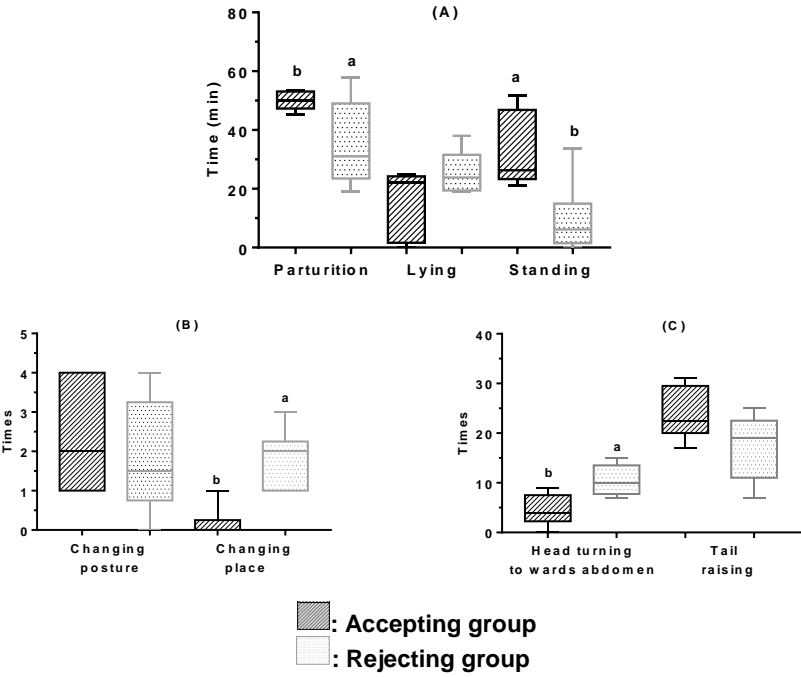
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594 **Fig. 1.**

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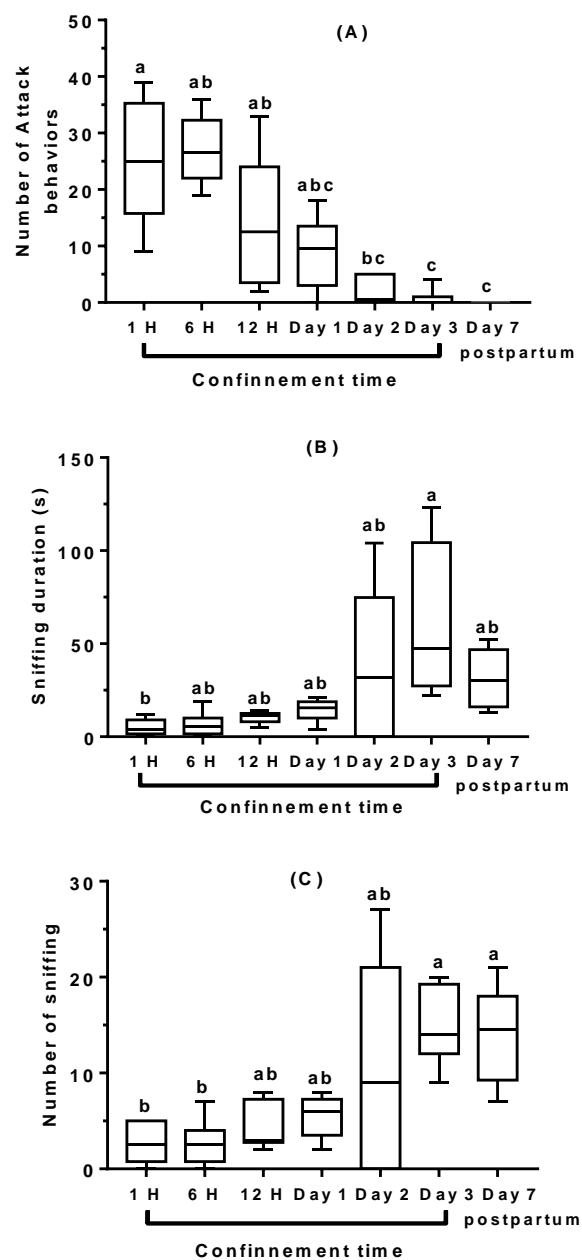
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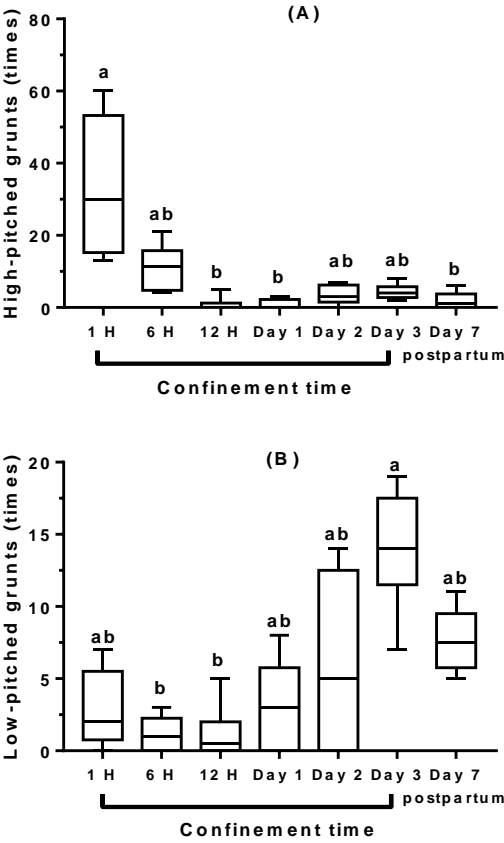
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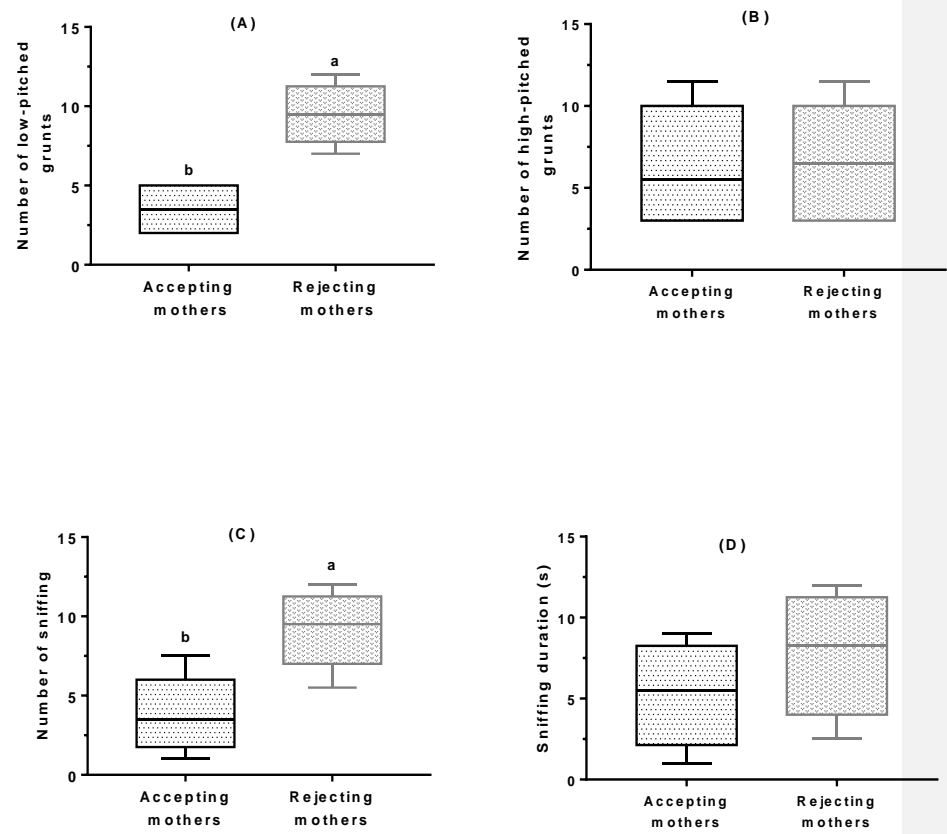


609 **Fig. 3.**



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620 **Fig. 4.**



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629 **Table 1**

630 Ethogram of calving and maternal behaviour in Maghrebi dromedary camels

631 (adopted with some modifications from Hammadi et al., 2021).

Variable	State/ Event	Definition
Behaviors during parturition (second stage)		
Parturition	Duration	Duration (min) of the birth process (second stage): from appearance of the amniotic sac to total expulsion of fetus.
Lying position	Duration	Duration (min) during which the female lies on the ground.
Standing position	Duration	Duration (min) during which the female stands upright on all four legs.
Changing posture	Event	Switching from lying to standing positions or vice versa.
Changing place	Event	Female changes birth site from one place (17.5 m ²) to another during parturition.
Number of tail raising	Event	Number of up and down tail movements away from the body.

Head-turning towards abdomen	Event	Head lifted and oriented towards the abdomen with stretched neck.
Kicking	Event	Mother kicks with her hind legs during expulsion.
Position during expulsion	Event	Position adopted by the mother during the complete phase of expulsion (lying or standing position).
Behaviors after parturition		
Moving away from the newborn	Event	Mother moving more than 2 m away from her newborn just after giving birth.
Pain associated with parturition	Event	<ul style="list-style-type: none"> - Long duration of the first and the second stages of parturition (Hammadi et al., 2021), - Placenta takes longer than 12 hours to shedding, - Uterus slips down into or protrudes out of the vagina,
Attack	Event	Number of aggressive behaviours (kicking, biting, and head pushing) displayed by the mother toward her calf.

Low-pitched grunt	Event	Number of quiet vocalizations emitted with the mouth closed.
High-pitched grunt	Event	Number of loud calls emitted with the mouth open.
Sniffing	Event and duration	Number and duration (s) of contacts between the mother's nose and the newborn.

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652 **Table 2**

653 Calving date, age, parity, and body condition score (BCS) of mother and the cause of
654 each case of camel calf rejection.

Camels id	Calving date	Age	Parity	Cause of calf rejection	Duration of the 2 nd stage of parturition (min)
#9810	09/10/2016	18	Multipara	Repeated rejecter	48
#513	28/10/2016	11	Multipara	Acceptance of an alien calf	45
#9606	03/01/2017	21	Multipara	Dystocia and uterine prolapse	53
#413	06/03/2017	13	Multipara	Dystocia	52
#913	06/03/2017	8	Multipara	Dystocia	54
#9810	23/10/2018	20	Multipara	Repeated rejecter	48

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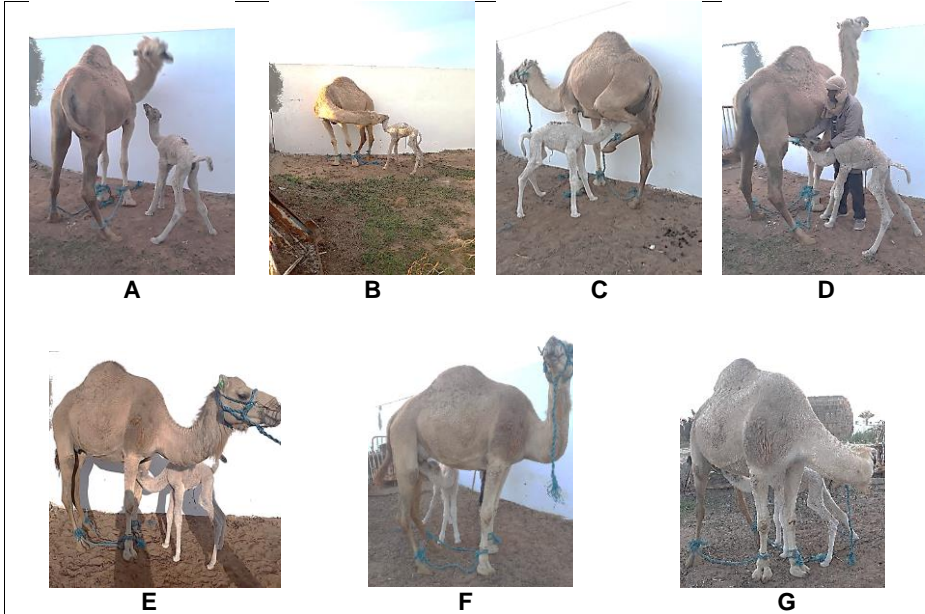
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Table 3

Difference between the accepting and rejecting mothers in the expression of maternal behaviours during the first hour *postpartum*. Data are expressed as medians and 1st and 3rd quartiles.

Maternal behaviours	Accepting mothers	Rejecting mothers	<i>P</i> - value
Sniffing duration (s)	297.5 [228.5 - 669.0] ^a	1.5 [0.0 - 3.5] ^b	0.002
Number of Sniffing	73.5 [56.2 - 96.5] ^a	0.5 [0.0 - 2.5] ^b	0.002
High-pitched grunt	25.0 [17.5 - 32.0] ^a	1.5 [0.0 - 4.25] ^b	0.001
Low-pitched grunt	38.0 [32.0 - 49.5] ^a	0.0 [0.0 - 0.0] ^b	0.001

a-b: *P* < 0.001.



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680 **Photos 1:** Steps in calf acceptance during the confinement period in dromedary

681 camels.

682 A: attacking the calf; B: biting the calf; C: refusing suckling; D: colostrum collection

683 from the mother and Bottle-feeding the calf near to the udder; E: mother accepts

684 body contact; F: suckling acceptance without maternal care; G: suckling process

685 with maternal care (sniffing).