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One health approach based descriptive study on *Coxiella burnetii* infections in camels and abattoir workers in the United Arab Emirates

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Coxiellosis is a zoonotic bacterial disease caused by *Coxiella burnetii* (*C. burnetii*) infection that occurs as subclinical and clinical infections in animals and humans worldwide except in the Antarctica and New Zealand. The objectives of this study were to estimate the seroprevalences of *C. burnetii* infections in slaughtered camels and abattoir workers as well as to detect *C. burnetii* DNA in the clotted blood in the same study subjects at Al Bawadi abattoir of Al Ain city, in the United Arab Emirates, UAE. A cross-sectional study design was used to test 393 slaughtered camels and 86 abattoir workers for *C. burnetii* antibodies between March 2022 and July 2023 using enzyme-linked immunosorbent assay (ELISA) kits supplied by ID Vet multispecies and Abbexa, respectively. Besides, real-time polymerase chain reaction (qPCR) was used for the detection of *C. burnetii* DNA in clotted blood of 366 camels and 86 abattoir workers. The seroprevalences of *C. burnetii* infection were 52.9% (95% confidence interval, CI: 46.0, 60.6%) and 24.4% (95% CI: 15.1, 37.3%) in camels and abattoir workers. But, *C. burnetii* DNA was not detected in clotted blood samples of camels and abattoir workers. Sex, age and body condition of the camels were not associated with the seroprevalence of *C. burnetii* while abattoir workers of African origin were more likely to be seropositive (odds ratio, OR = 3.70; 95% CI: 1.05, 13.60) than abattoir workers of south Asian origin. The seroprevalences of *C. burnetii* infections were high in both slaughtered camels and abattoir workers although its DNA was not detected in the clotted blood of either of the study subjects.

Keywords Abattoir workers, *Coxiella burnetii* infection, Dromedary camels, Q fever, Seroprevalence, United Arab Emirates

Abbreviations

ELISA Enzyme-linked immunosorbent assay
qPCR Real-time PCR

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UAE	United Arab Emirates
OD	Optical density
OD _{PC}	Optical density of positive control
OD _{NC}	Optical density of negative control
S/P%	Sample percentage
SPSS	Statistical Package for Social Sciences
ANOVA	Analysis of variance

Coxiellosis is a bacterial zoonosis caused by *Coxiella burnetii* (*C. burnetii*), a deadly pathogen of worldwide distribution with the exception of Antarctica and New Zealand¹. *C. burnetii* is a Gram negative obligate intracellular bacterium which is able to survive in phagosome of the phagocytes². Although, *C. burnetii* was initially classified within the Rickettsiaceae family, 16s RNA gene-based phylogenetic analysis later showed that it is different from the Rickettsia³. Potentially, *C. burnetii* may infect all species within the animal kingdom including arthropods² although coxiellosis, as a disease, is mainly seen in humans, cattle, sheep and goats⁴. While domestic ruminants are the main reservoirs of *C. burnetii*, cats, dogs, rabbits, and birds have also been reported to be sources of the human infection². It is currently known that *C. burnetii*-infected animals excrete the bacterium in body fluids such as milk, urine, feces, birth products or semen^{5,6}.

As *C. burnetii* is mainly transmitted from animals to humans through infected animal body secretions, livestock farmers⁷, veterinarians⁷, and abattoir workers⁸ are at increased risk of infection with *C. burnetii*. Besides, the inhalation of desiccated aerosol particles is considered as major route of infection of humans by *C. burnetii*⁹. Studies reported have shown that the occurrence of coxiellosis in domestic animals tends to parallel with coxiellosis outbreaks in humans^{10–12}. Human infection with *C. burnetii* may result in different outcomes ranging from asymptomatic disease to an acute febrile illness associated with headache, myalgia, and atypical pneumonia¹³. Although most *C. burnetii* infections are self-limiting in humans, some patients may develop a chronic disease associated with life-threatening complications which include endocarditis and hepatitis^{14–17}. However, because of lack of awareness among healthcare workers and the lack of routine laboratory tests in many Low- and Middle-Income Countries (LMIC) settings, it is presumed that clinical *C. burnetii* infection (Q fever cases) are largely misdiagnosed and thus under reported^{18,19}.

In domesticated ruminants, clinical coxiellosis is associated with late-term abortions and other related reproductive disorders such as premature births, stillbirths, or birth of weak offspring⁴. Additionally, affected ruminants may demonstrate metritis and infertility². Thus, clinical coxiellosis may be considered an important production disease potentially responsible for reproductive losses, reduced milk production and chronic mastitis²⁰.

Recent studies in Africa, the Arabian Peninsula, and Asia reported high seroprevalence values of coxiellosis in dromedary camels¹. Dromedary camels play a major socioeconomic role for millions of people who live in the arid zones of Africa, Middle East and Asia. Thus, camel meat and milk are widely consumed in these regions, which can pose a risk of transmission of *C. burnetii* from camels to humans. For example, consumption of raw camel milk is widespread in the Arab world due to the perception of considering the camel as a uniquely clean livestock species that was indicated in the Qur'an and Islamic scriptures; which could suggest role the camel in the transmission of *C. burnetii* to humans²¹.

Within the greater Middle Eastern region, Q-fever has been documented in Saudi Arabia²², Oman¹², and Iran²³. In the UAE, few seroprevalence studies were done on coxiellosis in cattle²⁴ and small ruminants²⁴. Besides, only one study on coxiellosis in dromedary camel nearly three decades ago²⁵. However, none of these UAE-based studies have evaluated the potential zoonotic transmission of *C. burnetii* from livestock species to humans. Thus, although the role of ruminants as source of infection of *C. burnetii* to humans has been reported from different parts of the world, there is a shortage of scientific evidence on the role of dromedary camels in transmitting *C. burnetii* to humans. Hence, the role of camels as reservoirs of *C. burnetii* requires investigation. Owing to their continuous exposure to potentially infected material from slaughter livestock including camels, abattoir workers are at high risk of *C. burnetii* infection. The objectives of this study were to investigate the seroprevalence on the *C. burnetii* infection in camels and abattoir workers, and to detect *C. burnetii* DNA in the clotted blood of study subjects in the Al Ain city of Emirate of Abu Dhabi, the UAE.

Materials and methods

Study setting

The present study was conducted at the Al Bawadi abattoir which is located on the outskirts of Al Ain city within the Emirate of Abu Dhabi, UAE. The Al Bawadi abattoir was established in 2007 and has two sections, namely the commercial and the public section. The former section is designated for slaughtering animals for merchants and organizations while the latter slaughters animals for the general public. When this study was performed the total number of workers at the Al Bawadi abattoir was 110. Study camels included randomly were selected from among the camels brought to the abattoir from different farms located across the UAE along with a minority of camels originating from Oman. According to the information obtained from the Al Bawadi abattoir, about 98% of the camels originate from the UAE while the remaining 2% are sourced from Oman. Inclusion and exclusion criteria were not considered. During the study period, the number of camels slaughtered at the Al Bawadi abattoir on daily basis was low. Hence, all camels brought to the abattoir were subjected to blood sample collection for serum extraction.

Study subjects, design and sample size

The study was a cross-sectional study that was conducted at the Al Bawadi Abattoir between March 2022 to July 2023. The camel sample size was calculated by considering a camel population size of 450,000 in²⁶ the UAE, and

an expected prevalence of 50% at 95% confidence interval and 5% margin of error. Furthermore, the sample size calculation assumed that all the study animals originated from the UAE since about 98% of the camels slaughtered at the Al Bawadi abattoir were sourced from the farms located within the UAE. Accordingly, a total of ≥ 384 camels were required for the study while nine additional camels were added to the minimum sample size. In addition, after obtaining consent from the abattoir workers, blood samples were collected from 86 (out of 110 abattoir workers) abattoir workers who agreed to participate in the study.

Data and sample collection

During antemortem examination of the study camels, data on the age, sex and body condition of the animals were collected. The estimation of the ages was made based on the dental eruption and/or wearing according to the protocol reported by Bello et al.²⁷. Accordingly, the ages of camels with partial or all erupted deciduate teeth were estimated to be less one year while the ages of camels with partial or all worn deciduate teeth were estimated to be ≤ 4 years. Furthermore, the ages of camels with partial or all erupted permanent incisors and canine teeth were estimated to be > 4 years and ≤ 7 years, respectively while those with partial or all worn permanent incisors and canine teeth were estimated to be > 7 years and ≤ 15 years, respectively.

Body condition scoring was done based on the protocols previously published by other researchers^{28,29}. Based on the criteria set by these researchers, the amount of fat deposition at specific anatomical sites was evaluated to assess the body condition of camels. Accordingly, if the ribs, ischiatic and coxal tuberosities, and scapula were visible, the flanks were hollow, the recto-genital zones deep and the humps small, the body condition was classified as “thin”. While the body condition of camels with slight visibility of the aforementioned body tissues, slight hollow flanks, slightly deep recto-genital zones and intermediate hump sizes was considered as “medium”. On the other hand, the body condition of camels in which the ribs, the ischiatic and coxal tuberosities, and scapula were not visible, the flanks were not hollow, the recto-genital zones were not deep and the humps were large were grouped as “fat”.

Blood samples were collected from the jugular veins of the study camels into 5 ml plain vacutainers for serum extraction. Besides, 5 mL of blood samples were also collected from cubital veins of the abattoir workers by experience phlebotomist into plain vacutainers tubes for serum extraction. Furthermore, demographic data of the abattoir workers such as age, nationality, occupation, duration of working in the abattoir were collected and analyzed.

Detection of *C. burnetii* antibody in camels

The detection of *C. burnetii* antibody in camel sera was done using the ID Screen® *C. burnetii* Indirect Multispecies ELISA Kit (ID VET Innovative Diagnostic, ID Screen®, Montpellier, France) following the manufacturer's instructions. Briefly, the samples and the controls were diluted to 1:50 by mixing 245 μ l of dilution buffer and 5 μ l either positive control, negative control or serum sample into the designated wells of pre-coated 96 microplate. Thereafter, the plate was covered and incubated at 21 °C for 45 min. Then, the contents of the wells were discarded and the plate was washed with 300 μ l wash solution three times. Thereafter, the plate was dried, 100 μ l conjugate 1x was added into each well, covered and incubated at 21 °C for 30 min. This was followed by discarding the contents of the plate wells, washing and drying the plate in the same way described above. Thereafter, 100 μ l of the substrate solution was added into each well and the plate was incubated at 21 °C for 15 min in the dark. Lastly, 100 μ l of the stop solution was added into each well and then the optical densities (OD) values were determined at 450 nm using a BioTek spectrophotometer plate reader (BioTek Instrument Inc, Highland Park, US). Then, the assay result for each plate was evaluated for its validity based on the OD₄₅₀ values of the positive and the negative controls in line with the manufacturer's recommendation. The assay result of each plate was considered to be valid when the mean OD₄₅₀ value of the positive control (OD_{PC}) was greater than 0.350 (OD_{PC} > 0.350) and if the ratio of the mean OD₄₅₀ value of the positive and negative controls (OD_{PC}/OD_{NC}) was greater than 3.0. After validity was confirmed, the result of each plate was interpreted individually. Briefly, the sample percentage (S/P%) was calculated as $S/P\% = (OD_{\text{sample}} - OD_{NC}) / (OD_{PC} - OD_{NC}) \times 100$. Then, samples with S/P% $\leq 40\%$ were considered as negative; samples with S/P% between 40% and 50% including those with 50% were considered doubtful while samples with S/P% > 50% were considered positive. In this study, however, all the inconclusive samples were considered as negatives.

Detection of *C. burnetii* antibody in abattoir workers

The wells of pre-coated microtiter ELISA plates were set for the assay as per the recommendations of the kit manufacturer (Abbexa LTD Cambridge, UK; website: www.abbexa.com). Accordingly, 2 positive controls, 2 negative controls, test sample, and control i.e. zero or blank well were labeled. Then, 50 μ l of negative control and 50 μ l positive control were added to their designated wells while 50 μ l of sample diluent was added into the zero (blank) well. And 50 μ l of diluted serum samples were added into the sample wells. Thereafter, the plates were covered and incubated at 37 °C for 30 min, and then removed, washed five times with 1x wash buffer and dried. Following this step, 50 μ l of the kit detection reagent was added into each well except the blank wells and then further incubated at 37 °C for 30 min. The plates were removed, washed five times with 1x wash buffer and then dried. Thereafter, 50 μ l of TMB substrate A and 50 μ l TMB substrate B were added into each well, mixed well and then the plates were incubated at 37 °C for 15 min. Then, 50 μ l of stopping solution was added into each well and the plates were immediately read at 450 nm using the BioTek spectrophotometer plate reader. Then, the validity of the assay was checked based on the recommendation of the kit manufacturer. The test was considered to be valued when the mean OD value of the positive control was ≥ 1.0 and when the OD value of the negative control is ≤ 0.20 . The interpretation of the result was based on the cut-off value. The cut-off value = mean OD value of negative control + 0.15. Then, samples with OD values < cut-off value were considered as negative while samples with OD values $\geq$ cut-off were considered as positive.

Detection of *C. burnetii* DNA in clotted blood by qPCR

C. burnetii DNA samples were extracted from clotted blood samples of 86 abattoir workers and 366 slaughtered camels. Taco™ DNA/RNA extraction kit (GeneReach Biotechnology, Taiwan) and Taco™ Nucleic Acid Automatic Extraction System (GeneReach Biotechnology, Taiwan) DNA extraction kits were used as per the manufacture instructions. Insertion sequence 1111 (IS1111) gene was as a target gene by qPCR as described earlier³⁰. The validation of the performance of IS1111 based qPCR was done earlier by Klee et al.³⁰. According to the result of the validation done by these authors, the sensitivity of IS1111-based qPCR is 95% and the minimal number of genome equivalents that could be detected was 6.5. In the present study, the minimal number of genome equivalents was set at 10 per reaction.

The primers used were Cox-F: GTCTTAAGGTGGGCTGCGTG (219–238) and Cox-R: CCCCGAATCTCA TTGATCAGC (493–513). The primers for TaqMan probe were Cox-TM: FAM-AGCGAACCATTGGTATCGG ACGTTTAMRATATGG (259–287)³⁰. In brief, the PCR master mix (QuantiFast Probe PCR kit {Qiagen}) was prepared in a total volume of 10 µl which consisted of 0.65 molecular-grade water, 7.5 µl of QuantiFast Probe PCR master mix (2 ×), 0.75 µl of each primer (10 pmol/µl) and 0.35 µL of each probe (10 pmol/µl). The DNA template used was 5 µl making a total volume of 15 µl. The amplification was conducted in BioRad CFX 96 (BioRad) with cycling conditions consisting of 95 °C for 3 min initial heating, and 40 cycles at 95 °C for 0.3 s and 60 °C for 30 s.

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 28.0 (IBM Corp 2021, Armonk, NY), R software version 4.1.2, and GraphPad Prism 9.4.1 (681) version (GraphPad Software, 225 Franklin Street. Fl. 26, Boston, MA 02110) were used for data analysis. The data variables were summarized using frequencies and percentages for categorical variables and median and interquartile range (IQR) for skewed numeric variables. Chi-square/ Fisher’s exact test, Mann-Whitney U test, one-way ANOVA, and binary logistic regression were used for the evaluation of associations or variations. In human study, for ease of interpretation, nationality was categorized into two – Africans (abattoir workers from Egypt, Sudan, Morocco, and Ethiopia); and South Asians (abattoir workers from Pakistan, Bangladesh, Nepal, Sri Lanka, and Afghanistan). The overall and category-specific prevalence of *C. burnetii* was estimated and presented as percentages along with the corresponding 95% confidence intervals. The independent variables examined were age, occupation, and nationality for abattoir workers while sex, age and body condition were considered as independent variables for the camels. In human study, the variable years of experience was not included in the model as it exhibited high multicollinearity with age, hence, only age was used in the model.

Results.

Seroprevalence of *C. burnetii* infection in camels slaughtered at Al-Bawadi abattoir

The seroprevalence of *C. burnetii* infection in camels slaughtered at Al-Bawadi abattoir was 52.9% (95% CI = 46.0–60.6%). Table 1 shows the result of bivariable and multivariable binary logistic regression analyses of the effect of host factors on the seroprevalence of *C. burnetii* infection in camels slaughtered at the Al-Bawadi abattoir. As it is presented in Table 1, sex, age nor body condition were not ($p < 0.05$) associated with the seroprevalence of *C. burnetii* infection in camels.

The intensity of anti- *C. brunetti* antibody response in the 208 seropositive camels was classified into low (50% $\geq$ S/P% $\leq$ 100%), medium (100% $>$ S/P% $\leq$ 200%) and high (S/P% $>$ 200%) based on the intensity of OD values. The intensity of the OD values among the three groups differed significantly (one-way ANOVA; $F_{(2, 205)} = 699.4$; $p < 0.0001$; Fig. 1).

Seroprevalence of *C. burnetii* infection in abattoir workers

Eighty-six abattoir workers, comprising butchers (71; 83%), laborers (13; 15%), and supervisors (2; 2%) participated in the study (Table 2). The median age of the workers was 36 years (IQR = 30, 40) with those between the age of 30–39 years making up the majority (47%). Eight years was the median length of work experience of the participants (IQR = 6, 14). In terms of nationality, the workers were grouped a south Asians (79%) and Africans (21%).

Factor		No. positive	Percent positive	Total	Crude odds ratio	95% CI	Adjusted odds ratio	95% CI
Sex	Male	54	55.1	98	0.89	0.56, 1.41	0.94	0.57, 1.531
	Female	154	52.2	295	Reference		Reference	
Age in years	< 3	66	56.4	117	1.03	0.61, 1.74	0.91	0.48, 1.73
	3–5	64	57.1	112	0.59	0.34, 1.01	0.92	0.50, 1.69
	5–7	41	43.2	95	0.89	0.49, 1.62	1.60	0.85, 3.01
	7–12	37	53.6	69	Reference		Reference	
Body score	Thin	18	51.4	35	0.97	0.48, 1.95	1.52	0.68, 3.40
	Medium	138	50.5	273	1.49	0.67, 3.29	1.60	0.96, 2.65
	Fat	52	61.2	85	Reference		Reference	
	Total	208	52.9%	393				

Table 1. Association of the characteristics of camels on the Seroprevalence of *C. burentii* infection.

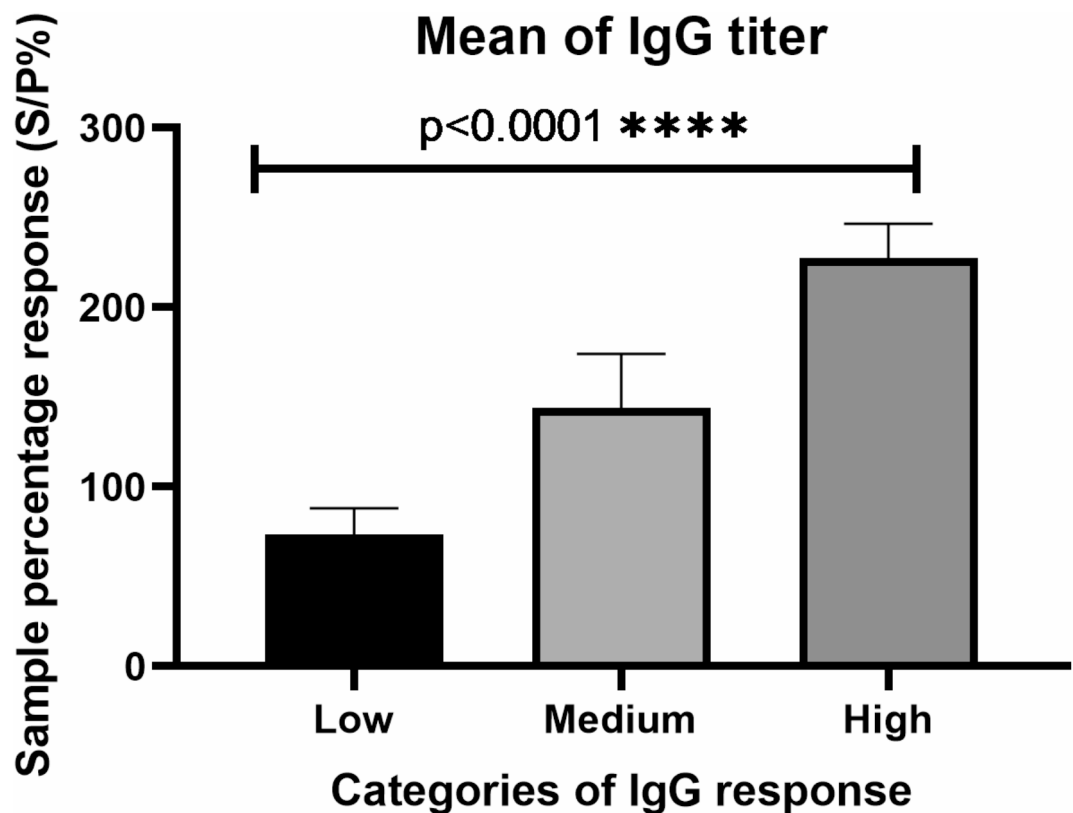


Fig. 1. Mean percentage optical density (OD_{450}) *ant*-*C. burnetii* antibody using ELISA in dromedary camels slaughtered at the Al-Bawadi abattoir. The OD_{450} values of 208 positive camels were grouped into low, medium and strong based on the intensity of OD_{450} values. The intensity of the OD values among the three groups differed significantly (one-way ANOVA; $F_{(2, 205)} = 699.4$; $p < 0.0001$).

Characteristic	Frequency (%)
Age, median (IQR)	36 (30, 41)
Age category	
20–29	19 (22%)
30–39	40 (47%)
>=40	27 (31%)
Occupation	
Butcher	71 (83%)
Laborer	13 (15%)
Supervisor	2 (2%)
Years of experience, median (IQR)	8.0 (6, 14)
Nationality	
Africans	18 (21%)
South Asians	67 (79%)

Table 2. Demographic characteristics of the abattoir workers ($N = 86$) at the al Bawadi abattoir.

The seroprevalence of *C. burnetii* in abattoir workers was 24.4% (95% CI = 16.1–35.1). It is noteworthy that the highest seroprevalence (26.3%) was observed in workers within the age group of 20–29 years, followed by those in the age group of 30–39 years (25.0%) and finally those age 40 years and above (22.2%) (Fig. 2). Although not statistically significant, *C. burnetii*-seropositive workers had a lower median age (32 versus 36 years), while the butchers had a higher *C. burnetii*-seroprevalence than other workers (25% versus 20%) (Table 3).

Adjusting for age and occupation, the abattoir workers from Africa had significantly higher odds of *C. burnetii* antibodies than those from south Asia (AOR = 3.70, 95% CI = 1.05–13.60, $P = 0.042$). On the other hand, age and occupation were not associated with *C. burnetii* seropositivity in abattoir workers (Table 4).

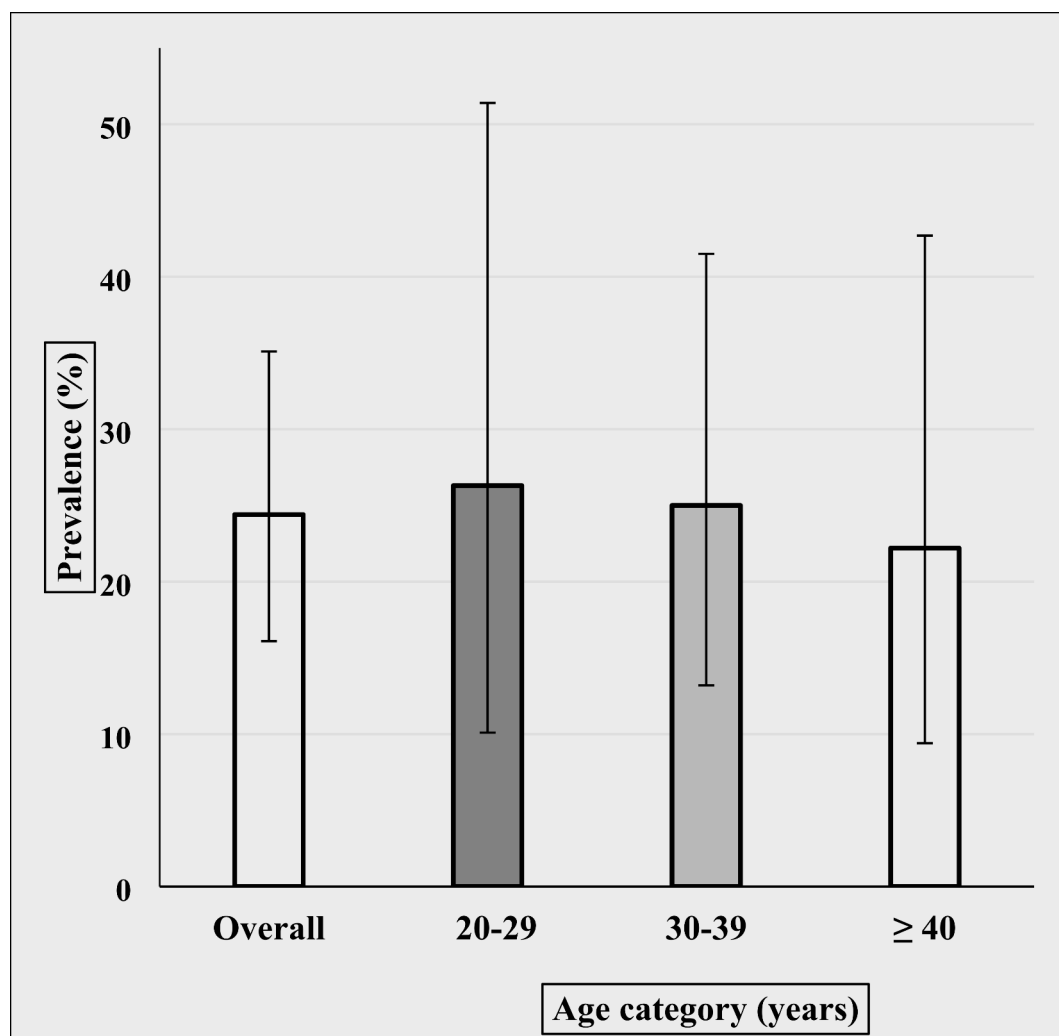


Fig. 2. Seroprevalence (and 95% CI) of *C. burnetii* infection in abattoir workers by age categories ($N=86$). The bars present the prevalence of *C. burnetii* infection while the error bars represent the 95% confidence intervals of the prevalence.

Characteristic	Negative	Positive	P value
	n (%)	n (%)	
Age, median (IQR)	36 (30, 41)	32 (30, 40)	0.259
Occupation			
Butchers	53 (75%)	18 (25%)	> 0.999
Others [#]	12 (80%)	3 (20%)	
Years of service in abattoir, median (IQR)	8.0 (6.0, 14.0)	8.0 (6.0, 14.0)	0.769
Years in abattoir			
<=5	15 (75%)	5 (25%)	0.949
6-10	25 (78%)	7 (22%)	
>10	25 (74%)	9 (26%)	
Nationality			
Africans	11 (61%)	7 (39%)	0.132
South Asians	53 (79%)	14 (21%)	

Table 3. Seroprevalence and factors associated with *C. burnetii* infection in abattoir workers ($n=86$). [#]Others: cleaners and supervisors.

Characteristic	Crude OR (95% CI)	P value	Adjusted OR (95% CI)	P value
Age	0.96 (0.90–1.02)	0.200	0.94 (0.87–1.00)	0.065
Occupation				
Butcher				
Others	0.74 (0.16–2.64)	0.900	0.71 (0.14–2.79)	0.600
Nationality				
South Asians				
Africans	2.41 (0.77–7.34)	0.120	3.70 (1.05–13.60)	0.042

Table 4. Univariable and multivariable binary logistic regression for factors associated with *C. burnetii* seropositivity in abattoir workers.

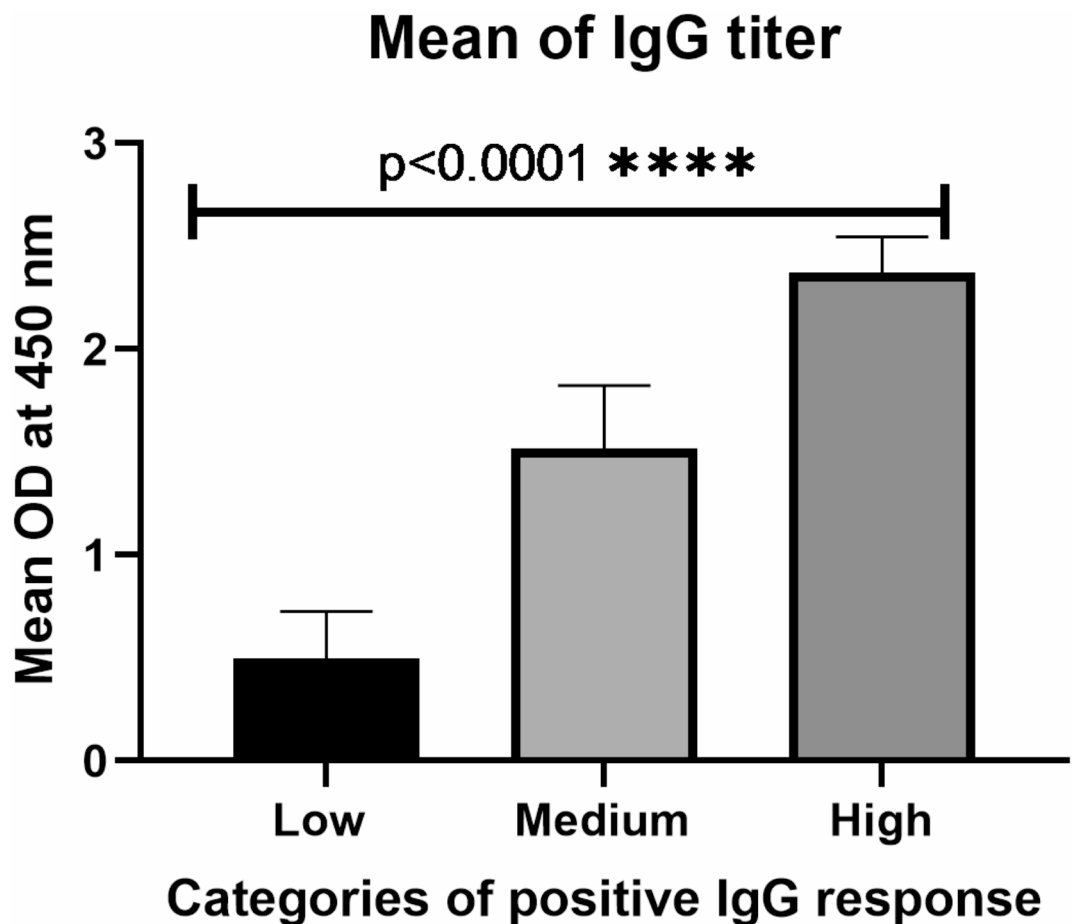


Fig. 3. Mean optical density (OD) in abattoir workers following ELISA for anti-*C. burnetii* antibodies at Al-Bawadi abattoir. The OD₄₅₀ values of the positive abattoir workers were grouped into low ($n = 7$), medium ($n = 9$) and high ($n = 5$) based on the intensity. The difference in the intensity of response among the three groups was significant (one-way ANOVA; $F_{(2, 18)} = 79.99$).

The intensity of *C. burnetii* antibody response in the 21 seropositive abattoir workers was classified into low (OD₄₅₀ ranges from 0.339 to 1.00), medium (OD₄₅₀ > 1.00 and ≤ 2.00) and high (OD₄₅₀ > 2.00) based on the OD₄₅₀ values. The difference in the intensity of response among the three groups was significant (one-way ANOVA; $F_{(2, 18)} = 79.99$; $P < 0.0001$; Fig. 3).

Detection of *C. burnetii* DNA in the clotted blood of camels and abattoir workers

C. burnetii DNA could not be detected from the clotted blood samples collected from 86 abattoir workers and 366 camels. Figure 4 shows the amplification curves of internal controls while all samples were negative for DNA of *C. burnetii*.

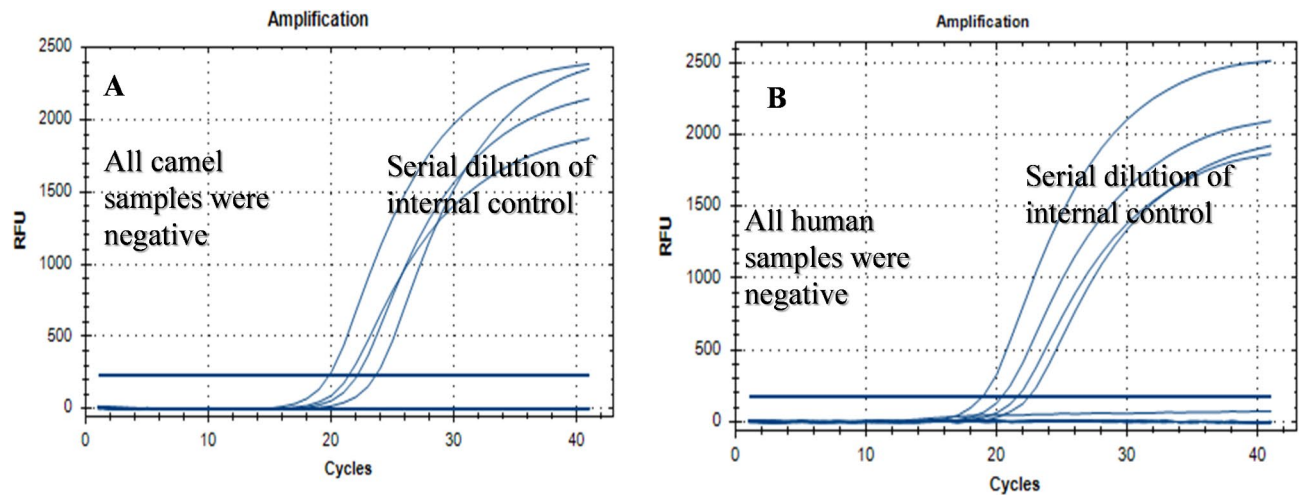


Fig. 4. Results of q-PCR of sera samples camels and abattoir workers. The DNA samples were extracted from clotted blood of 86 abattoir workers and 366 camels, and then amplified using qPCR. However, none of the samples from both camels (A) and abattoir workers (B) were positive for the DNA of *C. burnetii*.

Discussion

The present study was an observational study that evaluated the seroprevalence of *C. burnetii* infection and attempted the detection of *C. burnetii* DNA in clotted blood derived from camels and abattoir workers in the UAE. The study on the abattoir workers was the first report documenting apparent *C. burnetii* infection in humans in the UAE along with the implied zoonotic transmission of the pathogen from domestic animals to humans. Apart from a coxiellosis study performed earlier by Afzal et al.²⁵, this was the only study focusing on dromedary camels in the UAE. Although this study did not include human subjects from the general population for comparison, the recorded 24.4% seroprevalence in abattoir workers could be considered high⁸. It is plausible that this could be the result of a significant risk of exposure to infected animals as the seroprevalence in slaughtered camels recorded in the present study was relatively high (52.9%).

Subsequent to the study reported by Afzal et al.²⁵, serological evidence of coxiellosis in animals in the UAE was reported by Chaber et al.³² who detected *C. burnetii* antibodies in semi-free-ranging ungulates in the Emirate of Dubai. These authors reported a 6% seropositivity of *C. burnetii* infection by testing 333 semi-free-ranging ungulates. More recently, Barigye et al.²⁴ have reported a seroprevalence of 36.5% in cattle by testing 759 bovine sera collected from the Al Ain region of the Abu Dhabi Emirate. In addition, El Tigani-Asil et al.³³ detected *C. burnetii* antibody in three camels tested in the Al Dhafra region of the Abu Dhabi Emirate. Furthermore, El Tigani-Asil et al.³³ sequenced the DNA of *C. burnetii* from the three camels and observed that the UAE isolates exhibited phylogenetic similarity with the strains from Europe, Africa and Asia.

However, in this study, the DNA of *C. burnetii* could not be detected in the clotted of both seronegative and seropositive camels and abattoir workers. The failure of detection of *C. burnetii* DNA in this study could partly be due to the use of clotted blood for DNA extraction. Clotted blood may not represent an ideal sample for the extraction of *C. burnetii* DNA. Moreover, the other reason could be due to the use of the primers of IS1111 repetitive region for the diagnosis of *C. burnetii*, as IS1111 repetitive element is missing in some strains of *C. burnetii*³⁴. Previous studies have used conventional PCR and qPCR to detect the DNA of *C. burnetii* in the sera of both humans and animals^{35–40}. Fenollar et al.³⁵, assessed the effectiveness of nested PCR in detecting of *C. burnetii* DNA extracted from the sera. According to the findings of these authors, as the IgG titer against *C. burnetii* increases, the sensitivity of the nested PCR in detecting the DNA of *C. burnetii* decreases. As the result, the authors suggested that using nested PCR could help establish an early diagnosis of chronic *C. burnetii* infection. Marmion et al.³⁶, used qPCR assay with Taqman probe targeting insertion sequence (IS)1111a and IS30a to test the sera of 546 individuals for the presence of *C. burnetii* DNA. They identified 34 individuals as qPCR positive, with 22 having active acute Q fever and six having active Q fever endocarditis. Hence, these authors indicated that IS1111a repetitive element-based PCR is the best method for the detection of *C. burnetii* in patients with active infection.

Ughetto et al.³⁷ reported that qPCR is a sensitive and a specific rapid tool for the diagnosis of Q fever during the early infection. Furthermore, Schneeberger et al.³⁸ reported the percentage of qPCR positivity declines as the *C. burnetii* infection progresses from acute phase to convalescent phase. Additionally, Bae et al.³⁹ observed that conventional PCR is more suitable than serology for detecting *C. burnetii* infection within the first 14 days of illness. While, similar to the result of the present study, Dhaka et al.⁴⁰ reported high seroprevalence (89.5%) of *C. burnetii* infection in farm workers using ELISA although they did not detect the DNA of *C. burnetii* in the seropositive workers using PCR.

Researchers from various countries reported variable seroprevalence values in different camel-rearing countries^{41–47}. A seroprevalence of 71.2% was reported from Algeria by testing 184 camels⁴² while two studies conducted on coxiellosis in camels in Egypt reported seroprevalence values of 40.7% (215/528)⁴⁴ and 22.0% (69/315)⁴⁵. Additionally, studies conducted in southern Ethiopia on 458 camels⁴¹ and in eastern Ethiopia on 150

camels⁴⁶ reported seroprevalence of 90% and 55.7%, respectively. Furthermore, studies conducted in Kenya⁴³ on 344 camels and in Pakistan⁴⁷ on 920 camels reported seroprevalence of 18.6% and 31.3%, respectively. Additionally, Pirouz et al.⁴⁸ reported a seroprevalence of 28.26% by testing 167 one-humped camels in Iran.

Thus, when compared with the results of the previous camel studies, the seroprevalence value of 52.9% recorded in the present study is higher than the seroprevalence values reported from Kenya^{43,49}, Pakistan⁴⁷ and Iran⁴⁸ but lower than those reported from Algeria⁴² and southern Ethiopia⁴¹. On the other hand, seroprevalence of *C. burnetii* infections recorded in the present study is comparable with camel studies from eastern Ethiopia⁴⁶, Saudi Arabia^{50,51} and Jordan⁵².

Recently, Devaux et al.¹ published a review on *C. burnetii* infection in dromedary camels from the studies conducted in north Africa, and the Near and Middle East region. The review also reported the detection of *C. burnetii* infection in *Hyalomma dromedari* and *Hyalomma impeltatum* ticks collected from camels. As camels play significant role in socioeconomics of millions of people in the arid regions of the world as a valued source of milk and meat, they could potentially be a significant source of *C. burnetii* infection in humans in the UAE and region. There is speculation about the possibility of persistence infection of *C. burnetii* in the adipocytes of camel hump thus making camels as continuous source of infection¹. Thus, as described by Devaux et al.¹, the observation of high seroprevalence values of *C. burnetii* infection in camels in the arid regions could be a potential threat to the other livestock and humans requiring for the screening of camel herds and implementation of control measures.

In the present study, the seroprevalence of *C. burnetii* infection in abattoir workers was 24.4%. Although a few UAE-based studies have previously reported on the seroprevalence of *C. burnetii* infection in domestic and wild animals^{24,32,33}, no study was conducted on the seroprevalence of *C. burnetii* infection in humans in the country. Nonetheless, a few studies were conducted on the seroprevalence of *C. burnetii* in humans in east and north Africa, and Middle East^{12,53,54}. Scrimgeour et al. (2000) reported two confirmed cases of Q fever in Oman while Almogren et al.⁵³ detected *C. burnetii* IgG antibodies in 35.2% of the 51 patients tested in Saudi Arabia. In Israel, 30% of the 125 patients were confirmed to be acute cases of Q fever using definitive diagnostic methods⁵⁴. Besides, Ibrahim et al.⁴⁶ reported a seroprevalence of 27.0% *C. burnetii* infection by testing 188 humans in eastern Ethiopia.

On top of research reports, a sizable number of review articles has reported the results of meta-analysis of research work on seroprevalence of *C. burnetii* infection^{1,55–58}. Vanderburg et al.⁵⁵ reviewed the epidemiology of *C. burnetii* infection in Africa in animals and humans in one health approach. These authors reviewed 24 articles and re-analyzed the seroprevalence of *C. burnetii* infection in humans. According to these authors, the average seroprevalence of *C. burnetii* infection in Africa is less 8%; but higher seroprevalence values (10–32%) were observed in children in Egypt.

In addition to the review published by Vanderburg et al.⁵⁵, other authors⁵⁸ published a similar review article on the epidemiology of *C. burnetii* infection in Africa from 88 studies conducted in animals and humans. According to the result of the meta-analysis these studies, the average seroprevalence of *C. burnetii* infection in humans was 16%. Besides, Mobarez et al. performed meta-analysis of seroprevalence of *C. burnetii* infection on 28 studies conducted in humans in Iran. According to the report of these authors, the seroprevalence of IgG phase I and phase II antibodies in humans in Iran were 19.8% and 32.9%, respectively. Furthermore, Devaux et al.¹ published a review that documented the presence of human cases of Q fever in North America, South America, Europe, Asia, Africa, and Australia/Oceania; but not in Antarctica and New Zealand. Furthermore, Ahmadinehad et al.⁵⁷ reviewed 112 articles published on Q fever from the Eastern Mediterranean region and reported an average seroprevalence of 25.5% in humans. As it can be noted from these reports, the seroprevalence of *C. burnetii* infection recorded in humans by the present study was higher than those reported from African countries with the exception of those reported from the North African region. However, the seroprevalence value of *C. burnetii* infection from the present study is comparable with the mean seroprevalence values reported from the Mediterranean region. The differences the seroprevalences of *C. burnetii* in human reported by different studies are influenced by the level of exposure of the study participants to the potentially infected animals and their products. As the present study included highly exposed groups and hence high level of seropositivity is expected in this study human subjects.

The seroprevalence values recorded in both camels and abattoir workers in the present study could be considered comparable to the seroprevalence values previously from other countries. Though there is a shortage of epidemiological studies on *C. burnetii* infection both in humans and animals worldwide, research done so far has shown that *C. burnetii* infection may be associated with significant economic and public health impacts as documented by the World Organization for Animal Health². In ruminants, a significant number of *C. burnetii* infection is subclinical, but the clinical form (Q fever) causes abortions and reproductive disorders such as metritis and infertility⁴. Similarly, the effect of *C. burnetii* infection in camels is expected to be similar with its clinical effects in ruminants. However, additional studies are required on the impact of *C. burnetii* infection in camels. In humans, *C. burnetii* infection causes either acute, chronic or asymptomatic infection⁵⁹. The acute infection is characterized by clinical manifestation ranging from a self-limiting flu-like symptoms to serious disease conditions such as pneumonia or granulomatous hepatitis while the chronic form is characterized by endocarditis, vascular or valvular infection, hepatitis, pneumonia or chronic fatigue².

Since *C. burnetii* infection is zoonotic, its control efforts should involve coordination of human health and veterinary authorities in integrated multidisciplinary approach. Control measures in ruminants and camels could include testing and culling of shedding animals, control of animal movement, preventive vaccination, farm management, biosecurity and tick control. *C. burnetii* is classified as a group B biological agent and it is occupational zoonosis that is extremely hazardous to humans⁶⁰. Hence, personal protective equipment should be used when handling infected animals, humans and specimens or contaminated materials. Laboratory

specimens should be handled inside a biological safety cabinet level III. Selective vaccination should be given to occupationally exposed groups such as abattoir workers, veterinarians and laboratory workers.

Study limitations

The study is not without limitations. The first limitation was that the study was conducted at one abattoir and low number of study subjects. Secondly, failure to identify the origin of each study camel. Although 98% of the study camels were originated from the UAE, the camels could not further be identified at the level of emirates and regions. This information would help to trace back and identify the districts with high seroprevalences. The third weakness of the study was failure to collect appropriate samples for the detection of the DNA of *C. burnetii*. The chance of extraction of DNA from the buffy coat, tissues (liver, spleen), aborted materials, environmental samples airborne dusts and vectors such as ticks. Lastly, the use of only IS1111 repetitive region primers for qPCR to amplify *C. burnetii* DNA could be considered as this repetitive region is not found in all strains of *C. burnetii*.

Conclusion

In conclusion, the present seroprevalence values recorded in both camels and abattoir workers were among the high seroprevalence values reported so far from the other countries. However, additional extensive studies are required to estimate the seroprevalence of *C. burnetii* infection in livestock and human occupational contacts in the UAE. It is also recommended to isolate and characterize the strains of *C. burnetii* circulating in the UAE. Parallel to conducting further research on *C. burnetii* infection in livestock and humans, implementation the existing control tools in both livestock and human occupational contacts is highly recommended.

Data availability

“The data that support the findings of this study are available from the corresponding authors upon reasonable request.”

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Author contributions

“M.S.H., B.A., M.E.H., R.B. and G.A. conceptualized, designed the study and edited the manuscript. A.Z. and N.A.H. collected field data, conducted serological assays and edited the manuscript. A.S.A. performed statistical

analyses and edited the manuscript. J.A.N., B.O. and A.A.H. helped with the field data collection and edited the manuscript. H.Z.A.I., M.F.S., M.S.A.B., and A.A.M.S. performed molecular typing and edited the manuscript. G.A. supervised the study, analyzed the camel data, and drafted the manuscript. M.M.A.N., K.K., A.R.A. and R.B. edited the manuscript. All authors reviewed the manuscript”.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

The human and animal studies were approved by the Abu Dhabi Health Research and Technology Ethics Committee (ADHRTC) with a Ref No. DOH/CVDC/2022/1136. ADHRTC is composed of experts responsible for human ethics and animal ethics. Thus, all the animal and human experiment protocols were approved by ADHRTC. In addition, all the methods used in animal and human studies were carried out in accordance with the relevant guidelines and regulations. Furthermore, informed consent was obtained from all abattoir workers included in the study. On top of these, an approval was obtained from the Al Ain city Municipality (reference No. AAM/PSH/OUT/2022/2191). In addition, all the methods used in animal and human studies were carried out in accordance with the relevant guidelines and regulations. The study is reported in accordance with ARRIVE guidelines 2.0. for animal research³¹.

Consent for publication

The Ministry of Climate Change and Environment (MOCCAE) of the UAE approved the publication of this manuscript via email sent to the corresponding author on the 2nd of February 2025.

Additional information

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