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Cover Photo: The camel group representing Africa at the northeast corner of the Albert Memorial. Source: https://en.wikipedia.org/wiki/Albert_Memorial#/media/File:Albert_Memorial_statue.JPG

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Volume 31 **August 2024** **Number 2**

EXPLORATION OF CAMELS IN ARCHIVES AND HERITAGE IN DIFFERENT COUNTRIES BY R. TREVOR WILSON

R. Trevor Wilson's maiden contribution to the world of camels was a minor paper published in 1978 in the journal Tropical Animal Health and Production as part of a series on the domestic livestock of Southern Darfur in Sudan where he worked and lived with his family in 1972-1974 and 1976-1978. His reference book "The Camel" was published in the year 1984. The book proved a plethora of scientific information about camels in a classified manner. The book received a big opening with great appreciations because at that time there was a big void of camel related books. In the International Year of Camelids 2024, it is important to recall the outstanding research done by R Trevor Wilson on camel archives and heritage in different countries through several monuments, pictures, statues, stamps, archives, old literature and other relevant evidences. He reviewed the presence and performance of the one-humped camel - exotic to Tanzania[1]. Accordingly, camels appeared in annual veterinary reports in 1926-1934: numbers varied from 26 (1926) to 67 (1930) and 5 (1934). In this pre-independence period they occurred mostly in the coastal provinces and since independence some 340 camels have been imported privately and by NGOs.

Later, Dr Wilson and his co-researchers explored camels in Turkey[4] and found that camels were first known to have been in Turkey some 2600 years ago when they were used as animals of war. There has been continued presence ever since and the country is unusual as it is home to both one-humped and bactrian types. During the nineteenth and as late as the early twentieth century there was an important exchange of breeding animals between Turkey and Syria. Numbers declined rapidly after the 1930s and at the end of the first decade of the twenty-first century the country's camel population was little more than 1000 animals. These are now mainly used for sport and as a tourist attraction with meat being a minor product.

He gave first comprehensive account of the presence of camels and of camel production in Uganda. The dromedary camel started to appear in the arid northeast of the country during the 1960s/1970s. In 2008 the national camel population was about 31 000 but in 2017 could go as high as or more than 40 000. Traditional pastoral tribes have become camel keepers for the production of milk, some meat, some transport and for medical uses. It was inferred that these camels contribute to food security and to the livelihoods of pastoralists in some of the remote parts of Uganda[2].

His further research focused on Somaliland which is a self-proclaimed republic and had about 1.7 million camels and the camel has always been an icon in the culture and customs of the ethnic Somali. The British administration organised a Camel Corps to help in the maintenance of law and order in the then Protectorate but it also distinguished itself against the troops of Italian Somaliland in the World Wars of 1914-1918 and 1939-1945 before it was disbanded in 1946[3].

His further research revolved around Eritrea and Ethiopia, among the poorest in the world[5] Ethiopia has the greatest number of livestock in Africa at an estimated 120 million ruminant animals of which 1.1 million are camels. In contrast Eritrea's livestock population is under 10 million in which camels may number 320 000. The one-humped camel possibly arrived in the area of study about 1900 years ago. In Eritrea camels were owned by Beja tribes near the border with Sudan, by Tigre clans in the north and by Afar and some Somali in the east along the Red Sea littoral. Ownership in Ethiopia was mainly by the Somali people and by the Afar in their respective Regional States in eastern Ethiopia and by the Boran in the south.

His most recent publication unfolds the use of camels in the British military and in transport of trade goods for British trading companies from their areas of origin and have been recognised as

making considerable economic contributions to Britain in these roles. In recognition of this there are several monuments and memorials to the animal around the country. Camel is also a word used in British geography for some British towns and villages and as names for geographic features such as rivers and hills. This paper provides a repertoire of such monuments, memorials and place names[6].

This editorial is specially dedicated to R. Trevor Wilson with a big salute because he chose the Journal of Camel Practice and Research as a platform for publication of his research on this aspect.

(Dr. Tarun Kumar Gahlot)
Editor

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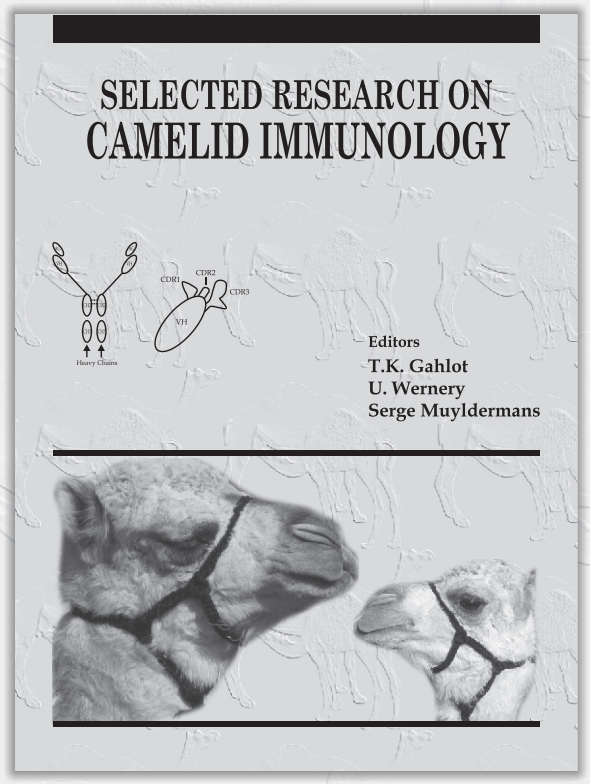
SELECTED RESEARCH ON CAMELID IMMUNOLOGY

(Hard Bound, 392 pages, few figs coloured, Edition 2016)

In 1989 a group of biologists led by Raymond Hamers at the Free University Brussels investigated the immune system of dromedaries. This discovery was published in Nature in 1993. Based on their structure, these peculiar camelid antibodies have been named Heavy Chain Antibodies (HCAb), as they are composed of heavy chains only and are devoid of light chains. Sera of camelids contain both conventional heterotetrameric antibodies and unique functional heavy (H)-chain antibodies (HCAbs). The smaller size and monomeric single domain nature make these antibodies easier to transform into bacterial cells for bulk production, making them ideal for research purposes. Camelid scientists world over were greatly fascinated by a new field of research called "Camelid Immunology". Significant research has been done on camelid immunology in recent decade. In order to benefit future camelid immunology researchers, this book was planned in the series of "Selected Topics" by Camel Publishing House with a title- "Selected Research on Camelid Immunology" edited by T.K. Gahlot, U. Wernery and Serge Muyldermans. This book is a unique compilation of research papers based on "Camelid Immunology" and published in Journal of Camel Practice and Research between 1994-2015. Research on this subject was done in 93 laboratories or institutions of 30 countries involving about 248 scientists. In terms of number of published papers in JCPR on the immunology the following countries remain in order of merit (in parenthesis), i.e. Iran (1), India and UAE (2), China and Saudi Arabia (3), Sudan (4), Kenya and Belgium (5), USA (6), Germany (7) and so on. The book contains 11 sections and is spread in 384 pages. The diverse sections are named as overview of camel immune system; determinates of innate immunity, cells, organs and tissues of immune system; antibodies; immunomodulation; histocompatibility; seroprevalence, diagnosis and immunity against bacteria, viruses, parasites and combination of other infections; application of camel immunoglobulins and applications of immune mechanisms in physiological processes. The camelid immunology has to go a long way in its future research, therefore, this reference book may prove quite useful for those interested in this subject. Book can be seen on www.camelsandcamelids.com.



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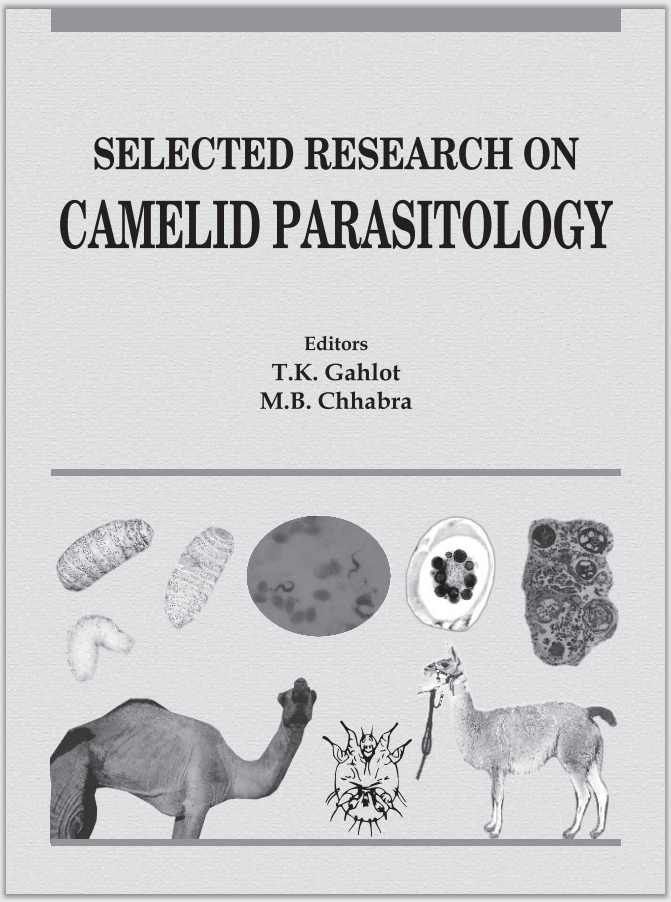
SELECTED RESEARCH ON
CAMELID PARASITOLOGY

Hard bound, 291 pages, few figures coloured

New research and experience always broaden our knowledge, and help us adopting new diagnostic methods and treatments. Camel Publishing House has taken a step forward to compile this knowledge in form of a book and this Herculian task was accomplished with the help of dedicated editors. viz. Drs. T.K. Gahlot and M.B. Chhabra. ***Selected Research on Camelid Parasitology*** is most comprehensive guide to Camelid Parasitology. The classic reference book serves as a one stop resource for scientific information on major aspects of Camelid Parasitology. Featuring abundant photographs, illustrations, and data, the text covers camelid protozoa, helminths, and arthropods of dromedary and New World camelids. This hard bound book of 304 pages contains seroepidemiological studies, immunological and other diagnostic procedures, and new treatments of parasitic diseases. There are at least 17 countries involved in camelid parasitology research, viz. Ethiopia, France, India, Iran, Jordan, Kenya, Libya, Mauritania, Nigeria, Sultanate of Oman, Pakistan, Saudi Arabia, Sudan, Sweden, United Arab Emirates, Uganda and U.S.A. As per published papers in Journal of Camel Practice and Research (JCPR), 173 authors have contributed 72 manuscripts which are appropriately placed in 5 sections. The text of each manuscript published previously in JCPR remains the same except the pattern of numbering the references in the body of text. This book indicates a swing of camelid research during period 1994-2008 and will help identifying the missing links of research in this subject.



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THE ONE-HUMPED CAMEL IN THE UNITED KINGDOM: MONUMENTS, MEMORIALS AND MUNICIPALITIES

R. TREVOR WILSON
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ABSTRACT

The one humped camel (*Camelus dromedarius*) has never been numerous in the United Kingdom and in British law is classed as a dangerous wild animal for which a licence is needed by the keeper. It is now illegal to use camels for entertainment, for example in circuses. There have been, nonetheless, both one humped and two humped (*Camelus bactrianus*) camels in Britain since the early 12th century, 900 years ago. Camels have seen service in the British military and in transport of trade goods for British trading companies from their areas of origin and have been recognised as making considerable economic contributions to Britain in these roles. In recognition of this there are several monuments and memorials to the animal around the country. Camel is also a word used in British geography for some British towns and villages and as names for geographic features such as rivers and hills. This paper provides a repertoire of such monuments, memorials and place names.

Key words: Albert Memorial, Bactrian camel, Cleopatra's Needle, General Charles Gordon, Imperial Camel Corps, Kitchener of Khartoum

Most of the world's countries class the camel as a domesticated animal but the UK is among a small minority that considers camels as wild. Camels – unspecified as to being Old World or New World – are classified in British Law as 'Dangerous Wild Animals' for which a licence is required in order for the general public to keep them (LGU, 1976). There are separate regulations for zoos, circuses and some other bodies but live performances in circuses have been banned since January 2020 (LGU, 2019). Up until 2019 two circuses in the UK held wild animal licences but the Wild Animals in Circuses Act 2019 banned their use in the entertainment industry from January 20, 2020. Several British zoos and wildlife parks continue to exhibit Bactrian camels but only two 'safari' parks keep the one humped camel. It seems there is only one commercial herd of one humped camels in the UK. The herd, with animals obtained from Europe and maintained under a Dangerous wild animal licence, comprised 17 animals aged from 2 to 25 years old in May 2024. The unit was founded as a pseudo-safari business in the 2nd decade of the 21st century but converted to a dairy herd, milked by a mobile machine, as a result of the Covid pandemic in 2020 when movements were not allowed. Milk was not being produced in May 2024 because imports of pregnant females were stopped, as with all ruminants, due to the risk of contracting BTV-3 (bluetongue disease) (Joseph and Rebecca Fossett, personal communication 13 May, 2024).

There has never been more than a very small number of camels in the United Kingdom. There is, however, solid evidence for the presence of both one- and two-humped camels in England, Scotland and Ireland at least as far back as the early 12th century (900 years ago). Henry I of England (king from 1100 to 1135 AD) is known to have had camels in his menagerie at Woodstock near Oxford (Mynors *et al*, 1998) with potential hints of an even earlier presence. Later, in 1466 in the mid 15th century, the Patriarch of Antioch (a city in Greece) presented four "dromedaries" and two "camels" (i.e. Bactrians) to the English King Edward IV (Searle, 1902). The tomb of a John Camel in the Church of St John the Baptist in Glastonbury in Somerset, southwest England dated 1487 has a carving of a Bactrian camel: the history of this camel does not appear to be known but it may be a pun on the occupier's name.

Several geographical place names contain the word camel in addition to Camelford in Cornwall (see below). There is a West Camel village on the River Cam in Somerset and another nearby village

SEND REPRINT REQUEST TO R. TREVOR WILSON email: trevorbart@aol.com

known as Queen Camel: none of these places has any connection with the camel as an animal but have been derived from earlier indigenous place names. The Sopwith Camel was a single engine biplane fighter aircraft of the First World War whose name was said to derive from the hump at the front of the aircraft that housed the machine guns.

In spite of there only ever having been very few camels in the United Kingdom their various contributions to military operations and to international trade the country has several "hard" memorials to their role in these contexts. This paper provided a partial repertoire of such mementos.

Methodology

This paper is based on the author's own knowledge and experience and on a thorough review of the literature. In view of the rather unusual subject formal sources are relatively few. Much of the text is thus based on grey literature and the ever-growing number of internet sources usually under the epithet of "blog"

Monuments, Memorials and Municipalities

Prince Consort National Memorial (The Albert Memorial)

The Albert Memorial, north of the Royal Albert Hall in Kensington Gardens, London, was commissioned by Queen Victoria in memory of her husband Prince Albert, who died in 1861. Designed by Sir George Gilbert Scott in the Gothic Revival style it is an ornate canopy or pavilion 176 feet (54 m) tall, like a ciborium over a church high altar with a statue of the prince facing south below (Risebero, 1985) (Fig 1). It took more than ten years to complete, the £120,000 cost (the equivalent of about £19,000,000 in 2024) met by public subscription. The memorial was opened in July 1872 by Queen Victoria although Albert's statue was not ceremonially "seated" until 1876. It has been Grade I listed since 1970 (Appendix A).[1]

Each of the four corners of the central area has an allegorical sculpture depicting Victorian industrial arts and sciences, these being agriculture, commerce, engineering and manufacturing. At the outer corners are four more groups representing the traditional four continents: Africa, the Americas, Asia and Europe. Each of these groups comprises several ethnographic figures and a large animal: a bison is represented for the Americas, an elephant for Asia, a bull for Europe and a one-humped camel for Africa (Fig 2).

The memorial was planned by a committee of well-known architects that was led by Sir George Gilbert Scott. The sculptural work was coordinated by Henry Hugh Armstead who recruited many of the artists from the Royal Academy. William Theed, who was a favourite of Prince Albert, was chosen to carve the "Africa" group.

Imperial Camel Corps Memorial, Victoria Embankment Gardens, London WC2

The beginning of what eventually became the Imperial Camel Corps was four Company-strength units raised in Egypt in January 1916. The companies comprised, respectively, Australian troops that had returned from the disastrous Gallipoli Campaign, New Zealand, British and Indian troops. A Company of 130 men comprised a small Headquarters and four Sections, each of 7 groups of 4 men armed with Lee-Enfields, the then standard British Army bolt action rifle. The first camels were heavy baggagers from the Bikaner Camel Corps but these were later replaced by lighter Egyptian camels for riding mounts (Falls and MacMunn, 1930; Clayton and Killingray, 1989). Six new companies were raised from British yeomanry regiments in March 1916, four additional Australian companies were raised in June from reinforcements intended for the Australian Light Horse regiments and reinforcements intended for the New Zealand Mounted Rifles Brigade formed two companies, one in August and the other in November (NZMCH, n.d.).

Initial activities were confined to long range patrols around the Suez Canal and the Sinai Desert. In August 1916, a transition to a more active combat role took place when each Company added a machine gun Section of 15 men with three Lewis guns. Additional staff on the Headquarters section brought each Company's strength to 184 men. Companies operated independently as cavalry whilst on the march but dismounted to fight as infantry in actual battle and thereafter, the Corps (as it eventually became) continued to fight as mounted infantry.

The unit eventually expanded to Battalion size. Four such entities were eventually formed, one each from Great Britain (also known as the Imperial) and New Zealand (ANZAC) and two from Australia, each of 770 men and 922 camels. When Brigade status was achieved on 19 December 1916 support troops

1. Buildings, scheduled monuments, parks and gardens, battlefields and shipwrecks judged of national importance in the United Kingdom in terms of architectural or historic interest are "listed" in one of three grades. These are: Grade I (buildings of exceptional interest); Grade II* (particularly important buildings of more than special interest); and, Grade II (buildings of special interest).

included a mountain artillery battery (Hong Kong and Singapore (Mountain) Battery), machine gun squadron (265th (Camel) Machine Gun Squadron), Royal Engineers (10th (Camel) Field Troop), field ambulance (Australian (Camel) Field Ambulance) and 97th Australian Dental Unit, this last comprising only four men!, the Mobile Veterinary Section and – inevitably – an administrative train including a Brigade Ammunition Column and the Brigade Train which carried five days of supplies (Underwood, 2003). Brigade strength at this stage was about 4150 men and 4800 camels (NZMCH, n.d.).

The Imperial Camel Corps (ICC) eventually became part of the Egyptian Expeditionary Force (EEF).[2] It fought in many battles in the Senussi Campaign (November 1915-February 1917), the Sinai and Palestine Campaign (January 1915-October 1918) (Reid, 1934; Robertson, 1938) and in the Arab Revolt (June 1916-October 1918). The ICC was disbanded in May 1919 after the end of the war having had more than 240 men killed over the period of its existence.

A memorial to the Imperial Camel Corps was unveiled in the Victoria Gardens on the Thames Embankment in London on 22 July 1921 (Ward-Jackson, 2012) and listed as Grade II in 1958 (Appendix B). The bronze effigy of a rider carrying a rifle was sculpted by Major Cecil Brown (who had himself served in the Corps) in 1919-1920 and unveiled in July 1921 (Fig 3). The monument is mounted on a two-stage pedestal of Portland stone with the upper part bearing bronze bas-relief images of various actions. The lower part has bronze plaques, the one with a sentiment commemorating those men who made the supreme sacrifice:

> To the Glorious and Immortal Memory of the Officers, N.C.O.s and Men of the Imperial Camel Corps -- British, Australian, New Zealand, Indian -- who fell in action or died of wounds and disease in Egypt, Sinai, and Palestine, 1916, 1917, 1918. (Fig 4).

The other sides carry the names of all the members of the Corps who were killed or died of their wounds during the war and all the battles and engagements fought by the Corps;

> 1916: Romani, Baharia, Mazar, Dakhla, Maghara, El Arish, Maghdaba.
>
> 1917: Rafa, Hassana, Gaza 1, Gaza 2, Sana Redoubt, Beersheba, Bir Khu Weilfe, Hill 265.
>
> 1918: Amman, Jordan Valley, Mudawar (Hedjaz).

2. It is not clear how the camel fighting force became a Corps. In the British Army a Corps (commanded by a Lieutenant General) comprises at least two Divisions (each commanded by a Major General) made up of several Brigades (each commanded by a Brigadier)

Statue of General Gordon at the Royal School of Military Engineering, Brompton Barracks

Charles George Gordon was born into a military family in Woolwich on 28 January 1833. He obtained a commission as Second Lieutenant in the Royal Engineers in 1852. After fighting in the Crimean War in 1853-1856 he was then in China in 1860 with the Anglo-French forces. At 30 years of age in 1863 Gordon commanded a force established in Shanghai to protect Europeans from Chinese rebels and within two years the revolt known as the Taiping Rebellion was put down. As a result, the Chinese Emperor honoured him with the yellow jacket and peacock feather of a mandarin after which he became known by the soubriquet of "Chinese" Gordon although, he was promoted only to Captain in the British Army (Barnes, 1885; Trench, 1979).

Promoted Colonel in 1872 Gordon accepted an offer from the Egyptian Khedive in 1874 – with British Government consent – to join the Egyptian army. He was shortly appointed Governor of Equatoria Province (now mainly South Sudan and northern Uganda), where he attempted to suppress the slave trade and where he stayed until 1876. Gordon then returned to England but was eventually persuaded by the Khedive to accept the Governor-Generalship of the entire Sudan which also carried the Ottoman title of Pasha (Sparrow, 1962).

Gordon tried hard to suppress the slave trade but was hindered in this by not only the corruption of his Egyptian official but also of his British colleagues (Moore-Harell, 1998). He resigned as Governor General in 1879. Offered positions in the Belgian Congo and in the Cape Colony, Gordon refused but then accepted a post as Private Secretary to the Governor-General of India before returning to China (Galbraith, 1971; Hsu, 1964). He spent much of 1881 in Mauritius and the Seychelles before moving to Palestine. Gordon was promoted to Major General in the British Army in March 1882 (Boulger, 1897).

In January 1884, Gordon was again sent to the Sudan by the British Government. At this time, the country was in turmoil as a result of the carnage being created by a religious fanatic known as the Mahdi and his followers who were winning battles against the Egyptian army over most of the country.[3]

3. Mahdi is an Arabic word that means "guided to the right path" or "rightly guided". In Islam, Mahdi is the prophesied messianic figure who will appear at the end of the world to rid humanity of evil and injustice. Mahdi is also a popular and deeply spiritual choice given by Muslim parents to their children (https://www.thebump.com/b/mahdi-baby-name).

Gordon's brief was to evacuate the Egyptian garrisons endangered by the revolt of the Sudanese rebels and then to leave the country himself. He successfully evacuated several expatriate families but refused to leave himself and sought to hold the central areas but was besieged in Khartoum. The city held out for 10 months before it fell on 26th January 1885 as the rebels stormed the Governor's Palace. The whole garrison was slaughtered, Gordon being killed, supposedly through a spear thrust from one of the attackers. A relief expedition sailing up the Nile, for which the British public had been demanding for a considerable time but over which the Government had prevaricated, reached Khartoum two days later. It was at this point that Gordon was hailed as a martyr and a national hero. There were calls for revenge but this did not come until 13 years later when another British General, Herbert Kitchener, recaptured Khartoum and reinstalled a kind of peace (Ziegler, 1973).

There was a general feeling that a permanent memorial to Gordon in the form of a statue should be created but it was Gordon's own Corps, the Corps of Royal Engineers that took the initiative. Officers and other ranks contributed money to a fund to commission a statue of Gordon. The original specification was for a statue on foot in the uniform of an Egyptian General. The selected sculptor, Edward Onslow Ford, considered it more appropriate for Gordon to be seated on a camel.[4] Ford studied the camels at London Zoo and made casts of a dead camel (said to be a one humped beast). The resulting monument, of bronze and stone is of a one humped camel that is correct in most details. The exception is that the beast has a horse's tail rather than that of a camel intended as a sop to late Victorian (and perhaps especially Queen Victoria's) morality (Droth *et al*, 2014; Darke, 1991). The statue was first exhibited and unveiled by the Prince of Wales at the Royal Academy in 1890. It was later moved to Brompton Barracks, the home of the Royal School of Military Engineering in Chatham, where it still stands (Fig 5). It became Grade II* listed in 1998 (Appendix C).

Statue of General Gordon at Gordon's School

A considerable grounds well persisted in favour of a statue to Gordon being put on public display at the site of his death in Khartoum. The hero of the recapture of Khartoum, General Kitchener together with Algernon Borthwick, the owner of the Morning Post newspaper, persuaded the paper's readers to subscribe to a fund for this to happen. By 1902, there was sufficient money for a second statue to be cast. The new effigy was erected in St Martin's Place in London (Fig 6). In 1904, it was shipped for Khartoum although it survived two major mishaps, the first being that of the Cedarden which sank in the Thames and the second being the SS Lesbian which was submerged in the Nile! Finally it arrived in Khartoum where it was placed at the intersection of Gordon and Victoria Avenues, some 200 metres south of the new palace that had been built in 1899 after the former edifice had been destroyed (Fig 7).

The Anglo-Egyptian Sudan, a Condominion ruled jointly by the United Kingdom and Egypt, gained its independence on 1 January 1956 to become the Republic of Sudan. In 1958, the Sudanese government removed the Gordon statue and a second one of Kitchener which had been erected later. Both statues were offered to the UK, the offer being accepted and the statues were shipped back to England.

The UK government then offered the Gordon statue to Gordon's School, founded as the Gordon Boys' Home in 1885, in Woking in the county of Surrey. The statue was erected at the School in April 1959 and unveiled in May 1959 (Fig 8). Time has wreaked its worst on the statue and eventually the Portland stone plinth and the bronze statue were degraded and tassels and reins were missing. The statue was eventually given a make over and HRH The Earl of Wessex unveiled a plaque to mark the restoration of the statue on 10 October 2014. The front of the plinth now bears the inscription "Charles George Gordon". On the left side the inscription reads "Born Woolwich 28th January 1833, killed Khartoum 26th January, 1855"; the right side is inscribed with "This Statue was Erected at Khartoum in 1904. Removed and presented to the School in 1959" with the remaining side bearing the words "This plinth has been presented in memory of Major-General Sir Hubert J. Huddleston, G.G.M.C., G.G.B., C.B, D.S.O., M.C., who served the Sudan for 28 years and was Governor-General 1940-47." The statue was listed as Grade II on 29 April 2015 (Appendix D).

Camel benches on Victoria Embankment of River Thames, London WC2

Following British victories at the Battle of the Nile in 1798 and the Battle of Alexandra in 1801 the

4. Edward Onslow Ford RA (27 July 1852 - 23 December 1901) was an English sculptor whose early success was with portrait heads or busts of prominent people. Several of Ford's monumental commissions celebrate the British Empire either by promoting imperial values or as memorials to military figures.

Fig 1. Full view of the Albert Memorial in front of the Royal Albert Hall, London. Source: Photo by the Author.

Fig 2. The camel group representing Africa at the northeast corner of the Albert Memorial. Source: https://en.wikipedia.org/wiki/Albert_Memorial#/media/File:Albert_Memorial_statue.JPG.

Khedive of Egypt, Muhammad Ali, sought to reward the victors with some unwanted pieces of Egyptian antiquity. One was an obelisk which became known as Cleopatra's Needle presented to the United Kingdom in 1819. The British Government, however, were unable to justify the cost of its transport to England at that time. It therefore remained in

Fig 3. Memorial to Imperial Camel Corps in Victoria Gardens on Thames Embankment. Source: https://en.wikipedia.org/wiki/File:Statues_in_Victoria_Embankment_Gardens_-_geograph.org.uk_-_1729996.jpg.

Alexandria for more than 50 years until anatomist and dermatologist Sir William James Erasmus Wilson provided the money for the obelisk – of red Aswan granite, 68 feet (21 metres) tall and weighing more than 220 tons – to be dug out of the sand and transported to London. Encased in an iron cylinder and towed by a ship the obelisk left Alexandria on 21 September 1877 and after a perilous journey through stormy waters and via a harbour in northwest Spain it arrived at Gravesend in southeast England on 21 January 1878. Transported to London, Cleopatra's Needle was erected on the Victoria Embankment of the River Thames on 12 September 1878 (Wilson, 1877; Dickens, 1885).[5]

5. Two other "Cleopatra's Needles" are extant: one in New York which is the precise image of the London one in 1881 and one in Paris which is of a different provenance to the London and New York obelisks.

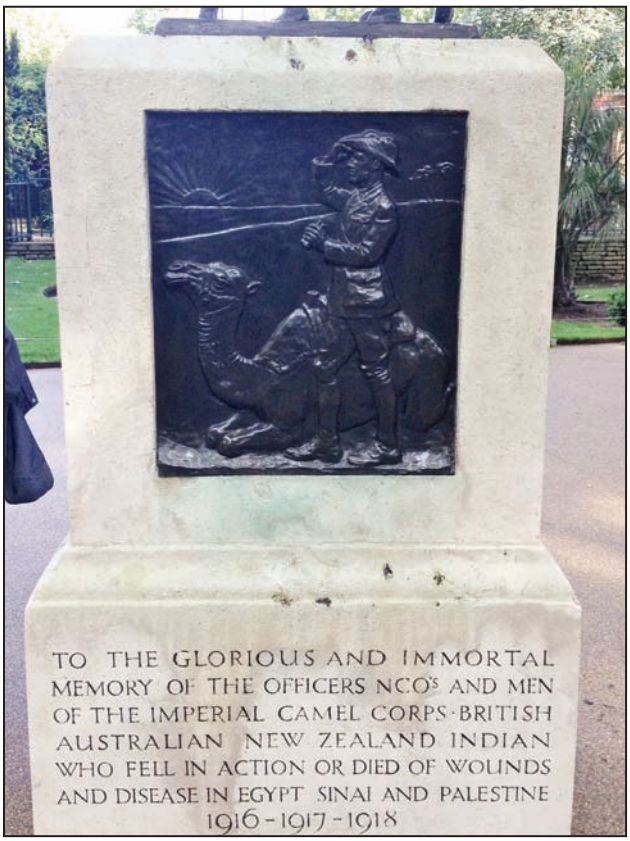

Fig 4. Detail of inscription on ICC statue. Source: enlarged from Fig 3.

Fig 5. Gordon's statue at the Brompton Barracks, School of Military Engineering in Chatham. Source: https://en.wikipedia.org/wiki/Statue_of_General_Gordon#/media/File:Gordon_Memorial,_New_Brompton,_England-LCCN2002708002.jpg.

During the 1860s, some 22 acres (8.9 ha) of marshland along the River Thames were drained and reclaimed, a retaining wall was built and a new sewage system and other infrastructural improvements were constructed. The new – now the Victoria Embankment – terrace thus created needed,

Fig 6. The second cast of Gordon on a camel in St Martin's Place, London before shipment to Khartoum in 1902. Source: https://www.londonremembers.com/memorials/general-gordon-on-a-camel.

Fig 7. General Gordon's statue *in situ* in Khartoum 1936. Source: Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA. https://hdl.loc.gov/loc.pnp/pp.print.

to the minds of London's councillors, appropriate street furniture so that people could rest after their perambulations.

George John Vulliamy, architect to the Metropolitan Board of Works, designed an ornamental "dolphin" lamp (the ornament is actually a sturgeon), along with cast iron and slatted wood benches that featured sphinx and camel-shaped armrests that expanded on the perceived historic, patriotic and imperial concepts of the obelisk (Fig 9; Fig 10). The benches were cast and constructed by Z.D. Berry & Son of Regent Street (a well-known and respected manufacturer of cast-iron street furniture and heating and lighting equipment) and installed on the embankment partly in the City of Westminster and partly in the City of London in 1877, one year before the Needle was erected in 1878.

Fig 8. Statue of General Gordon at Gordon's School, Woking, Surrey. Source: geograph.org.uk - 44414.jpg.

Fig 9. A camel bench on Victoria Embankment. Source: © Copyright N Chadwick and licensed for reuse under creativecommons.org/licenses/by-sa/2.0; https://www.geograph.org.uk/photo/2714246.

Fig 10. Detail of bench end from Fig 9 (Note: stamp of manufacturer at base).

Fig 11. Location view of Peek House at 20 Eastcheap, London. Source: Copyright Mike Quinn and licensed for reuse under Creative Commons Licence.

The Westminster ones feature sphinxes whereas the London ones feature camels. Some 21 benches were listed Grade II in 1987 of which only one featured a camel (Appendix E). By the time, the benches were listed, many had been replaced due to wear and tear and replaced by reproductions in 1960-1985. The originals have become "collectors' items": one was sold at auction in 2015 by the renowned auctioneers Bonhams at an asking price of £8000-£10,000 (even one of the later reproductions sold in 2019 for £3750) with the description:

Lot 284: A Victorian cast iron black painted 'Camel' bench by Z.D. Berry & Son, designed by George John Vulliamy, circa 1878

The later slatted scrolling back and seat with ends cast as recumbent laden camels with pierced scrolling leaves

Fig 12. Detail of the camel train above the main entrance to Peek House showing latest office tenant. Source: Photograph courtesy of Andrew G Wilson, 7 December 2022.

Fig 13. A sprandrel with two supporting camels on the former Oriental Bank Corporation building at London's EC2 area. Source: https://lookup.london/eastcheap-camels-peek-house/

and flowerheads, on plinth bases, 213 cm wide, 79 cm deep, 83 cm high (83 ½ in wide, 31 in deep, 32 ½ in high).

Camel train relief sculpture in Eastcheap, London EC3 and other London wall sculptures

A relief of a camel train is sculpted above the entrance to a building that was once a bank after it had been the offices of a tea and coffee importing business at the corner of Eastcheap with Lovat Lane, London EC3.

Fig 14. Camels supporting the Coat of Arms of the Merchant Tailors on the wall of this Livery Company's home since 1347 almost opposite the previous Figure. Source: https://lookup.london/eastcheap-camels-peek-house/

Fig 15. The camel sculpture on the front of the Liberty store in Regent Street, London. Source: http://www.speel.me.uk/gp/camels.htm.

Fig 16. The Asia Tympanum on the facade of the Manchester Free Trade Hall. Source: (http://www.speel.me.uk/sculptplaces/manchfreetradehall.htm).

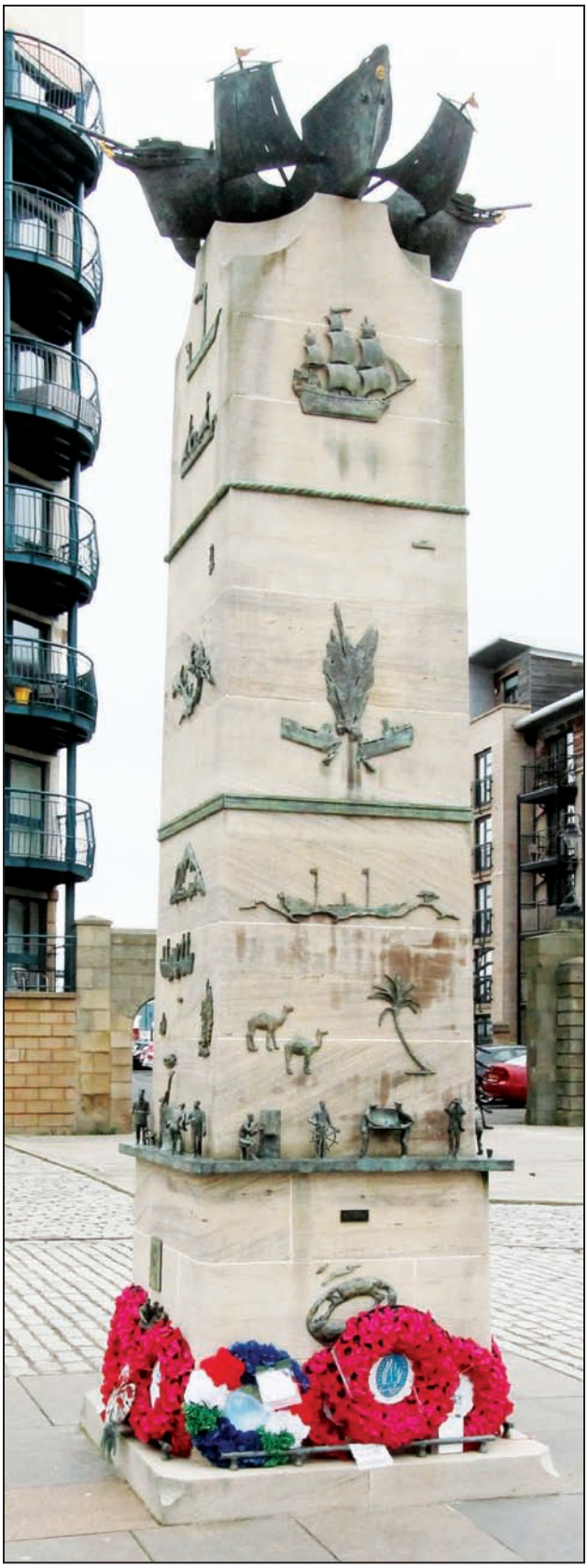

Fig 17. The Obelisk memorial to Scottish Merchant seamen on the Shore, Leith, Scotland. Source: Photograph by the Author.

Fig 18. Detail of the bronze casting of camels on the Scottish Merchant seamen memorial. Source: Photograph by the Author.

Fig 19. Windvane in the shape of a one humped camel on the old Town Hall, Camelford. Source: Photograph by the Author.

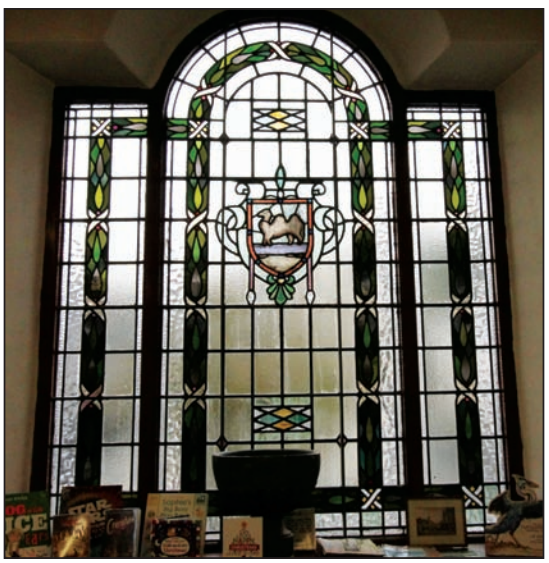

Fig 20. The Coat of Arms of the Borough of Camelford showing a two humped camel crossing a stream. Source: Photograph by the Author.

Peek Bros, established in 1823 by three siblings, was a firm of Tea and Coffee Importers. It was a very successful business and imported 5 million pounds weight (2232 tonnes, 2,267,960 kg) of tea to England in 1865. Their office building, known as Peek House, together with much of the street of Eastcheap was demolished in 1882 so that the ground could be excavated to allow the Metropolitan Underground Line to be built. An impressive new 4-storey building was erected at No 20 Eastcheap during 1883-1885 and again named Peek House. The two fronts in Eastcheap and Lovat Lane are joined by a quadrant turning through 90 degrees and it is above the main entrance on this quadrant that the carving is sculpted. The building (Fig 11) is now home to a number of offices including a major branch of the Hongkong and Shanghai Banking Corporation (HSBC).

The carving in high relief (alto-relievo) on Portland stone was created by William Theed the Younger. Theed loved exotic subjects and had already carved the Africa section on the Albert Memorial (see above). The 3 camels and the Arab leading them – effectively the Peek logo – are estimated to be about one quarter of life size and are carrying, respectively, tea, coffee and spices which were the main commodities traded by Peek Bros (Fig 12).

A sprandrel on the wall of a building that was the office of the Oriental Bank Corporation between 1845 and 1892 situated where Adam's Court meets Threadneedle Street in London has two camels sculpted alongside two seated figures on each side of the central boss (Fig 13). Geographically, almost opposite the previous sculpture is one that is the Coat of Arms supported by 2 camels of the Merchant Tailors' Company (Fig 14). The Company is one of the twelve great Livery Companies established in Medieval times. It was originally the regulator and trade body of tailoring but over time it has become a philanthropic organisation (https: //www.merchant-taylors.co.uk/). Liberty is a fashionable store in Regent Street, London W1 which describes itself as a "Designer Department Store Selling Luxury Brands". Liberty was established by the homonymous Arthur Lasenby Liberty in 1875 with the dream of setting up an emporium laden with luxuries and fabrics from distant lands (https://www.libertylondon.com/ uk/ information/our-heritage.html). In keeping with this dream is the camel sculpture on the long frontage of Liberty's in Regent Street, probably indicating trade and one of the exotic sources of Liberty's wares. The camel is seated with two Arabic traders and one naked worker who is pushing the camel possibly urging it to stand up (Fig 15).

Manchester Free Trade Hall Tympanum

In the 19th century the city of Manchester and its surrounds were a major industrial area on a world scale. The Manchester Free Trade Hall dates from the Victorian era (1853-1856) and is an important decorated building in a Renaissance style that is 9 bays wide and 2 storeys high. Its glory is the tympani (tympanum -- a half-round recessed space above a window with an arch on top) of decorative allegorical sculpture on the upper level. The sculptor was John Thomas, an esteemed architectural sculptor, whose work was always of consistently high quality, with the Free Trade Hall sculptures showing him at his best. These sculptural groups in the tympani comprise a central classically-draped seated female figure has around her accoutrements appropriate to the idea she represents.

The central group represents Free Trade with 3 others relating to commerce, industry and manufactures, and the arts (http://www.speel.me.uk/ sculptplaces/manchfreetradehall.htm). The remaining 5 represent the continents with which Manchester trades. Asia is the one of interest to this paper. The female figure is modestly garbed and wears a turban. There is a small treasure chest in her lap, a large cornucopia is held in one arm and other sculptures include the prow of a bird-headed trade ship, a tea chest with exotic fruit on top, an ornamented pot and rolls of fabric. The lady is seated on a camel (Fig 16).

Memorial to Scottish Merchant Navy at Leith, Scotland

On 16 November, 2010 a memorial was unveiled by Her Royal Highness Princess Anne, daughter of her Majesty the Queen Elizabeth II, to sailors of the Merchant Navy who had been killed in or died as result of conflict from the start of World War I in 1914 to the unveiling of the memorial in 2010 (https://www.iwm.org.uk/memorials/item/memorial/87515).

The Memorial, located on The Shore in Leith near Edinburgh, is an 18 feet (5.5 m) tall sandstone obelisk featuring seafaring scenes (Fig 17). Each of the four sides has four tiers faced in light-coloured, grained Beryl sandstone and each panel contains a bronze relief. The architect and sculptor was the well-known Jill Watson: the nearby Powderhall Foundry cast the bronzes.

The upper panels represent the variety of merchant ships throughout history, the middle panels

have war scenes including destruction by torpedo, convoys with protection by Coastal Command and danger from rocks and storms at sea, the eye level panels are images of the world's trading routes, the ground level panels commemorating the educational role of Leith Nautical College and its training ship "Dolphin" and an empty lifebuoy evokes the loss of life at sea. One of the World Trade panels includes the Suez Canal and it is here that are shown two camels indicating that the Merchant Navy travelled world wide (Fig 18).

The town and parish of Camelford, North Cornwall, West of England

Camelford, a town in northeast Cornwall in southwest England, was first given a charter as a borough more than 800 years ago. The town has no real connection to a camel. The Cornish language name for the town, reskammel, derives from a combination of the Middle Cornish "rys" (ford) and the local river's Cornish name "kammel" (Ekwall, 1940; Mills, 2003). The English name, Camelford, was formed by Anglicisation of the river's name to Camel plus Ford, giving it an identical meaning to its Cornish counterpart. Due to the river's name sounding similar to the English word "camel" the animal is seen as a symbol of the town.

There are two obvious representations of a camel within the town limits. The most obvious is the model of a one humped camel acting as a weather vane atop the building in the town centre, erected in 1806, that was formerly the Town Hall and is now the Market Hall on the Ground Floor and the Public Library on the First Floor (Fig 19). The building was listed as Grade II in 1952 and then again listed Grade II in an amendment to the original heritage description in 1988 (Appendix F). As an integral part of the listed building the weather vane is protected under the Listing. The second representation comprises a stained glass window on the first floor of the building (and thus also protected) which shows a two humped camel crossing a body of water (Fig 20). The seal of the borough of Camelford is described as "Arg. a camel passing through a ford of water all proper" with the legend "Sigillum Vill de Camillford" (Pascoe, 1979). The logo of the town's Sir James Smith High School also is dominated by a silhouette of a one humped camel.

Discussion

As a generally perceived and legally classed exotic or wild animal little is known by the British people of the contributions the one humped camel has made to society over an extended time frame. Most of these contributions derive from outside the territorial UK where there has never been more than a few resident animals. This small number is likely to decease in view of the legislation now in force. For more than two hundred years, however, camels have supported Britain and its economic success in a number of ways. Few memorials celebrate these contributions. In the area of military conflict it has supported conventional forces as a cavalry animal and kept troops in the field through its activities in transport. Its contribution to overseas trade is little understood other than by a minority of people. The few examples of such activities provided in this paper are, however, adequate testament to the position it has occupied and the esteem in which it is still held by a discerning establishment.

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Thanks to Andrew Wilson for the photo of the camel train on the wall in Eastcheap. Jill Watson, the sculptor of the Scottish Merchant Navy memorial very kindly provided me with information on her work on the obelisk. Joseph and Rebecca Fossett of Joseph's Amazing Camels kindly provided information on their camel herd and its operations.

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Appendix A

Prince Consort National Memorial (Albert Memorial), Westminster

Heritage Category: Listed Building // Grade: I // List Entry Number: 1217741 // Date first listed: 14-Jan-1970 // List Entry Name: PRINCE CONSORT NATIONAL MEMORIAL (ALBERT MEMORIAL) // Statutory Address: PRINCE CONSORT NATIONAL MEMORIAL (ALBERT MEMORIAL), KENSINGTON GORE SW7

TQ 2679 NE CITY OF WESTMINSTER KENSINGTON GORE, SW7. 85/2

14.1.70 Prince Consort National Memorial (Albert Memorial). GV I

Memorial. 1862 to 1875. George Gilbert Scott, with sculpture and other decorations by numerous Victorian artists and craftsmen. Granite, marble, limestone and metal. Square decoratively paved podium reached by steps to south; superimposed podia with steps to all sides, surmounted by ciborium-like canopy with clustered granite columns to four corners. Elaborate sculptured spire. Giant seated figure of Prince Albert within. Gables to all sides with pinnacles between. Richly sculptured band to base breaking outward at corners to support sculptured groups representing the industrial arts:- Agriculture, Manufacture, Commerce and Engineering. Further sculptured groups to four corners of stepped podium representing Europe, Asia, Africa and America, and linked by elaborate railings. Monument enriched with much figure and other sculpture and decorated also in numerous other techniques including mosaic, enamel, etc.

Appendix B

Imperial Camel Corps Memorial

Heritage Category: Listed Building // Grade: II // List Entry Number: 1238057 // Date first listed: 24-Feb-1958 // List Entry Name: IMPERIAL CAMEL CORPS MEMORIAL // Statutory Address: IMPERIAL CAMEL CORPS MEMORIAL, VICTORIA EMBANKMENT GARDENS WC2

TQ 3080 NW CITY OF WESTMINSTER VICTORIA EMBANKMENT 72/148 GARDENS, WC2 Imperial Camel Corps 24.2.58 Memorial G.V. II .

Memorial. 1920 by Cecil Brown. Bronze statuette of figure mounted on camel set on Portland stone pedestal with bronze bas-relief.

Appendix C

Memorial to General Gordon, Brompton Barracks

Heritage Category: Listed Building // Grade: II* // List Entry Number: 1375610 // Date first listed: 07-Jul-1998 // List Entry Name: MEMORIAL TO GENERAL GORDON, BROMPTON BARRACKS // Statutory Address: MEMORIAL TO GENERAL GORDON, BROMPTON BARRACKS, PASLEY ROAD

TQ 7669 SW GILLINGHAM PASLEY ROAD (east side), Brompton 3/32 Memorial to General Gordon, Brompton Barracks GV II*

Equestrian statue. 1890. Bronze statue and Portland stone plinth. Moulded plinth, with a bronze cartouche, with a full-sized figure of General Gordon, d.1885, seated on a camel with tasselled saddle. Attached a well-cast and expressive figure with free-hanging tassels; placed symmetrically on the axis with the Institute, memorial arches and barracks (qqv).

Appendix D

Statue of General Gordon, Gordon's School

Heritage Category: Listed Building // Grade: II // List Entry Number: 1424607 // Date first listed: 29-Apr-2015 // List Entry Name: Statue of General Gordon, Gordon's School // Statutory Address: Gordons School, Bagshot Road, West End, Woking, GU24 9PT

Statue on plinth. A 1902 second casting of the sculptor Edward Onslow Ford's statue of General Gordon (first cast in 1890). The plinth is of circa 1959. Bronze statue on stone plinth. A thirteen feet high, bronze, full-sized statue of General Gordon in the uniform of an Egyptian general, seated on a tasselled saddle upon a standing camel. The base is inscribed 'GORDON' on the front and has a decoration of olive branches. The classical style rectangular stone plinth has recessed corner piers, a moulded cornice and base. An inscription on one side of the plinth reads 'THIS STATUE WAS ERECTED AT KHARTOUM/ IN 1904 AND PRESENTED TO/THE SCHOOL IN 1959.' An inscription on the base of the plinth records that the plinth was presented in memory of Major General Sir Hubert J Huddleston who served the Sudan for 23 years. The statue of General Gordon at Gordon's School by the sculptor Edward Onslow Ford RA, cast in 1902 with a 1959 plinth, is listed at Grade II for the following principal reasons: Aesthetic quality: a fine bronze sculpture by a reputable sculptor with the subject unusually mounted on a camel; Historic interest: General Gordon is a figure of national importance and this statue is located at the school founded in his memory; Group value: with other listed buildings and structures at the school.

Appendix E

Bench seats on Victoria Embankment

Heritage Category: Listed Building // Grade: II // List Entry Number: 1357348 // Date first listed: 01-Dec-1987 // List Entry Name: 21 BENCH SEATS SET ON EMBANKMENT PAVEMENT // Statutory Address: 21 BENCH SEATS SET ON EMBANKMENT PAVEMENT, VICTORIA EMBANKMENT SW1

TQ 3079 NW, 3080 SW and NE CITY OF WESTMINSTER VICTORIA EMBANKMENT, 3180 NW SW1 73/57;74/19;83/61;92/12 21 Bench Seats set on Embankment Pavement G.V. II Public seats. 1872-74 designed by Lewis and G F Vulliamy. Cast iron mounted and timber slatted. The seats take the form of long benches with curved backs supported on cast iron brackets, the terminal arm-brackets designed as winged sphinxes, with the exception of the bench opposite the junction with Horseguards Avenue which has the feature of seated camels instead of sphinxes. Included in their own right as original street furniture and as part of the Embankment design.

Appendix F

Library, Market Place, Camelford, Cornwall

Heritage Category: Listed Building // Grade: II // List Entry Number: 1138348 // Date first listed: 19-Jan-1952 // Date of most recent amendment 13-Jan-1988 // List Entry Name: LIBRARY // Statutory Address: LIBRARY, MARKET PLACE

CAMELFORD MARKET PLACE, Camelford SX 1083 - 1183 8/76 (1/3) Library (previously listed as Town Hall - 19.1.52) GV II. Townhall erected over market house, now library, exhibition hall and meeting room. 1806. Financed by John, 6th Duke of Bedford. Slate stone rubble with dressed quoins and dressed stone arches to window openings. Rag slate roof with hipped ends. Rectangular plan with internal partitions altered. Originally the market house on the ground floor with a central entrance on the front and the town hall above with a staircase to a doorway at the rear where the ground is at a higher level. Ground rises to left and to rear. 2 storeys. Symmetrical 3 window front faces onto Market Place; 5 semi-circular headed windows; the window frames replaced in circa mid C20, the central window in an earlier blocked door opening. First floor has 3 semi-circular windows with horned sashes with intersecting glazing bars. Lower side on right has a C20 glazed door with a Venetian window above, the central horned sash with intersecting glazing bars. The higher side on the left has a C20 door on the ground floor and a Venetian window above with stained glass window with Camelford arms. The wall above has been partly rebuilt. The rear elevation has 4 blocked round headed openings on the ground floor and a central double flight of steps which lead up to the first floor entrance with a C19 timber porch with flat roof and moulded cornice. 2 sash windows with round headed arches and intersecting glazing bars to right and left. Timber cupola on roof with clock and weather vane. This cupola originally had 2 bells dated 1807 and 1699. Interior : remodelled in circa mid C20. Bell from cupola in entrance inscribed 'W. Prideaux Mayor, 1699'. The Charter of Camelford was confirmed in 1259 and the rotten borough was created in 1552 to bolster the Earl of Northumberland's government. The rotten borough was abolished in 1831(Kelly's Directory, 1910. Polsue, J. Lake's Parochial History of the County of Cornwall 1872 Volume I).

16th ANNUAL SOUTHWEST CAMEL CONFERENCE AND TRAINING CLINIC AT LAS VEGAS

16th Annual Southwest Camel Conference and Training Clinic will be oragnised at Las Vegas, USA in partnership with North American Camel Ranch Owners Association (NACROA) from 25-27th October, 2024. The conference will involve guest speakers, training sessions and many aspects of camels. Various presentations in the conference would cover camel welfare, safe transport, international resources, general health assessments and advancing the camel science knowledge. The contact persons are Doug Baum (texascamelcorps@gmail.com) and Valeri Crenshaw (crenshawvaleri@ hotmail.com). Registration fee for NACROA members is $ 600 and for non-members it is $750. Camels may attend for free. Registration/payment will be open from August 1st to 1st October 2024.

BEYOND DESERTS AND HIGHLANDS- held at Vienna International Centre, Vienna, Austria on 10 June 2024

The Joint FAO/IAEA Centre organised an international on "Beyond Deserts and Highlands– Global Celebration of the International Year of Camelids 2024". It was in response to the growing global interest and the need for a collaborative platform that brings together experts, researchers, policymakers, and breeders to share knowledge, discuss challenges, and explore innovative solutions. The event aligned with the global agenda for promoting biodiversity conservation, given the unique ecological niches that camelids occupy. Recognising the potential of camelids in sustainable agriculture, ecotourism, and poverty alleviation, The event sought to foster international collaboration and partnerships that will contribute to the well-being of both camelid-dependent communities and the broader global population.

The objectives of the event were to facilitate the exchange of cutting-edge research, technological advancements, and best practices in camelid science, husbandry, and management, to provide a platform for participants to network with fellow researchers, breeders and policymakers, to share knowledge on various aspects of camelid husbandry, including genetics, nutrition, health, and socio-economic impacts and to raise awareness about the significance of camelids in diverse fields and advocate for their sustainable integration into global agricultural and economic systems. Keynote address by Dr B. Faye was in the field of camelid research and husbandry. Technical Sessions covered diverse topics such as genetics, nutrition, health, socio-economic aspects, and cultural significance of camelids. There were panel discussion on emerging challenges and opportunities in camelid management together with an exhibition.

CAMEL HIDES ARE SECOND ONLY TO CROCODILE HIDES

The camel industry is expected to become one of Saudi Arabia's foremost non-oil resources if it achieves its targets in accordance with the Kingdom's Vision 2030 plan. Currently, a company called Sawani, affiliated with the Public Investment Fund, focuses on investing in the transformative camel industry, including liquid and powdered camel milk. Their products have already been exported to over 25 countries worldwide. They have utilised camel milk in the production of "Camelicious" ice cream, available in eight flavours, as well as in the cosmetics industry. In addition to Sawani, the Saudi brand "Ibil" established in 2021, has been involved in manufacturing clothing, bags, and shoes using camel wool and hides. Their aim is to become a global brand within 15 years. It is a known fact that camel hides are durable and long-lasting, second only to crocodile hides. Even their bones are used in construction practices. The camel plays a key role in the Saudi tourism sector.

(Source: https://arab.news/222ke, January 2024)

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CAMELOLOGY : DEFINITIONS, HISTORY AND SCIENTIFIC CHALLENGES

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ABSTRACT

Since centuries, the camel is fascinating scientists over the world. If the first scientific investigations were focused on his remarkable adaptability to desert conditions and to his health management in the context of colonial expansion of European countries in desert areas, recent researches have mobilised several specific disciplines as archaeology, physiology, immunology, breeding and genetics, parasitology, surgery, imaging, diseases, food sciences, economy, or sociology. However, the camel can be regarded as a "full scientific object" legitimising the use of the word "camelology". Present paper is an overview of chronological development of camel cultures, production and science.

Key words: Adaptation, camel, science history, scientific approach

The concept of "camel science" or "camel research" is commonly used by the scientists working on camel as "object of study", but as researcher, they decline their speciality as parasitologist, or anatomist, or immunologist or those of other specialities. Moreover, in language other than English, the literal translation is usually not correct. In French for example, the translation of the sentence "I'm camel scientist" will mean "I am a scientist with a camel character". Unless you use a periphrasis ("I am a scientist studying camel"), your interlocutor will not understand you properly. It is the reason why the concept of "camelology" is better to be used. In French, the word "camelologie" was reported for the first time on the website https://camelides.cirad.fr in 2002 as a neologism regarding camel among other words as "camelodrome" or "cameliculture". Few times later, the word was discussed to be included in the dictionary of the French Academy. It was therefore, the humble reply was "I'm a camelologist" when people asked for our speciality.

The concept of camelology needs to be elaborated. If camelology is a discipline, we have to define the history and the field or scope of this science. The present paper is specially proposed for the international year of camelids (2024) and it aims to investigate the chronological development of camel culture and science from it's primitive form to a modern but updated format.

A brief history of the camelology in the world

• ***The pioneers***

Georges-Louis Leclerc, Count of Buffon, known usually under the single name of Buffon, a French aristocrat living in the XVIIIth century, was probably one of the first "naturalist" describing the camel in his book "Histoire Générale des animaux" (General history of the animals), written between 1753 and 1767. Dromedary and Camel (in fact Bactrian camel) anatomy, physiology, feeding behaviour, geographical distribution and utilisations were widely described with accuracy (Fig 1). It was the first scientific description of the large camelids since the succinct mentions of Aristote in his "history of animals" written in 343 BC (Gallimard Ed., Paris, 1994). There appears to be no specific mention of camel in the studies or publications of the most famous Arabic scholar during the middle age (except Ibn Al-'Awwâm, the master of Moorish Agronomy-Pereira, 2024) although it was mentioned several times in the Holy Koran.

In the XIXth century, Alexandre Vallon, a French veterinarian from the imperial School of Cavalry, published a book on the natural history of camel (Vallon, 1856). But, the first scientific investigations regarding camel could be dated to the colonial period, especially when the French and English troops were invading North Africa and Sahara from Mauritania to Somaliland, especially

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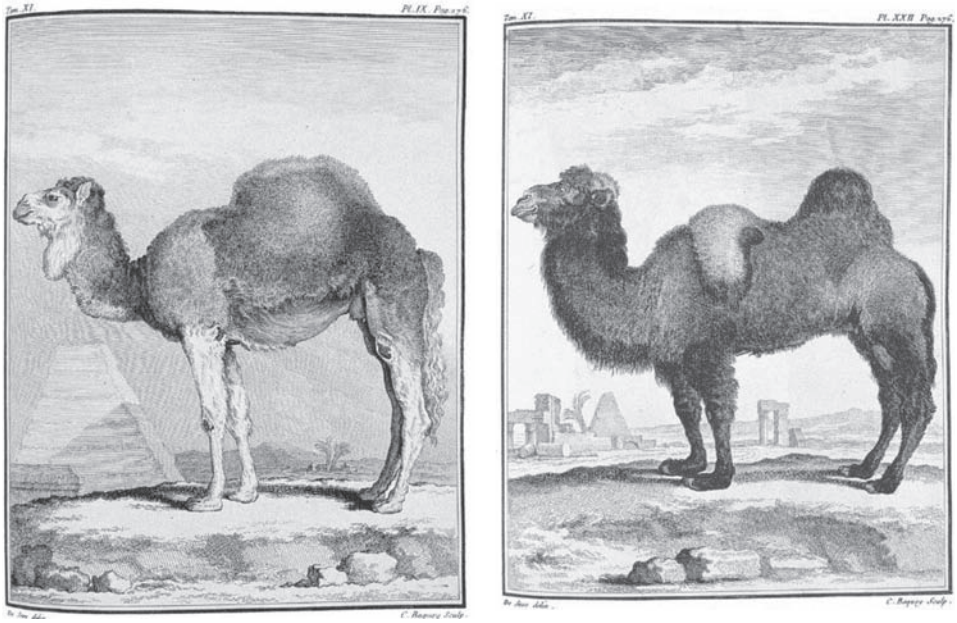

Fig 1. The "dromedary" and the "camel" (Bactrian) represented in the volume VI of the General history of the animals ("*les quadrupèdes*") written by Buffon in the XVIIIth century.

with the support of "Meharist companies" and other "camel corps" where military veterinarians played military and medical role.

Indeed, the first publications were mainly focused on camel diseases. Among the first books regarding camel, one could cite that of Cross (1917), a British vet serving as "camel specialist" to the Punjab Government, in India. Later, another British vet serving in India, then in Somaliland, Arnold Leese, was known for his wide experience regarding camel diseases and management, before known to be as a fascist activist. His book, "A Treatise on the Humped Camel" was published in 1927 (Leese, 1927), but previous papers were published in the Journal of Tropical Veterinary Science from 1909. The Italian military vets contributing to the colonial invasion of Libya and Somalia were not left out: Ivo Droandi who published many papers from 1920 in the Italian Colonial Institute of Agriculture (Florence) on camel surgery and diseases, published a book in 1936, after his experience in Libya. In France, the first military group using camel was created by Napoleon Bonaparte during the Egyptian campaign in 1799, but the "Meharist company" was established in 1902 in Sahara and some description regarding camel management were proposed by the vets accompanying the soldiers, as it was the case of the commandant Cauvet (Cauvet, 1925). However, the first comprehensive book regarding camel diseases was written by Gaston Curasson, a French general inspector of Veterinary Services in French colonies (Curasson, 1947). In the same period, some books focused on generalities regarding the life of camel were published, for example, in France (Finbert, 1938).

• ***The mysteries of the camel physiology***

After the second world war and before the independence of the colonies in the years 60, the first studies on camel were focused on the physiology of adaptation, notably the works of Knut Schmidt-Nielsen (Norwegian) and his wife Bodil (American scientist) who established the bases of the camel physiology, for example on water balance or urea excretion (Schmidt-Nielsen *et al,* 1956 and 1957). At the same time, Hilde Gauthier-Pilters started publications on camel ecology in 1958 and gathered all these observations in a book in 1981 (Gauthier-Pilters and Dagg, 1981). Physiological studies, especially regarding metabolism were continued by Emmanuel from the University of Shiraz, in Iran (Emmanuel, 1979). Renal function and physiology were later studied in details by Dr Reuven Yagil, Israel (Etzion and Yagil, 1986) and Dr N.Kataria from India (Kataria *et al,* 2002 a,b,c,d,e; 2003 and 2007). Physiology of forestomach of camelids was studied in detail by Engelhardt *et al* (1988). Physiology of racing camels was studied by Saltin and Rose (1994). More recently, "Camel Clinical Biochemistry and Haematology" was another important publication in 2018 by Bernard Faye and Mohammed Bengoumi. In Morocco, the University of Casablanca and Agro-veterinary Institute at Rabat, achieved many studies

in collaboration on water and mineral metabolism (Bengoumi *et al,* 1993; Riad *et al,* 1994). Later, the team of Casablanca University was renown for its work on camel stress (Lemrahmed *et al,* 2019).

- ***The emergence of the camelology in the southern countries: Research institutes, specialised journals and general books***

After most of independences following the colonial time, more and more scientist from southern countries, especially from Egypt, Sudan, India, Morocco started to publish papers on camel anatomy, physiology and diseases. Some institutions began to be recognised for their research activities on camel, i.e. College of Veterinary and Animal Science, Bikaner and the National Camel Research Centre (NRCC), Bikaner, India, University of Alexandria and the Desert Research Centre (DTC) in Egypt and University of Khartoum in Sudan, Agro-veterinary Institute (IAV) in Morocco and later the Institute of Arid Lands (IRA) in Tunisia. Meanwhile, the Central Veterinary Research Laboratory (CVRL) was founded in 1985 by HH Sheikh Mohammed Bin Rashid Al-Maktoum, Vice President and Prime Minister of the UAE and it was a Government diagnostic centre that provided testing and research facilities on camels and other animals including falcons and raptors, to the UAE and neighbouring countries. CVRL is the OIE Reference laboratory for Glanders, Camel Pox, Brucellosis (*Brucella abortus, B. melitensis, B. canis*) and MERS (Middle East Respiratory Syndrome).As Scientific Director of CVRL, Dr. Wernery leads to his disease diagnosis research in camels among other species. He and the CVRL team pride themselves on being at the forefront of camel research worldwide, especially in veterinary field. In the year 2000, the World Animal Health Organisation (OIE) in Paris, decided to create a camel disease ad-hoc group gathering some camel experts in order to define the list of infectious diseases, their convenient diagnosis tools and the list of references labs throughout the world. Dr Wernery with the authors of the present paper were among the first experts contributing to this group.

The Camel Applied Research and Development Network (CARDN) was created at Damascus (Syria) in 1991 under the umbrella of the Arab Centre for the studies of Arid Zones and Drylands (ACSAD), publishing a Camel Newsletter, then the first specific journal devoted to camel, the Journal of Camel Sciences (Wardeh, 1986) which unfortunately was stopped after few issues. In India, a book on Camels and their Management was published in 1986 by Rathore (Rathore, 1986). The book "The Camel" authored by R. Trevor Wilson in UK (Wilson, 1984) was published as an important reference book. In 1984, too, the British Veterinary Journal also published a series of papers on Camel in Health and Disease (Higgins and Kock, 1984). In 1986, another book on camel in health and disease was authored by Higgins (1986). Then, Camel Publishing House at Bikaner (India) started publishing the Journal of Camel Practice and Research since 1994 as biannual but later in 2017, it became a triannual journal (Gahlot, 1994). In the year 2000 onwards, "The Camelid Publishers" brought out 3 important publications edited by T.K. Gahlot from India (Gahlot, 2000, 2004 and Gahlot *et al,* 2002). Compilations of the papers published in the Journal of Camel Practice and Research in the field of parasitology (Gahlot and Chhabra, 2009), gross anatomy and histology (Gahlot *et al,* 2011) and immunology (Gahlot *et al,* 2016) were proposed by Camel Publishing House. In Israel, Yagil and his team from University of Negev published many papers on physiology of adaptation and contributed also by a book on camel physiology (Yagil, 1985) to advance the knowledge of the camel. In Soviet Union also, camel sciences were implemented, especially in genetic and milk production and many books were published in Russian language (Terentyev, 1975). Few books on camel surgery were also published (Gahlot and Chouhan, 1992; Ramadan, 1994; Siddiqui and Telfah, 2010).

Scientists from the French speaking countries in Africa also started to publish the papers on camel science in the Revue d'Elevage et de Médecine Vétérinaire des pays Tropicaux (REMVT) which was integrated to CIRAD in 1996 where the coordination unit on camel breeding (UCEC in French) was created. A first comprehensive book was edited by Richard in 1984 (Hoste *et al,* 1984) and a special issue of REMVT was published in 1989 ("Le dromadaire", n°1, 1989). Then, Faye and other contributors participated to one book as support for new line of veterinary medicine proposed by SANOFI © ("Guide l'élevage du dromadaire", 1997), available also in Arabic. In Germany, in 1992, the book was published on the "One-Humped Camel In East-Africa" (Schwartz and Dioli, 1992) and in Pakistan, another book was edited (Chaudhary and Akbar, 2000). From this period, many books were published in local languages in Mongolia (Indra *et al,* 2003; Adams, 2024), China (Zhao Xin Xu, 1996), Kazakhstan (Moussaiev *et al,*

2007) and Germany (Weiss and Wernery, 2021). Recently, the French general book "Elevage des grands camélidés" (Faye *et al,* 2022) was translated in Turkish, Arabic, Spanish, Kazakh and English (Faye *et al,* 2023).

• ***The camel conferences***

During the post-independence period, there were few camel conferences. These were held in the year 1970-90s in Khartoum (Sudan), Tobruk (Libya) and later in Paris (France) on the reproduction (1990) and in Nouakchott (Mauritania) on camel milk (1994) by UCEC (Saint-Martin, 1993; Bonnet, 1998), Israel (1996), Al-Ain (1998), Algeria (1989) and Kazakhstan (2000). However, one of the first important organised camel conference was at Dubai in 1992, concomitant with emergence of advanced research in the Gulf countries on the physiology of racing camel (Saltin and Rose, 1994), biotechnology of reproduction (Tibary and Anouassi, 1997) and camel diseases (Wernery and Kaaden, 1995).

In some cases, more specialised workshops were organised. For example in Morocco (1999) on the young camel and in 2000 on camel diseases (Dakkak, 2000), in Niger (2003) on camel milk in Africa organised by FAO (Lhoste, 2003), in Turkmenistan in 2004 on the role of camel in desertification combat (Faye and Esenov, 2005). Other conferences were organised in UAE (1991), India (2004 and 2007), Saudi Arabia (2007), Kenya (2010) and many others that we cannot cite all these here. The proceedings of those conferences have significantly added to the camelid literature.

In 2006, four camel scientists (B. Faye, M. Bengoumi, K. Alhadrami, A. Tibary) created the International Society of Camelid Research and Development (ISOCARD) with the objective to gather all the camelid scientists (camelologists) of the world in triennial international conferences. Nowadays, 6 conferences were organised, i.e. in 2006 (Al-Ain-UAE), 2009 (Djerba-Tunisia), 2012 (Muscat, Oman), 2015 (Almaty, Kazakhstan), 2018 (Laayoune, Morocco) and 2023 (Al-Ahsa, KSA). The Society also published an on-line journal (Journal of Camelids Sciences) available on line on the website of the society. Some of the proceedings of the ISOCARD conferences are also available on the website (Johnson *et al,* 2012; Konuspayeva, 2015; Sghiri and Kichou, 2018).

Some advanced camel researches

It is not possible to be exhaustive and obviously, some important topics regarding camelology are not mentioned in detail here. The authors assume that the selected topic below are subjective.

• ***Immunology***

Camel immunology has experienced important progress (Hussen and Schuberth, 2021), One of the most remarkable features of the camelid family is their unique immune system. A break-through in the camelid humoral immune system was achieved by Hamers-Casterman *et al* in 1993, who showed that the camel possesses novel class single-domain antigen binding fragments. These proteins are the naturally occurring antigen-binding domains known today as VHHs (single variable heavy-chain) or nanobodies. These nanobodies are very small and possess several bio-physical properties, that offer great advantages in various medical and biotechnological applications (Muyldermans and Lauwereys, 1999), including cancer treatment (Al-Numair *et al,* 2022), producing hyperimmune serum against snake bites and more (Tanwar *et al,* 2017). These extra ordinary camelid nanobody particularities were shown in a recent documentary by Marc Jampolsky film, DW documentary. A.K. Kataria and co-researchers from India carried out important research and studies on dromedary immunoglobulins (Kataria *et al,* 1994, 1999, 2002; Kataria, 2001; Kataria and Sharma, 1999, 2000, 2003; Kataria and Kataria, 2004).

Genetics and genomics

Since the years 2000, important advanced researches were performed on genetics and genomics (Burger *et al,* 2019) allowing new knowledge regarding camel biodiversity (Gaouar and Ciani, 2023), history of domestication (Almathen *et al,* 2014) or selection (Al-Abri and Faye, 2019). Scientists from Riyadh's King Abdulaziz City for Science and Technology and China's Shenzhen-based BGI (formerly the Beijing Genomics Institute) were able to decode the entire genetic makeup of the single-humped camel (*Camelus dromedarius*), thus the Arabian camel today enters a highly exclusive club of selected few mammals which have had their full genome sequenced and analysed. Genomic sequencing and analysis of eight camel-derived middle east respiratory syndrome coronavirus (MERS-CoV) isolates was done in Saudi Arabia (Al-Shomrani *et al,* 2020). Chinese scientists found origin and migration of domestic and wild Bactrian camels through genome sequencing (Jirimutu *et al,* 2012; Ming *et al,* 2020). The preservation of the camel biodiversity as an important element of the sustainable development, especially among

pastoralists is also recommended in several research papers (Kohler-Rollefson, 2022 and 2023).

• ***Camel milk and meat studies***

Considerable progress was done in the knowledge of camel milk gross composition and fine composition of camel milk since the pioneer work of Farah (1993). A first book on milk and meat composition and processing milk was published in 2004 by Farah and Fisher. The first meta-analyse of camel milk composition was proposed by Konuspayeva *et al* (2009). The fine composition was explored by many scientists emphasising the particularities of camel milk (El-Agamy, 2017). Based on the research of Kappeler *et al,* on the camel chymosin structure in 2006, significant progress were done on the camel cheese making (Konuspayeva *et al*, 2017) and knowledge of milk microflora (Kaindi and Njage, 2020) With the emergence of the camel milk industry, especially in the Gulf countries and Central Asia, notably the establishment of Emirates Industry For Camel Milk & Products (EICMP) in the year 2006, camel milk products appeared on the market (including at international level thanks to the EU agreement) under more diversified form (Konuspayeva and Faye, 2021). The implementation of big camel dairy farms as Camelicious (EICMP) gathering thousands camel under similar environment has boosted original research on camel milk production, milk microbiology and milking management (for example, Nagy *et al,* 2013a and 2015). Intensification of the camel milk production (Nagy *et al,* 2022) by using machine milking has also boosted research on the physiology of lactation (Ayadi *et al,* 2016) and adaptation of camel to machine milking (Atigui *et al,* 2014; Nagy and Juhasz, 2016; Kaskous, 2023). The health effect linked to the regular consumption of camel milk was explored by many camel scientists with variable scientific rigour as mentioned in the recent review of Faye and Konuspayeva (2024). The impact on human diseases as autism (Adams, 2019; Gahlot and Adams, 2023), diabetes (Ashraf *et al,* 2021; Alkhurd *et al,* 2022), Crohn's disease (Rosenheck *et al,* 2012) or even some cancers (Badawy *et al,* 2021; Lal *et al,* 2023) are among the numerous recent *in vitro* and *in vivo* investigations. In addition, the interest of health effect of camel products was extended to the camel urine. Its potential anticancer, antiplatelet, gastroprotective and hepatoprotective effects were explored by different scientists in the world (Salamt *et al,* 2021). A synthetic book on the health and environmental benefits of camel products in general was published in 2020 (Alhaj *et al,* 2020).

Camel meat studies have shown recent interest due to its dietetic properties (Raiymbek *et al,* 2015 and 2018). Meat studies included research on the meat composition (Kadim *et al,* 2008), meat processing (Baba *et al,* 2021), slaughtering conditions (Moussahil *et al,* 2022) and even the health benefit of its consumption (Kadim *et al,* 2022). A synthetic book was published in 2013 (Kadim *et al,* 2013) gathering all aspects of camel meat industry, from the production to the consumption.

• ***Biotechnology of reproduction and cloning***

Since the first conference on camel reproduction, held in Paris and cited above, many advanced researches were achieved especially in the Gulf countries (Skidmore *et al,* 2024), India (Purohit *et al,* 2023) or Egypt (El-Bahrawy *et al,* 2015). Artificial insemination and overall embryo-transfer are nowadays used routinely in intensive big farms (Nagy *et al,* 2013b). World's first cloned camel named "Injaz" was produced in year 2009 (Wani *et al,* 2010). A first report on interspecies embryo transfer which gave birth to Bactrain camel calves from dromedary camels, was published by the scientists of Iran (Niasari-Naslaji *et al,* 2009). Dozens of cloned dromedary camels have been produced from the embryos reconstructed with cells from racing champions, winners of beauty contestants, high milk yielders and elite bulls (Wani, 2021). The first cloned Bactrian camel calf was produced by interspecies SCNT using dromedary camel as a source for oocytes as well as a surrogate for carrying the pregnancy to term (Wani *et al,* 2017). Multiple cloned camels from racing, show and dairy exemplars were produced in a recent research (Olsson *et al,* 2021).

• ***Camel health and welfare***

Health is one of the most important constraints in camel farming, both in traditional production and intensive system. Thus, it is not surprising to see that veterinary science was the most cited topic in the scientific literature devoted to camel as mentioned in the different scientometric studies assessing the number of publications, the different topics and the main journals, authors or institutions contributing to the camel sciences (Faye *et al,* 2000; Rathinasabapathy and Rajendran, 2013; Gupta *et al,* 2015; Kandeel *et al,* 2023). Several books or review papers are nowadays available for giving comprehensive information on infectious diseases (Wernery and Kaaden, 1995; Werney *et al,* 2014), zoonotic diseases (Khalafalla, 2023) and even global health disorders affecting camels notably in traditional farming systems

(Kohler-Rollefson *et al,* 2001). The emergence of MERS-CoV in Middle East and the role of dromedary camel in the disease transmission has stimulated an important volume of research on virology and epidemiology (Ngere *et al,* 2020; Azhar *et al,* 2023). Few studies based on ecopathological approach of multifactorial diseases as calf diarrhoea were achieved (Bengoumi *et al,* 2003).

Camel welfare is an important emerging topic, formerly focused on the assessment of the stress in different conditions (dehydration, heat stroke, transport, slaughtering…) and nowadays, more and more is focussed on good management practices and globally good farming conditions for the camel (Menchetii *et al,* 2021). Recently, a book was gathering the knowledge regarding this topic including health management, environmental conditions, handling and assessment of behaviour (Padalino and Faye, 2024).

Camel celebrations

World Camel Day is celebrated on 22nd June in many countries to raise awareness about camels and their importance to human societies and ecosystems and to celebrate these unique creatures. United Nations has declared the year 2024 as International Year of Camelids. Several organisations are celebrating it in form of meetings, workshop or conferences as LPPS (Lokhit Pashu Palak Sansthan) in India; CAMENET (Middle East Camel Network); NACROA (North America Camel Ranch Owner Association), IAEA (International Atomic Energy Agency) in Austria, many universities throughout the world (Algeria, Morocco, Tunisia, Saudi Arabia, UAE, Kowait…) and of course, FAO.

The camelology, a science?

In a world where disciplinary approaches are no longer enough to understand complexity, considering a livestock species such as the camel, in all its dimensions (from the cell functioning to the farming system or desert ecosystem, passing by metabolic functions and behaviour, diseases and cognition) can be considered a scientific challenge by itself. In this context, the camel is not only an animal, but an object of study that responds to 3 levels of investigation: (i) the camel as biological model, notably for medicine and adaptative studies, (ii) the camel as productive animal in desert areas or in intensive farms for providing milk, meat and other services for humanity and (iii) the camel as an element of complex desert ecosystem in relationships with changing environment, economic challenges and human or pastoral society (Faye and Brey, 2005; Kohler-Rollefson, 2023 and Rollefson, 2004). Considering camel from such angle, the camelology faces to different challenges that can be summarised into few non-comprehensive topics as:

- To deepen the mechanisms explaining the health effect of camel milk and meat consumption
- To achieve convenient clinical trials to support the health claim of the consumption of camel products
- To implement efficient systems of selection and of feeding for improving the camel productivity (production, reproduction) in the frame of the specialisation of the farming systems
- To increase the studies for allowing sustainable development of more intensive camel systems by respecting animal welfare and health
- To investigate the multifactorial diseases by using more holistic approach and identifying the individual and environmental risk factors
- To understand and characterise the role of camel extensive systems in the desertification combat
- To evaluate the place of camel in the micro-meso- and macro-economy worldwide

And many other topics…

Conclusion

The camel, irremediably linked to arid ecosystems, has a specific physiology and metabolism allowing its adaptation, but this desert animal is also fundamentally an element of the economy in those ecosystems and of the local culture. Moreover, it allows adding zootechnical value for people, pastoralists or settlers, living in such harsh environment. Another very important fact should be highlighted that the ship of the desert is an environmentally friendly species unlike bovines, sheep and especially goats. Reducing camel numbers on open-range land could redress desertification by allowing vegetation to recover from overgrazing. Prototype camel farming should encourage owners, to move most of their camels from open range into intensive farming. Initiating camel farms, where camels are fed on native deserts or salt-tolerant plants may help further the restoration of the ecosystem (Breulmann *et al,* 2007; Kohler-Rollefson, 2023). Like

"eremology", the science of desert (Heuse, 1992), the camelology can consider the camel as a "full scientific object". The camel scientists should go beyond their specific disciplines for a better understanding of the camel in his all dimensions.

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THE TRENDS OF CAMEL RESEARCH IN NORTH AMERICA: A BIBLIOMETRIC APPROACH

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ABSTRACT

Camels are witnessing global attraction even in countries outside the natural camel habitat. This study aims to provide a comprehensive bibliometric analysis of camel research in North America, identifying key trends, influential contributors, and collaborative networks. Data was sourced from the Scopus database, yielding 786 papers on camel research affiliated with institutions in the United States and Canada. Bibliometric tools such as VOSviewer and R Studio's Bibliometrix package were used to visualise and analyse the data. The bibliometric analysis of camel research in North America highlights substantial collaborative efforts between the North American countries and international partners. The data spans 493 sources, with an annual growth rate of 1.89%. The research involves 3127 authors and a notable international co-authorship rate of 52.04%. Camel research in North America spans multiple disciplines, including Agricultural and Biological Sciences, Medicine and Veterinary Sciences, Chemistry, Genetics and Molecular Biology, Immunology and Microbiology, Environmental Science, Engineering, and Social Sciences. This interdisciplinary approach underscores the broad impact and significance of camel studies. The international partnerships have facilitated significant advancements in understanding zoonotic diseases, genetic diversity, and the nutritional benefits of camel milk, underscoring the importance of maintaining robust international research networks to enhance the quality and impact of camel studies. This bibliometric analysis highlights the growing significance of camel research in North America, with strong international collaborations driving advancements. However, gaps remain in integrating advanced technologies and exploring socio-economic impacts in non-traditional regions. Continued investment and international collaboration are essential to address these gaps and drive innovative research initiatives.

Key words: Bibliometric analysis, camel research, interdisciplinary collaboration, North America, publication trends

Camel research holds substantial importance due to the unique characteristics and vital roles camels play in arid and semi-arid regions (Adah *et al,* 2023). Camels are renowned for their exceptional adaptability to harsh environments, making them invaluable for sustaining livelihoods in regions where other livestock might not thrive (Sahoo, 2020). They provide essential resources such as milk, meat, and transportation, and their resilience against extreme temperatures and water scarcity positions them as key assets in the face of climate change (George, 2024). Moreover, camels have unique physiological and genetic traits that offer significant insights into medical and biological sciences, contributing to advancements in understanding disease resistance, metabolic processes, and potential biomedical applications (Hedayat-Evrigh *et al,* 2020; Ming *et al,* 2020).

Recently, we provided a bibliometric analysis of camel research, which showed increasing global attention (Kandeel *et al,* 2023). This surge in interest can be attributed to a growing recognition of camels' ecological and economic significance, as well as their potential contributions to global health and scientific knowledge. Researchers in the United States and Canada have been particularly active in studying various aspects of camel biology, health, and management (Camel sciences and economy in the world: current situation and perspectives). The collaborative efforts between North American institutions and international partners have led to significant advancements in understanding camels' role in zoonotic diseases, genetic diversity, and the nutritional benefits of camel milk.

The primary objectives of this study are to provide a comprehensive bibliometric analysis of camel research in North America, identifying key trends, influential contributors, and collaborative networks. By analysing a robust dataset sourced from the Scopus database, this study aims to map the evolution of camel research over time, highlighting

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significant periods of growth and identifying the most productive researchers and institutions. Additionally, this study seeks to elucidate the interdisciplinary nature of camel research, exploring how collaborations between North American and international researchers have contributed to the advancement of this field. Furthermore, this study intends to show the global relevance of camel research and its implications for various scientific and practical domains. By identifying gaps in the existing literature and highlighting emerging trends, this study aims to foster stronger international collaborations and drive innovative research initiatives.

Materials and Methods

Data Source and search strategy

The data was sourced from the Scopus database using a targeted search query: TITLE (camel) AND (LIMIT-TO (AFFILCOUNTRY , "United States") OR LIMIT-TO (AFFILCOUNTRY , "Canada")). This search yielded a total of 786 papers. The data extraction process involved gathering essential bibliographic details for each paper, including the title, authors, abstract, keywords, publication year, source (journal or conference), document type, and subject area.

Inclusion and exclusion criteria

The inclusion criteria for the bibliometric analysis on camel research in North America were established to ensure the relevance and quality of the data collected. Studies were included if they were indexed in the Scopus database, focused on camel research, and affiliated with institutions in the United States or Canada. The search was conducted using a specific query that targeted articles with the term "camel" in the title and limited the results to those affiliated with North American countries. Additionally, only peer-reviewed articles, reviews, conference papers, letters, book chapters, notes, and short surveys were considered to provide a comprehensive overview of the scholarly contributions in this field. Exclusion criteria were applied to maintain the dataset's integrity and relevance. Duplicate records were checked to avoid redundancy, and erratum records were excluded to focus on original research contributions.

Data Cleaning and Preprocessing

The data from Scopus database were exported in CSV file. The data were cleaned and pre-processed to remove duplicates and irrelevant records.

Bibliometric analysis

The bibliometric analyses were conducted using two primary tools: VOSviewer and R Studio with the Bibliometrix package (Aria and Cuccurullo 2017; Arruda *et al,* 2022; Wong 2018). VOSviewer was employed for constructing and visualising bibliometric networks, such as co-authorship, and keywords networks.

Publication Trends Analysis

Trends over time were examined to comprehend the expansion of research in this area, focusing on annual publication numbers, the most productive authors, and significant papers. Descriptive statistics were computed to give an overview of the dataset, covering the distribution of papers by year, document type, and subject matter.

Results and Discussion

Dataset characteristics

The dataset comprises 786 articles, each detailing various aspects of scholarly articles indexed in Scopus. The data includes 1) the authors information, such as their names, full names, and unique ID. Additionally, the dataset captures the titles of the articles, providing a quick reference to the subject matter of each entry. 2) Bibliographic details of the articles, including the year of publication, the source title (journal or conference name), volume, and issue numbers.

The provided PRISMA flow diagram presents a systematic approach to the bibliometric analysis of camel research trends in North America (Fig 1). The screening process, dated June 10th, 2024, identified a total of 786 records, 784 of which were deemed suitable for inclusion in the bibliometric analysis after confirming there were no duplicates, and 2 erratum records were removed.

Document Types

The bar chart illustrates the distribution of various document types included in the bibliometric analysis of camel research in North America (Fig 2). The data shows that out of the 784 total records, the majority are research articles (634), followed by review papers (41), conference papers (36), letters (22), book chapters (20), notes (17), editorials (11), and short surveys (3). The x-axis of the bar chart represents the number of documents, while the y-axis lists the different types of articles. This representation underscores the predominance of primary research articles in the field and highlights

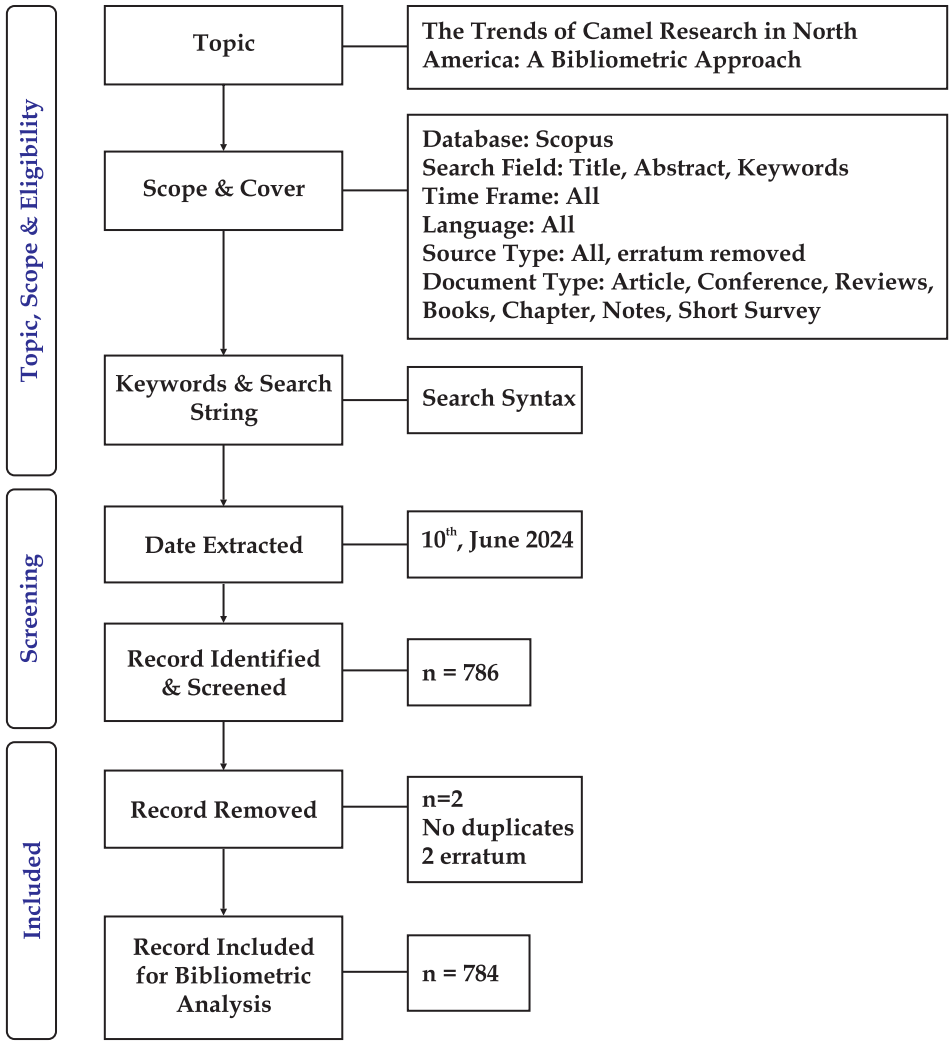

Fig 1. PRISMA flowchart for the bibliometric analysis on trends of camel research in North America.

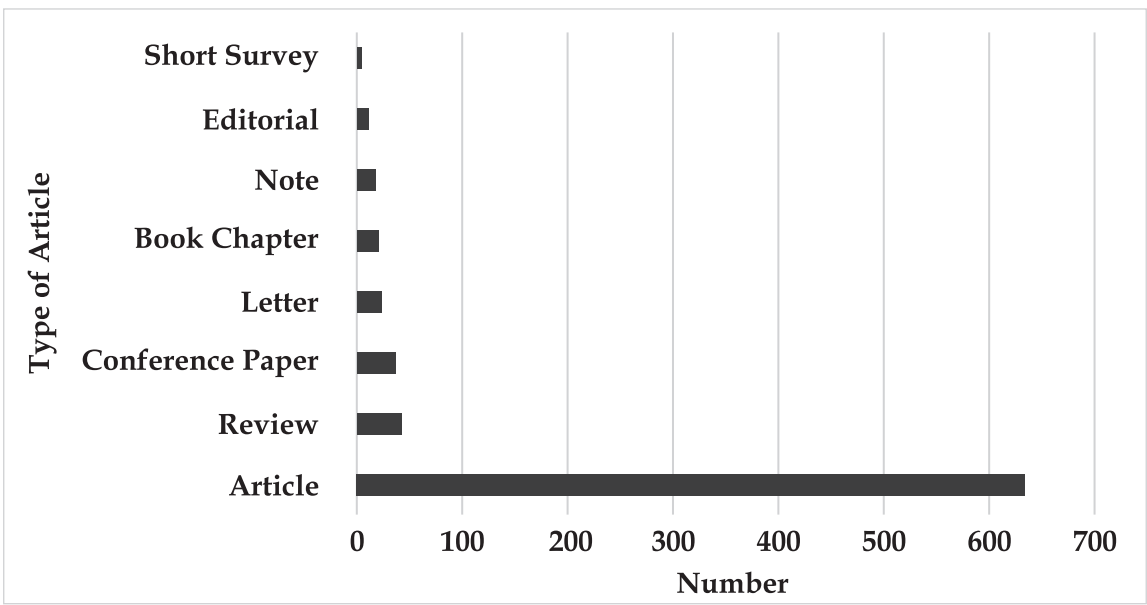

Fig 2. Distribution of document types in camel research in North America.

the diverse mediums through which camel research is communicated.

Publication Trend

The trends in camel research publications in North America can be delineated into three distinct phases based on the graph provided (Fig 3). The first phase, spanning from 1859 to the mid-20th century, is characterised by a sparse and inconsistent publication output. During this period, the number of publications remained very low, often with multiple years passing without any new articles. This phase reflects the nascent stage of camel research in North America, where interest and resources dedicated to this field were minimal. The sporadic publications during this time may have been driven by isolated scientific inquiries or specific historical events that briefly captured academic interest.

The second phase, from the mid-20th century to 2008, marks a period of gradual growth and increased consistency in camel research publications. Starting around the 1960s, there is a noticeable, albeit slow, rise in the number of publications. This phase is indicative of a growing but still limited interest in camel research, possibly fuelled by expanding academic institutions and a broader recognition of the ecological and economic importance of camels. During this period, the research output began to stabilize, with a small but steady stream of publications each year, setting the stage for more significant developments in the subsequent phase.

The third phase, from 2009 to 2024, is characterised by a sharp and sustained increase in the number of camel research publications. The data showed a clear upward trend, with the number of publications accelerating rapidly, peaking in recent years, particularly in 2021-2023. This explosive growth can be attributed to that camel studies have become a well-established and actively pursued area of scientific inquiry in North America.

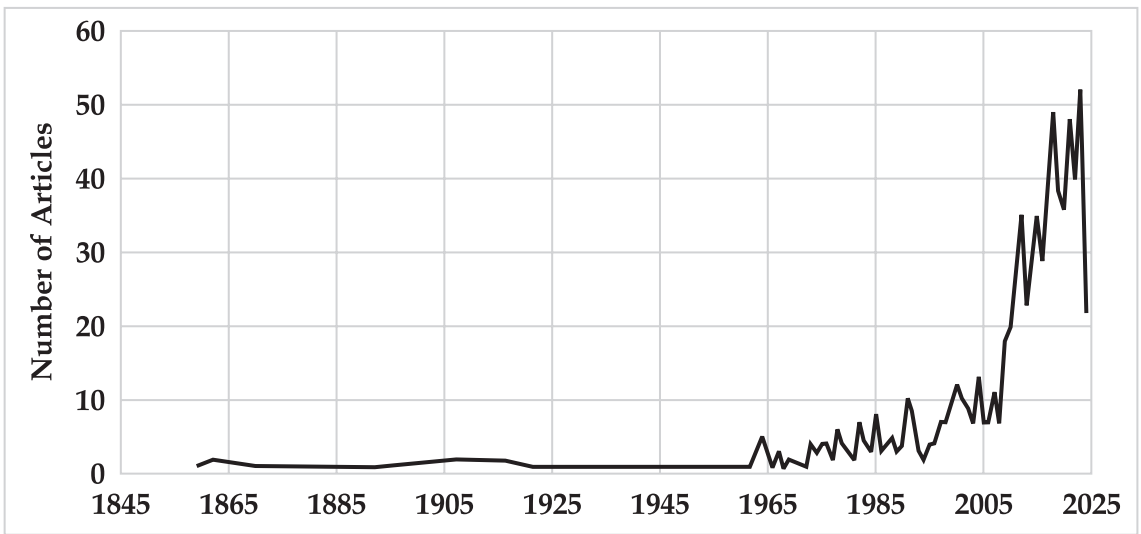

Fig 3. The Trend of publications in camel research in North America.

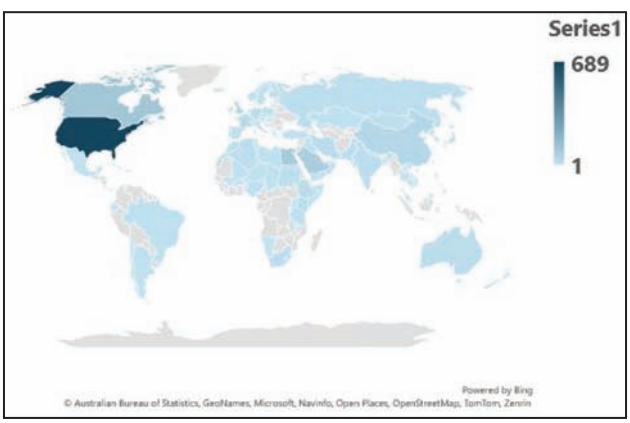

Fig 4. Geographic distribution of camel research publications in North America and in collaboration with other countries. The intensity of the colour shading indicates the number of publications, ranging from 1 to 689.

International collaboration

The geographic distribution of camel research publications from North America, with a focus on collaborative work with other countries, reveals significant trends in academic contributions (Fig 4). The United States leads by a substantial margin, producing 689 publications. Canada, with 112 publications, also shows a strong research presence.

The collaborative nature of camel research is evident from the involvement of several countries. Egypt (94 publications) and Saudi Arabia (83

publications) are notable partners. These countries' high publication numbers highlight the importance of collaborative research efforts. The United Kingdom (51 publications) and the United Arab Emirates (46 publications) also have significant academic output, indicating strong international partnerships with North American researchers.

Other countries such as China (40 publications), France (29 publications), Germany (24 publications), and Jordan (23 publications) contributed to the global research landscape through collaborations. These numbers reflect diverse research interests and the importance of international collaborations in advancing camel research. The involvement of countries like Kenya (20 publications) and Ethiopia (18 publications) in Africa underscores the collaborative efforts to address region-specific challenges and leverage local expertise. The widespread distribution of collaborative publications across various countries demonstrates a global recognition of the importance of camel research, with contributions spanning from North America to Europe, Asia, and Africa.

Active institutions

The bar chart in Fig 5 shows the number of camel research publications produced by various institutions in North America and their collaborations with other countries. The Fig was set to display affiliations with 10 or more publications. The x-axis represents the number of publications, while the y-axis lists the institutions involved. The data highlights the significant contributions of multiple institutions from Asia and Africa implying the predominance of collaboration research.

King Saud University stands out with the highest number of publications, indicating its leading role in camel research, likely due to its geographical and cultural proximity to camel populations. This prominence is followed by Columbia University, and the Centers for Disease Control and Prevention (CDC). These institutions are known for their strong research programs and resources, which likely facilitate extensive studies and collaborations.

Other notable institutions include Washington State University Pullman, the University of South Florida, and the University of Florida, all of which have made significant contributions to the field. The presence of international institutions like Cairo University, Suez Canal University, and the United Arab Emirates University highlights the collaborative nature of camel research, emphasising the global effort to advance knowledge in this area. The diverse range of institutions, including veterinary schools, universities, research centers, and specialized institutes, underscores the interdisciplinary and collaborative approach required to address the complexities of camel research.

The most active funding agents

The bar chart in Fig 6 illustrates the contributions of top funding agencies to camel research projects, highlighting those with five or more funded projects. The x-axis represents the number of funded projects, while the y-axis lists the funding agencies involved.

The National Institutes of Health (NIH) stands out as the most prominent funding agency, supporting the highest number of projects, with a total of 37. This highlights the NIH's commitment to diverse research areas, including camel studies, which may intersect with broader health and biomedical research interests. The National Science Foundation (NSF) follows closely with 32 funded projects, reflecting its role in promoting scientific research and education across various disciplines, including the biological and environmental sciences related to camels.

Other notable funding agencies include the National Institute of Allergy and Infectious Diseases (NIAID) and the National Cancer Institute (NCI), each supporting 27 and 14 projects respectively. The National Natural Science Foundation of China (NSFC) and the U.S. Department of Health and Human Services (HHS) also contribute significantly, with 13 and 12 projects funded, respectively, showing international and interdisciplinary support for camel research. Additional key funding sources include the Biotechnology and Biological Sciences Research Council (BBSRC) with 9 projects, King Abdulaziz City for Science and Technology (KACST) with 9 projects.

The top publishing journals

The analysis of journals publishing camel research reveals a diverse and interdisciplinary landscape, underscoring the multifaceted nature of this field (Fig 7). The Journal of Camel Practice and Research leads with 20 publications, highlighting its specialisation and central role in disseminating camel-specific studies. This journal serves as a dedicated platform for researchers focusing on various aspects of camel biology, health, and management, reflecting its importance in the academic community dedicated to camel studies.

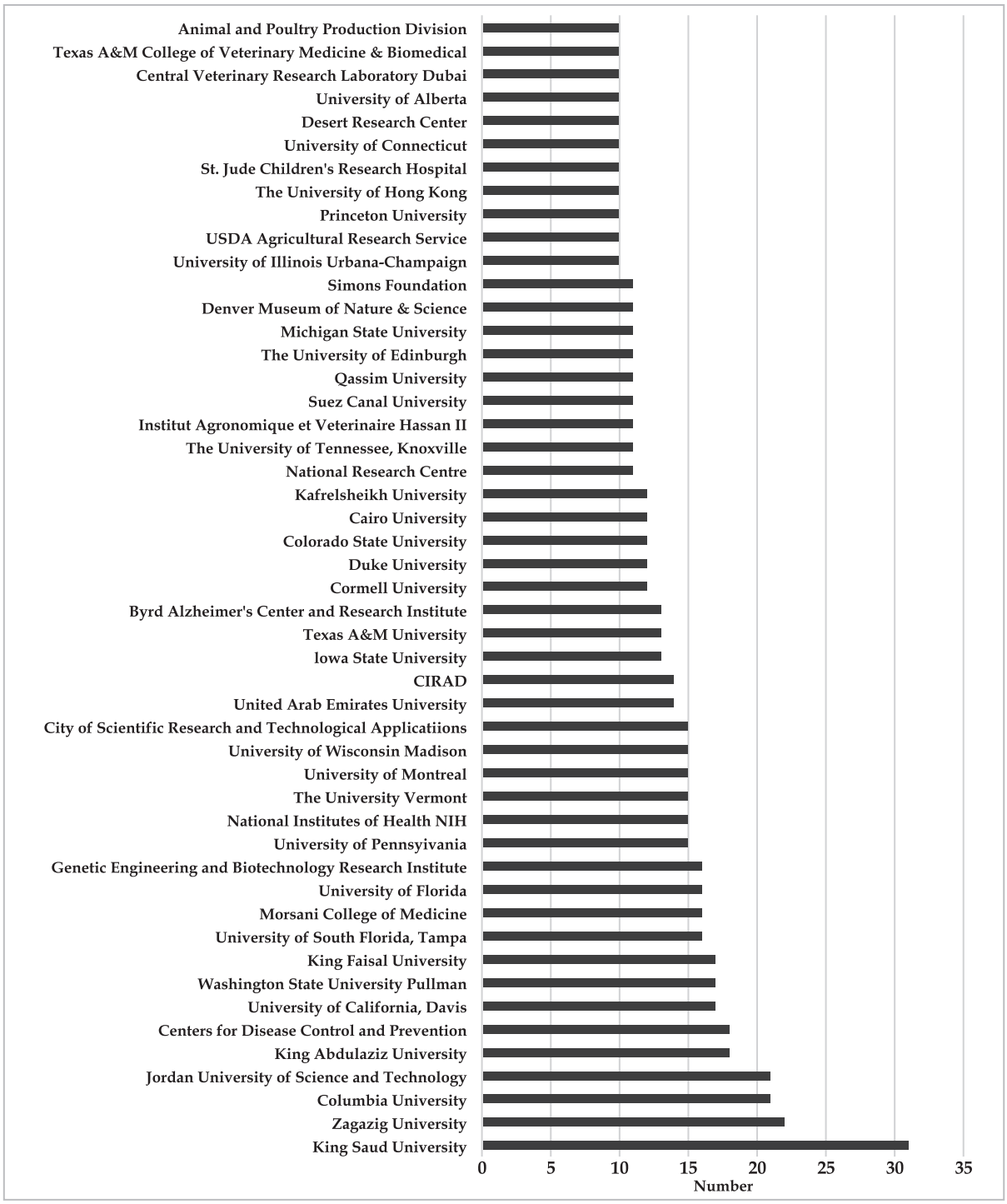

Fig 5. Active institutions of camel research publications in North America and in collaboration with other countries. The listed affiliations include only those having 10 or more publications.

Veterinary and health-related journals also play a crucial role in camel research. The Journal of the American Veterinary Medical Association and Emerging Infectious Diseases have published 11 and 10 articles, respectively, indicating a strong interest in the veterinary and zoonotic disease aspects of camel research.

The diversity of journals, such as Animal Reproduction Science, Journal of Dairy Science, and PLOS ONE, which have each published multiple camel research articles, reflects the wide-ranging applications and interests in camel studies. From reproductive science and dairy production to general scientific inquiries and public health implications,

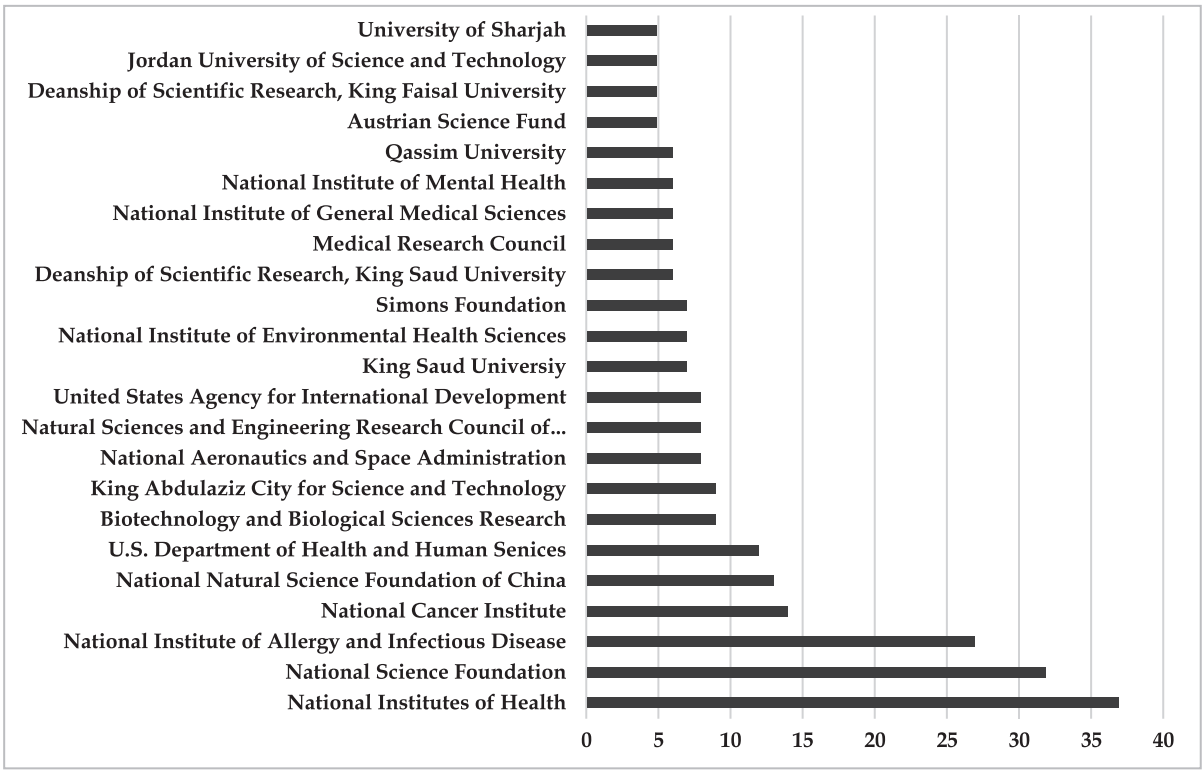

Fig 6. Funding agencies with five or more camel research projects.

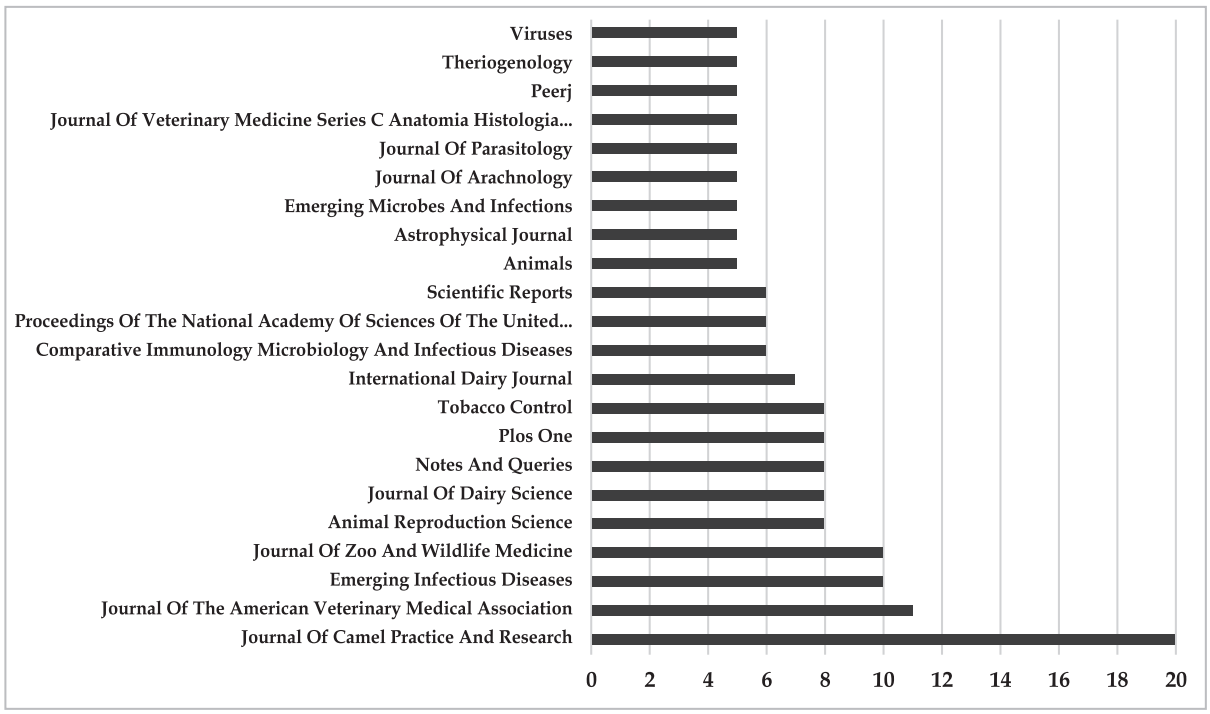

Fig 7. Journals with five or more camel research publications.

these journals show the interdisciplinary nature of camel research.

Academic disciplines

The bar chart in Fig 8 illustrates the distribution of camel research publications across a wide range of academic disciplines. The x-axis represents the number of publications, while the y-axis lists the academic fields. This distribution highlights the interdisciplinary nature of camel research and its relevance across multiple domains.

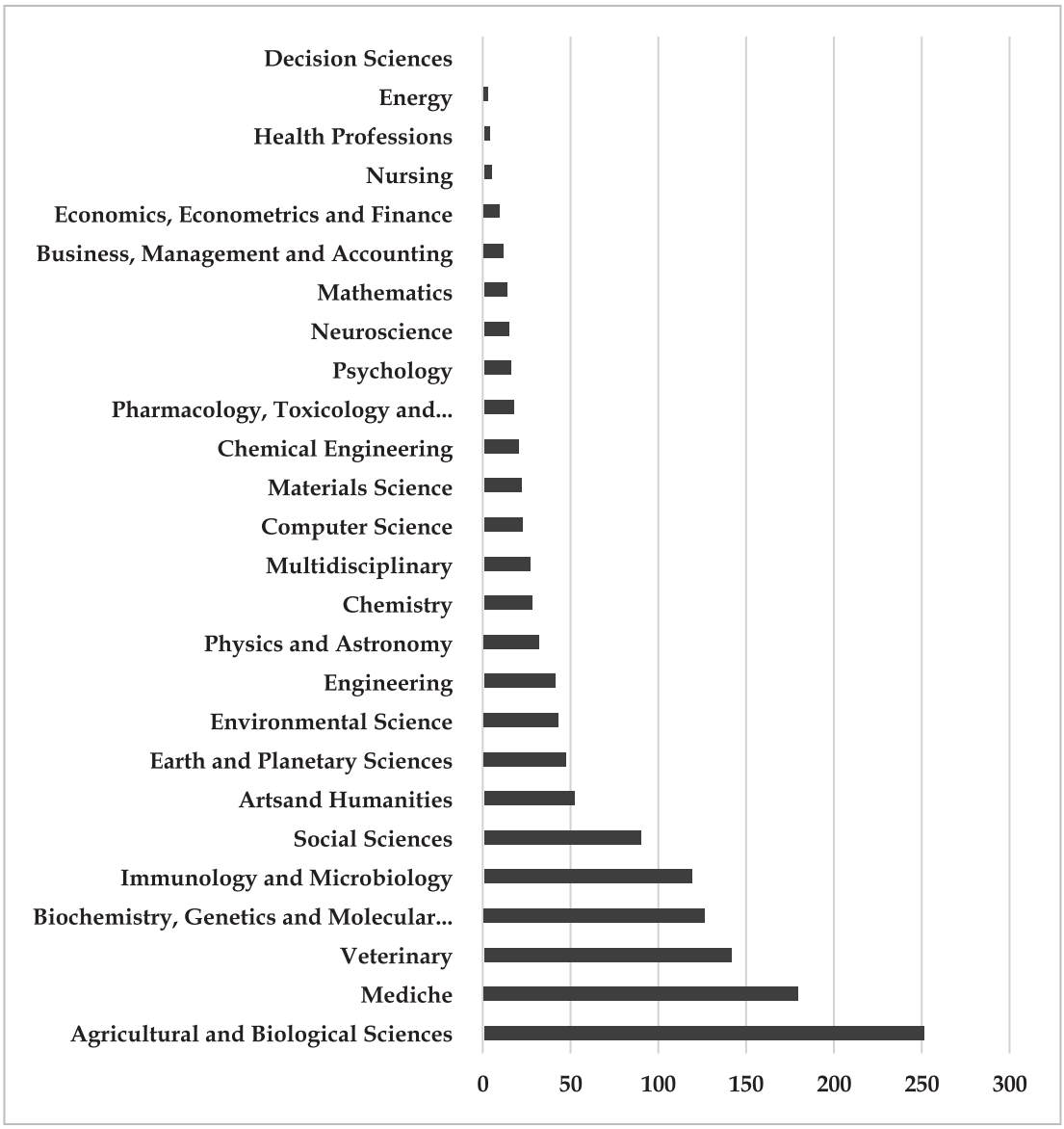

Fig 8. Distribution of camel research publications across various academic disciplines.

Agricultural and biological sciences dominate the chart with the highest number of publications, reaching 250. This prominence underscores the central role of camels in agricultural research and their biological significance, including studies on camel physiology, genetics, and their utility in farming systems.

Medicine and veterinary sciences also feature prominently, with 180 and 142 publications, respectively. The significant number of publications in these fields highlights the health and veterinary aspects of camel research, including disease prevention, treatment, and overall animal health management.

Other notable fields include chemistry, genetics and molecular biology, and immunology and microbiology, each with substantial contributions. These disciplines focus on the molecular and genetic aspects of camel biology, exploring areas such as disease resistance, genetic diversity, and molecular mechanisms underlying camel physiology. The presence of camel research in fields like Environmental Science, Engineering, and Social Sciences further illustrates the diverse applications and broad impact of camel studies.

Bibliometric Coupling Analysis of the Top Collaborations

The authors are grouped into three clusters based on their collaborative networks (Fig 9). Cluster 1 includes Benaissa, M.H., Burger, P.A., Faye, B., Kaidi, R., and Youngs, C.R. This cluster

indicates a strong interconnected network with notable contributions from Faye, B., who has the highest number of documents (12) and significant link strength (15). Cluster 2 features Ali, M.A., Kayali, G., Shehata, M.M., and Webby, R.J., with Ali, M.A. showing the highest total link strength (14) and document contributions (7). Cluster 3 includes Alagaili, A.N., Daszak, P., Munster, V.J., And Van Doremalen, N., where Munster, V.J. leads with 10 documents and notable link strength (10), indicating significant collaborative influence.

The number of documents authored by each researcher varies, highlighting their productivity and influence in the field. Faye, B. and Munster, V.J. stand out with 12 and 10 publications respectively, reflecting substantial research contributions. The link strength metric, which indicates the degree of collaboration, is highest for Ali, M.A., Faye, B., and Kaidi, R., showing their extensive collaborative efforts. Authors like Benaissa, M.H. and Youngs, C.R. also demonstrate strong link strengths, emphasising their roles in interconnected research networks.

The average publication year provides insights into the temporal trends of these researchers' contributions. Researchers like Burger, P.A., Faye, B., and Ali, M.A. have more recent average publication years (around 2016 and 2019), indicating ongoing research activities and recent contributions to the field. In contrast, authors like Kayali, G. and Shehata, M.M. have slightly older average publication years (around 2014), suggesting an earlier peak in their research output. The distribution of publication years across these authors reflects both longstanding contributions and emerging research activities, highlighting the dynamic and evolving nature of camel research.

Co-occurrence of Keywords

The co-occurrence of keywords was done to represent the research cooperation trends. The input data were set to a minimum of 10 times keywords co-occurrence. Of 6731 keywords 176 met this threshold.

The VOSviewer visualisation and the co-occurrence map data provide a comprehensive view of the most frequently occurring topics and their interconnections in camel research. Each node represents a keyword or topic, with the size indicating its frequency and the links illustrating the co-occurrence with other keywords (Fig 10).

The keyword "camel" forms the central node of the network, highlighting its primary importance in the dataset. Closely connected to it are significant topics like "dromedary", "camel milk", "genetics", and "physiology". These connections indicate that a large portion of the research focuses on the biological and physiological aspects of camels, as well as specific interests in camel milk and genetic studies.

The network also shows strong interdisciplinary connections. Keywords like "human", "female", "animal tissue", and "immunology" illustrate the crossover of camel research into areas of human health, veterinary sciences, and broader biological studies. For instance, the presence of "human" and "female" nodes, along with "immunology", suggests significant research on zoonotic diseases and the health implications of camel products on humans.

Certain clusters reveal emerging or niche research areas. Keywords such as "antibiotic resistance", "virus transmission", and "serology" indicate a growing focus on infectious diseases and public health. The connections to "MERS-CoV" and "coronavirus infections" reflect recent research trends likely influenced by outbreaks of Middle East Respiratory Syndrome.

The inclusion of geographic-specific keywords like "United States", "Egypt" and "Saudi Arabia",

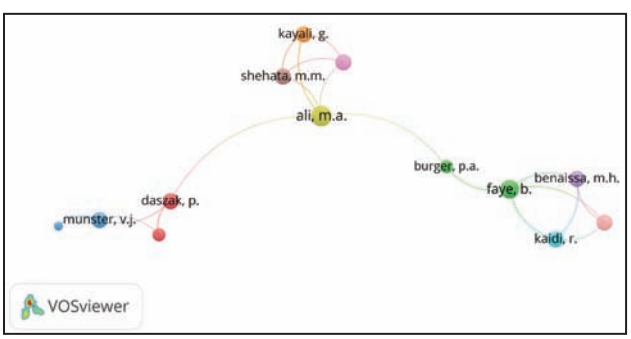

Fig 9. Bibliometric coupling analysis of author contributions and collaboration in camel research.

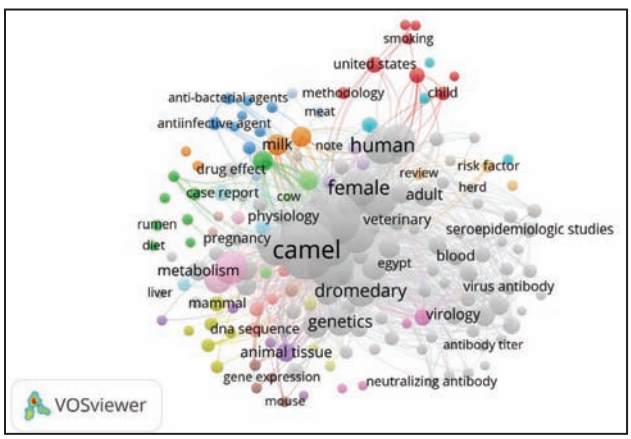

Fig 10. Bibliometric coupling analysis of keywords co-occurrence in camel research.

along with demographic terms such as "child", "adolescent", and "adult", points to studies focusing on specific regions and population groups.

The co-occurrence network analysis reveals 22 distinct clusters, each representing a focused thematic area in camel research. In the top 10 clusters, Cluster 1, encompassing keywords such as "adolescent", and "child", highlights research themes related to public health and human demographics. This cluster suggests significant interest in the impact of camel-related factors on human health, including zoonotic diseases and nutritional studies involving camel products. The presence of keywords like "united states" and "young adult" further indicates that this research might be geographically focused on regions with substantial camel populations or significant camel product consumption.

Clusters 2 through 5 primarily focus on biological and anatomical studies. Cluster 2 includes keywords like "bacteria", "fermentation", and "microbiology", indicating research on microbial communities associated with camels and their fermentation processes. Cluster 3, with keywords such as "anti-bacterial agents", "antibiotic resistance", and *"Escherichia coli"*, underscores the importance of addressing bacterial pathogens and the effectiveness of antibiotics in camel health management. Meanwhile, Cluster 4, featuring "artiodactyla", "mammal", and "histology", focuses on the anatomical and histological characteristics of camels and related species, revealing an interest in the structural and morphological analysis of these animals.

Clusters 6 through 10 highlight advanced research methodologies and genetic studies. Cluster 6, with keywords like "major clinical study", "procedures", and "randomised controlled trial", emphasises the use of clinical trials and evidence-based research approaches in camel studies. Cluster 7, including "camel milk", "milk protein", and "milk", focuses on the nutritional and biochemical properties of camel milk, exploring its health benefits and nutritional value. Cluster 8, featuring "gene expression", "human cell", and "mouse", highlights genetic and cellular research involving camels, human, and mouse cells to understand genetic expressions and their implications. Cluster 9, with "antibodies", "antibody", and "single-domain antibodies", centres on immunological studies, exploring various antibodies and their roles in immune responses related to camels. Finally, cluster 10, including "DNA sequence", "molecular genetics", and "sequence analysis, DNA", underscores the application of molecular genetics and sequencing techniques in camel research, revealing advanced genetic research trends in this field.

The diversity of clusters in the co-occurrence network analysis reflects a robust and interdisciplinary research landscape in camel studies. The 22 clusters cover a wide range of topics, from public health and microbiology to advanced genetic research and clinical studies, indicating the multifaceted nature of camel research and its relevance to various scientific and health-related fields.

Bibliometric Analysis of the Top Highly Cited Publications

The dataset comprises a variety of highly cited research articles focusing on camel-related studies, spanning several decades and involving multiple countries (Table 1). These studies highlight significant contributions in fields such as infectious diseases, veterinary sciences, and public health. The oldest article in the dataset, "Isolation and structure of an untriakontapeptide with opiate activity from camel pituitary glands" by Li and Chung, dates back to 1976 and has amassed 530 citations, indicating its lasting impact on biochemical research. This paper, published in the prestigious "Proceedings of the National Academy of Sciences of the United States of America," underscores early explorations into bioactive peptides derived from camels.

Recent studies in the dataset, such as "Chronic Infection with Camelid Hepatitis E Virus in a Liver Transplant Recipient Who Regularly Consumes Camel Meat and Milk" by (Lee *et al,* 2016) and "Middle East Respiratory Syndrome Coronavirus Infection in Dromedary Camels in Saudi Arabia" by (Alagaili *et al,* 2014), reflect contemporary research priorities. These papers, cited 428 and 374 times respectively, discuss the zoonotic diseases and their transmission between camels and humans. The involvement of multiple countries (USA, UK, Singapore for the former, and USA, Saudi Arabia for the latter) highlights the global collaborative effort to understand and mitigate these health risks. Notably, these studies were published in high-impact journals like "Gastroenterology" and "American Society for Microbiology," further attesting to their scientific significance.

The dataset also includes impactful public health studies, such as those examining the influence of marketing on children's recognition of

Table 1. The Topmost Highly Cited Publications in Camel Research in North America and in Collaboration with other Countries.

Title	Authors	Journal	Affiliations Countries	Year	Citations	References
Isolation and structure of an untriakontapeptide with opiate activity from camel pituitary glands	Li C. H. Chung D.	Proceedings of the National Academy of Sciences of the United States of America	USA	1976	530	(Li and Chung, 1976)
Chronic Infection with Camelid Hepatitis e Virus in a Liver Transplant Recipient Who Regularly Consumes Camel Meat and Milk	Lee G. H. Tan B. H. Chi-Yuan Teo E. Lim S. G. Dan Y. Y. Wee A. Kim Aw P. P. Zhu Y. Hibberd M. L. Tan C. K. Purdy M. A. Teo C. G.	Gastroenterology	USA, UK, Singapore	2016	428	(Lee *et al,* 2016)
Middle east respiratory syndrome coronavirus infection in dromedary camels in Saudi Arabia	Alagaili A. N. Briese T. Mishra N. Kapoor V. Sameroff S. C. de Wit E. Munster V. J. Hensley L. E. Zalmout I. S. Kapoor A. Epstein J. H. Karesh W. B. Daszak P. Mohammed O. B. Ian Lipkin W.	American Society for Microbiology	USA, Saudi Arabia	2014	374	(Alagaili *et al,* 2014)
The CAMELS data set: Catchment attributes and meteorology for large-sample studies	Addor N. Newman A. J. Mizukami N. Clark M. P.	Hydrology and Earth System Sciences	USA, UK	2017	313	(Addor *et al,* 2017)
Brand Logo Recognition by Children Aged 3 to 6 Years: Mickey Mouse and Old Joe the Camel	Fischer P. M. Schwartz M. P. Richards J. W. Goldstein A. O. Rojas T. H.	JAMA: The Journal of the American Medical Association	USA	1991	296	(Fischer *et al,* 1991)
Seroepidemiology for MERS coronavirus using microneutralisation and pseudoparticle virus neutralisation assays reveal a high prevalence of antibody in dromedary camels in Egypt, june 2013	Perera, R. A. Wang, P. Gomaa, M. R. El-Shesheny, R. Kandeil, A. Bagato, O. Siu, L. Y. Shehata M. M. Kayed A. S. Moatasim Y. Li M. Poon L. L. Guan Y. Webby R. J. Ali M. A. Peiris J. S. Kayali, G.	Eurosurveillance	USA, China, Egypt, Hong Kong	2013	271	(Perera *et al,* 2013)

MERS coronaviruses in dromedary camels, Egypt	Chu D. K. W. Poon L. L. M. Gomaa M. M. Shehata M. M. Perera R. A. P. M. Zeid D. A. El Rifay A. S. Siu L. Y. Guan Y. Webby R. J. Ali M. A. Peiris M. Kayali G.	Emerging Infectious Diseases	USA, Egypt, Hong Kong	2014	240	(Chu *et al,* 2014)
RJR Nabisco's Cartoon Camel Promotes Camel Cigarettes to Children	Difranza, J. R. Richards J. W. Paulman P. M. Wolf-Gillespie N. Fletcher C. Jaffe R. D. Murray D.	JAMA: The Journal of the American Medical Association	USA	1991	234	(Difranza *et al,* 1991)
Antibacterial and antiviral activity of camel milk protective proteins	El Agamy E. S. I. Ruppanneb R.	Journal of Dairy Research	Canada, France, Egypt	1992	220	(El Agamy and Ruppanneb 1992)
Replication and shedding of MERS-CoV in upper respiratory tract of inoculated dromedary camels	Adney D. R. van Doremalen N. Brown V. R. Bushmaker T. Scott D. de Wit E. Bowen R. A. Munster V. J.	Emerging Infectious Diseases	USA	2014	214	(Adney *et al,* 2014)

cigarette brands and the seroepidemiology of MERS coronavirus in camels. For instance, Fischer *et al* (1991) "Brand Logo Recognition by Children Aged 3 to 6 Years: Mickey Mouse and Old Joe the Camel," with 296 citations, published in "JAMA: The Journal of the American Medical Association," investigates early brand recognition and its implications for public health. Similarly, Perera *et al* (2013) study on MERS coronavirus in Egyptian camels, cited 271 times, reveals a high prevalence of antibodies in camels, offering crucial insights into disease transmission dynamics.

Recent interest in camel research fields has surged (Kandeel *et al,* 2023), driven by the growing recognition of camels' ecological, economic, and health-related significance (Masebo *et al,* 2023). This heightened interest is particularly evident from the sharp increase in publications in the past decade, with substantial contributions from North American institutions in collaboration with international partners. Advances in molecular genetics, vaccines and immunology, and zoonotic disease research have positioned camels as important subjects in understanding disease transmission and developing

Fig 11. Summary of camel research statistics in North America.

biomedical applications (Abri and Faye, 2019; Ahmed and Mahmoud, 2023; Al Ramadan *et al*, 2021). Additionally, the unique properties of camel milk and its potential health benefits have spurred research in nutrition and food sciences. The advent of AI technologies is expected to revolutionize camel health and welfare (Alsaleem *et al*, 2024).

Summary of camel research in North America

Fig 11 presents a detailed summary of camel research statistics in North America from 1859 to 2024. It includes data spanned 493 sources and 786 documents, showing an annual growth rate of 1.89%. The research involves 3127 authors, with 130 single-authored documents, and a notable international co-authorship rate of 52.04%. Each document averages 5.35 co-authors, with a total of 1698 author's keywords and 26,275 references. The average age of documents is 16.3 years, and they receive an average of 21.38 citations per document.

Fig 12 presents a three-field plot illustrating the associations between countries, affiliations, and keywords in camel research in North America. The left column (AU_CO) represents various countries, including Italy, USA, Brazil, China, Saudi Arabia, and others. The middle column (AU_UN) shows affiliations with prominent research institutions such as Inner Mongolia Agricultural University, King Abdulaziz University, Jordan University of Science and Technology, King Saud University, and many more. The right column (ID) lists the most frequently used keywords in camel research, such as "camel," "article," "nonhuman," "animals," "dromedaries," and others. This visualisation highlights the network of international collaborations, institutional contributions, and key research themes prevalent in the field of camel studies in North America. Wile USA is dominating in the right column, the middle column shows collaboration between USA and a lot of universities oversees.

Strengths and limitations of this study and future directions

The strengths of the bibliometric analysis of camel research are manifold. First, the comprehensive data collection from the Scopus database ensures a robust and extensive dataset, encompassing a wide range of publications and document types. This inclusivity allows for a thorough examination of trends, key contributors, and collaborative networks. Additionally, the identification of significant periods of growth and the mapping of international collaborations highlight the global nature and interdisciplinary scope of camel research.

Despite its strengths, this bibliometric analysis of camel research has several limitations. One major limitation is the reliance on the Scopus database, which, although comprehensive, may not include all relevant publications, especially those in non-indexed regional journals or grey literature. Additionally, the analysis primarily focuses on quantitative measures such as publication counts and citation metrics, which may not fully capture the qualitative aspects of research impact and innovation.

Future direction involves fostering stronger ties between researchers in North America and those in camel-rich regions such as the Middle East and Africa. This includes tackling zoonotic diseases, which

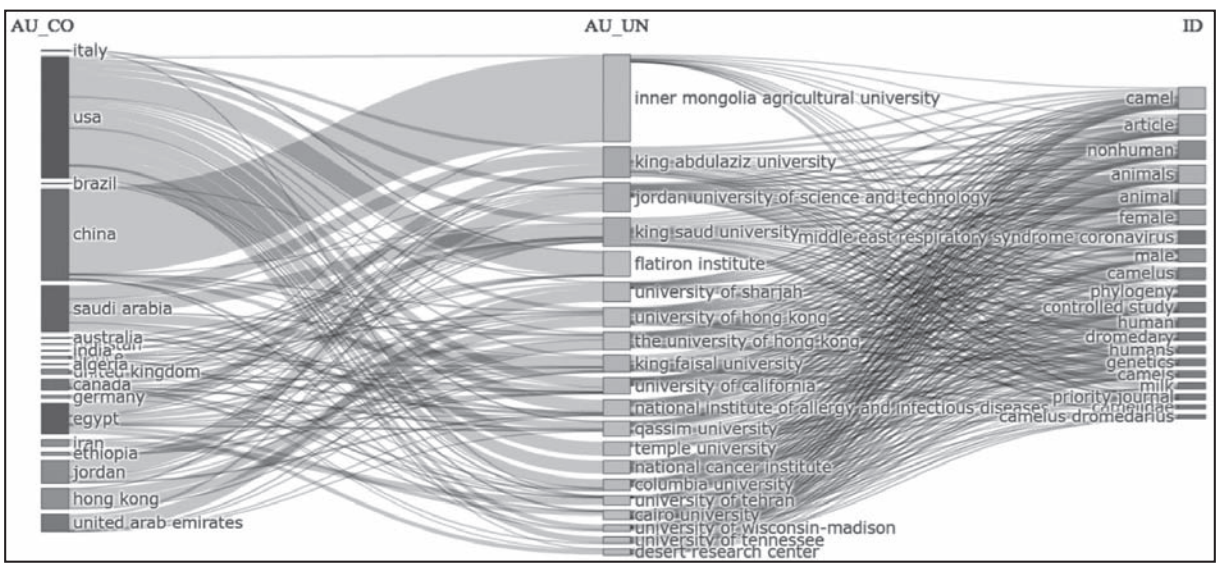

Fig 12. Three-field plot for countries, affiliations and keywords association in camel research in North America.

have significant public health implications, as well as addressing issues related to climate change and sustainability, where camels' resilience offers valuable lessons. Furthermore, the integration of advanced technologies such as artificial intelligence and big data analytics into bibliometric studies can provide deeper insights into research trends and impact, guiding policy-making and funding decisions.

Conclusions

This bibliometric analysis underscores the growing significance of camel research in North America, driven by the ecological and economic importance of camels. The study reveals robust collaborative efforts between North American researchers and international partners, leading to advancements in understanding zoonotic diseases, genetic diversity, and the nutritional benefits of camel milk. Despite these achievements, gaps remain in integrating advanced technologies and exploring the socio-economic impacts of camel products in non-traditional regions. Addressing these gaps through continued investment and fostering international collaborations is essential to drive innovative research and enhance the overall impact of camel studies.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

There is no conflict of interests

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Authors' contributions

"Conceptualisation, M.K.; methodology, M.K.; software, M.K.; validation, M.K.; formal analysis, M.K.; investigation, A.A. and M.K.; resources, M.K.; data curation, A.A. and M.K.; writing—original draft preparation, M.K.; writing—review and editing, A.A. and M.K; funding acquisition, A.A. and M.K. All authors have read and agreed to the published version of the manuscript.

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JOURNAL OF CAMEL PRACTICE AND RESEARCH BEING THE MOST PROLIFIC SOURCE OF RESEARCH ON CAMEL MILK AND URINE

Research on camel milk and urine (CMUR) has gained significant attention because of its nutritional and medicinal applications. The aim of this study was to conduct a bibliometric analysis of the CMUR from 1947 to 2023. Following PRISMA rules, the Scopus database was used to extract 1338 English-language studies, which were analysed using Scopus Analytics, Bibliometrix, and VOSviewer. The findings indicated that 7.78% of studies focused on camel urine within the CMUR domain. The analysis showed a steady increase in the number of publications over 77 years (R-squared = 0.8308). The CMUR encompasses a wide range of research disciplines, with particular emphasis on the agricultural and medical fields. Saudi Arabia is the top producer of CMUR. In terms of the most prolific sources of publications in the CMUR, the Journal of Camel Practice and Research takes the lead, with 80 papers. This was followed by the Journal of Dairy Science with 51 papers, the Emirates Journal of Food and Agriculture with 39 papers, the International Dairy Journal with 39 papers and Food Chemistry with 36 papers.

King Saud University contributed 103 documents to the CMUR, making it the most prolific institution globally. The co-word analysis identified seven prominent research themes within the CMUR, which can be further categorised into four distinct clusters. Notably, 'Probiotics', 'Anti-inflammatory', and 'Diabetes' emerged as trending subjects. The analysis of the CMUR yielded significant insights into the present research trends, identified gaps in the existing knowledge, and provided valuable recommendations for future investigations.

(Source: Abdelwahab, S. I., Taha, M. M. E., Mariod, A. A., Mohamed, H. Y., Farasani, A. M., & Jerah, A. (2024). Unleashing the potential: Camel Milk and Urine Research insights for performance, collaboration, structure and future trends (1947–2023). Cogent Food & Agriculture, 10(1). https://doi.org/10.1080/23311932.2024.2311435)

GENETIC STRUCTURE OF CAMELS UNDER FOCUS

Thirteen countries participated in a conference from April 7 to 9, 2024 in Riyadh which looked at changing the genetic structure of camels to improve milk and meat yields. The three-day conference focussed on ways to improve the performance of camels based mainly on genetic tools. International experts on camels were invited to present new techniques for implementing a program for camels. In December 2011, a national workshop on camel biodiversity was held in the Saudi capital with the help of two international experts. On that occasion, it was concluded that there was a need for further studies on camels. The conference was held as part of the technical cooperation programme between the Ministry of Agriculture and the FAO.

3rd ANNUAL INTERNATIONAL CAMEL PARADE IN PARIS

The event in Paris was organised by the French Federation for the Development of Camelids in France and Europe, under the umbrella of the International Camel Organisation, and was sponsored by the Saudi Ministry of Culture and the Kingdom's Camel Club. This was the third year in which the event took place. The event was first held in January 2019 and repeated in 2022. The participants in the parade of camels, llamas, alpacas and other members of the camelid family of creatures participated from more than 50 representatives of camel-related organisations from more than 30 countries, along with camel breeders, government officials, and others with an interest in the animals, and entertainers from various branches of the performing arts.

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SOME ASPECTS OF CAMEL MILK AND ITS SAFETY FOR HUMAN CONSUMPTION-AN OVERVIEW

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ABSTRACT

Camel milk is in high demand in many countries around the world. There appears to be increasing awareness of the use of camel milk in human diet. Therefore, the aim of this study was to determine the importance of camel milk and its safety for human consumption. Camel milk contains numerous antimicrobial components and protective factors, making it a unique milk compared to the milk of other lactating animal species. Camel milk production varies between 1000 and 12000 kg during the lactation period of 8 to 18 months, with large differences between geographical regions, feeding and husbandry conditions. The composition of camel milk is 2.5-5.5% fat, 2.2-4.5% protein, 2.5-5.5% lactose, 0.7-1.0% ash and 8.0-15% dry matter. To increase milk production for each camel and improve the quality and safety of raw camel milk, the use of a suitable milking machine such as StimuLactor is necessary. In addition, correct husbandry, feeding and hygiene measures must be considered. In conclusion, regarding the importance of camel milk and the associated related health benefits of its bioactive ingredients, improvements in milking hygiene, milk storage and transport conditions are required to ensure the quality of camel milk meets consumer needs.

Key words: Camel, human milk, milking machine, milk yield

Camel milk is one of the most important nutritional sources for the population in many arid and semi-arid areas of the world, as it contains almost all the vital nutrients needed in dry climate. The camel population in the world is approximately 35 million, about 95% of which are dromedaries (FAO, 2022). Camel milk yield varies between 1000 and 12000 kg during the lactation period of 8 to 18 months (Boujenane, 2020; Swelum *et al,* 2020). However, the amount of milk per lactation depends on many factors such as breed (Type), animal health, lactation stage, lactation number, living conditions and season (Yamina *et al,* 2013; Chamekh *et al,* 2020; Swelum *et al,* 2021; Boudalia *et al,* 2023). Camel milk was named as the most valuable product (Davati *et al,* 2015) and it is known as "white gold of the desert" (Wernery, 2006). However, camel milk contains numerous minor components that have special bioactive properties (Kaskous and Pfaffl, 2017; Swelum *et al,* 2021; Oselu *et al,* 2022). These are present in significant concentrations and are extremely important and beneficial to human nutrition and health (Kaskous, 2016). Therefore, camel milk is usually consumed as a fresh or naturally fermented product and is therefore not pasteurised (Mehari *et al,* 2007; Matofari *et al,* 2013; Abera *et al,* 2016; Mwangi *et al,* 2016; Serda *et al,* 2018). But camel milk is an excellent food for the growth of microorganisms (Zangerl, 2007; Matofari *et al,* 2013) and non-heat-treated milk and raw milk products are the main cause of diseases caused by pathogens (De Buyser *et al,* 2001; Smits *et al,* 2023). It is noteworthy that the milk from a healthy udder is usually "sterile" (Johnson *et al,* 2015) because the camel udder is protected by a variety of defence mechanisms such as innate or specific immunity as well as physiological peculiarities and is only contaminated with germs when it passes through the teat canal (Zangerl, 2007). In addition, the germs that get into the milk come from the udder-and teat-surface, the stall, the air, the water, the feed, the milker, and the milking equipment. Contamination of raw camel milk can be very high if udder health is not checked, plastic containers are used during milking and storage, hygiene measures are not carried out during milking, and water is not available to clean the teat and udder before milking (Mulwa *et al,* 2011; Ismaili *et al,* 2019; Atigui *et al,* 2023). During milk transportation, especially when the route is long, and poor and the milk is not refrigerated, the microbial content of the milk multiplies rapidly (Mulwa *et al,* 2011; Ismaili *et al,* 2019). Due to the many contaminated factors, it has been shown that the poor hygiene status in the

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production and handling of camel milk as well as the lack of low-cost post-harvest technologies mean that camel milk has lost its potential to improve the living conditions of the camel farmer (Matofari *et al,* 2007; Ismaili *et al,* 2019; Hassen *et al,* 2022) and this limitation leads to losses in quality and quantity after harvest, especially physical-chemical and microbiological deterioration of the milk (Odongo *et al,* 2016; Ismaili *et al,* 2019; Atigui *et al,* 2023). The production of hygienically perfect, ready-to-process milk places high demands on the camel farmer. This means optimal animal husbandry, animal care, good feeding, ideal milking machines and cooling of the milk during storage and transport to deliver consistently high-quality milk to the consumer. To achieve this goal, the transition from traditional production systems to intensive production systems must be accelerated. In the following some aspects of camel milk and its safety for human consumption are presented and discussed.

Composition of camel's milk

The composition of camel milk is different from those of other lactating animals' species particularly due to its protein composition, milk fat structure and mineral and vitamin content (El-Hatmi *et al,* 2015; Abduku and Eshetu, 2024), but it contains all the important nutrients (Farah, 2011; Kanca, 2017; Boujenane, 2020; Swelum, 2021; Lajnaf *et al,* 2023). Camel milk contains the following components: 2.2-4.5% protein, 2.5-5.5% fat, 2.5-5.5 lactose, 0.7-0.95% ash and 8.0-15% total dry matter (El-Hatmi *et al,* 2006; Konuspayeva *et al,* 2009; Kaskous *et al,* 2012; Ali *et al,* 2019; Ismaili *et al,* 2019; Roy *et al,* 2020; Seifu 2022; Kaskous, 2023). However, the composition varies greatly and depends on various factors, such as the breed (type), individual, husbandry and feeding condition, age, milking interval, stage of lactation, number of lactations, season, management, and udder health (Wernery, 2007; Shuiep *et al,* 2008; El-Hatmi *et al,* 2015; Jrad *et al,* 2015; Patel *et al,* 2016; Ismaili *et al,* 2019; Swelum *et al,* 2021; Behrouz *et al,* 2022; Kraimia *et al,* 2024). In general, camel milk has lower amounts of fat, protein, and lactose compared to bovine milk (Smits *et al,* 2011; Konuspayeva *et al,* 2011; Arab *et al,* 2014; Alhaj *et al,* 2022).

Camel milk Proteins

Camel's milk is a rich source of proteins with potential anti-microbial and protective activity (Kaskous and Pfaffl, 2017; Mohamed *et al,* 2020; Lajnaf *et al,* 2023). It was observed that camel milk has 21 different amino acids compared to 18 amino acids in bovines. Such amino acids are the synthesis basis of all proteins in camel milk (Fig 1). Practical results have shown that the average protein content of camel milk under European conditions was 3.34% in the Netherlands (Smits *et al,* 2011), 2.28% in Germany (Kaskous, 2019) and 2.39% in Switzerland (Kaskous, 2023), while the average protein content in camel milk outside Europe was 3.1% (Konuspayeva *et al,* 2009; Al haj and Al Kanhal, 2010). In general, the protein content of camel milk ranges between 2.2 and 4.5% (Konuspayeva *et al,* 2009; Yadav *et al,* 2015; Kula and Dechasa, 2016; Patel *et al,* 2016; Swelum *et al,* 2021; Seifu, 2022). This difference is due to environmental conditions and the availability of food and water for the lactating camels (Yamina *et al,* 2013; Ismaili *et al,* 2019). Camel milk proteins appear as: Casein, whey proteins, fat globule membrane proteins. However, the average casein content and whey protein content of camel milk vary between 1.9 and 2.3% and 0.7 and 1.0%, respectively (Farah, 2011). Caseins make up the highest proportion of the protein fraction in camel milk (Hamed *et al,* 2012; Swelum *et al,* 2021). This represents 65-70% of total proteins compared to an average of 83% in bovine milk (Khaskheli *et al,* 2005; Frister, 2007; Hamed *et al,* 2012). Like cow's milk, casein in camel milk consists of four fractions. These are αs1, αs2, β and k-casein (Al haj and Al kanhal, 2010; Abbas *et al,* 2013). However, camel milk contains more β-casein (75%) than α-casein (21%) of total casein, compared to cows' milk, which contains approximately the same content of β-casein and α-casein (36 and 38%) (Devendra *et al,* 2016; Kappeler *et al,* 2003; Yirda *et al,* 2020). Interestingly, camel milk contains very little k-casein (3.5%) of total casein, compared to the k-casein content (13%) in cow's milk (Devendra *et al,* 2016; Mbye *et al,* 2022). It was observed that whey proteins in camel milk constituted about 30-35% of total protein (Khaskheli *et al,* 2005; Jilo and Tegegne, 2016; Dugassa, 2021; Vincenzetti *et al,* 2022). Camel milk as human milk does not contain β-Lactoglobulins (El-Hatmi *et al,* 2007; Elagamy *et al,* 2009; Kaskous and Pfaffl, 2017; Rahmeh *et al,* 2019). Therefore, α-lactalbumin is the main whey protein in camel milk (Wernery, 2007; Redington *et al,* 2016; Lajnaf *et al,* 2023). Camel milk contains other important components of whey proteins such as serum albumin with a variation of 2.9 and 13.8 g/l (El-Hatmi *et al,* 2006) and lactoferrin with 227-229 mg/l (Konuspayeva *et al,* 2007; Kaskous *et al,* 2012). In addition, several reports have shown that camel milk has higher immunoglobulins (0.72 g/l) than cow's milk (0.47 g/l) (Kaskous and Pfaffl, 2017).

Camel milk fat

The fat content of camel milk varies between 2.5 and 5.5% depending on the nutritional status, stage of lactation, breed and the season of the year (Mal *et al,* 2006; Yamina *et al,* 2013; Devendra *et al,* 2016; Kaskous, 2019; 2023; Abduku and Eshetu, 2024). The fat globules in camel milk are the smallest among all ruminants ranging from 0.1 to 18 micrometers in diameter (El-Zeini, 2006), and these do not naturally aggregate due to the absence of agglutinin (Khalesi *et al,* 2017). 96% of the fat in camel milk is triacylglycerol (Nikkhah, 2011; Dugassa, 2021). Compared to cow's and buffalos' milk, camel milk fat contains lower concentrations of short-chain fatty acids and higher concentration of long-chain fatty acids (C_{14}-C_{18}) (Abu-Lehia, 1989; Konuspayeva *et al,* 2008; Abbas *et al,* 2013; Sara *et al,* 2022). The saturated fatty acid (SFA) in camel milk varied between 50% (Bactrian camel milk) and 60% (dromedary camel milk) of total fatty acids (Rahmeh *et al,* 2019) and about 65% of total fatty acids according to Wang *et al* (2011) and Oselu *et al* (2022). However, the monounsaturated fatty acids (MUFA) in dromedary camel milk were 56-80% of total fatty acids (Medhammar *et al,* 2012). In addition, the proportion of unsaturated fatty acids in camel milk was between 35 and 50% of the total fatty acids (Izadi *et al,* 2019). It is noteworthy that the proportion of unsaturated fatty acids in the fatty acid pattern of camel milk in the intensive production system was 43.1% (Stahl *et al,* 2006). In addition, the fat content in camel milk was found to be highly dependent on the stage of lactation, with the highest concentration occurring in the first three months of lactation (34.67±1.30 g/l), compared to the concentration in the middle (27.40±5.69 g/l) and the end of lactation (29.12±2.83 g/l) (Kraimia *et al,* 2024).

Camel milk lactose

The lactose content in camel milk is not stable, although it is involved in the osmotic pressure in the udder. It is noteworthy that a different mechanism exists in camels, as regular feeding and water are not available in many regions of the world. Therefore, different concentrations of lactose have been found in camel milk. Milk lactose content was observed to be 4.3 ±0.2% higher in camels deprived of water for four days compared to 4.1±0.2% for 16 days (Bekele *et al,* 2011). These results illustrate that the variation in lactose content in camel milk is mainly related to water intake and the type of feed consumed (Al haj and Al kanhal, 2010; Kula and Dechasa, 2016). In general, the lactose content in camel milk varied between 2.5% and 5.5% (Khan and Iqbal, 2001; Konuspayeva *et al,* 2009; Devendra *et al,* 2016; Faraz, 2020; Dugassa, 2021; Alhaj *et al,* 2022; Karaman *et al,* 2022). In addition, lactose content in camel milk was observed to be high in the first months of lactation (42.5 g/l), followed by a significant ($P<0.05$) decrease at the end of lactation (38.35 g/l) (Kraimia *et al,* 2024). At this point, it must be said that the significant change in lactose concentration in camel milk is due to the health of the udder. It is known that in clinical or subclinical mastitis, the lactose content of the milk decreases and new synthesis is reduced (Schulz, 2003). New research has shown that the average lactose content in the milk of a healthy camel udder was around 4.09±0.03% after using new "StimuLactor" milking machines on a practical farm in Switzerland (Kaskous, 2023).

Camel milk vitamins and minerals

Studies on the vitamin content of camel milk have been carried out for a long time (Sawaya *et al,* 1984; Farah *et al,* 1992). Stahl *et al* (2006) found that fresh dromedary milk contains less vitamin A, E, B_1 and β-carotene than cow's milk. An interesting aspect: The vitamin C content in camel milk (34.16 mg/l) was 2 to 3 times higher than in cows' milk (Farah *et al,* 1992) and 6 times higher than in human milk (Gizachew *et al,* 2014). However, the vitamin C content of camel milk was between 24 and 52 mg/kg and was therefore, 2-4 times higher than that of cow's milk (15±6.3 mg/l) (Mehaia, 1994; Stahl, 2005; Kamal and Karoui, 2017). The high vitamin C content in camel milk makes nutritional sense because fruits and vegetables are rarely part of the human diet in dry areas and intake of vitamin C *via* camel milk can help prevent vitamin deficiencies in humans. It has also been found that the lower carotene content makes the colour of camel milk whiter compared to cow's milk (Stahl *et al,* 2006; Devendra *et al,* 2016). In addition, studies using Bactrian camel milk showed that camel milk was rich in vitamin D and riboflavin and consumption of two cups daily provided 160% of the recommended dietary intake of vitamin D (5 µg/day) and riboflavin (0.5 mg/day) (Wijesinha-Bettoni and Burlingame, 2013).

Furthermore, research has shown that camel milk is rich in minerals such as calcium, phosphorus, sodium, potassium, chloride, iodine, and magnesium (Shamsia, 2009; Gizachew *et al,* 2014; Aljumaah *et al,* 2012; Alhadrami and Faye, 2016). The average contents of Ca, K, Mg and Na in camel milk were 1.47±0.38, 0.98±0.24, 0.07± 0.01, and 0.65±0.11 g/l,

respectively (Jrad *et al,* 2015). However, the average ash content in camel milk varied between 7.5 and 8.8 g/l (Jrad *et al,* 2015; Abdel Galil *et al,* 2016). It is noteworthy that the content of iron, zinc and copper in camel milk was higher than in cows' milk (Singh *et al,* 2006). It should be noted that many factors such as breed (type), diet, water consumption and analytical methods can affect the mineral content of camel milk (Mehaia *et al,* 1995; Haddadin *et al,* 2008). A new study has shown that the season can have an impact on the minerals in camel milk (Kraimia *et al,* 2024) (Table 1).

Safe raw camel milk for human consumption

In many countries, particularly in Africa and the Middle East, the consumption of raw camel milk has increased and is often considered as a "health food" with positive effects on digestion, the immune system and for treatment of various diseases (Gonfa *et al,* 2001; Seifu, 2007; Zaitlin *et al,* 2013). According to an online survey of 852 consumers conducted in the United Arab Emirates (UAE), about 58.4% consumed unpasteurised camel milk (Cheikh Ismail *et al,* 2022). The reason for consuming unpasteurised camel milk was that this milk strengthens the immune system and has higher nutritional content (Smits *et al,* 2023). Therefore, raw camel milk was used to treat, alleviate, or prevent health conditions such as diabetes, autism, cancer, dementia, allergies, and parasites (Kaskous, 2016). In Ethiopia, most of camel milk is consumed in the raw state without any heat treatments (Eyassu, 2007; Mehari *et al,* 2007; Roess *et al,* 2023). In the Arabian Peninsula, consumption of unpasteurised camel milk is also common (Omrani *et al,* 2015). Furthermore, fresh and fermented camel milk has been also used in India, Russia, and Sudan for human consumption as well as for treatment of a series of diseases (Kumar *et al,* 2016). Unpasteurised sour camel milk and fresh cow's milk form the core of the Somali diet (Seifu, 2007; Sadler and Catley, 2009; Carruth, 2014). On the other hand, some countries like UAE, Australia and USA warned that camel raw milk was not generally recognised as safe or effective for the therapeutic uses. However, consuming raw or unpasteurised dairy products poses several known risks, especially if refrigeration is not ensured (Zaitlin *et al,* 2013; Carruth *et al,* 2017). The Food and Drug Administration (FDA) in USA warned that if the camel farmer was going to market their product as a "drug", they needed to get federal approval, which would require the farm to provide scientific data demonstrating the safety and effectiveness of their product. Moreover, FDA warned that a consumption of raw camel milk is a health risk, because it is associated with foodborne illness caused by pathogens including *Campylobacter, Escherichia coli, Listeria, Brucella, Staphylococcus* and *Salmonella* (Yamina *et al,* 2013; Swinburne, 2017; Wernery *et al,* 2017; Dadar *et al,* 2019). Based on the observation of Spargue *et al* (2012) that brucellosis a bacterial disease caused by various infectious Brucella

Table 1. Some factors that affect the concentration of minerals in camel milk, according to Kraimia *et al* (2024), with some changes.

Factors		Minerals in camel milk					
		Na (g/l)	K (g/l)	Ca (g/l)	Mg (g/l)	I (g/l)	P (g/l)
Day	Morning	0.39	2.44	1.90	0.07	0.13	0.70
	Evening	0.45	2.39	1.73	0.07	0.13	0.83
	P<0.05			*			**
Stage of lactation	Beginning	0.43	2.63	1.51	0.07	0.15	0.72
	Middle	0.44	2.35	1.67	0.07	0.14	0.65
	End	0.41	2.37	1.75	0.07	0.12	0.69
	P<0.05					*	
Lactation number	1	0.49	2.28	1.67	0.07	0.13	0.63
	2-6	0.46	2.19	1.48	0.07	0.12	0.78
	>6	0.44	2.40	1.66	0.08	0.11	0.66
	P<0.05						
Season	Winter	0.46	2.26	1.48	0.07	0.12	0.66
	Spring	0.39	2.44	1.90	0.07	0.13	0.70
	Summer	0.45	2.38	1.55	0.08	0.15	0.68
	Fall	0.52	2.28	1.61	0.08	0.13	0.77
	P<0.05	***		***	***	**	

*: P<0.05; **: P<0.01; ***: P<0.001

species and is transmitted through both close contact with camels and consumption of raw camel milk. However, camel brucellosis has been diagnosed in all camel-rearing countries except Australia and mainly depends on the management system (Wernery, 2014). Zimmermann (2016) reported that one of the primary risks of camel's milk is consumed in unpasteurised form. Reviewed by Roess *et al* (2023) found that consumption of days-old unrefrigerated raw camel milk was significantly associated with gastrointestinal symptoms. The Saint Louis Institute for conservation medicine studied the consumption of camel milk in northern Kenya, where around 10% of people drink unpasteurised camel milk, exposing themselves to a few animal-based pathogens. The study found a higher prevalence of pathogenic bacteria in raw camel milk than in sheep and cattle milk. Furthermore, Musinga *et al* (2008) found that contaminations of raw camel milk in Kenya can occur along the chain from producers to final consumers and the consumption of raw camel milk should be of major concern to public health. Research in Saudi Arabia and Morocco found that raw camel milk samples were contaminated due to poor handling practices and hygiene conditions (El-Ziney, 2007; Alaoui Ismaili *et al,* 2019). Matofari *et al* (2013) found in Kenya that salmonella enteric occurrence along the camel milk chain had an incidence of 13% with the highest being in the farm environment. The sources of this pathogen may constitute the risk factors that are associated with its prevalence in the environment. However, milk from individuals without clinical or subclinical mastitis may also contain mastitis-causing pathogens, and other factors, such as soil, water, and pastoralists (Elmoslemany *et al,* 2010). Farm management practices and seasonality have also been shown to have a significant impact on the contamination of raw camel milk (Shuiep *et al,* 2008; Smits *et al,* 2023). The control of raw camel milk is an important issue for human consumption (Alebie *et al,* 2021). In fact, pasteurisation is a good preservation method to produce high-quality milk.

Raw camel milk and udder inflammation

Camel udder can get clinical or subclinical mastitis, like other dairy animals (Alebie *et al,* 2021; Rahmeh *et al,* 2022). A high percentage of subclinical mastitis in camels is reported by several authors (Obeid *et al,* 1996; Almaw and Molla, 2000; Wanjohi *et al,* 2013; Niasari-Naslaji *et al,* 2016) and the values varied between 15 and 70% (Bhatt *et al,* 2004; Abera *et al,* 2010; Seifu and Tafesse, 2010; Alamin *et al,* 2013). In general, 46% of the global camel population suffers from mastitis (Aqib *et al,* 2022). It was shown that mastitis pathogens of the dromedary are the same as cultured from the mammary gland of bovines and these are *Streptococcus agalatiae, Staphylococcus aureus, Coagulse- negative Staphylococcus, Streptococcus bovis, Streptococcus uberis, Streptococcus dysagalactia*e (Wernery *et al,* 2008). In the traditional husbandry systems, poor management, and unhygienic milking lead to mastitis in camels (Obeid *et al,* 1996; Almaw and Molla, 2000). The results from Golestan province in Iran have shown that out of 243 camel milk samples from individual quarters (95 milking camels), 18.1% were subclinical mastitis and somatic cell count values beyond 306 x 10^3 cells/ml could be considered as subclinical mastitis in camel (Niasari-Naslaji *et al,* 2016). Bekele and Molla (2001) reported that, out of 152 camels in Afar Region, north-eastern Ethiopia examined, 19 (12.5%) were diagnosed as clinical mastitis cases based on clinical signs and bacteriological examinations. The main mastitis pathogens isolated were *Staphylococcus aurous, coagulate negative staphylococci, Streptococcus agalactiae, S. dysgalactiae,* and other species of *streptococci, Pasteurella haemolytica* and *E. coli*. Similar results have been shown by Wanjohi *et al* (2013) that subclinical mastitis was prevalent in dromedary camels of two districts of north-eastern province of Kenya, and that Gram-positive cocci (*Staphylococcus* and *Streptococcus*) were the dominant mastitis pathogens isolated. Other isolated bacteria were found as *Klebsiella/Enterobacter, Escherichia coli* and *Bacillus*. In addition, *Staphylococcus aureus, Streptococcus agalactiae, Escherichia coli* and *Corynebacterium bovis* were the main pathogens of camel mastitis (Aqib *et al,* 2022). Rahmeh *et al* (2022) found that the genera *Staphylococcus, Streptococcus, Schlegelella,* unclassified *Enterobacteriaceae, Lactococcus, Jeotgalicoccus* and *Klebsiella* were abundant in mastitis milk compared to healthy samples. Abdel Gadir Atif *et al* (2006) have performed comparison of California mastitis test (CMT), somatic cell counts (SCC) and bacteriological examinations for detection of camel mastitis in Ethiopia. A total of 956 quarter milk samples from 253 camels were detected. 59.7% quarter milk samples had microorganisms. A positive correlation was found between CMT scores and bacteriological classes ($P<0.001$) and SCC ($p<0.001$). Detection of subclinical mastitis in dromedary camels using somatic cell counts, California mastitis test and udder pathogen was also done in Saudi Arabia (Saleh and Faye, 2011). A total of 120 quarter milk samples from 30 clinically healthy dromedary camels were cultured. SCC varied from 9000 to 2 000.000

cells/ml with an average of 125000. Intramammary infections were present in most of examined quarter milk samples. The current review by Aqib *et al* (2022) showed the forms of camel mastitis. Clinical mastitis is characterised by hardening and swelling of the udder, pain on palpation, and visible changes in the colour and texture of the milk. Subclinical mastitis is inflammation without obvious signs (El Tigani-Asil *et al*, 2020) that can be detected by CMT, SCC and microbiological examination. It is noteworthy that an increase in SCC above the physiological value not only indicates a problem with udder health, but also leads to reduced milk yield, a change in milk composition, an impairment of milk processing and a change in the bioactive ingredients of camel milk (Kaskous *et al,* 2021)

Based on that, the disease has been reported in numerous camel-producing countries in Africa and Asi (Aqib *et al,* 2022). The following table presents the results of some works on contaminated udder quarters with microorganisms (Table 2).

In Sudan, raw camel milk samples were collected and the isolated aerobic bacteria (115 isolates) were identified as Gram-negative (85.26%), while 14.73% of samples were Gram-positive. The authors emphasised that raw camel milk is a source of many bacteria which may lead to health hazards for men (Elhaj *et al,* 2014). In the southern province of Jordan, raw camel milk samples were collected from 90 dromedary camels. About 21% of the camels revealed clinical signs of mastitis. The most predominant bacteria isolates were *Staphylococcus aureus*, *Streptococcus* spp. *Micrococcus* spp. and *Corynebacterium* spp. (Hawari and Hassawi, 2008). The microbial quality of raw camel milk in United Arab Emirates was investigated, 50 samples were analysed for: Aerobic plates count, total coliform, total *Staphylococcus aureus*, total yeast, and Mold. The results indicated that the mean value of aerobic plate count was 1.8×10^5 cfu/ml, the mean value of total coliform was 6.8×10^{-1}, the mean value of *Staphylococcus aureus* was 1.2×10^3, and the yeast mean value was 4.1×10^{-1} cfu/ml (Omer and Eltinay, 2008). Furthermore, it should also be noted that the calf may be a source of prevalence of microbes in camel milk. So, in many countries, the calf will have their mother suckle to induce the milk ejection reflex. But the calf may compromise the udder hygiene since

Table 2. Raw camel milk with subclinical and clinical mastitis in some countries.

Country	Number of milk samples (quarter or udder)	Positive samples of subclinical or clinical mastitis (%)	References
Egypt	90 (udder)	87.78	Asfour and Anwer (2015)
Ethiopia	956 (quarter)	59.7%	Abdel Gadir Atif *et al* (2006)
Ethiopia	205 (quarter)	37.6%	Abdurahman (2006)
Ethiopia	145 (udder)	29%	Abera *et al* (2010)
Ethiopia	47 (udder)	76.60%	Abera *et al* (2016)
Ethiopia	543 (quarter)	63%	Bekele and Molla (2001)
Ethiopia	34 (udder)	5.88 %	Hadush *et al* (2008)
Ethiopia	374 (quarter)	8.9%	Alebie *et al* (2021)
Iran	243 (95)	18.1%	Niasari-Naslaji *et al* (2016)
Jordan	90 (udder)	21%	Hawari and Hassawi (2008)
Kenya	86 (quarter)	81.4%	Guliye *et al* (2002)
Kenya	107 (udder)	66%	Matofari *et al* (2013)
Kenya	66 (udder)	Most of examined quarter milk samples	Odongo *et al* (2016)
Kenya	380 (quarter)	44.5%	Toroitich *et al* (2017)
Kenya	207 (udder)	23%	Younan *et al* (2001)
Kenya	384 (udder)	61.2%	Wanjohi *et al* (2013)
Kuwait	25 (udder)	36%	Rahmeh *et al* 2022
Saudi Arabia	120 (quarter)	Most of examined quarter milk samples	Saleh and Faye (2011)
Saudi Arabia	740 (quarter)	33 % of tested quarters had subclinical mastitis based on CMT	Al Jumaah *et al* (2012)
Sudan	160 (udder)	71.9%	Elhaj *et al* (2014)
Sudan	391 (quarter)	43.5%	Abdurahman *et al* (1995)

after suckling no cleaning of the udder before milking is done (Noor *et al,* 2013). Several lines of evidence suggest that the risk factors for camel mastitis were severe tick infestation, teat injuries, poor milking hygiene and physiological disorders (Ahmad *et al,* 2012; Aqib *et al,* 2022). Finally, the negative effects of mastitis on camel owners include a reduction in milk production, deterioration in milk quality, a decrease in milk price due to high SCC, loss of milk due to antibiotic treatment, and increased animal care costs (Hertl *et al,* 2010; Tuteja *et al,* 2013).

Using a milking machine to obtain safe raw camel milk for consumption.

Usually, camels are milked by hand in most countries of the world in traditional farming systems (Bekele *et al,* 2002; Alhadrami and Faye, 2016; Atigui *et al,* 2023). The introduction of machine milking makes only slow progress and is limited to intensive dairy camel farms in a few countries (Kaskous and Fadlelmoula, 2014). To improve the quality and the safety of raw camel milk, machine milking must be used instead of hand milking (Hammadi *et al,* 2010; Nagy and Juhasz, 2016; Kaskous, 2018a, 2019). Saleh *et al* (2013) showed a clear difference between two milking methods in terms of udder health and milk quality. Therefore, microbiological contamination was higher in farms with hand milking than in farms with machine milking (Table 3).

Table 3. Bacteriological finding of camel milk samples in two farms with different milking methods (Saleh *et al,* 2013).

Parameters	Farm with machine Milking	Farm with hand milking
Number of Camels	14	14
Duration of the investigation	6 months after calving	6 months after calving
Total samples	84 (100%)	84 (100%)
Uninfected samples	65 (77.4%)	53 (63.1)
Coagulase-negative Staphylococci	15 (17.8%)	22 (26.2%)
Staphylococcus aureus	-	3 (3.6%)
Micrococcus	4 (4.8%)	6 (7.1%)

However, it must be noted that many milking machines used do not succeed in completely emptying the udder. The amount of residual milk after machine milking was high (up to 30% or even more) (Kaskous, 2018b). Review by Ayadi *et al* (2013) clearly showed that low fat levels were observed in milk during mechanical milking, indicating incomplete milk letdown. In addition, it has also been found that improper use of the milking machine, especially improper use of liners, can damage the camel's udder, lead to oedema, and promote the colonisation of *Staphylococcus aureus* during the time of machine milking (Juhasz and Nagy, 2008). Results from Tunisia have shown, that the use of machine milking in the field was associated with higher milk yields, but also resulted in increased microbial contamination compared to hand milking (Atigui *et al,* 2023). Kaskous (2023) has shown reverse results that no pathogenic bacteria were detected in the milk produced after using the milking machine (StimuLactor). Improper use of the milking machine is known to have negative effects on udder health as the udder cannot be completely emptied (Kaskous and Pfaffl, 2023). As a result, the remaining milk after milking can serve as a substrate for pathogens and increase the risk of mastitis (Bruckmaier and Wellnitz, 2008). Therefore, completely emptying the udder during milking promotes milk synthesis and secretion and ensures that the udder remains healthy.

As the market is looking for a suitable milking machine for camels, a special modern milking machine called "StimuLactor" was developed by Siliconform, Germany in 2018, which has been used in practice since then (Fig 2). This milking machine for camels was necessary to enable rapid and complete milk extraction during milking and to maintain udder health. A field study showed that the udder remained healthy and completely emptied after using the "StimuLactor" milking machine (Kaskous, 2019), since this milking machine has been adapted to the anatomical, morphological, and physiological characteristics of the camel's udder.

Training on the milking machine is an important point because by getting the camels used to machine milking, their stress behaviour is reduced, their milk production is increased and the milking time is normalised (Brahmi *et al,* 2024).

Finally, maintaining healthy udders and teats during milking is a key component of an effective milking machine to achieve good and higher quality milk production by preventing mastitis and maintaining animal welfare. In this way, we can help provide consumers with good and safe camel milk.

Factors affecting safe raw camel milk after harvest

Raw camel milk is a natural food that can be contaminated with microbiota in the chain from the milking to the consumer as the milk is very good

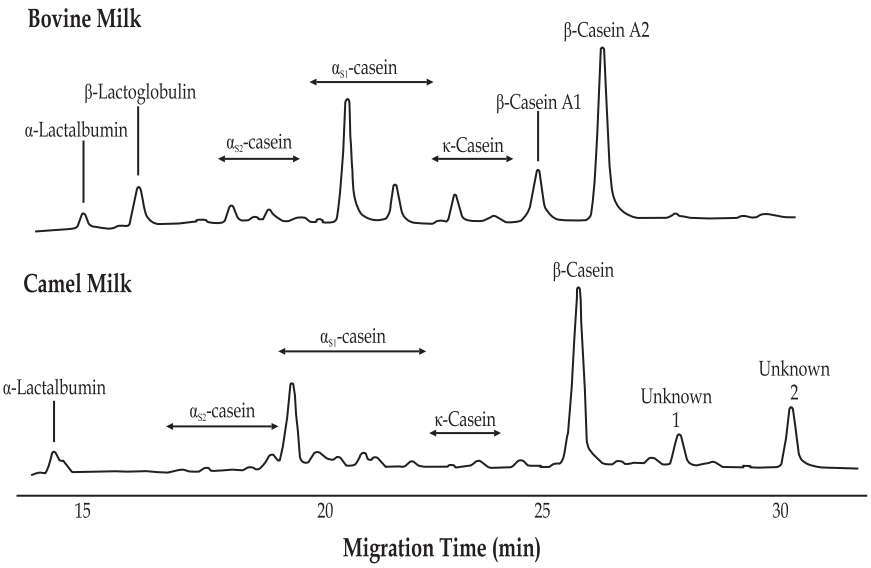

Fig 1. Representative electropherogram of bovine and dromedary camel milk samples determined by capillary electrophoresis according to Mohamed *et al* (2020).

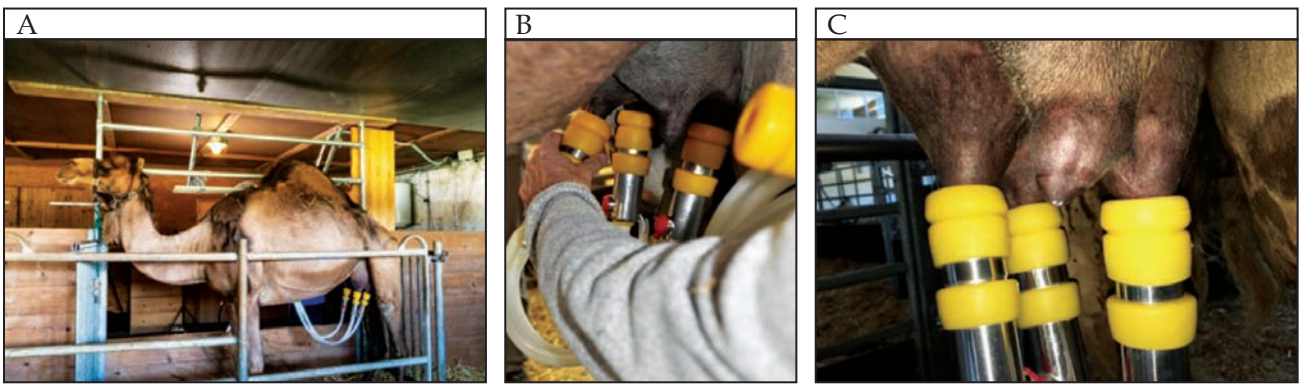

Fig 2. A: A StimuLactor milking machine during milking in camel farm, B+C: Attach milk teat cups.

suitable liquid for these microbiotas (Mohammed *et al,* 2016; Kaskous, 2018a). Therefore, a great deal of research has been done to determine the prevalence of microbial content in the raw camel milk after harvesting from the healthy udder (Wanjohi *et al,* 2013; Matofari *et al,* 2013; Odongo *et al,* 2016; Serda *et al,* 2018; Ismaili *et al,* 2019). Autochthonous microbiota from the exterior of the camel's udder and teats can contribute to the contamination as well as microbiota that are derived from the environment in which the camel is housed and milked (Bachmann,1992; Bekele and Molla, 2001; Hawari and Hassawi, 2008; Omer and Eltinay, 2008; Wanjohi *et al,* 2013; Atigui *et al,* 2023). However, most important it appears to be the contribution of microbiota from teats soiled with manure, mud, and feed. Teats and udders of camels inevitably become contaminated while they are lying or when allowed in dirty lots. The influence of dirty camels on total bacteria counts depends on the extent of soiling of the teat surface and the udder prep procedures employed. Such microbiota could be reduced if hygiene measures were implemented during milking. However, many milkers or camel owners did not adhere to the hygiene measures during milking (Hassen *et al,* 2022). This means that the milk can become contaminated after it leaves the streak canal. Therefore, due to the traditional nature of camel milk production and the lack of appropriate hygiene measures, there is a high risk of milk contamination with microbiota in the milk production sector in many developing countries (Getachew, 2003). The factors that increase microbiota contamination are mainly due to the high ambient temperatures coupled with a lack of on-farm refrigeration, long distances to markets and a lack of transportation options (Husein *et al,* 2016). Matofari *et al* (2013) reported that camel milk is less contaminated at farm because it has not undergone

many handlers. The only contamination at this stage may come from the infected udder mostly caused by the cocci group. Abera *et al* (2016) reported that the two dominant factors of the quality of camel raw milk after harvesting are the condition of keeping the product and the time before delivery to the consumer. In any case, a high number of microbiotas in the collected milk samples is an indication of unhygienic milk production conditions (Abdurahman, 2006; Kamal *et al,* 2010). It is noteworthy that many farmers store their raw camel milk in plastic canisters after harvest (Hassen *et al,* 2022). An interesting aspect was that 66% of raw camel milk samples at the farm (Production area) had a microbial load less than 10^5 cfu/ml, compared to 54% at the collection point (bulk tank) and marketing where the microbial load was above 10^6 cfu/ml (Matofari *et al,* 2013). In addition, bicycles, donkeys, and existing vehicles were used to transport raw camel milk from production areas in Kenya to collection or market centres 10 to 20 km away. The ambient temperature in the production areas and on the transport, route was around 39 °C. The raw camel milk reaches the collection points in 2 to 3 hours and the large markets in the cities in 6 to 8 hours (Matofari *et al,* 2013). Through these transportation processes, the raw camel milk could maintain millions of microbiotas, and when this raw camel milk is consumed, the health situation will be severely affected. In this context, Husein *et al* (2016) reported that consuming raw camel milk from production areas was less dangerous than consuming raw camel milk from the market. Furthermore, Abera *et al* (2016) found that about 85.7% of raw camel milk samples in Somali Regional State of Ethiopia were bacterially contaminated and the total bacterial count (TBC) of the contaminated raw camel milk samples was on average 4.75±0.17 log cfu/ml. These bacteria multiply rapidly from the udder to the market. These results indicate that there was a lack of hygiene in the production and milking areas, during transport, and during sale of raw camel milk. A new study in Nigeria has shown that milk samples were taken from five healthy dromedaries and the microbiota *Escherichia coli, Salmonella* in the first camel and *Staphylococcus aureus* in the remaining camels were found (Dogondaji *et al,* 2023). The authors emphasise that the consumption of raw camel milk should therefore, be done with caution. Kaskous (2019) found that by adhering to hygienic measures, good, safe raw camel milk with normal composition was obtained. Therefore, hygiene measures must also be observed after the harvest in order to maintain the quality standard of raw camel milk.

Conclusion

- Regarding the importance of camel milk and the associated related health benefits of its bioactive ingredients, improvements in milking hygiene, milk storage and transport conditions are required to ensure the quality of camel milk meets consumer needs.
- Camels must be kept healthy and raw milk must be refrigerated immediately after milking and during storage and transport.
- The used milking system should adapt to the morphological, anatomical, and physiological characteristics of the udder and teat of the lactating camels and it should achieve a physiologically ideal milking process that meets high animal welfare standards and increases milk production with a high-quality standard.
- To obtain safe camel milk for human consumption, it is recommended to consume pasteurised camel milk.

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SAUDI EXHIBITION IN GENEVA SHOWCASES CAMEL CONVERSION PRODUCTS' SIGNIFICANCE IN FOOD SECURITY

The Saudi Exhibition at the International Year of Camelids (IYC) 2024 was inaugurated in Geneva, Switzerland from June 25 to 28. Dr. Ali Al-Shaikhi, undersecretary for fisheries and livestock wealth at the Ministry of Environment, Water, and Agriculture, inaugurated the event.The event was held in partnership with the State of Bolivia at the United Nations Palace in Geneva. The event was attended by United Nations Human Rights Council Vice President Mayra Mariela Macdonal Alvarez, UN Food and Agriculture Organisation (FAO) Director General Qu Dongyu, Saudi Ambassador to Switzerland Dr. Adel Merdad, and several ministers, ambassadors, and senior officials representing about 100 UN member states.

At least 13 government and private entities participated in the Saudi exhibition, showcasing the most important locally manufactured camel conversion products and their significance in achieving food security. The exhibition also included leather, medical, and cosmetic products derived from camels. It sought to embody the great cultural value of camels in Saudi society. The Kingdom's participation in the event stems from its presidency of the International Year of Camels 2024 in partnership with the Group of Latin American and the Caribbean (GRULAC), represented by Bolivia. Saudi Arabia has taken important steps to develop the camel sector, including raising public awareness about the importance of camels and their role in providing food and livelihood for their owners and breeders, encouraging increased productivity, combating diseases and epidemics that afflict them, vaccinating them periodically, and improving the marketing of camel products to raise the income of breeders and thus maximise and raise their living standards. Saudi Arabia emphasised the significance of camels in promoting economic development, contributing to food security, and achieving sustainable development goals for livestock, all in line with the adoption of several initiatives to support the camel sector, which represents a cultural heritage and a long-standing tradition.

(Source: Staff Writer, Saudi Gazette, June 26, 2024 RELATED TOPICS FOOD SECURITY ENVIRONMENT SAUDI ARABIA SUSTAINABILITY)

CAMEL CRAZY: A QUEST FOR MIRACLES IN THE MYSTERIOUS WORLD OF CAMELS: MONGOLIAN EDITION

The award-winning book CAMEL CRAZY: A Quest for Miracles in the Mysterious World of Camels, by Christina Adams, gained wide global acclaim in the original English version. It is now available in the Mongolian language from NEPKO Publishing of Ulaanbaatar, Mongolia. The new edition is updated with photos of Mongolian camel herders, the camel dairy farm of Solid Partners Group, and a new table on the nutritional content of Bactrian camel milk, as well as information on the endangered wild camel species found in Mongolia.. A "page turning odyssey of a mother on a mission-from Bedouin camps in the Middle East to Amish farms in Pennsylvania to camel-herder villages in India--to obtain camel milk, which dramatically helps her son's autism symptoms. Adams' work uncovers studies of camel milk for possible treatment of autism, allergies, diabetes, and immune dysfunction, as well as ancient traditions of healing. But the most fascinating aspect of Adams' discoveries is the gentle-eyed, mischievous camels themselves." Contact Bayarmagni Ganbold of NEPKO Publishing for copies at phone 976-8810 1714 or email gbayarmagnaid@gmail.com. Website: www.nepoko.mn.

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MORPHOLOGY AND FUNCTION OF THE SPLEEN IN CAMEL: A COMPARATIVE REVIEW

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ABSTRACT

The morphology of the spleen varies among different mammalian species. In camels, it is C-shaped, while in dogs, it is elongated, dumbbell shaped, and ventrally oversized. Ruminants have a flat and oblong spleen, while in horses it is comma shaped. The spleen is located in the left upper quadrant of the caudal peritoneal cavity, behind the diaphragm, and in close proximity to the colon, kidney, lower ribs, stomach, and pancreas in camels and other mammalian species, respectively. The camel's spleen is enclosed within a thick capsule. This capsule is divided into an inner layer composed of smooth muscle cells and an outer layer primarily made of connective tissue. The two layers of the capsule are smooth muscle and dense irregular connective tissue. Species differences exist in both the overall thickness and relative quantity of smooth muscle. Collagen and elastic fibres make up trabeculae, while smooth muscle cells extend into the parenchyma from the capsule and the hilus. The spleen in camels plays a crucial role in the storage and regulation of blood supply. The central artery, which emerged from the periarterial lymphatic sheath, was branched to four penicilli and then extended as sheathed arterioles, which were found near or surrounded by blood sinusoids of the red pulp. The white pulp is surrounded by a broad marginal zone that lacks marginal sinuses but has sheathed arteries. The marginal zone macrophages, a key player in the spleen's immune response, were characterised by its large size and intimate connections between its cell processes and the nearby marginal zone B cells. Scanning electron microscopy of the camel foetus's spleen demonstrated the primary structure, including mesothelium, numerous erythrocytes, medium-sized and small lymphocytes, reticular cells, and reticular connective tissue fibres. Differential features of spleen of other animals are also discussed.

Key words: Anatomy, camel, function, histology, spleen, ultrastructure

The spleen is an intriguing organ that performs various functions such as haematopoiesis, immunological response, blood filtration, and blood storage, and these functions vary among different animal species. As the animal develops, there are exciting changes in the presence and significance of each function, with a reduction in haematopoietic activities and an increase in the specialisation of other tasks over time (Udroiu and Sgura, 2017).

The spleen, an intraperitoneal lymphoid organ, is situated on the left side of the abdomen, below the diaphragm (Dyce *et al,* 1987). During gestation, the spleen plays a significant role in haematopoiesis, (Boes and Durham, 2017). Post-birth, the spleen carries out a range of vital physiological functions, including haematopoiesis and lymphopoiesis (lymphocyte proliferation and maturation), blood filtration via recycling of senescent and damaged erythrocytes, erythrocyte and thrombocyte storage, iron metabolism, and immune surveillance (Cheung and Nadakavukaren, 1983; Mebius and Kraal, 2005; Cesta, 2006; Eurell and Frappier, 2006; Moura *et al,* 2008; Khalil *et al,* 2009; Bello *et al,* 2019; Gnanadevi *et al,* 2019; Lewis *et al,* 2019; Xu *et al,* 2020; Abdellatif, 2021).

The spleen's structure reflects its complexity. It is primarily composed of red and white pulp (RP and WP), with a distinct marginal zone between them (Bronte and Pittet, 2013). The WP, despite occupying less than a quarter of the spleen's tissue, is its principal immunologic zone. The RP makes up the majority of the tissue and serves a different immunological function than the WP. The absence of afferent lymphatic arteries in the spleen contributes to its unique structure, as all cells and antigens enter the spleen via the blood (Lewis *et al,* 2019).

This shift from scattered lymphocytes to the segregation of the WP indicates a rise in the complexity of immunological characteristics and the

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organisation of T and B lymphocyte regions, leading to the formation of germinal centres. Additionally, different features of the RP have evolved in mammalian species, enhancing the specialisation of the filtration function of the pulp sinuses and the storage function (Udroiu and Sgura, 2017).

In adult animals, lymphopoiesis is the spleen's main haematopoietic activity, while erythropoiesis occurs during foetal life. However, splenic erythropoiesis persists in newborn horses and ruminants for several weeks postpartum (Boes and Durham, 2017). Erythrocytes and thrombocytes are typically stored in the RP and splenic cords. As animals age, the elasticity of the erythrocyte cell membrane decreases, leading to the detection and removal of old and damaged erythrocytes by the splenic cords' reticuloendothelial system and macrophages in the red pulp's venous sinuses. A reticular fibre network of macrophages and reticular cells across the reticuloendothelial system helps the spleen filter blood more effectively, resulting in numerous macrophages containing engulfed erythrocyte fragments and hemosiderin pigment in the RP (Eurell and Frappier, 2006).

Gross anatomy of the spleen in camel

The morphology of the spleen varies among different mammalian species (Fig 1). In camels, it is C-shaped, while in dogs, it is elongated, dumbbell-shaped, and ventrally oversized. Ruminants have a flat and oblong spleen, while in horses it is comma-shaped. According to Smuts and Bezuidenhout (1987) and Dyce *et al* (1987), the spleen is located in the left upper quadrant of the caudal peritoneal cavity, behind the diaphragm, and in close proximity to the colon, kidney, lower ribs, stomach, and pancreas in camels and other mammalian species, respectively. The spleen is typically not noticeable on physical inspection, but in thin adults, children, and adolescents may be detected (Nguyen and Zhang, 2020).

Accessory spleens, also known as supernumerary spleens, splenules, or splenunculi, are benign and asymptomatic. They are estimated to be present in 10% to 30% of the population, with an individual potentially having one to six accessory splenic buds. Accessory spleens are typically only a few millimetres long, but can occasionally grow to a few centimetres in length, resulting in variation in size (Nguyen and Zhang, 2020; Yildiz *et al,* 2013; Mohammadi *et al,* 2016).

Khalel (2010) conducted a comprehensive study on the gross anatomy of the spleen in Awasi sheep, unearthing unique findings that significantly advanced our understanding in the field. The spleen, for instance, was found to possess a distinctive triangular shape with rounded corners, weighing approximately 69±6.7 g and measuring an average length and width of 9.93±0.3 and 6.48±0.2 cm, respectively. It reached its maximum thickness near the hilus (2.48±0.1 cm). The spleen also exhibited two distinct surfaces: the visceral, which was concave and had a hilus, and the parietal, which appeared to be convex. In sheep, the spleen had two ends: the ventral end, which was narrower and thinner than the base end, and the base end, which was broad and thick. These detailed observations, alongwith other intriguing findings such as the quadrangular shape of goat spleens (Suri *et al,* 2017; Gnanadevi *et al,* 2019) have significantly enriched our understanding of the gross anatomy of the spleen in various animal species.

The spleen, a vital organ in camels, was characterised by its dark brown colour and unique C-shape with blunt, rough surfaces and edges. It was thick at the hilus and the midline and thin at the edges (Maina *et al,* 2014). According to Nawal and Maher (2018), the spleen of a camel had four segments, two hilus, and two splenic arteries and veins. The same authors stated that the splenic blood supply had only one arterial segmentation with no anastomosis. In buffalo calves, sheep, and goats, only one tiny hilus was found, and anastomosis and venous segmentation between the dorsal and intermediate segments were absent. According to Marwa-babiker *et al* (2023), the spleen has C-shaped, rough surfaces and serrated edges in camel foetuses. It is located on the caudolateral side of the abdominal cavity, medially to the ribs and caudally to the stomach. These findings underscore the practical importance of understanding the gross anatomy of the spleen in different animal species, making a significant contribution to the field of veterinary medicine and anatomy.

The spleen of the Asian elephant was dark reddish, long and narrow. The caudal-visceral surface was concave and displayed a longitudinal hilus towards its cranial border; the cranial-parietal surface was convex with serrations on the caudal and cranial splenic borders (Rajani *et al,* 2021).

Histology of mammals' spleen

Zidan *et al* (2000) found that the camel's spleen is enclosed within a thick capsule. This capsule is divided into an inner layer composed of smooth muscle cells and an outer layer primarily made of connective tissue. The same authors showed that

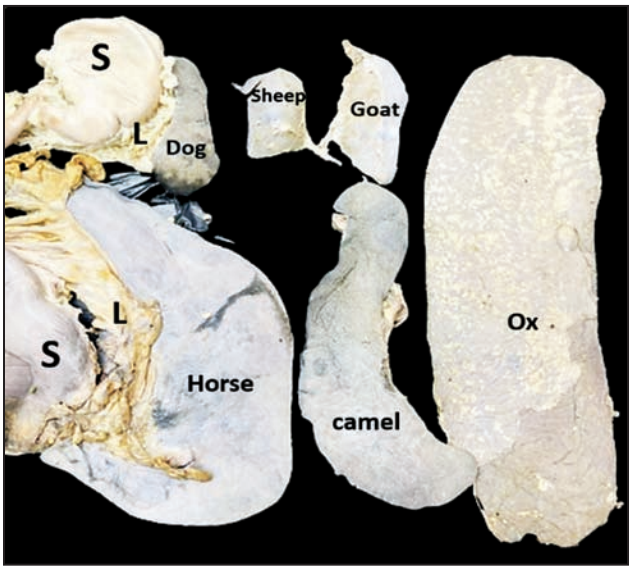

Fig 1. Photograph showing the spleen of different domestic mammalian species, S: stomach, L: gastro splenic ligament.

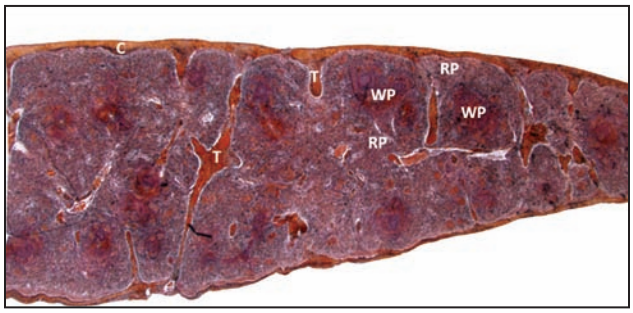

Fig 2. Photomicrograph showing general histological view of the mammalian (rat) spleen: stroma of the spleen consists of connective tissue capsule surround the spleen (C), which sends the connective tissue trabeculae (T). The parenchyma consists of white pulp (WP) and red pulp (RP).

the vascular and avascular trabeculae extending from the capsule to the parenchyma, subcapsular, and per trabecular blood sinuses around primary and vascular trabeculae are unique structures of the camel spleen. These unique structures are not found

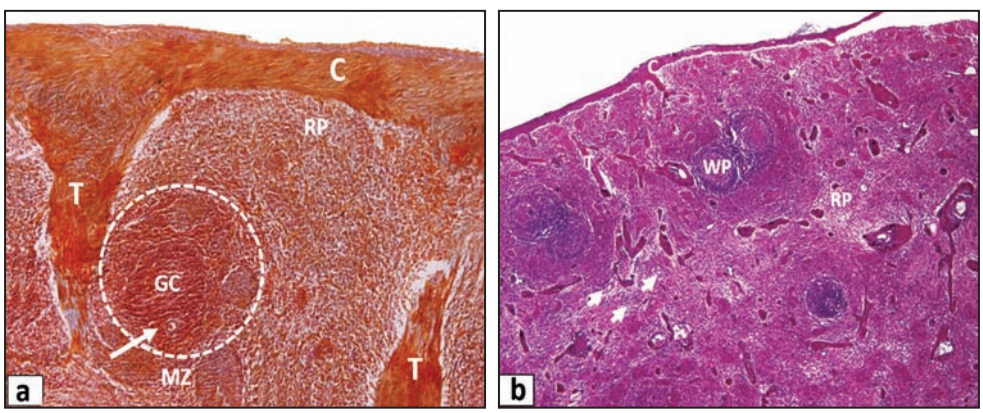

Fig 3. a and b: Photomicrograph showing the spleen; C: connective tissue capsule, T: connective tissue trabeculae, GC: germinal centre of the splenic corpuscle (dotted circle). MZ: marginal zone, which found between the white pulp and the red pulp (RP). Central arteriole (arrow) and splenic sinuses (arrows head).

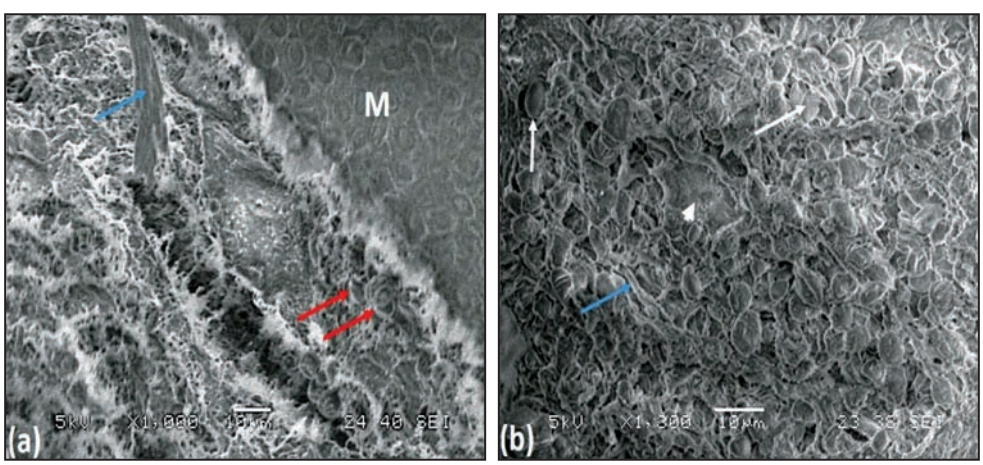

Fig 4. a and b: Scanning electron micrograph of spleen of camel foetus showing mesothelium (M) erythrocytes (white arrows), lymphocytes (red arrows) reticular cells (arrowhead) and reticular connective tissue fibres (blue arrows).

in other mammalian species, indicating a distinct evolutionary path for the camel spleen. In other mammalian species, the spleen is surrounded by a capsule of thick connective tissue invested by the peritoneum (Eurell and Frappier, 2006) (Figs 2 and 3).

The two layers of the capsule are smooth muscle and dense irregular connective tissue. Species differences exist in both the overall thickness and relative quantity of smooth muscle (Eurell and Frappier, 2006 and Marwa-babiker *et al,* 2023). Collagen and elastic fibres make up trabeculae, while smooth muscle cells extend into the parenchyma from the capsule and the hilus.

The spleen, a vital component of the body's immune system, is a complex organ. It is composed of RP, responsible for storing red blood cells, and WP, rich in lymphocytes and active in immune responses (Eurell and Frappier, 2006; Bloom and Fawcett, 1986). The RP is made up of cell cords and sinusoids, while WP is lymphoid in nature, with a marginal zone containing pores where cells can leak (Van Krieken, 1997). The WP houses two types of blood vessels: one with muscled walls, and the other with thinner walls sheathed by reticular cells. Within the reticular cells, a network of lymphoblast, small and medium lymphocytes, and dendritic macrophages is formed. This intricate network of cells and vessels is crucial to the body's defense system, underscoring the importance of studying the unique camel spleen.

According to Zidan *et al* (2000), the spleen in camels plays a crucial role in the storage and regulation of blood supply. The central artery, which emerged from the periarterial lymphatic sheath, was branched to four penicilli and then extended as sheathed arterioles, which were found near or surrounded by blood sinusoids of the RP. The WP is surrounded by a broad marginal zone that lacks marginal sinuses but has sheathed arteries. The RP was divided into cords by secondary trabeculae and contained numerous sizes of venous sinusoids. The observation demonstrated that the spleen of the camel was a sinusal type that can store blood, as well as the thick muscular capsule and trabeculae pump according to the body's need. Closed and open circulations facilitated the blood supply of the spleen. A unique venous return was drained from the venous sinusoids of the RP to the peritrabecular sinuses and subcapsular sinuses to the splenic vein. These histological structures showed no significant differences related to age.

During the first trimester of pregnancy, the spleen's capsule in camels was made of a thin connective tissue, indicating a relatively low blood storage capacity. However, as the pregnancy progressed into the second and third trimesters, the spleen underwent significant changes. The capsule transformed into a thick, dense, irregular connective tissue with descending trabeculae of collagen fibres and bundles of smooth muscle fibres, suggesting an increased blood storage capacity. The parenchyma, which consisted of a variety of cell types in the first trimester, differentiated into white and red pulps in the second and third trimesters. The RP contained megakaryocytes in all three trimesters, indicating a continuous production of blood cells throughout the pregnancy (Marwa-Babiker *et al,* 2022).

The marginal zone macrophages, a key player in the spleen's immune response, were characterised by its large size and intimate connections between its cell processes and the nearby marginal zone B cells. It also boasts a highly developed phagocytic potential (Dijkstra *et al,* 1985). In mice, Humphrey and Grennan (1981) noted that the marginal zone macrophages were larger than the other macrophages in the spleen and had a distinct morphology. These unique characteristics of the marginal zone macrophages contribute to our understanding of the spleen's immune system and its role in maintaining the camel's health.

In a meticulous study of rats, the authors observed that the spleen, before differentiated into the periarteriolar lymphoid sheath in the interior layer of the marginal zone (MZ), migrating lymphocytes tended to gather in some places near marginal-zone macrophages (Dijkstra, 1982; Brelinska and Pilgrim, 1983). This careful observation underscores the importance of understanding the spleen's structure in different animal species.

In rats (Figs 2 and 3), in line with Suri *et al* (2017) and Gnanadevi *et al* (2019) in goats, has revealed that the spleen was enclosed in a thick capsule of irregular dense connective tissue, and red and white pulps. The WP, a crucial component, is composed of periarterial lymphatic sheath and splenic nodule, which are scattered throughout the RP. The RP, another key element, consists of splenic cords and sinusoids; the endothelial cells with prominent nuclei that protruded into the sinusoidal lumen bordered the sinusoids (Gnanadevi *et al,* 2019 and Suri *et al,* 2017).

Rahman *et al* (2016) studied the histo-mophometry of spleen in human, goat, buffalo, rabbit and rat and found significant implications. Identical capsular thickness measurements were observed in goats and buffaloes, whereas the thin and thinnest capsule was measured in rat and rabbit, respectively.

In sheep, the capsule was made of collagen, elastic, reticular, and smooth muscle fibres (Thanvi *et al,* 2020). The red and white pulps, the main components of the splenic parenchyma, play a crucial role in the spleen's function. The WP, consisting of lympho-reticular tissue, lymphatic nodule and periarterial lymphatic sheath, is less abundant. The RP, made up of pulp arterioles, splenic sinusoids, splenic cords, and sheathed and terminal capillaries, is also less abundant and poorly developed (Thanvi *et al,* 2020).

A novel finding conducted by Rajani *et al* (2021), described that the spleen of the Asian elephant is surrounded by a thick capsule of dense irregular connective tissue. Most of the splenic parenchyma, a unique feature, consisted of RP, while the remaining 20.25% was WP, composed of the periarterial lymphatic sheath and splenic nodules (Rajani *et al,* 2021). Many investigators have observed numerous megakaryocytes in the RP of adult and foetal dromedary camel (Zidan *et al,* 2000; Marwa-Babiker *et al,* 2022), whereas it was observed in both the spleen and bone marrow of pregnant rats (Marien and McFadden, 1970). The findings are significant in understanding the spleen's structure in different animal species.

Ultrastructure of spleen

Scanning electron microscopy of the camel foetus's spleen demonstrated the primary structure, including mesothelium, numerous erythrocytes, medium-sized and small lymphocytes, reticular cells, and reticular connective tissue fibres (Fig 4). During the first trimester of pregnancy, a comparatively limited number of reticular cells were observed in the parietal sheath, marginal zones, and cordal gaps. Dendritic macrophages and lymphoblasts were organised into a network by the reticular cells throughout the second and third trimesters. Marwa-Babiker *et al* (2023) investigated the spleen of a camel foetus and found that it was lined with mesothelial cells and divided by reticular connective tissue fibres using scanning electron microscopy.

Weiss (1974) studied the scanning electron microscopy of normal rat spleen and demonstrated that the reticulum and vascular sinuses were made of macrophages, erythrocytes, thrombocytes, and other migratory elements. Large, bulky, irregular reticular cells with broad processes were found in the periarterial lymphatic sheath, the marginal zone and cordal spaces. Flattened reticular cells at the periphery of the periarterial lymphatic sheath formed cylinder shapes attached to the central artery and associated with unusually heavy extracellular fibres. Vascular sinuses were suspended in the reticulum by attachments of cordal reticular cells to the adventitial surface. Adventitial cells of the sinus were branched into the cords. Endothelial cells were typically laid side by side without gaps, except as migratory cells which passed through the wall. The erythrocytes were observed in passage across the sinus wall. Sinuses and cords were often swollen, irregular, and bore blebs. Macrophages displayed rich surface folds and processes, whereas the thrombocytes were abundant and adherent to the endothelium of sinuses and the surface of reticular cells.

Polak *et al* (2009) demonstrated that the splenic cords originated from a three-dimensional network of fibroblastic reticular cells situated among branched sinuses and artery terminals in human spleen. A unique variety of rod-shaped endothelial cells that were oriented perpendicular to the longitudinal axis of the sinuses lined their interior walls. The fibroblastic reticular cells were transformed into fixed phagocytes with no phagocytosis properties. The capsule and trabeculae were composed of random smooth muscle fibres.

The reticular cells in the spleen were three-dimensional stellate shapes with smooth surfaces that extended slender processes. Although the reticular cells they exposed in some places, the reticular fibres were typically covered by reticular cell processes (Fujita and Ushiki, 1992).

Electron microscopy of albino rabbit's spleen revealed that the white pulp was arranged in clumps or nests separated by a loose-irregular meshwork composed of basement membrane-like material, collagen, and the cellular prolongations of fibroblasts and stellate cells, lymphocytes, and numerous reticular cells. The plasma cells, macrophages, erythrocytes, and thrombocytes were situated at the periphery of the white pulp and adjacent to the marginal zone. The lymphocytes of the white pulp varied in size and was difficult to differentiate from the polymorphic reticular cells (Burke and Simon, 1970).

According to Kashimura and Fujita (1987), the central arteries in human were continuous and without branching into follicular arteries in the white pulp, while developing into penicillar arteries in the red pulp. Although some penicillar arteries retreated in the marginal zone, others travelled through it, penetrating the white pulp and developing into follicular arteries.

In humans and rats, the spleen was examined using scanning electron microscopy (Sasou *et al,* 1986). Both species had the marginal zone and white and red

pulps; however, there were considerable differences in the artery termination in the marginal zone. In rats, the follicular arteries formed the marginal sinus, a circulatory net that terminated at the edge of the white pulp. Numerous vascular termini of the follicular and sheathing arteries were dispersed throughout the human's marginal zone. Despite these differences, both in humans and rats, the central artery was found to be surrounded by flat reticular cells, a reassuring similarity. In the red pulp of rats, the vascular termini were funnel- or tubular-shaped. The sheath of human arteries had a circumferential lamellar structure consisting of flat reticular fibres (Sasou *et al*, 1986).

Conclusion

The spleen, a vital organ in various mammals, exhibits significant variations in shape. For instance, it was bigger ventrally and bell-shaped in dogs, comma-shaped in horses, C-shaped in camels, and elongated in ruminants. The celiac plexus provides precise innervation and blood supply via the splenic artery and vein. This intricate network ensures the organ's optimal functioning. The spleen is a soft, reddish-purple organ with two surfaces, visceral and diaphragmatic, and its limits are divided into three areas: cranial, caudal, and intermediate. The splenic hilum, located on the caudomedial side of the gastric impression, contains nerves, splenic vessels, splenorenal, and gastrosplenic ligaments and is enclosed in an elastic and fibrous tissue capsule that extends into the parenchyma as trabeculae. The parenchyma, supported by an exemplary network of reticular fibres, comprises two types of tissue: white pulp and red pulp, separated by marginal zones.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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INTERNATIONAL WORKSHOP ON CAMELID PASTORALISM

The International Workshop on Camelid Pastoralism, held in Sadri, Rajasthan February 2024, marked the inauguration of the International Year of Camelids in 2024. Hosted by Lokhit Pashu-Palak Sansthan (LPPS), the League for Pastoral Peoples (LPP), and the Godwar camel pastoralist milk producers, the event gathered stakeholders from across the globe. Participants hailed from regions like Rajasthan, Gujarat, Mongolia, Kenya, Iran, UK, Germany, Peru, Pakistan, UAE, and USA, representing a diverse array of perspectives and experiences in camelid pastoralism.

The workshop highlighted the indispensable role of camelids in ensuring food security and biodiversity protection, particularly in arid and semi-arid regions worldwide. Participants emphasised the importance of mobile management systems, recognising camelids' resilience and environmental benefits, including their soft-footed grazing habits. Traditional knowledge held by camelid pastoralists, accumulated over centuries, was acknowledged as invaluable in sustaining camelid herds and producing a wide range of camelid-derived products.

Women emerged as leaders in camelid development, driving innovation and marketing efforts for camelid-based products. Their contributions not only enrich their own communities but also support camelid pastoralists globally. However, camelid pastoralists face numerous challenges, including land dispossession, policy neglect, and encroachment by extractive industries and urbanisation.

Rejecting the extractive model inherited from colonial legacies, participants advocated for a fossil-fuel-free approach to camelid development. They called upon governments to recognise camelids' territories of life, respect customary rights, and provide legal, institutional, and financial support. Access to veterinary services and incentivizing youth engagement in mobile camelid pastoralism were deemed essential for ensuring the continuation of traditional practices.

To preserve camelid herding as a cultural heritage and ensure the well-being of pastoralists and their herds, participants stressed the need for fair and ethical value chains. Community-based initiatives that prioritise the pastoralists' benefits and remunerate them fairly for their products were identified as development priorities.

As the International Year of Camelids unfolds, stakeholders are urged to centre their efforts on understanding and valuing the knowledge and work of camelid-herding communities. Collaboration and solidarity among global camelid pastoralists are essential to promote a development model that benefits camelids, people, and the planet, setting the stage for a successful International Year of Rangelands and Pastoralists in 2026.

(Courtery: Ilse Kohler Röllefson and Hanwant Singh, LPPS, Sadri, India)

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HISTOLOGICAL STRUCTURE OF THE PROSTATE GLAND DURING ANTE AND POSTNATAL PERIOD OF ONTOGENESIS IN DROMEDARY CAMEL IN ALGERIA

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ABSTRACT

The current investigation was aimed to assess morpho-functional (histological) variations in the prostate of clinically healthy dromedaries during both ante- and postnatal phases of ontogeny. Thirty prostates from two distinct age cohorts (ante- and postnatal) were procured from the EL OUAD slaughterhouse (located in the eastern region of ALGERIA) for microscopic examination, with a focus on delineating the microscopic architecture of the prostate in this species. A range of staining methods, including Haematoxylin and Eosin, as well as silver nitrate impregnation, were employed to elucidate the normal histological framework and developmental trajectory of the prostate across different age groups. Subsequent statistical analysis was conducted to interpret the acquired data with significance set at $P<0.05$. Our findings revealed discernible patterns of structural and functional differentiation, specialisation and integration within the prostate gland parenchyma. Notable milestones in structural markers were identified, during the seventh month of the intrauterine phase and the eleventh and twelfth months of the foetal period. Epithelial cell secretory activity commenced during the animal's 36th month, while the formation of lobules and thickening of the capsule layer were observed during the terminal phase of gestation and the postnatal period, respectively. Concurrently, interlobular connective tissue expanded alongside epithelial cell formation and an increase in terminal capillary count, peaking during the pubertal phase of the animals. In summary, our results underscore the association between ante- and postnatal phases of ontogenesis and the initiation of puberty, shedding light on the intricate anatomical and histological dynamics of the dromedary prostate.

Key words: Anatomy, dromedary, histology, ontogenesis, prostate

The camel prostate, notably substantial and easily identifiable, comprises of two distinct elements: a compact and a diffuse segment and divides into three zones: central, peripheral and transition (Mahmud *et al,* 2016). Together, these segments form an L-shaped structure positioned dorsally to the pelvic urethra. Shaaeldin and Tingari (2019) found that the camel prostate is oval-shaped, encircling the proximal part of the urethra at the bladder neck, with ducts opening around the entire urethral circumference. Dorsally, the prostate splits into two lobes separated by a septum.

Ultrastructure of the prostate of camel has been studied previously (Ali *et al,* 1976; Soliman *et al,* 2010), illustrating it as a complex of branched tubule-alveolar glands whose ducts open into the prostatic urethra. Moreover, it is enveloped by a fibro-elastic capsule rich in smooth muscle cells, with septa from this capsule effectively segmenting the gland into lobes, albeit indistinct in adult male camels, a finding echoed in research on gazelles by Mohammed *et al* (2007).

While existing literature elucidates the anatomy, topography (Degen and Lee, 1982) and histological structure of the camel's prostate (Luo *et al,* 2016), there is a paucity of studies examining its prenatal and postnatal developmental phases. Building upon this gap, Biancardi *et al* (2017) emphasised the importance of morphological developmental analysis, linking it to systems theory and organ tissue regional concepts. Consequently, the aim of this study was to conduct a comprehensive investigation into the histological changes in the prostate gland of camel from prenatal to postnatal stages, elucidating critical developmental periods and their relationship with the onset of puberty.

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Materials and Methods

Ethical approval

The sampling and data collection in this study was performed in accordance to the ethical recommendations of the Algerian government.

The present research was conducted on camels from a slaughterhouse in El-Oued -a province in the southeast of Algeria- and spanned from July 2021 to May 2023. Thirty prostates were obtained from clinically healthy and unvaccinated male foetuses aged between 07 to 13 months, neonatally. They were taken from animals aged 12, 24, 36, 48 and 60 months postnatally, with foetal age verified through femur length measurement. The methodological framework adhered to in this study followed the protocols outlined by Kadim *et al* (2008) and Saber *et al* (2020).

The investigations took place at the Laboratoire des Sciences et Techniques du Vivant, Institut d'Agriculture et des Sciences Vétérinaires, Université de Souk Ahras, Algeria. Specimens selected to elucidate morpho-functional changes in prostates concerning age were preserved using a 10% neutral buffered formalin solution. Subsequently, some fixed organ fragments were embedded in paraffin to facilitate the creation of thin sections measuring 3-5 microns thick.

For histological examination of the prostate's structure, staining with haematoxylin and eosin, the protocols of Cardiff *et al* (2014) and Abrahamsson *et al* (1989) were employed. Additionally, frozen sections of prostate tissue underwent staining with silver nitrate impregnation to highlight proteins prominently expressed on silicone.

Stained histological sections were examined and morphometry and microphotography were conducted using a MOTIC DM-52 light microscope, mono, digital (eyepiece x4, objective x10/0.25, x40/0.65).

Statistical analysis was carried out using standard "statist SF" software, with data analysis performed using SPSS Version 26.0.2019 (SPSS, Armonk, NY: IBM Corp). Data were expressed as means ± SD (standard deviation) and subjected to statistical analysis using Duncan's test, with statistical significance set at $P<0.05$.

Results

Histological analysis of neonatal camel prostates revealed a thin prostatic capsule that was mainly composed of collagen and which is surrounded by isolated cells and isolated bundles of internal smooth muscle. Each tubuloalveolar gland was encapsulated in fibrous connective tissue that contained delicate bundles of smooth muscle fibres. This glandular organisation takes the form of lobes subdivided into lobules by thin collagenous partitions, with scattered smooth muscle cells in this arrangement (Fig 1).

Examination of the thickness of the prostatic capsule revealed a significant variation ($P < 0.01$) with the age of the subjects studied. At the 7th month of gestation, capsule thickness reached 54.32 ± 0.67 µm, increasing significantly to 76.32 ± 1.96 µm at the end of gestation. During the postnatal period in the spring, the thickness of the prostatic capsule in newborns measured 85.1 ± 1.04 µm ($P <0.05$). At the age of 60 months, this measurement reached a value of 98.6 ± 1.27 µm.

Concerning the secretory ducts, the application of silver nitrate to the histological sections revealed three distinct colours, indicating different cellular structures. At low magnification, the presence of multiple lumens suggests the presence of grouped empty spaces, with two forms of these lumens observed in foetal prostates.

The intra-lobular ducts were lined with tall columnar secretory cells The interlobular ducts and the main excretory ducts were lined with stratified transitional epithelium visible in histological sections in neonatal prostates. Light brown staining indicated the presence of reticular tissue which was concentrated around urethral areas rich in this type of tissue.

Moreover, the intensity of the proliferative process in the connective tissue of the prostate varied, creating a distinctive architecture of the acini, leading to active proliferation of the mucous glands, a feature only observed in animals aged two years and over, while the acinar cells of the intercalary glands showed less active proliferation, the proliferative activity of the acinar cells of the main glands was lower during the prenatal period. These results justify the rejection of the term "prostatic activity" (Fig 2).

At higher magnification, the glandular epithelium appeared with a white lumen and a pale eosinophilic layer bordering the prostate glands. Papillary projections, sometimes with a connective or vascular axis, bordered the prostate glands and were seen in this lumen. Although this feature was absent in the prostates of camel foetuses, it was visible in those of newborns, particularly the older ones (Fig 3).

The development of true acini in the glandular epithelium is exceptionally rare, beginning only from the age of 24 months according to the researcher's observations.

The secretory endings revealed that large fibromuscular septa originate in the muscle bundles, distinctly delimiting the lobules of the gland, particularly in neonates. The branches of these septa, also fibromuscular, give rise to intra-lobular collecting ducts, lined with a two-layered pseudostratified epithelium, at the heart of each lobule. Numerous small ducts branch into tubular outgrowths which terminate in tubular endings.

In fact, it was noted that myoepithelial cells were absent and these septa, which were seen as detached filaments in the lobules, form a delicate intra-lobular stroma surrounding the alveoli that was constituting the secretory endings. These endings, aligned in the active secretory gland, were characterised by simple cylindrical cells with compressed nuclei. Each alveolus was surrounded by a capillary network within a sparse framework of loose connective fibres. There were variations in the stages of secretion. While some alveoli have glandular cells with dark pink cytoplasm, others had less dilated cytoplasm due to secretion.

The body of the prostate remaines inactive in late-gestation foetuses with groups of undilated intra-lobular ducts without tubular secretory endings. It was also revealed from the sections of the pelvic part of the urethra that the transitional epithelium was similar to that of the body.

As far as the glandular epithelium is concerned, from the 7^{th} month of gestation, the prostate takes the form of solid cell buds on the urethral epithelium. By the 8^{th} month, some tubules are ducted, but most remain without a lumen. At this stage, the prostate is lined with a morphologically identical simple epithelium, frequently expressed by large pyramidal cells with flattened nuclei at the base. These characteristics persist in the prostate of the 9-month-old embryo.

The excretory ducts were initially lined with a two-layer epithelium, replaced by a transitional epithelium near the point of entry into the urethra. These changes occurred at a stage when the appearance of the prostate approaches that of a normal adult camel. The number of glandular tubules increases, accompanied with an increase in intertubular connective tissue.

Examination of the glandular epithelium's height of neonatal prostate glands reveals significant fluctuations throughout the postnatal period, with a minimum height at 12 and 60 months. Between 24 and 48 months, the height of the glandular epithelium was relatively uniform in the central, peripheral and transitional zones. From 36 months, the epithelium in the central zone became significantly higher than that in the other two zones. At 48 months, the thickness of the lobule mucosa in postnatal study animals differed slightly by about 2 to 3 µm. The epithelial height of all three layers of the prostate in 48-month-old animals was greater, suggesting a decrease in epitheliocyte height. In the 60-month-old animals, the surface area of the lobule was significantly increased, reaching around 1.5 times its initial size.

Concerning the lumen and number of glands, lobular formations of different sizes were observed in the prostatic part of 12-month-old foetuses. In newborns aged 60 months and over, a significant increase in prostate volume was observed, accompanied with a dilatation of the terminal sections of the prostate. The septa became thin and narrow. As such, the smooth muscle fibres became thinner, leading to a visible reduction in the thickness of the interlobular septa and a slight increase in the height of the epithelium of the terminal sections of the prostate was seen.

Observation of the interlobular connective tissue in foetal prostates showd that it appeared around the 9^{th} month of gestation, with an initial thickness of 26.61 ± 3.21 µm, increasing to 45.41 ± 3.15 µm at the end of gestation. The height of the epithelium of the secretory endings in the foetal prostates reached 4.57 ± 2.45 µm at the 9^{th} month of gestation and increased to 16.58 ± 2.67 µm at the end of gestation.

The diameter of the secretory ducts reached 13.57 ± 2.07 µm at the 9^{th} month of gestation and doubled to reach 16.58 ± 2.67 µm at the end of gestation. It doubled to reach 26.12 ± 3.47 µm at the end of gestation, with the thickness of the epithelium increasing by 4.68 ± 3.47 µm to 12.35 ± 3.78 µm. The diameter of the illuminated acini was 21.65 ± 3.87 µm at the 9^{th} month of gestation and increased to 38.25 ± 2.74 µm at the end of gestation. The diameter of the non-illuminated acini was 14.57 ± 2.36 µm at the 9th month of gestation and increased to 32.47 ± 2.74 µm at the end of gestation. It was also noted that the lumen of the glands decreases significantly from 12 to 36 months and remained relatively constant up to 60 months. This trend, correlated with previous data in the tables on glandular content at different ages, suggests an increase in the number of glands over time.

Examination of the number of glands in the prostates of camels at different stages of development revealed their presence after birth, with a slight increase at two months, followed by a significant decrease towards the third year of life, to reach minimum values (Table 1).

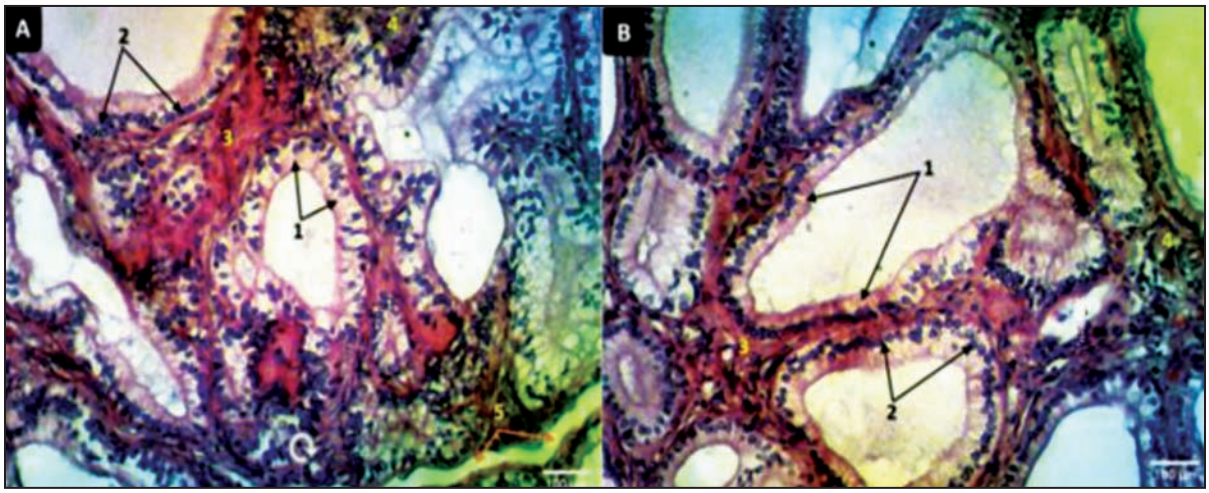

Fig 1. Histological section of the dromedary prostate gland in the postnatal period, **A:** 12th month after birth, **B:** 60th month after birth, stained with Hematoxylin and Eosin; 1-acinar cells; 2- connective tissue; 3-intraluminal secretions; 4-stroma; 5-duct. X 100.

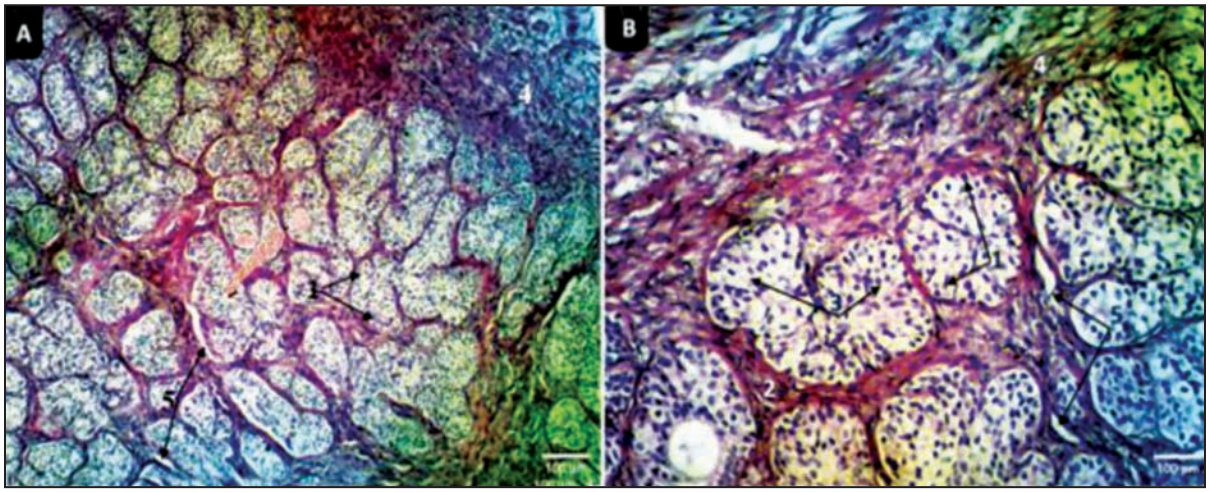

Fig 2. Histological section of the dromedary prostate gland during the antenatal period, **A:** 7th month of gestation, **B:** 11thh month of gestation, Hematoxylin and Eosin staining; 1-acinar cells; 2-connective tissue; 3-intraluminal secretions; 4-stroma; 5-duct. X100.

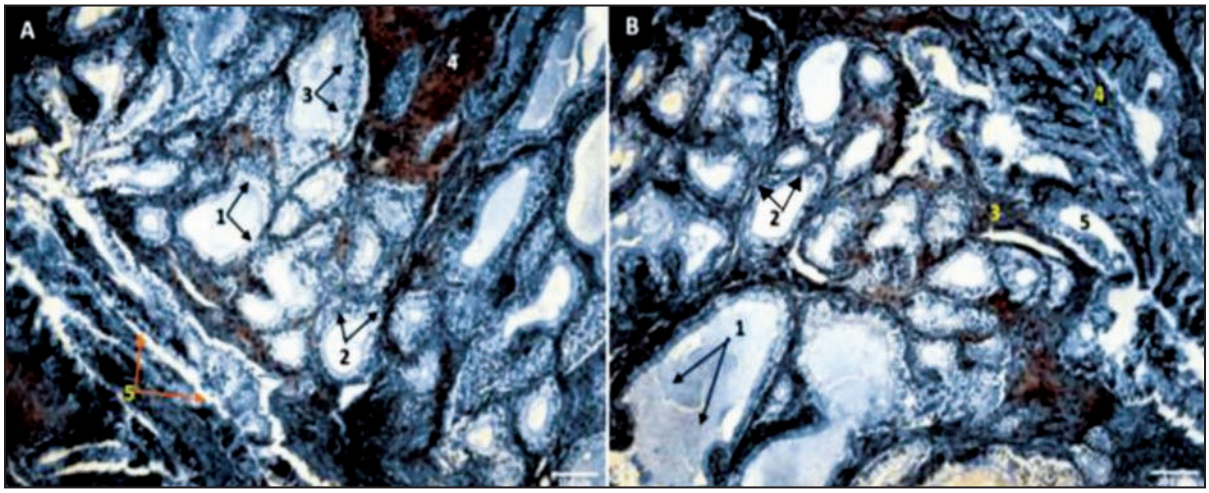

Fig 3. Histological section of the dromedary prostate gland during the antenatal period, **A:** 7th month of gestation, **B:** 11th month of gestation, silver nitrate staining; 1-acinar cells; 2-connective tissue;3-intraluminal secretions; 4-stroma; 5-duct. X 100.

Discussion

The histological description of the developing prostate during the prenatal and postnatal period in animals has been studied extensively. The present research focuses on the analysis of prostate development in the dromedary. As an organ, the prostate is surrounded by a fibromuscular capsule. Previous studies on boars (Sakairi *et al,* 2003) have reported that the gland is covered externally by striated urethral muscles and lined internally by an intermittent layer of smooth muscle. In contrast, studies on bovines (Abou-Elmagd and Wrobel, 1989) described the capsule surrounding the gland as a dense, irregular connective tissue containing numerous smooth muscle cells and striated muscles. Our research findings are consistent with those of Gibson *et al* (2013), who observed that the prostate surrounds the urethra at its origin from the urinary bladder. This finding may be related to the need to produce a large amount of seminal fluid to ensure reproduction under dry conditions. The smooth muscle cells present in the capsule of the prostate could help to control the flow of seminal fluid towards the urethra.

Previous research on sheep by Lopes *et al* (2011) showed that the interlobular ducts were characterised by a low cylindrical epithelium lining. In contrast, the gland ducts in the current study were found opened into the urethral canal, with the excretory ducts exhibiting a single cylindrical epithelium lining. In addition, we observed a transition in the epithelial composition of the prostate, where single columnar epithelium becomes transitional epithelium in the terminal segments of the ducts. This may be related to the difference in environmental conditions, prostate epithelial cells may be more sensitive to desiccation in a desert climate. In this case, the presence of transitional epithelium in the terminal segments of the prostate ducts could help to protect the epithelial cells from desiccation.

Conversely, Hafez and Hafez (2001) reported the presence of predominantly serous glands with some mucosal acini in the disseminated pars of camels, which is also consistent with current observations, with columnar pseudostratified epithelium lining the disseminated pars. The solid and luminal secretory ends of the pars disseminata remained undifferentiated until three years of age. In this research, similar results were found at this stage of foetal development as the prostatic epithelium showed distinctive features. The results also indicated that the formation of the main definitive structural features of the prostates as peripheral reproductive organs occur in camels during the foetal period of stepwise ontogeny. Similarly, results from Xia *et al* (1990) mentioned the same suggestions for other mammals. However, the prostatic body does not appear in pigs in textbook descriptions. In that regard, Lossi *et al* (2016) reported that the disseminated Pars appears in the early postnatal period, but a narrower band of white glandular tissue with a glandular mass was found in camels. It is reported that this band has a condensed structure and is deeply buried in the muscle tissue of the urethra during the foetal period of the animal with a progressive increase in the degree of structure and differentiation of the different organ components. Consequently, the lobular structure of mammalian prostates is formed during the foetal period and the base of each component of these organs is a distinct gland. The number of which in some prostates is genetically determined (Angelsen *et al,* 1997). The body of the prostate is a glandular mass surrounded by a distinct fibrous capsule and exposed by the urethral muscle. The fibroreticular capsule of the gland also contains abundant smooth muscle cells. Similar findings have also been described by the authors and this remark has been found in prostates of mouse (Oliveira *et al,* 2016).

While interlobular connective tissue decreases in quantity with age, the remaining glandular

Table 1. Morphometric parameters of the prostate in a mature one-humped camel (x ± SD, n =8).

Months	Interlobular connective tissue thickness	Secretory tips			Secretory ducts	
		Diameter of illuminated acini	Diameter of non-illuminate acini	Height of epithelium	Duct diameter	Height of epithelium
Antenatal period						
9-10	26,61±3,21	21,65±3,87	14,57±2,36	4,57±2,45	13,57±2,07	4,68±3,14
11-12	45,41±3,15	38,25±2,74	32,47±3,74	16,58±2,67	26,12±3,47	12,35±3,78
Postnatal period						
0-12	33,45±2,54	36,14±3,18	42,68±2,24	15,57±2,47	43,14±3,14	11,24±2,11
48-60	11,34±3,41	49,54±2,54	45,73±3,22	21,24±3,28	49,47±3,14	18.24±3,87

SD: Standard Deviation of the mean

components increase. This result may be linked to the increased production of male sex hormones androgens, which stimulate the growth and differentiation of the glandular cells of the prostate. It should be noted that the main excretory duct of the gland is lined with stratified cuboid epithelium. In comparison, the epithelium in the prostate of rams is characterised by a simple cuboid to cylindrical structure with the presence of some basal cells (Odabaş and Kanter, 2008). This is probably due to lower androgen levels in this species. Rams also have a shorter reproductive cycle than dromedaries, which may also contribute to the difference in epithelium. The ducts were more abundantly branched with age and terminated in more luminal secretory ends. Initially, they were mainly mucous, but serous components were added by differentiation of the non-luminous secretory tips later in foetuses and neonates as confirmed by Krill *et al* (1999). Rodger and Hughes (1973) reported the presence of numerous tubular compounds in the prostate. Thus, the free surface of the glandular epithelium is clearly delineated and the epithelium is bilayered. Again, the proportion of glandular tissue to connective tissue is roughly the same in the late foetus. Nevertheless, the epithelial cells are larger, although still slightly smaller than in camel foetuses. In this study, we noted that whereas the prostatic ducts start to appear from the 7th month of gestation, they develop and come into place in cattle between 1 and 15 days after birth and 2 weeks after birth according to Groot and Biolatti (2004).

Studies performed on Bengal goat prostates by Gofur (2019) showed that only luminous acini were considered for micrometry, although some non-luminous acini were observed in the prostatic body of day-old goats. In contrast, the diameter of the acini found with a value of 44.98a±1.31 µm and that of our results, maximum sums of 49.54±2.54 µm for luminous acini and 45.73±3.22 µm for non-luminous acini of 48-60 month old neonates, the height of the epithelial cells found in the same breed was 12.89±0.28 µm, whereas in our research, we found a sum of 18.24±3.87 µm in neonates aged 48-60 months. We conclude that these indices vary according to the animal species by its body structures and its state of evolution.

The most important development of the prostate parenchyma growth took place during the prepubertal phase and spanned from birth to 18 months. These results are consistent with the observations made by Higgins and Gosling (1989) regarding the growth of parenchymal components in human newborns, which persisted until the age of 12 months before reaching a static phase until 60 months.

Conclusion

Histological differentiation and complete formation of prostatic tissue have been observed in the dromedary throughout its life, from the ante-natal period to adulthood, in three main phases:

_Embryonic phase (7^{th} month of gestation): formation of the first epithelial cords and glandular tubules, lined with an undifferentiated stratified epithelium.

_ Neonatal phase (8^{th} month-end of gestation): development of the parietal and caudal parts of the gland. The parenchyma is represented by epithelial cords derived from the mucosa of the urogenital canal.

_ Postnatal phase (1^{st}-3 years): maturation of the gland, with increase in size, glandular and connective tissue and decrease in muscular tissue.

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Competing interest statement

The authors state that there is no competing interest in this research.

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CAMEL CONSERVATION AND WELL-BEING

The workshops held in Nagaur, Rajasthan, India, 16-17 Febuary 2024 focusing on Camel Conservation and Well-Being, shed light on the precarious state of the region's camel population. Despite being revered as the state animal, camels have faced a troubling decline exacerbated by legislative measures aimed at their protection, such as the Rajasthan camel law enacted in 2015. This legislation, while well-intentioned, has led to unintended consequences, including increased suffering and mortality rates among camels. Against this backdrop, stakeholders gathered to discuss strategies for improving camel welfare, enhancing economic opportunities, and preserving traditional camel husbandry practices.

One significant aspect addressed by the workshops was the empowerment of women stakeholders in the camel husbandry sector. Working Group 1 emphasised the importance of women's active participation and leadership in the industry, advocating for training programs, ownership policies, and the creation of fair value chains. By providing women with the skills and resources to engage in camel husbandry and milk-based product production, these initiatives not only enhance economic viability but also promote gender equality and community development.

Another critical focus area was the expansion of market reach for camel milk, recognised for its nutritional value and potential to support sustainable agriculture. Working Group 2 devised a multi-faceted strategy to increase consumer awareness, engage health professionals, and diversify distribution channels. By positioning camel milk as a beneficial dietary supplement and advocating for ethical production practices, stakeholders aim to elevate its profile and consumption, thereby enhancing economic opportunities for camel pastoralists.

In addition to these efforts, Working Group 3 concentrated on improving the well-being of camels in Rajasthan through initiatives such as rehabilitating grazing lands, establishing camel sanctuaries, and addressing mistreatment issues. These measures aim to create suitable habitats for camel herds, promote conservation efforts, and ensure access to proper care and nutrition for all camels, regardless of their past treatment.

Lastly, Working Group 4 proposed strategies for enhancing camel grazing access in Rajasthan, emphasizing the conservation of grazing lands, establishment of camel sanctuaries, and creation of connecting corridors between traditional grazing grounds. These efforts seek to safeguard the well-being of camels while maintaining ecological balance and promoting sustainable land management practices.

Overall, the workshops underscored the importance of collaborative efforts to address the complex challenges facing Rajasthan's camel population. By empowering women stakeholders, expanding market opportunities for camel products, improving camel welfare, and enhancing access to grazing lands, stakeholders aim to ensure the sustainable coexistence of agriculture, animal husbandry, and natural ecosystems in the region. The insights and recommendations gleaned from these workshops offer a roadmap for charting a sustainable path forward for camel conservation and livelihoods in Rajasthan and beyond.

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HAEMATOLOGICAL PROFILE VARIATIONS IN FEMALE DROMEDARY CAMELS DURING DRY PERIOD, EARLY PREGNANCY, LACTOGENESIS AND GALACTOPOIESIS IN ALGERIAN DROMEDARY CAMELS

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ABSTRACT

The present study investigated the effects of different reproductive stages on haematological parameters of mature local dairy female dromedary camels (n=52) in El Oued region in southeastern Algeria under a semi-intensive breeding system. The haematological parameters analysed included white blood cell count (WBC), lymphocyte count (LYM), lymphocyte percentage (LYM%), monocyte count (MON), monocyte percentage (MON%), granulocyte count (GRAN), granulocyte percentage (GRAN%), red blood cell count (RBC), haemoglobin (HGB), haematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), and platelet count (PLT). The study focused on four distinct stages: dry period, early pregnancy, lactogenesis, and galactopoiesis. Significant increases ($P<0.001$) were observed in MON% and GRAN% during the dry period and early pregnancy. MCV values were significantly higher ($P<0.05$) during the dry period than early pregnancy. However, GRAN during these stages was significantly lower ($P<0.001$) than during galactopoiesis. Lactogenesis and galactopoiesis stages were characterised by significant elevations ($P<0.001$) in WBC, LYM, and LYM%. Additionally, HGB, MCHC, and MCH values were significantly higher ($P<0.001$) during these stages. Conversely, RBC, HCT, and PLT were significantly lower ($P<0.001$) during lactogenesis and galactopoiesis. Interestingly, the MON during galactopoiesis was significantly lower ($P<0.001$) than during the dry period. These findings demonstrate that haematological parameters in female dromedary camels undergo significant alterations across different reproductive stages. This knowledge can contribute to improved reproductive management strategies and provide insights into the physiological adaptations of camels during various reproductive phases in semi-intensive breeding systems.

Key words: Camel, dry period, haematology, galactopoiesis, lactogenesis, pregnancy

Assessing the physiological, nutritional and pathological conditions of animals and their productivity, including camels, is often evaluated through haematologic profiles (Hafez, 2006; Tharwat *et al,* 2015). Various factors such as breed, sex, age, nutrition and seasonal changes have been observed affecting haematologic values (Tornquist, 2010; Farooq *et al,* 2011). The reproductive status of animals can also influence these parameters due to the effects of the endocrine system on multiple organs (Tharwat *et al,* 2015; Jalali *et al,* 2018). Dromedary camels exhibit seasonal breeding patterns, with breeding seasons during winter and spring, while summer and autumn are typically non-breeding seasons for females (Tibary and Anouassi, 1996). Additionally, they are induced ovulators (Eman, 2019) and their pregnancy lasts approximately 387 days (Wilson and Payne, 1999).

Some studies have investigate the impact of different reproduction periods on haematological parameters (Hafez, 2006; Muhammad *et al,* 2011; Tharwat *et al,* 2015; Jalali *et al,* 2018; Ebissy *et al,* 2019; Elkhair, 2019; Chikha *et al,* 2024). However, there

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remains a lack of documented data on the impact of various reproductive periods, including the dry period, early pregnancy, lactogenesis and galactopoiesis on haematological parameters in semi-intensive breeding system of camel population in the south east of Algeria. Therefore, this study aimed to evaluate the effects of different reproductive periods on haematological attributes in one-humped female camels (*Camelus dromedarius*) in the southeast of Algeria.

Materials and Methods

In this research, 52 adult female dromedary camels were used. The camels kept in a semi-intensive breeding system situated in El Oued region, southeastern Algeria. Throughout the study duration, the camels were found to be free of both internal and external parasites and with good health status.

Blood Collection and analysis

In this study, blood samples were collected from a total of 52 animals, out of which 15 samples were obtained during the dry period, 13 during early pregnancy (first month), 12 during lactogenesis (last month of pregnancy) and 12 during early galactopoiesis (first month of lactation). The samples were collected and transported to the laboratory for haematological analysis. Haematological parameters including white blood cell count (WBC), lymphocyte count (LYM), monocyte count (MON), granulocyte count (GRAN), lymphocyte percentage (LYM%), monocyte percentage (MON%), granulocyte percentage (GRAN%), red blood cell count (RBC), haemoglobin concentration (HGB), haematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), platelet count (PLT) and mean platelet volume (MPV) were determined using a MINDRAY haematology auto analyser (BC-3000Plus, China) as used in the study of Chikha *et al* (2024).

Statistical analysis

The haematological parameters data were analysed using IBM SPSS Statistics, version 25.0, based in Armonk, NY, USA. The findings were expressed as mean values ± standard deviation (SD). To assess group differences across various lactation stages, a one-way ANOVA test was applied, followed by Tamhane T2 test as a post hoc analysis. The significance level was established at $p < 0.05$.

Results and Discussion

The results of white blood cell (WBC), red blood cell (RBC) and platelet parameters are summarised in Table 1 and Table 2, respectively. As depicted in Table 1, there was no significant difference between the WBC count in early pregnancy and the dry period, which was notably lower compared to the values during lactogenesis and galactopoiesis. Consistent with these findings, previous work (Atta *et al,* 2021) reported lower values of these parameters during the dry period and early pregnancy. This alteration was linked to physiological adaptations associated with foetal growth and development throughout pregnancy (Muhammad *et al,* 2011). Conversely, other studies (Saeed *et al,* 2011); Ebissy *et al,* 2019) did not demonstrate any notable variance induced by pregnancy. Early pregnancy was associated with a significantly lower lymphocyte count than both the lactogenesis and galactopoiesis phases as well as the dry period. Similar results (Atta *et al,* 2021) were reported where the number of lymphocytes significantly increased in lactating camels and decreased significantly in dry and pregnant ones. While the monocyte (MON) count during galactopoiesis was significantly lower than during the dry phase, it was not statistically different from the counts during early pregnancy and lactogenesis. In addition, a significant increase was observed during lactation in MON (Atta *et al,* 2021). In the current study, the granulocyte count during dry period and early pregnancy was significantly lower than during galactopoiesis. Atta *et al* (2021) also reported higher significant values of granulocyte count during lactation. The current findings indicated that there was a considerable variation in LYM% between the various times; the value was low during early pregnancy and extremely significant during galactopoiesis in comparison to other periods. Parallel to the current findings, a significant decrease in lymphocyte percentage was noted during late pregnancy compared to early lactation (Elkhair, 2019). However, no significant difference was reported between the dry period and early pregnancy, but a high value was reported during lactation (Atta *et al,* 2021). Data of the current study indicated that, during the dry period MON% was significantly higher compared to the early period, lactogenesis and galactopoiesis, with the lowest value observed during galactopoiesis. Consistent to the current study, a significant increase in monocyte percentage was observed during early lactation compared to late pregnancy periods (Elkhair, 2019). In the current study, the percentage of granulocytes showed no significant difference between the different periods. A significant difference between the dry period, pregnancy and lactation was reported earlier (Atta *et al,* 2021). The significant

changes observed in the percentages of lymphocytes, monocytes and granulocytes could be linked to the release of cortisol and ACTH in response to the stresses of pregnancy and lactation (Ahmed, 2017; Jainudeen and Hafez, 2000).

In the current study, RBC and HCT were significantly lower during lactogenesis and galactopoiesis compared to the dry period and early pregnancy. A significant increase in the number of RBCs was reported in lactating camels compared to the dry period (Atta *et al,* 2021). The variation in erythrocyte parameters according to physiological status may be attributed to the heightened demand for oxygen consumption and the need for a higher metabolic rate to support growth, particularly during late pregnancy and early lactation (Elkhair and Minawy, 2018). The current study reported that, Haemoglobin (HGB) levels were significantly higher during lactogenesis and galactopoiesis compared to dry period and early pregnancy. Similar results (Tharwat *et al,* 2015; El Zahar *et al,* 2017), indicated that higher values of Hb were reported during late pregnancy and early lactation in camels. Contrarily, other study (Atta *et al,* 2021) reported a slight increase in HGB levels in dry camels compared to postpartum and lactating ones. The higher levels of haemoglobin during lactogenesis and galactopoiesis could be attributed to the combination of increased elevated metabolic rate and hormonal changes during these periods. In the current study, Mean Corpuscular Volume (MCV) values were significantly higher during dry period than early pregnancy and no significant difference was observed between lactogenesis and galactopoiesis. Similar results (Ebissy *et al,* 2019) were reported earlier. The low value of MCV during early pregnancy could be the result of hormonal changes that prioritise resources towards supporting foetal growth and development.

Table 1. White blood cell parameter values in female camels during different reproductive periods (Dry, Early Pregnancy, Lactogenesis, Galactopoiesis).

Parameters	Period				P value
	Dry period (n=15)	Early pregnancy (n=13)	Lactogenesis (n=12)	Galactopoiesis (n=12)	
WBC ($\times 10^9$/L)	12.50±2.87^a	11.65±2.30^a	27.06±8.95^b	65.77±19.17^c	0.000
LYM ($\times 10^9$/L)	3.60±1.40^a	1.23±0.35^b	35.30±13.45^c	47.38±15.59^c	0.000
MON ($\times 10^9$/L)	2.58±1.28^{ab}	1.71±1.03^b	2.22±0.77^b	2.64±1.44^a	0.000
GRAN($\times 10^9$/L)	6.34±3.12^a	8.76±1.71^a	9.54±3.44^{ab}	12.40±3.60^b	0.000
LYM%	29.06±8.60^a	12.16±2.54^b	63.60±8.009^c	73.041±7.38^d	0.000
MON%	15.16±3.31^a	10.80±3.03^b	9.17±2.38b^c	6.94±1.69^c	0.000
GRAN%	52.85±12.21^a	75.084±5.64^b	31.86±9.68^c	17.30±3.19^d	0.000

a,b,c; Values within a column that have different superscripts vary significantly from each other ($p<0.05$). WBC; Number of white blood cells, LYM; Lymphocyte, MON; Monocyte, GRAN; Granulocyte, LYM%; Per cent Ratio of Lymphocyte, MON%; Per cent Ratio of Monocyte, GRAN%; Per cent ratio of Granulocyte.

Table 2. Red blood cell and platelets parameter values in female camels during different reproductive periods (Dry, Early Pregnancy, Lactogenesis, Galactopoiesis).

Parameters	Stage of lactation				P value
	Dry period (n=15)	Early pregnancy (n=13)	Lactogenesis (n=12)	Galactopoiesis (n=12)	
HGB (g/dl)	11.06±1.39^a	14.23±1.34^b	124.38±9.44^c	121.41±6.27^c	0.000
RBC ($\times 10^{12}$/L)	5.38±0.62^a	5.34±0.54^a	4.60±0.43^b	4.23±0.58^b	0.000
HCT%	23.36±2.58^a	22.39±2.17^a	19.80±1.65^b	19.01±2.43^b	0.000
MCV fL	43.21±0.47^a	42±0.68^{bc}	43.15±1.43^{ac}	42.98±1.65^{ac}	0.029
MCH pg	23.34±1.85^a	26.05±1.97^b	28.25±4.19^b	28.72±3.82^b	0.000
MCHC g/dL	53.98±4.40^a	63.86±7.24^b	655.33±73.58^c	594±32.80^c	0.000
PLT ($\times 10^9$/L)	211.73±36.45^a	154.74±13.24^b	137.16±19.05b^c	139.91±12.38^c	0.000
MPV fL	6.62±0.56	6.33±0.84	6.47±0.75	7.058±0.83	0.110

a,b,c; Values within a column that have different superscripts vary significantly from each other ($p<0.05$). RBC; Number of red blood cells, HGB; Haemoglobin concentration, HCT; Haematocrit, MCV; Mean corpuscular volume, MCH; Mean corpuscular haemoglobin, MCHC; Mean corpuscular haemoglobin concentration, PLT; Number of Platelets, MPV; Mean Platelet Volume.

The current findings indicated that high significant values of Mean Corpuscular Haemoglobin (MCH) and Mean Corpuscular Haemoglobin Concentration (MCHC) were observed during lactogenesis and galactopoiesis. However, no significant difference was observed between lactogenesis and galactopoiesis in the current study. These results were in the contrary to the results that reported earlier (Ebissy *et al*, 2019), whereas, a significant difference was reported between antepartum and postpartum days. The high values of MCH and MCHC could be the result of adaptations to optimise oxygen transport and metabolism, including alterations in erythropoiesis and haemoglobin synthesis to meet the increased metabolic demands of milk production. In the current study, a low significant level of platelets (PLT) was observed during lactogenesis and galactopoiesis compared to dry period and early pregnancy. This low value could be attributed to the physiological stress associated with lactation and the demands of milk production, which can impact platelet levels. The current findings indicated that there was no significant difference in Mean Platelet Volume (MPV) values during the different periods.

In conclusion, the current data illustrates how several time periods such as the dry period, early pregnancy, lactogenesis and galactopoiesis affect the haematological parameters of dromedary camels and may serve as a useful guide for she-camels.

Conflict of interests

The authors have not declared any conflict of interests.

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PREVALENCE INVESTIGATION OF GASTROINTESTINAL NEMATODES IN SONID BACTRIAN CAMELS

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ABSTRACT

To investigate the prevalence, intensity and predominant species of gastrointestinal nematode infections in Sonid Bactrian camels, Inner Mongolia, a survey on the prevalence of gastrointestinal nematodes was conducted on 307 naturally grazed Bactrian camels from 5 regions in Inner Mongolia using faecal egg, larvae and adult nematode identification methods. The results showed that gastrointestinal nematodes were quite severe in Sonid Bactrian camels, with an overall infection rate of 87.6% (269/307) and an average infection intensity of 1,981 (EPG). Among them, the infection rates of Bactrian camels were generally higher in Abaga Banner, West Uzumqin Banner, Durbed Banner, Sonid East Banner and Sonid West Banner, which were 100% (15/15), 100% (15/15), 98.6% (71/72), 98.1% (101/103) and 65.6% (67/102), respectively with infection intensities ranging from 50 to 10,350 (EPG). *Trichostrongylus* spp. was the predominant species, followed by *Ostertagia ostertagi*. This result was validated through PCR testing of DNA extracted from 46 faecal samples collected from Sonid Bactrian camels, confirming the findings. Therefore, the present study provides preliminary epidemiological survey data on the major nematode infections prevalent in Sonid Bactrian camel herds in Inner Mongolia, contributing to the understanding of gastrointestinal nematodiasis in Sonid Bactrian camels.

Key words: Bactrian camels, epidemiological investigation, gastrointestinal nematodes, PCR

The gastrointestinal nematodes of Bactrian camels mainly include species such as *Haemonchus contortus, Trichostrongylus* spp., *Ostertagia ostertagi*, *Nematodirus* spp. and *Marshallagia* spp. Studies have reported that in Algeria, the infection rate of gastrointestinal parasites in dromedaries is 48.26%, with parasites from 12 genera identified, among which the infection by nematodes of the *Strongyloides* spp. is the most severe, while those of the *Cooperia* spp. were the least prevalent (Bouragba *et al,* 2020). Researchers conducted gastrointestinal nematode examinations on 144 dromedaries in Iran, identifying 26 species of nematodes with an infection rate of 86.3%, primarily by *Haemonchus contortus* and *Trichostrongylus colubriformis* (Anvari-Tafti *et al,* 2013). The population of Bactrian camels is relatively small, accounting for less than 10% of the total old world camelids population, most studies on gastrointestinal nematodes in camels have focused on dromedaries. Sonid Bactrian camels are mainly distributed in Inner Mongolia Autonomous Region, including Xilin Gol League, Ulanqab City and eastern Hulunbuir, with a focus on Sonid West Banner, Sonid East Banner, Abaga Banner and West Uzumqin Banner in Xilin Gol city (He, 2003). The modern Bactrian camel breeding industry is gradually shifting from simple labour purposes to comprehensive utilisation such as milk, meat and fur, with the breeding population showing an increasing trend year by year. However, nematode infections, mainly affecting Sonid Bactrian camels, are prevalent, significantly impacting the productivity of camel herds and hindering the healthy development of the local camel breeding industry. Moreover, the majority of herders have insufficient understanding of the harmfulness economic losses caused by gastrointestinal nematodes, leading to a lack of scientific and targeted approaches in the prevention and control of nematode diseases and a prevalence of indiscriminate drug administration, resulting in a significant lag in parasitic disease prevention and control efforts (Eyeledege, 2018).

In this study, a systematic investigation of gastrointestinal nematodes in Sonid Bactrian camels in 5 different pastoral counties in Inner Mongolia was conducted, aiming to understand the dominant species, epidemiological status and infection intensity of gastrointestinal nematodes in Sonid Bactrian camels.

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Materials and Methods

Ethics Statement

Animal procedures were performed in accordance with the National Standard Guideline for Ethical Review of Animal Welfare (GB/T 35892-2018) and approved by the Animal Care and Use Committee of Inner Mongolia Agricultural University.

Collection of Sample

From January 2022 to December 2023, a total of 307 Bactrian camel fresh faecal samples were collected in Durbed Banner, Sonid West Banner, Sonid East Banner, Abaga Banner and West Uzumqin Banner of Inner Mongolia Autonomous Region, China, with 72, 102, 103, 15 and 15 samples, respectively. Samples were collected by individuals wearing disposable gloves, who directly collected faeces from the rectum or the centre of faecal balls not in contact with the ground (10g-50g). The samples were then placed in self-sealing bags, labeled with the Bactrian camel's basic information and transported back to the laboratory under refrigeration for examination. Faecal samples that could not be examined immediately were stored in a 4°C refrigerator to prevent hatching of eggs that could affect the interpretation of the results.

Identification of nematode eggs

The identification of gastrointestinal nematode species is based on the morphological structure and characteristic features of different eggs, referring to the *Colour Atlas of Morphological Classification of Parasites of Domestic Animals in China*. Additionally, the identification of larvae structures cultured from faeces and the confirmation of adult worms obtained through dissecting deceased camels was done.

Faecal eggs quantitative examination

Faecal egg counts were undertaken using the modified McMaster technique, as described in Veterinary Clinical Parasitology (Anne and Gary, 2012).

PCR identification

Forty-six faecal samples of Bactrian camels were collected from Sonid West Banner, categorised into 5 groups (I, II, III, IV and V) based on the collection locations, with EPG (eggs per gram) values ≥500. PCR detection was conducted on faecal DNA samples extracted from each group using specifically designed primers for 8 common gastrointestinal nematodes of Bactrian camels (some specific primers can identify down to the species level, while other specific primers can only identify down to the genus level), negative control without DNA template.

DNA extraction was performed using the Stool DNA Kit D4015-01 from OMEGA Bio-Tek (USA), following the manufacturer's instructions and the extracted DNA was stored at -20°C. Specific primers (Appendix) for eight gastrointestinal nematodes

Appendix. Sequences of primers specific for 8 gastrointestinal nematodes of the bactrian camel.

Nematode species	Primer	Primer sequence (5′-3′)	Target fragment(bp)	Annealing temperature
Haemonchus contortus (Zou *et al,* 2023)	Upstream primer	ATTGTTCGTCAAATGGCA	270	53°C
	Downstream primer	AGTTTCTTTTCCTCCGCT		
Nematodirus spp. (Jia, 2014)	Upstream primer	GTAGGTGAACCTGCGGAAGGATCATT	800	45°C
	Downstream primer	TTAGTTTCTTTTCCTCCGCT		
*Trichuris ovi*s (Zhang *et al,* 2013)	Upstream primer	TTTGATATCTTTTTACCTTACCATT	900	55°C
	Downstream primer	AGGGCTTATTGCTATGTGGTTA		
Parabronema skrjabini (Zheng, 2015)	Upstream primer	TTTACAAGAGGGATACGCC	551	50°C
	Downstream primer	GGTATCACAAACTTATCGGG		
Strongyloides spp.	Upstream primer	CACCTCTTCAGGGACAT	433	47°C
	Downstream primer	TTTTGGAGCATTTGGAT		
Ostertagia ostertagi (Qu, 2013)	Upstream primer	CGCTTAGAGTGGTAAAATTTTGAAC	342	57°C
	Downstream primer	TTAGTTTCTTTTCCTCCGCTAAATG		
Chabertia spp. (Zhao *et al,* 2013)	Upstream primer	TTTTTTGGGCATCCTGAGGTTTAT	450	55°C
	Downstream primer	TAAAGAAAGAACATAATGAAAATG		
Trichostrongyle spp. (Li, 2020)	Upstream primer	TTGTCGAAACCAACACATGG	173	58°C
	Downstream primer	GGGAACTTCGCATGAACAAT		

synthesised from literature were utilised for PCR amplification (Table 1).

After PCR amplification, 5 µL of the product was taken for 1% agarose gel electrophoresis. The voltage was set to 110 V and electrophoresis was conducted for 30 minutes. Subsequently, the gel was placed into a UV gel imaging system for result observation and photographing for documentation.

Result

The infection status of gastrointestinal nematodes of Sonid Bactrian camels

According to Table 2, the overall infection rate of gastrointestinal nematodes in 307 faecal samples of Bactrian camels from Sonid is 87.6% (269/307), with 269 samples testing positive. The infection rates of gastrointestinal nematodes in Durbed Banner, Sonid West Banner, Sonid East Banner, Abaga Banner and West Uzumqin Banner were 98.6% (71/72), 65.6% (67/102), 98.1% (101/103), 100% (15/15) and 100% (15/15), respectively.

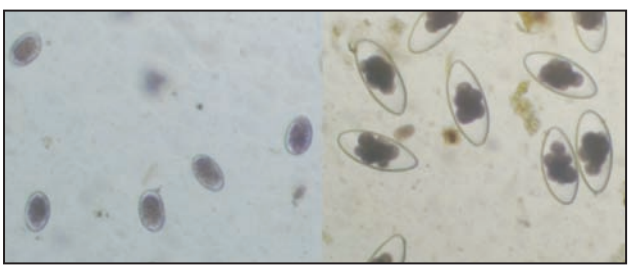

Fig 1. Eggs of *Trichostrongylus* spp. and *Nematodirus* spp. (100X).

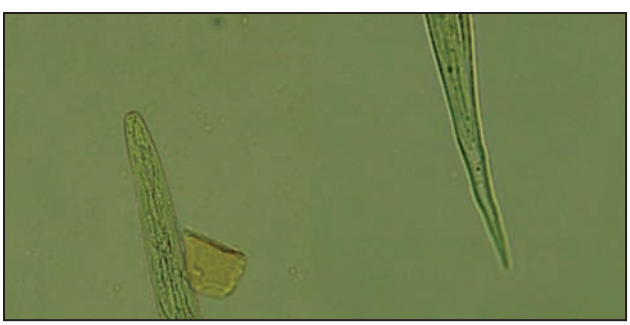

Fig 2. Third-stage (L3) larvae of *Trichostrongylus* spp. (400X).

Table 1. The PCR reaction system by special primers (25 µL)

Components	Volume
Upstream primer	1 µL
Downstream primer	1 µL
Premix Taq	12.5 µL
Template DNA	2 µL
dH_2O	8.5 µL
Total volume	25 µL

The highest EPG of gastrointestinal nematodes in Durbed Banner, Sonid West Banner, Sonid East Banner, Abaga Banner and West Uzumqin Banner

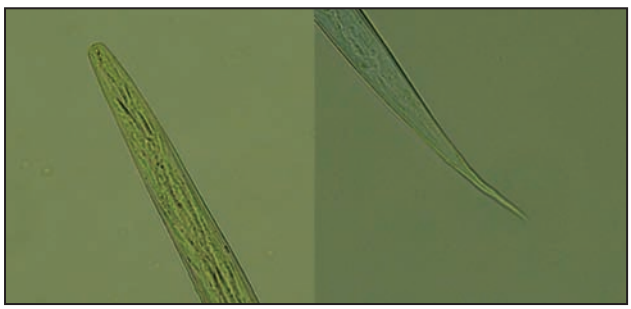

Fig 3. Third-stage (L3) larvae of *Ostertagia ostertagi* (400X).

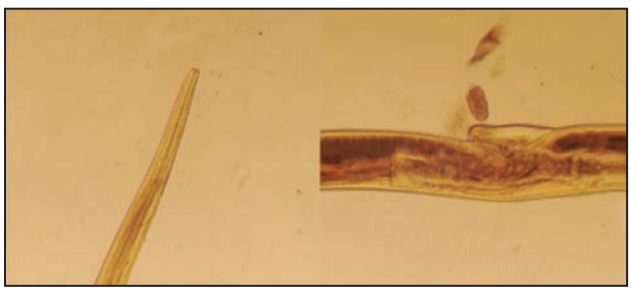

Fig 4. Female anterior end and vulva of *Trichostrongylus* spp. (100X).

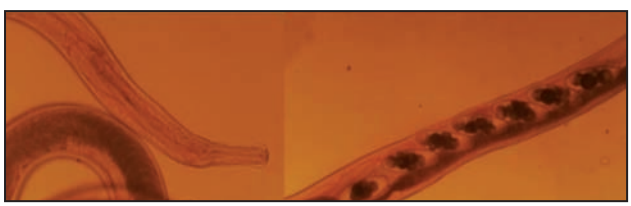

Fig 5. Female anterior end and reproductive tract of *Nematodirus* spp. (100X)

Table 2. Nematode infection in the digestive tract of Sonid Bactrian camels of Inner Mongolia.

Areas	No. Samples	No. Positives	Rate of infection (%)	Infection intensity (EPG)	Mean intensity of infection (EPG)
Durbed Banner	72	71	98.6	50-10,350	1,810
Sonid West Banner	102	67	65.6	50-1,800	396
Sonid East Banner	103	101	98.1	50-7,850	1,409
Abaga Banner	15	15	100	1,000-6,050	3,246
West Uzumqin Banner	15	15	100	250-5,750	3,043
Total	307	269	87.6	50-10,350	1,981

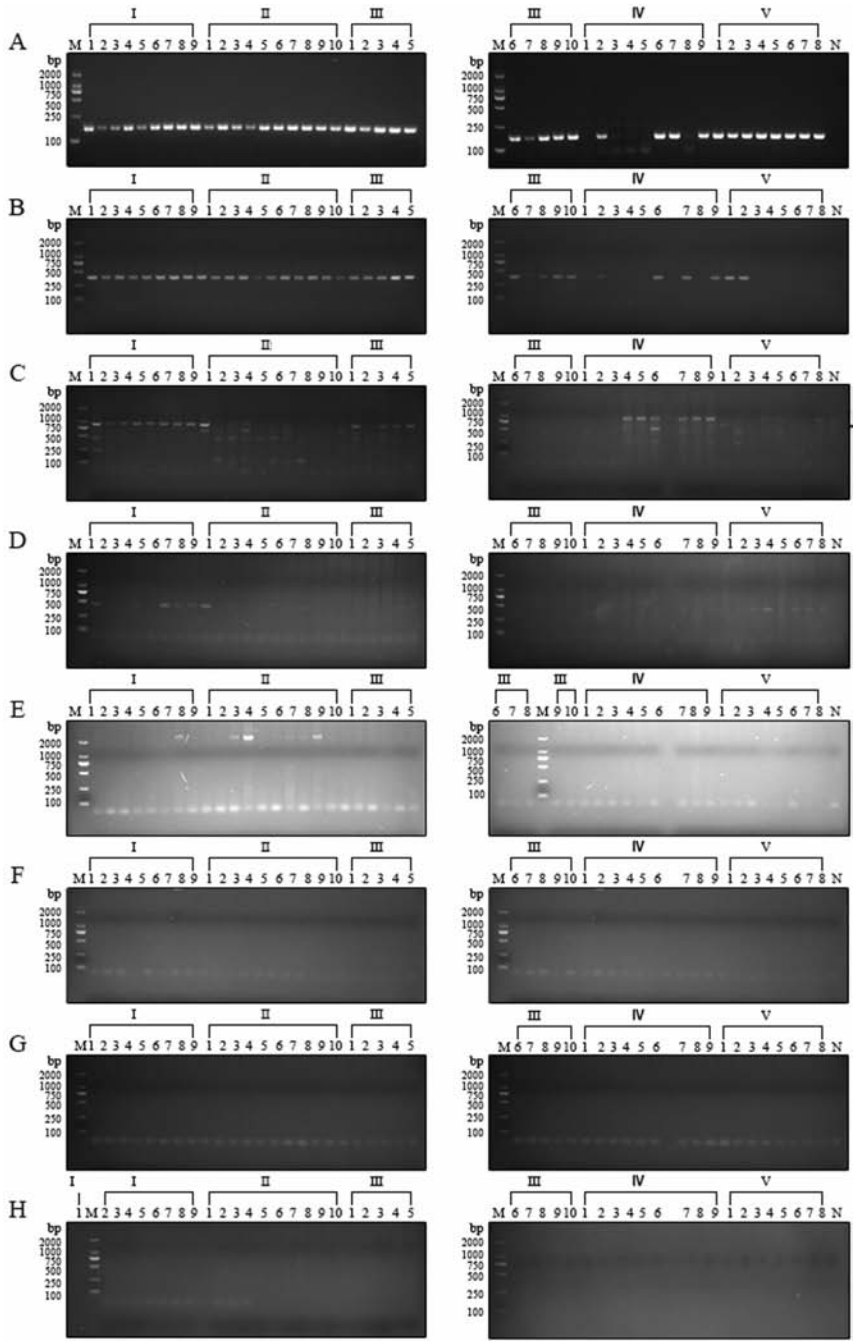

Fig 6. Electropherogram of PCR amplification results.
M: DNA Maker DL2000; A. *Trichostrongylus* spp. B. *Ostertagia ostertagi*. C. *Nematodirus* spp. D. *Chabertia* spp. E. *Haemonchus contortus*. F. *Trichuris ovis*. G. *Parabronema skrjabini* H. *Strongyloides* spp.; I, II, III, IV and V are subgroups; N: negative control.

were 10 350, 1 800, 7 850, 6 050 and 5 750, with average infection intensities of 1 810, 396, 1 409, 3 246 and 3 043, respectively.

Results of egg, larval hatching and adult worm dissection and identification

According to microscopic examination results, the most prevalent nematode species observed were from the Trichostrongylidae, mainly *Trichostrongylus* spp. (Figs 1,2,4) and *Ostertagia ostertagi* (Fig 3), followed by the *Nematodirus* spp (Figs 1,5).

The eggs of *Trichostrongylus* spp. measure 76-92×37-46 µm, with relatively well-filled contents. The eggs of *Nematodirus* spp. measured 165-175×76-86 µm and contained 6-8 embryonated cells (Fig 1).

The larvae have a relatively stout body, with a clearly visible excretory pore and 16 distinct triangular intestinal cells. The tail is thick and blunt, with either one or two segments or an indistinct rounded tail tip and a very short tail sheath. Measurements indicate a total length of 622-706 µm and a length from caudal end to tip of caudal sheath 31-39 µm.

The larvae were of moderate size, with two refractile bodies or a bright bar between the mouth and esophagus visible. The excretory pore was clearly visible and the tail was relatively thick with a short tail sheath.

Results of PCR Test

PCR testing was conducted on 46 faecal samples from Bactrian camels in Sonid, revealing 4 species of nematodes tested positive (Fig 6). *Trichostrongylus* spp. had the highest infection rate, followed by *Ostertagia ostertagi*. Among the 46 faecal samples from Sonid Bactrian camels, 41 were positive for *Trichostrongylus* spp., resulting in a total infection rate of 89.1% (41/46). The infection rates for Groups I, II, III, IV and V were 100%, 100%, 100%, 44.4% and 100%, respectively.

Ostertagia ostertagi. had a total infection rate of 76.1% (35/46), with infection rates in Groups I, II, III, IV and V being 100%, 100%, 100%, 44.4% and 25%, respectively.

Nematodirus spp. had a total infection rate of 54.3% (25/46), with infection rates in Groups I, II, III,

IV and V being 100%, 20%, 40%, 66.6% and 37.5%, respectively.

Chabertia spp. had a total infection rate of 13% (6/46), with infection rates in Groups I, II, III, IV and V being 44.4%, 10%, 0%, 0% and 10%, respectively.

Nematodes such as *Haemonchus contortus, Trichuris ovis, Parabronema* spp. and *Strongyloides* spp. all tested negative.

Discussion

Due to the rampant prevalence of gastrointestinal nematodes in Bactrian camels in the Inner Mongolia autonomous region of China in recent years, the productivity and product quality of Bactrian camels have declined, causing serious economic losses to the camel husbandry industry. This study conducted a preliminary investigation and analysis of the prevalence of gastrointestinal nematodes in Sonid Bactrian camels in Durbed Banner of Ulanqab City and Sonid West Banner, Sonid East Banner, Abaga Banner and West Uzumqin Banner of Xilin Gol city in Inner Mongolia. The results showed that the overall infection rate of gastrointestinal nematodes in 307 faecal samples from Sonid Bactrian camels was as high as 87.6% (269/307), indicating a severe situation of gastrointestinal nematodes in Sonid Bactrian camels in Inner Mongolia. The infection rates of Bactrian camels in the 5 investigated areas, namely Durbed Banner, Sonid West Banner, Sonid East Banner, Abaga Banner and West Uzumqin Banner, were 98.6% (71/72), 65.6% (67/102), 98.1% (101/103), 100% (15/15) and 100% (15/15), respectively. The highest EPG values were 10 350, 1 800, 7 850, 6 050 and 5 750, respectively. Morphological identification of eggs, infective larvae and adult nematodes revealed that the most commonly infected nematode was *Trichostrongylus* spp., followed by *Ostertagia ostertagi*. and *Nematodirus* spp.

In previous studies, the prevalence of gastrointestinal nematodiasis in Bactrian camels was highly common, with both high infection rates and intensity (Abubakr *et al,* 2000; Fraser and Craig, 1997; Abd El-Wahed, 2005). *Trichostrongylus* spp. was identified as the predominant species, which aligns closely with the findings of this study. For instance, El-Alfy *et al* (2019) using different molecular markers, identified infection rates of 26%, 65.2%, 60.8% and 95.6% for *Trichostrongylus axei, Trichostrongylus colubriformis, Cooperia oncophora* and *Haemonchus contortus,* respectively (El-Alfy *et al,* 2019) in faecal samples from 101 single-humped camels in Egypt. Similarly, researchers conducted PCR amplification and sequencing on faecal samples from 160 camels in central Iraq, revealing an infection rate of 18.13% (29/160) (Rasool *et al,* 2021). Research on gastrointestinal nematodes in Bactrian camels in China has primarily focused on the *Parabronema skrjabini* (Zhou, 2021; Li *et al,* 2020; Zhao *et al,* 2012). An epidemiological survey by Zheng (2015) reported a significant decrease in the prevalence of *Parabronema skrjabini* infection in Bactrian camels in Sonid, Xilin Gol League, from 4,696 worms per camel in 1988 to 16 worms per camel. In this study, *Parabronema skrjabini* was not detected in the genetic analysis of 46 faecal samples from Bactrian camels in Sonid West Banner, indicating some effectiveness in the prevention and control of *Parabronema skrjabini* disease in the Xilin Gol area over the past two decades.

In conclustion, the prevalence of gastrointestinal nematodes in Bactrian camels in Sonid, Inner Mongolia, is relatively common, especially with severe infections of *Trichostrongylus* spp., which significantly hinder the healthy development and economic benefits of camel husbandry in the region. The epidemiological findings of this study are of great significance for understanding the prevention and control of gastrointestinal nematodes in Sonid Bactrian camels, providing scientific evidence and technical support for the protection of Bactrian camel health and the promotion of sustainable development in animal husbandry.

Conflict of interests

The authors declare no conflict of interests.

Acknowledgements

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DETERMINATION AND IDENTIFICATION OF REFERENCE INTERVALS FOR SELECTED BLOOD PARAMETERS DURING DIFFERENT PHYSIOLOGICAL STATES IN FEMALE DROMEDARY CAMELS

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ABSTRACT

One hundred eighty female Arabian camels aged 3−16 years were used to determine the reference intervals for selected blood parameters during different physiological states. Venous blood was collected for determining erythrocyte and leukocyte parameters, blood glucose, protein fractions, Ca^{++}, Mg^{++} and Pi. The reference ranges for TEC, PCV, Hb, MCV, MCH, MCHC, TLC, neutrophils, eosinophils, basophils, lymphocytes and monocytes were 4.06−5.03×10^6/µL, 4.8−11.2 g/dL, 24.8−30.6%, 29.7−39.4 fl, 25.2−44.4 pg, 19.6−39.8 g/dL, 11−13×10^3/µL, 41−49%, 5−6%, 1−3%, 45−50% and 1−2%, respectively and for blood glucose, TP, albumin, α_1, α_2, β_1, β_2 and γ-globulins, A/G ratio, Ca^{++}, Mg^{++} and Pi were 67−100 mg/dL, 29−72 g/L, 46−78%, 1−7%, 2−10%, 5−14%, 3−14%, 10−27%, 1−15 and 5−9, 1−2, 4−6 mmol/L, respectively. The values of Hb were lower in the growing and early lactating camels than in dry ones, whereas TEC, monocytes percentage and serum Ca^{++}, Mg^{++}, Pi were higher ($P<0.05$). The TEC, TP and albumin were higher in late pregnant camels than in dry and early lactating ones ($P<0.05$). The α_1, α_2 and β_1 were lower in late pregnant camels than in dry females, whereas they showed higher values in early lactating ones ($P<0.05$). Neutrophil and lymphocyte percentages showed higher and lower values ($P<0.05$) in late pregnant and early lactating camels than in dry females, respectively. The blood parameters of female camels varied significantly depending on their physiological state. The findings are most likely applied to evaluate physiological and metabolic adaptations to growth, pregnancy and lactation.

Key words: Blood parameters, dromedary camel, physiological state, reference interval

Blood parameters are commonly utilised to assess the physiological state of the animals (Onasanya *et al,* 2015). Age, sex, breed, season, exercise, nutrition, stress, transport and diseases have been shown to alter haematological and serum biochemical parameters in all animal species (Jain, 1998; Faye and Bengoumi, 2018). In camels, significant differences have been found in these parameters in relation to age and during different physiological states (Tharwat *et al,* 2015; Elkhair and Elmgboul, 2015; Elkhair, 2016; Ahmed, 2017; Elkhair and Minawy, 2018; Ahmed and Elkhair, 2019; Islam *et al,* 2019; Waziri *et al,* 2019; Faraz *et al,* 2021; Mohamed *et al,* 2021; Martín-Barrasa *et al,* 2023).

It has been demonstrated that metabolic processes change significantly during pregnancy and lactation in camels; therefore, many investigators used blood parameters to evaluate the metabolic profile of pregnant and lactating camels (Ayoub *et al,* 2003; Ahmed, 2017; Axay *et al,* 2017; El Zahar *et al,* 2017; Abd El-Salaam and Arafa, 2018; Jalali *et al,* 2018; Elkhair, 2019; Ebissy *et al,* 2019; Atta *et al,* 2021).

Age, growth phase, pregnancy and lactation are physiologically critical states associated with significant metabolic alterations in all animal species. Regarding female camels, few data are available concerning the reference intervals of blood parameters as influenced by age, growth phase, late pregnancy and early lactation and to describe the haematology and serum biochemical profile of growing, pregnant and lactating camels reared under semi-intensive system. Therefore, the study was aimed to establish reference ranges for selected blood parameters of female camels under various physiological states.

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Materials and Methods

The study was conducted with utmost adherence to ethical guidelines, ensuring the welfare of the animals at all times. It was carried out at the Camel Research Centre of the Faculty of Veterinary Medicine, University of Khartoum (Sudan), after receiving approval from the Faculty Research Ethics Committee. The animal care protocol and sample procedures were conducted in strict accordance with the ethics regulations set by the same body and the guidelines established by the ARRIVE standards (https://arriveguidelines.org) for animal experiments.

Animals and Management

The selection process for the animals was rigorous and thorough. One hundred eighty clinically healthy female Arabian camels (ages: 3-5 years for growing females and 8−16 years for dry, late pregnant and early lactating camels, number of parities: 2−3) were randomly divided into four groups of 45 each. The females were raised in a semi-intensive system, browsing and grazing shrubs and trees; water was offered *ad libitum*. The females were fed a daily ration of fresh Abu 70 (*Sorghum biocolor L.*) and concentrate supplements (a mixture of crushed *Sorghum bicolor* grains 30%, wheat bran 40%, groundnut cake 25% and NaCl salt 5%). The pregnant animals were meticulously observed one month *prepartum* up to one month *postpartum* and were chosen based on mating records for each individual participant in the trial, which showed the predicted delivery.

Collection of blood sample

The experimental animals were sampled twice at two-week intervals in the morning before feeding. Approximately 7 mL of venous blood was obtained at 8:00 am via jugular venipuncture using disposable plastic syringes (Jiangsu Kangsu Medical Instrument Co., Ltd, China). A volume of 2 mL was placed into EDTA vacutainers for haematological analysis. Another 2 mL was drawn into sodium fluoride vacutainers for glucose determination. The remaining blood sample was drawn into plain plastic syringes (Pirmvetta®, Laboratory Technique, GmbH, Germany), centrifuged at 3000 rpm for 10 min (Gallenkamp Junior, UK). Free-hemolysis sera were placed into sterile vials (Eppendorf® Tube) and stored at –20 °C for serum biochemistry measurements.

Laboratory analysis

Haematological parameters: The URIT-3010 VET Haematology Analyser (URIT medical electronics) was employed to determine Hb, PCV, TEC, MCV, MCH, MCHC and TLC. The DLC was performed in thin Giemsa-Grunewald stained blood smears (Weiss and Wardrop, 2010).

Blood glucose and serum Ca^{++}, Mg^{++} and Pi concentrations: Standard spectrophotometric methods and Bio-systems kits (S. A. Barcelona, Spain) were used for determining blood glucose (Caraway, 1987), Ca^{++} (Gindler and King, 1972), Mg^{++} (Chromya *et al,* 1973) and Pi (Gamst, 1980).

Total protein (TP) and capillary electrophoresis: The Biuret standard spectrophotometric method described by Weichselbaum (1946) was performed for TP determination. Capillary electrophoresis was used to perform the percentages of albumin, α_1, α_2, β_1, β_2 and γ-globulins using an Automated MINICAP-SEBIA and MINICAP CDT kits (MINICAP-SEBIA Instrument, France). The instrument was checked for precision and accuracy following the guidelines of Sebia-MINICAP manual, Ref. 2208.

Statistical analysis

The IBM SPSS Statistics 20 (Inc. SPSS, 2011), a comprehensive and reliable tool, was used for data analysis. Resource Equation Approach was performed for computing the sample size (Mead, 1988; Arifin and Zahiruddin, 2017). The reference values for blood parameters were determined using the minimum sample size in the survey (n_{Min}) according to the formula adopted by Werner (1992).

$$nMin \geq \left(\frac{U_{1-\propto/2}}{\Delta}\right).\delta^2 \quad (1)$$

The Kolmogorov-Smirnov test was applied to determine the distribution of the individual values; the data were normally distributed. General linear model procedures for analysis of variance ANOVA tests and descriptive statistics were applied to evaluate the differences between the groups; the differences were separated at $P<0.05$ using LSD.

Results

Overall reference range

Tables 1 and 2 demonstrate the overall reference ranges of 180 female camels, i.e. TEC ($4.06-5.03\times10^6$/µl), Hb (4.8−11.2 g/dL), PCV (24.8−30.6%), MCV (29.7−39.4 fl), MCH (25.2−44.4 pg), MCHC (19.6−39.8 g/dL), TLC ($11-13\times10^3$/µl), neutrophils (41−49%), lymphocytes (45−50%), monocytes (1−2%), eosinophils (5−6%) and basophils (1−3%). The established reference ranges of blood glucose, serum TP, albumin, α_1, α_2, β_1, β_2, γ-globulins, A/G ratio,

Ca^{++}, Mg^{++} and Pi were 67−100 mg/dL, 29−72 g/dl, 46−78%, 1−7%, 2−10%, 5−14%, 3−14%, 10−27%, 1−15 and 5−9, 1−2 and 4−6 mmol/L, respectively.

Blood parameters of the growing females

The TEC, monocytes percentage, serum Ca^{++}, Mg^{++} and Pi in the growing females were significantly

Table 1. Statistical data of the haematological parameters in female camels (*Camelus dromedarius*) during different physiological states.

Parameter	Statistical values	Growing	Dry	Late pregnant	Early lactating
TEC ($\times 10^6$/µl)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	5.00±0.68^{A} 4.2−5.5 5.2 4.2−5.5	4.63±0.96^{Bb} 3.6−5.5 4.8 3.6−5.5	5.03±0.65^{a} 4.4−5.7 5.0 4.4−5.7	4.06±0.96 3.8−4.9 4.7 3.0−4.8
[Hb] (g/dl)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	7.80±2.7^{B} 4.8−10.2 8.3 4.8−10.2	9.40±1.9^{Ab} 7.4−11.2 9.6 7.4−11.2	9.90±0.89^{a} 8.9−10.6 10.2 8.9−10.6	8.02±1.2^{c} 6.8−9.2 8.1 8.9−9.2
PCV (%)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	27.76±4.7 24.8−30.2 28.3 24.8−30.2	29.4±4.9 27.4−31.2 29.6 27.4−31.2	29.9±4.89 28.9−30.6 30.2 28.9−30.6	28.02±4.82 26.8−29.2 28.1 26.9−29.2
MCV (fl)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	32.93±2.8 29.7−34.7 14.4 9.7−14.7	35.3±2.8 32.7−38.2 15 12.7−18.2	36.03±2.9 34−39.4 14.7 14−19.4	34.34±2.3 32.5−38.2 13.7 12.5−18.2
MCH (pg)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	21.67±4.35 25.2−41.5 38.3 15.2−41.5	20±0.62 39.5−40.7 39.8 39.5−40.7	28.67±0.6 38.1−39.3 38.6 38.7−39.7	20.76±2.7 38.1−44.4 41.3 38.2−43.1
MCHC (g/dl)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	26.47±11.5 19.6−39.8 20 19.6−39.8	20.27±0.3 20−20.6 20.2 20.0−20.6	19.63±0.9 18.6−20.2 20.1 18.6−20.2	21.10±1.88 19.1−23.4 21.8 19.2−22.7
TLC ($\times 10^3$/µl)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	11.93±4.9 11−12.8 12 11−12.8	11.97±4.85 11.8−12.1 12 11.8−12.1	12.3±4.82 12.1−12.5 12.3 12.1−12.5	12.22±4.9 11−13.3 12.5 11.3−13
Neutrophils (%)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	42.5±2.1 41−44 42.5 30.8−33	41.67±2.5^{b} 39−44 42 39−44	41.5±0.7^{c} 41−42 42 30.8−31.5	47.5±2.1^{a} 46−49 47.5 34.5−36.8
Lymphocytes (%)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	48.50±2.1 47−50 48.5 35.25−37.5	46.50±2.1^{c} 45−48 46.5 33.75−33	50.33±1.5^{a} 49−52 50 49−52	49.50±2.1^{b} 48−51 49.5 36−38.5
Monocytes (%)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	2±0.02^{A} 2−2.1 2 1.5−1.5	1±0.01^{B} 1−1.2 1 0.75−0.75	1±0.01 1−1.2 1 0.75−0.75	1.33±0.58 1−2 1 1−2
Eosinophils (%)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	5±0.04 5−5.2 5 3.75−3.75	3.5±0.7 3−4 3.5 2.3−3.0	5±1.4 4−6 5 3−4.5	4.3±0.58 4−5 4 4−5
Basophils (%)	$\bar{x}$ ±s Reference range[1] Median (1.-3. Quartile)	2±0.03 2−2.2 2 1.5−1.5	1.5±0.7 1−2 1.5 0.75−1.5	3±1.4 2−4 3 1.5−3	2.67±0.58 2−3 3 1.5−3

[1]m± s.d.×1.96 indicated the lower and the upper limits, Brackets ([ ]) denote concentration.

[Aa, Bb]Overall means within the same row bearing different superscripts are significantly different at P≤0.05.

Table 2. Statistical data of selected serum biochemical parameters in female camels (*Camelus dromedarius*) during different physiological states.

Parameter	Statistical values	Growing	Dry	Late pregnant	Early lactating
Blood glucose (mg/dL)	$\bar{x}$ ±s	71.67±0.58	78.33±11	82.33±10.4	76.80±11.1
	Reference range[1]	71−72	67−89	72−100	66−97
	Median	72	79	75	73
	(1.-3. Quartile)	71−72	67−89	72−100	68−87
Serum-[TP] (g/l)	$\bar{x}$ ±s	42.67±10.8	43.67±5.1^{c}	59.67±8.5^{a}	50.40±8.8^{b}
	Reference range[1]	35−55	39−49	47−72	38−61
	Median	38	36	60	53
	(1.-3. Quartile)	35−55	29−39	47−72	40−59
Albumin (%)	$\bar{x}$ ±s	62.62±8.4	59.85±6.2^{b}	63.33±9^{a}	57.25±9.6^{b}
	Reference range[1]	46−70	47−77	46−78	47−70
	Median	63	58	66	56
	(1.-3. Quartile)	46−70	47−75	46−78	48.75−67
α_1-globulins (%)	$\bar{x}$ ±s	2.5±2.07	2.71±2.13^{a}	1.33±0.58^{b}	3.75±3.4^{a}
	Reference range[1]	2−3	2−3	1−2	2−7
	Median	2.5	2.5	1	3
	(1.-3. Quartile)	2−3	2−3	1−2	2−6.3
α_2-globulins (%)	$\bar{x}$ ±s	4.88±3.13	4.86±3.38^{a}	2.67±1.2^{b}	6.50±3.7^{a}
	Reference range[1]	2−9	2−9	2−4	2−10
	Median	5	5	2	7
	(1.-3. Quartile)	2−9	2−9	2−4	2.8−9.8
β_1-globulins (%)	$\bar{x}$ ±s	9±3.2	9.29±3.4^{a}	7±2.6^{b}	11±2.9^{a}
	Reference range[1]	7−10	7−10	5−10	8−14
	Median	9	9	6	11
	(1.-3. Quartile)	7−10	7−10	5−10	8.3−13.8
β_2-globulins (%)	$\bar{x}$ ±s	6.71±4.8	7.5±4.8	9.5±4.9	6.5±5.1
	Reference range[1]	4−12	6−14	6−13	3−14
	Median	6.5	7.5	9.5	4.5
	(1.-3. Quartile)	3.5−12.8	5.5−11.8	4.5−9.8	3.3−11.8
γ-globulins (%)	$\bar{x}$ ±s	15.63±6.7	17.14±5.6	19.67±7.5	15.25±3.8
	Reference range[1]	11−18	11−19	12−27	10−18
	Median	16	17	20	16.5
	(1.-3. Quartile)	11−18	11−19	12−27	11.3−18
A/G ratio	$\bar{x}$ ±s	3.7±4.71	3.71±5.8	2.33±1.5	4.75±6.8
	Reference range[1]	3−4	3−4	1−4	1−15
	Median	3.5	3.5	2	1.5
	(1.-3. Quartile)	3−4	3−4	1−4	1−11.8
serum-[Ca^{++}] (mmol/l)	$\bar{x}$ ±s	8.33±1.2	5.67±1.2	5.67±0.58	7.2±1.8
	Reference range[1]	7−9	5−7	5−6	5−9
	Median	9	5	6	7
	(1.-3. Quartile)	7−9	5−7	5−6	5−9
serum-[Mg^{++}] (mmol/l)	$\bar{x}$ ±s	2±0.01	1.67±0.58	2±0.01	1.80±0.44
	Reference range[1]	2−2.1	1−2	2−2.1	1−2
	Median	2	2	2	2
	(1.-3. Quartile)	2−2.1	1−2	2−2.1	1.5−2
serum-[Pi] (mmol/l)	$\bar{x}$ ±s	6±0.04	5±1.0	5.67±0.58	4.8±0.45
	Reference range[1]	6−6	4−6	5−6	4−5
	Median	6	5	6	5
	(1.-3. Quartile)	6−6.2	4−6	5−6	4−5

[1]m± s.d.×1.96 indicated the lower and the upper limits, Brackets ([ ]) denote concentration.

[Aa, Bb]Overall means within the same row bearing different superscripts are significantly different at P≤0.05.

higher (P<0.05) than in dry adult ones, while Hb was lower (P<0.05). The PCV, MCV, MCH, MCHC, TLC, the percentage of neutrophils, lymphocytes, eosinophils and basophils, the blood glucose, serum TP, albumin and α_1, α_2, β_1, β_2 and γ-globulins did not change significantly in the growing females compared to the dry ones.

Fig 1 illustrates a serum protein electrophoretic pattern with six fractions. Albumin fraction exhibited approximately a similar pattern in growing (a) and dry females (b), while α_1, α_2, β_1, β_2 and γ fractions differed from those in dry adults.

Blood parameters of late pregnant and early lactating camels

The TEC and Hb were significantly higher ($P<0.05$) in late pregnant camels than in dry ones, while Hb was lower ($P<0.05$) in early lactating camels than in late pregnant and dry ones. Neutrophils percentage was significantly higher ($P<0.05$) in early lactating camels than in dry females. In contrast, their percentage was lower ($P<0.05$) in late pregnant camels than in early lactating and dry ones. Lymphocytes percentage was significantly higher ($P<0.05$) in late pregnant camels than in early lactating and dry ones. The PCV, MCV, MCH, MCHC and TLC values and the percentage of eosinophils and basophils did not change significantly in late pregnant and early lactating camels.

Serum TP was significantly higher ($P<0.05$) in late pregnant and early lactating camels than in dry ones (Table 2). The albumin fraction percentage was significantly higher ($P<0.05$) in late pregnant camels than in dry and early lactating ones; however, the percentage was significantly lower ($P<0.05$) in early lactating animals than in dry females. The percentage of α_1, α_2 and β_1-globulin fractions were lower ($P<0.05$) in late pregnant than in dry and early lactating camels, while the highest significant ($P<0.05$) percentage was observed during early lactation. Camels in late pregnancy and early lactation revealed no substantial change in blood glucose, β_2- and γ-globulins, A/G ratio and serum Ca^{++}, Mg^{++} and Pi.

Fig 2 shows albumin fraction exhibited approximately similar pattern in dry (a), late pregnancy (b) and early lactation (c). However, α_1, α_2, β_1, β_2 and γ- globulins displayed different patterns in response to the physiological state.

Discussion

Determination of the reference ranges for blood parameters is essential for monitoring health, prognosis, diagnosis and treatment of diseases. To the author's knowledge, there is relatively little published data on the reference intervals of blood parameters in female camels. Therefore, we established a reference range for these parameters during various physiological states, which might be utilised for the clinical monitoring of females health. In dromedary camels, most prior reference values were obtained on undefined and relatively small groups, with no consideration given to the physiological states (Faye and Bengoumi, 2018). In clinical practice, it is critical to assess the number of animals required for establishing representative reference ranges.

In this study, we applied equation (1), as established by Werner (1992), to determine the minimum number of samples (*nMin*) required. Equation (1) clearly demonstrated that the reference

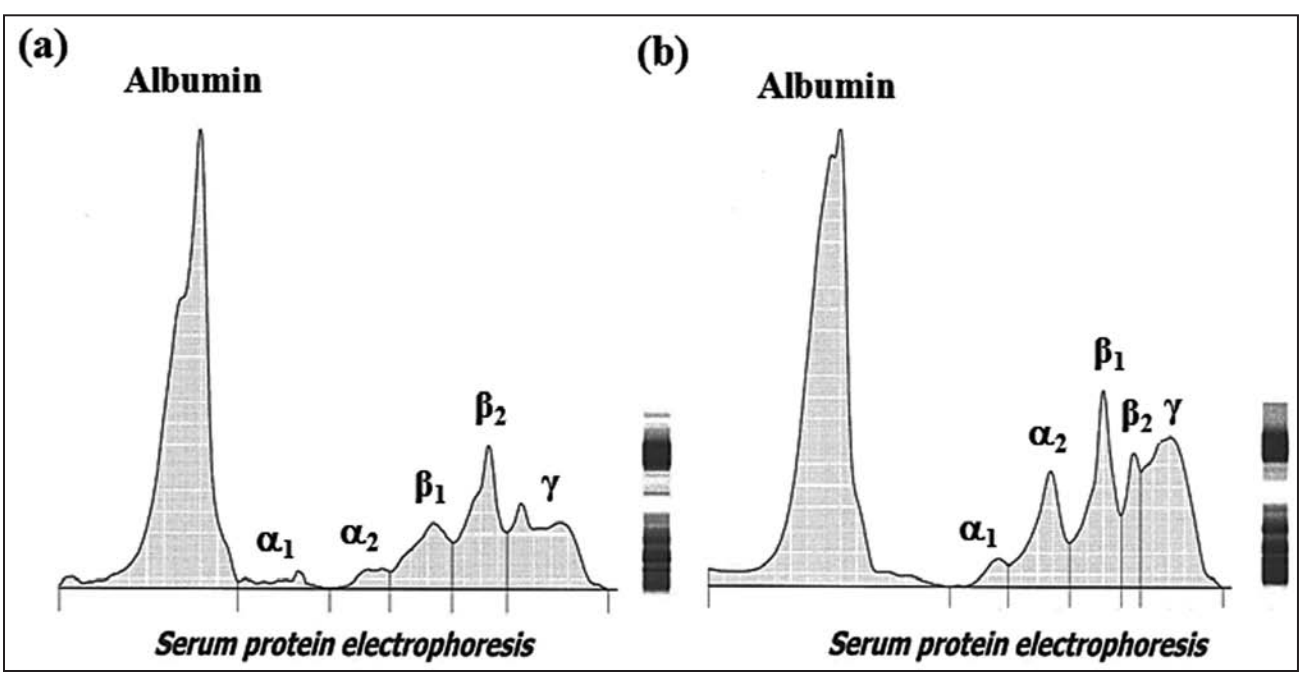

Fig 1. Serum protein capillary electrophoresis pattern of the growing (a) and dry adult female camels (b).

values for these parameters are mostly determined by the standard deviation of their individual values. The confidence level of Δ = 1 µl, g/dL, mmol/L and g/L indicates that the average δ of x values in the population with an error probability of α = 0.05 should not deviate more than 1 µl, g/dL, mmol/L, or 1 g/L from the mean value of the selected groups. The PCV, TLC and blood glucose demonstrated no significant differences between the experimental females (Tables 1 and 2); therefore, we computed a mean value for the standard deviation (s) of all groups for these parameters and substituted the estimated values of s = 4.8 as δ in Equation (1):

$$nMin \geq \left(\frac{1.96}{1}\right).(4.8)^2 = 45 \text{ animals}$$

The determined minimum number of camels (*nMin*) equal to or less than 45 represents the precise number of females in each group; hence, the reference ranges for each parameter suggest reference values under defined physiological conditions. The *nMin* for all parameters studied using the same equation was comparable to or less than the minimum number of animals employed (Tables 1 and 2).

The mean and reference interval for the erythrocytes parameters (PCV, Hb, TEC, MCV, MCH and MCHC) reported for the growing, dry, late pregnant and early lactating camels were similar to the reference range of dromedary camels (Faye and Bengoumi, 2018; Waziri *et al*, 2019; Islam *et al*, 2019; Martín-Barrasa *et al*, 2023).

The current study demonstrated significantly lower TEC and Hb in growing females than in dry ones, while PCV, MCH, MCV and MCHC exhibited no change. Conversely, many investigators reported significant changes in PCV, MCV, MCH and MCHC with age in camels (Al-Sultan, 2008; Elkhair and Elmgboul, 2015; Tharwat *et al*, 2015). Significant lower values of TEC and Hb have been reported by Yagoub (1988), who concluded that camels aged one to five years had lower TEC values than camels aged more than five years. Furthermore, Al-Busadah and Osman (2000) found that age influenced the erythrocytes parameters, with younger camels exhibiting lower TEC and Hb values than the older camels. In contrast, young camels showed higher TEC and Hb values than the older ones (Hussein *et al,* 1992; Martín-Barrasa *et al,* 2023; Monaco *et al,* 2024). Moreover, camel calves had significantly lower values for TEC and Hb than lactating females (Al-Rammahi *et al,* 2016).

The pattern of erythrocytes parameters (higher TEC and Hb) observed during late pregnancy could be explained by the increased metabolic demand for oxygen consumption required for rapid foetal growth and lactogenesis and suggesting a potential adaptation to the increased metabolic demands during pregnancy and redistribution of resources towards lactation. Conversely, TEC and Hb manifested significantly lower values in late pregnant and early lactating camels compared to early lactating and dry ones (Hussein *et al*, 1992; Al-Busadah and Osman, 2000; Elkhair, 2019; Mohamed *et al,* 2021). Saeed *et al* (2011) reported lower TEC, Hb and PCV in pregnant than those in non-pregnant camels. Other investigators reported higher values of Hb, PCV, TEC, MCV and MCH in late pregnant camels compared to non-pregnant (Abd El-Salaam and Arafa, 2018; Abdul-Rahaman *et al,* 2018), whereas TEC and MCV were significantly lower in lactating camels than those in non-lactating (Mohamed *et al,* 2021). Significantly higher values of PCV, Hb and TEC were recorded in pregnant and lactating camels and the transition period (Getnet and Abebe, 2005; Tharwat *et al,* 2015; Abd-El-Rahman *et al,* 2017). The non-significant variations in PCV and haematological induces (MCV,

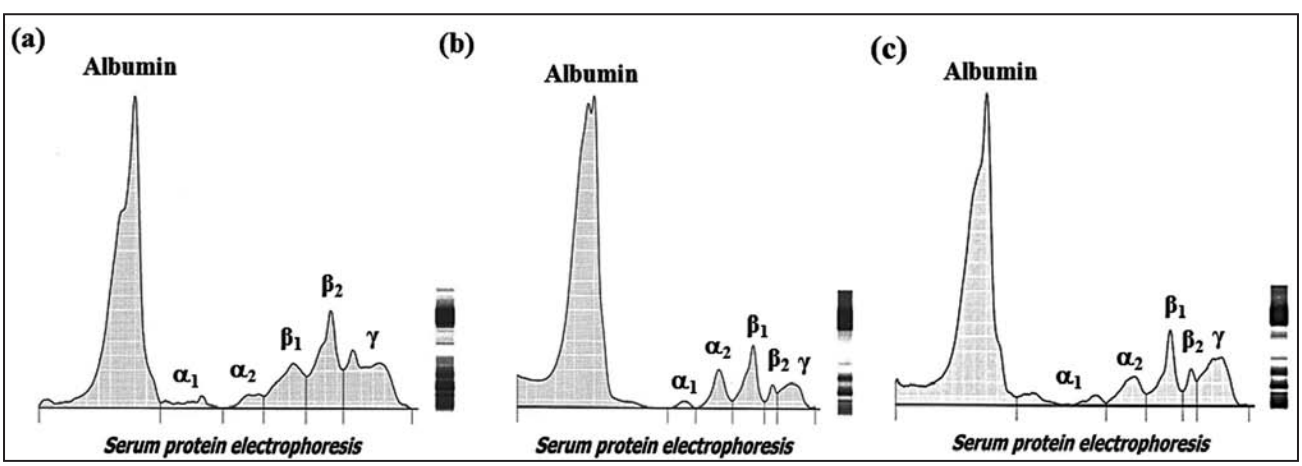

Fig 2. Serum protein capillary electrophoresis pattern of dry (a), late pregnant (b) and early lactating (c) camels.

MCH and MCHC) values recorded are comparable to those reported in late pregnant and early lactating camels and transition period (El Zahar *et al,* 2017; Elkhair and Minawy, 2018; Monaco *et al,* 2024).

The TLC in female camels corresponded with the reference range demonstrated in the literature for dromedary camels (Faye and Bengoumi, 2018; Waziri *et al,* 2019; Islam *et al,* 2019; Martín-Barrasa *et al,* 2023; Monaco *et al,* 2024). The TLC and eosinophils and basophils percentages did not change significantly in the growing females. The findings are comparable to previous results documented by many investigators in camels (Elkhair and Elmgboul, 2015; Omer *et al,* 2016; Ahmed, 2017). However, other investigators reported significant changes in TLC with age (Hussein *et al,* 1992; Al-Sultan 2008; Saeed and Hussein, 2008; Tharwat *et al,* 2015; Islam *et al,* 2019; Gaashan *et al,* 2020). Furthermore, TLC, eosinophils and basophils percentages did not differ significantly in late pregnant and early lactating animals; however, Axay *et al* (2017) reported marked leukocytosis in early lactating camels compared to late pregnant ones. Moreover, Al-Busadah and Osman (2000) reported that TLC of young camels was significantly higher compared to lactating camels. In other studies, TLC remained unchanged in late pregnant and lactating compared to dry camels (Ahmed, 2017; Elkhair and Minawy, 2018; Mohamed *et al,* 2021). The slight non-significant higher values of TLC recorded during early lactation compared to the dry females is attributed to neutrophilia recorded (Table 1).

The significant monocytosis obtained for the growing females contradicts the previous reports (Al-Sultan, 2008; Elkhair and Elmgboul, 2015; Omer *et al,* 2016). On the other hand, the significant neutrophilia and lymphocytosis observed during early lactation and late pregnancy, respectively, compared to the dry ones, potentially indicate an immune response to the stress of pregnancy, parturition and lactation, as well as the release of ACTH and cortisol (Getnet and Abebe, 2005; Omer *et al,* 2016; Ahmed, 2017; Mohamed *et al,* 2021). Neutrophilia and lymphocytosis during early lactation and late pregnancy were consistent with previous findings in camels (Muhammad *et al,* 2011; Tharwat *et al,* 2015; El Zahar *et al,* 2017; Ebissy *et al,* 2019; Elkhair, 2019).

The blood glucose concentration in camels, a key indicator of metabolic health, is comparable to the reference range established by Faye and Bengoumi (2018). The non-significant variation in glucose concentration in growing camels, specifically those between the ages of 1-5 years, is particularly significant as it aligns with a previous study by Ghodsian *et al* (1978), which found no significant difference in camels up to five years old. However, it also revealed a contrasting trend, with many investigators reporting that young camels, typically under the age of 5 years, were more hyperglycemic than adults (Elias and Yagil, 1984; Faye and Mulato, 1991; Souilem *et al,* 1999; Ben Romdhane *et al,* 2003; Roba *et al,* 2023). These findings underscore the importance of age as a factor in blood glucose regulation in camels.

It is widely known that the blood glucose in camels increases with progressive pregnancy and decreases during the first two weeks of lactation (Kelanemer *et al,* 2015; Souilem *et al,* 1999). The current study found no significant differences in glucose concentration in late pregnant and early lactating camels. The results are consistent with previous findings reported in late pregnant, early lactating camels and the transition period, such as those by Tharwat *et al* (2015), El Zahar *et al* (2017), Ebissy *et al* (2019), Faraz *et al* (2021) and Mohamed *et al* (2021). The non-significant hypoglycemia reported in early lactating camels compared to late pregnant ones is most likely attributable to volume expansion combined with increased consumption of large amounts of blood glucose for lactose synthesis (Jainudeen and Hafez, 1992; Kaneko *et al,* 2008). Many investigators concluded that the potential synthesis of milk lactose was linked to increased glucose uptake by the mammary glands (Afshar and Fathi, 2012; Zhao, 2014).

It is well established that protein requirement increases with progressive pregnancy and the onset of lactation, as indicated by decreased maternal serum protein concentration (Muhammad *et al,* 2011; Saeed *et al,* 2011; Roba *et al,* 2023). Farm animals consume more amino acids from the maternal bloodstream for protein synthesis due to the progressive increase in foetal growth (Jainudeen and Hafez, 1994). Compared to dry ones, the considerable hyperproteinemia observed in late pregnant camels combined with marked variations in albumin and α1, α2 and β1-globulins, indicates the critical metabolic changes during these stages required foetal growth and lactogenesis. The findings reveal unique metabolic changes in camels during late pregnancy and early lactation, such as hyperproteinemia and variations in albumin and globulin fractions, which are more pronounced in late pregnant and early lactating animals compared to dry females. These changes suggest a potential role of albumin and globulins in

regulating dynamic balance and immune response, respectively.

Camels in late pregnancy and early lactation revealed no substantial change in globulin fractions (β_2- and γ) and A/G ratio, confirming the stability of these parameters during these stages. Generally, the significant changes in serum protein profile observed in late pregnancy (↑TP and albumin ratio and ↓α1, α2 and β1-globulins) followed by a marked hypoproteinemia in early lactating camels than those in the dry females reflects the maternal requirement of proteins for foetal growth or to cope with colostrum and milk synthesis and production and providing immunoglobulins. Many investigators explained the changes in serum protein profile during late pregnancy and early lactation by the increased maternal requirement of proteins for foetal growth, colostrum and immunoglobulins synthesis (Kaneko *et al,* 2008; Tharwat *et al,* 2015; Elkhair, 2019). In contrast, pregnant and lactating camels showed a marked decrease in serum protein parameters (Elkhair and Hartmann, 2014; Kelanemer *et al,* 2015; Tharwat *et al,* 2015; Elkhair, 2016; 2019; El Zahar *et al,* 2017; Elkhair and Minawy, 2018; Elkhair *et al,* 2018; Ebissy *et al,* 2019; Mohamed *et al,* 2021).

Serum protein capillary electrophoretic pattern is widely used to indicate health status and may act as crucial diagnostic and prognostic biomarkers for numerous pathogenic disorders (Alberghina *et al,* 2011; Yang *et al,* 2012). The current results validated the application of capillary electrophoresis for serum protein fractionation in female camels during different physiological states. Many researchers found that age and growth phase have a significant influence on serum proteins electrophoresis components: albumin, α_1, α_2, β_1, β_2, γ-globulins and A/G ratios in camels (Ahmadi-hamedani *et al,* 2014; Elkhair and Hartmann, 2014; Abdoslam *et al,* 2018). Serum protein capillary electrophoretic pattern obtained produced six fractions, including albumin and five globulin fractions, consistent with previous camel results (Chaudhary *et al,* 2003; Abdoslam *et al,* 2018). The progressive, non-significant increase in globulin fractions observed in dry adult females compared to the growing camels can provide an age-related explanation. The significant decrease in α_1, α_2 and β_1 percentages during early lactation is probably due to the decrease in various α-fraction molecules and the passage of β_1-fraction molecules from the bloodstream to the mammary glands for milk and colostrum biosynthesis (Kaneko *et al,* 2008). The significant increase in albumin fraction percentage combined with a significant decrease in α_1-, α_2- and β_1-globulins has been observed in lactating camels, dairy cows and ewes (Piccione *et al,* 2011, 2012; Elkhair and Hartmann, 2014; Ebissy *et al,* 2019; Tóthová *et al,* 2018; Mohamed *et al,* 2021; Adam and Elkhair, 2023). In the present study, γ-globulins and A/G ratio showed non-significant changes during late pregnancy and early lactation. Conversely, significant higher values of γ-globulins accompanied by lower A/G ratio in lactating camels (Elkhair and Hartmann, 2014).

All animal species require mineral for growth, reproduction and lactation (Underwood and Suttle, 1999). The serum mineral profile obtained for Ca^{++}, Mg^{++} and Pi concentrations is comparable to the reference values for camels (Elkhair, 2016; Faye and Bengoumi, 2018). In the growing females, the significant hypercalcemia, hypermagnesemia and hyperphosphatemia observed could be attributable to their higher mineral requirements for growth. This finding raises intriguing questions about the unique mineral needs of growing female dromedary camels and the potential implications for their health and development. Goff (2015) stated that Ca^{++}, Mg^{++} and Pi were essential for blood and muscles functions, enzymatic reactions, cellular components synthesis and energy transferring molecules. Extensive research has consistently shown that young camels are hypercalcemic (Elias and Yagil, 1984; Rezakhani *et al,* 1997; Al-Busadah 2003, 2010; Ben Romdhane *et al,* 2003; Saeed *et al,* 2004; Barri *et al,* 2005; Tajik *et al,* 2015, Martín-Barrasa *et al,* 2023), hypermagnesemic (Barri *et al,* 2005; Tharwat *et al,* 2015; Elkhair, 2019; Martín-Barrasa *et al,* 2023) and hyperphosphatemic (Saeed *et al,* 2004; Al-Busadah, 2010; Elkhair, 2016; Martín-Barrasa *et al,* 2023) than adults. However, other researchers concluded that age had no remarkable influence on Ca^{++}, Mg^{++} and Pi (Faye and Mulato, 1991; Saeed *et al,* 2004; Tajik *et al,* 2015; Tharwat *et al,* 2015; Elkhair, 2016).

The serum concentrations of Ca^{++}, Mg^{++} and Pi in late pregnant and early lactating animals remained stable, a finding that aligns with previous reports in lactating camels (Singh *et al,* 2015; Tharwat *et al,* 2015; Ebissy *et al,* 2019). However, the observation of non-significant hypercalcemia and hypermagnesemia during these critical periods challenges the previously reported considerable hypocalcaemia and hypomagnesemia in camels. These conditions were attributed to excessive losses through urine and colostrum or impaired absorption of these minerals from the alimentary tract (Eltohamy *et al,* 1986; Kuria *et al,* 2006). The lack of statistical significance in serum

Pi during late pregnancy or early lactation also echoes the findings of several camel researchers (Khadjeh, 1998; Saeed *et al,* 2009; Ahmed, 2017; Faraz *et al,* 2021). However, a contrasting study by Mohamed *et al* (2021) suggests that hyperphosphatemia during early lactation is most likely caused by enhanced growth hormone (GH) activity combined with intestinal absorption and renal reabsorption of Pi, which stimulates GH synthesis by the alveolar cells of the mammary glands. This finding could have significant implications for our understanding of camel health and the management of late pregnancy and early lactation.

Conclusion

Blood parameters were affected significantly by the age, growth phase, late pregnancy and early lactation in female camels reared under a semi-intensive system. Critical alterations in these parameters concerning the corresponding physiological state could be associated with growth requirements, intensive foetal growth and lactogenesis. The data could be employed to evaluate the metabolic profile of growing, pregnant and lactating camels and to develop efficient management strategies for females in a semi-intensive system.

Abbreviations

Hb: Hemoglobin; PCV: Packed cell volume; TEC: Total erythrocytes count; MCV: Mean corpuscular volume; MCH: Mean corpuscular haemoglobin; MCHC: Mean corpuscular haemoglobin concentration; TLC: Total leukocytes count; Serum-[TP]: Serum total protein concentration; [Ca^{++}], [Mg^{++}] and [Pi]: calcium and magnesium and inorganic phosphate concentration.

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Conflict of Interest

The author declares no conflict of interest.

Data Availability data Statement

The data is available in the manuscript and from the corresponding author upon reasonable request.

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RADIOGRAPHIC EVALUATION AND SOFT PALATE DIVERTICULECTOMY OF IMPACTED DULAA IN TWO CAMELS (*Camelus dromedarius*)

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ABSTRACT

Two camels of impacted dulaa (soft palate diverticulum) were presented with a history of inability of soft palate protrusion, anorexia and dyspnoea. Clinical examination with radiographic evaluation was done. Clinical examination of throat region revealed pain and dyspnoea on palpation. Lateral radiographic view of cranial cervical region was taken and radiograph showed increased radiodensity of irregular soft tissue with scattered gaseous radiolucency. Complete clinical and radiographic examination revealed accumulation of food and pus in the soft palate and surgical resection of impacted dulaa was planned. Soft palate diverticulectomy was done by intraoral approach under general anaesthesia. Both the animals recovered uneventfully. The conclusion of the clinical case report was that, in case of impacted dulaa, pharyngeal region radiography helps delineating the larynx, proximal trachea, oesophagus, naso and oropharynx. Enlarged size and radiodense dulaa (impacted by feed material) were seen radiographically and helped planning the surgery.

Key words: *Camelus dromedarius*, impacted dulaa, radiographic evaluation, soft palate

The soft palate diverticulum (dulaa) is an oroventral projection of soft palate and is injured by the camel's own canine teeth or by other camels while fighting, or by thorns and wires commonly during breeding season. The signs may include oedema,perforation and haematoma depending upon the causal agent and degree of trauma (Gahlot and Chouhan, 1992; Tanwar *et al,* 2016; Kumar *et al,* 2017). The food sometimes becomes impacted in the dulaa. The size of impacted dulla may sometimes go up to the size of a football. The mass is very hard to touch. In the case of larger mass, the resection of the organ is required. Tracheotomy is also before resection (Choudhry *et al,* 2017). Clinical findings and surgical exteriorisation of dulaa has been reported following various types of dulaa injuries (Sadan and El-Shafaey, 2020). Radiography is scarcely reported for the diagnosis of injured dulla in camels. The present study described radiographic evaluation of impacted dulla and its surgical resection in two dromedary camels.

Materials and Methods

Two camels aged 7 and 12 years, were presented at Veterinary Clinical Complex, Rajasthan University of Veterinary and Animal Sciences, Bikaner, with the history of anorexia, dyspnoea, inability of dulaa protrusion and swelling at cervical region. Clinical examination along with aseptic fine needle aspiration of swollen area of throat region and radiographic evaluation was done. Clinical examination revealed pain and swelling on palpation and while straightening the neck (Fig 1). Complete clinical and radiographic examination revealed accumulation of food and pus in the soft palate and surgical resection of impacted dulaa or soft palate diverticulectomy was planned. Animals were kept off feed and water for 24 hours. Camels were restrained in sternal recumbency and surgical procedure was performed under general anaesthesia including (xylazine @ 0.2 mg /kg and ketamine @ 1mg / kg body weight). After induction of anaesthesia, a gag was placed between the upper and lower jaws and an attempt was made to pull the soft palate out of the oral cavity using a hook while the assistant was instructed to massage the proximal area of the neck with the palm towards the oral cavity and to squeeze the neck region but all went in vain. The surgeon's hand was inserted inside the oral cavity till the pharyngeal region and the distended soft palate was pulled out manually after removing the adhesions by holding the organ with a towel.

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The exteriorised soft palate was found gangrenous and the pus was drained out along with the feed material (Fig 2A&B). The soft palate was excised using long straight Mayo scissors by pulling it outwards and twisting it with a towel. The oral cavity was flushed daily with light potassium paramanganate solution for 5-7 day. Postoperatively streptopenicillin 7.5 g for 5 days and meloxicam @ 0.3 mg/kg body weight for 3 days were administered intramuscularly. The camels were given soft fodder for two weeks.

Fig 1. Swelling and pain on palpation and while straightening of neck.

Results and Discussion

Clinical signs, dyspnoea, i.e. pain and swelling were suggestive of severe inflammation throat region, even were straightening the neck. Aseptic fine needle aspiration of swelling at throat region revealed straw coloured fluid which was suggestive of presence of inflammatory fluid together with trapped feed. Lateral radiograph of cranial cervical region in both cases showed increased radiodensity of irregular soft tissue with scattered gaseous radiolucency close the epiglottis (Fig 3). Oral cavity examination under general anaesthesia found impacted soft palate with feed material. Soft palate was found gangrenous and contained pus (Fig 4). Soft palate diverticulectomy was performed and the camels recovered uneventfully (Fig 5).

Dulaa gets injured with its own teeth, biting of other camel and by external trauma (Gahlot, 2000 and Tanwar *et al,* 2016). Injury occurs commonly during rut season and injued dullla either hangs out or remain entrapped *in situ*. The affected animals usually show discomfort when swallowing, dysphagia, dyspnoea and are unable to extrude the dulaa due to lacerated wounds, gangrene, ulcers, abscesses or impaction with feed material (Ramadan, 2013). In animals of present study, dysphagia, dyspnoea and pain on palpation at throat region and while

Fig 2A. Gangrenous soft palate (arrow).

Fig 2B. Pus drained into oral cavity.

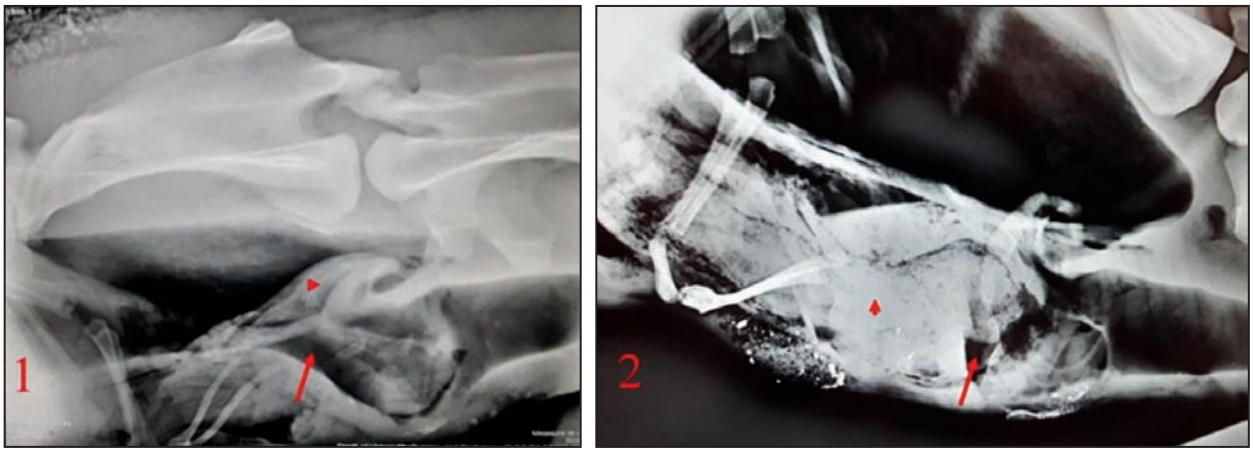

Fig 3. Lateral radiographic view of cranial cervical region was taken and radiograph showed increased radiodensity of irregular soft tissue with scattered gaseous radiolucency (arrow) in the camels.

Fig 4. Gangrenous soft palate.

Fig 5. Surgical wound after 15 days of excision of soft palate.

straightening the neck were observed. Rollefson *et al* (2001) also reported inability of dulaa ballooning as it remains entrapped condition or stays hanging outside the mouth. In present case report, the dulaa was entrapped and camel couldn't take feed and water in both the cases.

Radiography can be used for detection of impacted dulaa in pharyngeal region when the dulaa cannot be extruded by the animal. However, when the dulaa gets impacted with feed particles its size and density increases. It is pushed caudally to press against the epiglottis thus interfering with breathing (Ramadan, 2013). In present clinical case report dulaa was impacted with feed material and pus which appeared as radiopaque soft tissue mass in cranial cervical region radiography (Fig 3). Sadan *et al* (2023) reported that radiography is advanced non-invasive diagnostic technique for the diagnosis of oesophageal

obstruction in addition to exploratory surgery to confirm the condition. Dorsoventral and lateromedial standard radiographs of affected camels were obtained under light sedation and radiographs were subjectively interpreted before surgical interventions. Moreover, successful surgical resection of the dulaa could be used as curative treatment of such disorders in camels (Sadan *et al,* 2020).

Ramadan (2013) also secured camels in sternal position and sedated with 2% xylazine hydrochloride (0.2 mg/kg body weight) together with 10% ketamine hydrochloride at the dose of 1 mg/kg body weight given, intravenously for soft palate resection (Ramadan, 2013) and local infiltration analgesia using lidocaine HCL 2% which was infiltrated at the root of the dulaa (Al-Sobayil and Ahmed, 2011; Ramadan, 2013). Similarly, in present case report xylazine @ 0.2 mg /kg body weight and ketamine @ 1mg / kg body weight were used in soft palate diverticulectomy without local anaesthesia in both cases.

In present case report resection of soft palate was performed by intraoral route which is simple, less time consuming and doesnot subject the animal to the risk of general anaesthesia. However, Ramadan (2013) described resection of soft plate by pharyngostomy, where in dulla was pulled out through pharyngeal opening between intermandibular space. A temporary tracheotomy tube or a suitable endotracheal tube was inserted down the trachea in pharyngostomy approach.

In present study, soft palate found was gangrenous and impacted with feed material. Similar injuries of soft palate leading to gangrene and haematoma of the soft palate have been reported previously (Gahlot and Chouhan, 1992; Sadan and El-Shafaey, 2020).

In present clinical case report was dulaa resected after pulling the soft palate out with a cotton cloth and two long artery forceps were used to hold and crush the major blood vessels close to the origin of the dulaa. A purse string suture using polydiaxanone no. 2 was applied approximately 1 cm distal to the location of the artery forceps. The dissection was performed distal to the suture. The dulaa was removed and the stump was closed by cushing suture pattern using polydiaxanone no. 2. Al-Sobayil and Ahmed (2011) stated that in some cases, interrupted, overlapping horizontal mattress suture pattern was used before amputation and the wound was further closed by simple continuous sutures. The severed edges were cauterised with strong potassium permanganate solution. Haemostasis occurred in couple of minutes (Gharu *et al,* 2016).

Conclusion

The impacted dulaa can be diagnosed early with radiography which can help in deciding the extent of pathology before proceeding for its surgery.

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WEIGHT, GROWTH AND GENETICS IN SHAMI CAMELS (*Camelus dromedarius*)

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ABSTRACT

This study examines Shami camel calf rearing in semi-arid regions of Syria, focusing on weight and growth (birth to 1 year), heritability and breeding values of birth weight for breeding purposes. Birth weight, weight at 12 months and growth rate from birth to 12 months differed depending on the birth year. However, weight at 6 and 9 months and growth from birth to these ages did not show significant variation. The differences in weight at 6 and 12 months and growth from birth to 6 and 12 months, were highly significant according to calf sex, while differences at birth, at 9 months and in growth from birth to 9 months were not significant. Shami camel weights were correlated across growth stages, especially between weight at 6 months and growth rate from birth to 6 and 9 months. Male Shami camel calves and calves born to multiparous she-camels had slightly higher birth weights. Sire affected birth weight, with significant variation among them. The high heritability (0.80) of birth weight in Shami camels was found. Male camels were ranked according to the estimated breeding value of their birth weight, with the top sire (ID 126) expected to produce heavier calves. This study found that birth weight and growth rates varied by birth year and sex, emphasising the importance of Shami camel male selection in breeding programmes aimed at improving weights as early growth strongly influences later weight gain.

Key words: Breeding values, growth rates, heritability, live weights, Shami camel

The distinctive single hump of the Shami camel is adapted for fat storage, complemented by features like long legs, flat feet, bushy eyebrows, thin nostrils, thick lips and efficient water retention mechanisms (Osterloff, 2024).

Research estimates the Shami camel's growth and predicted weights from birth to 4 years of age. Genetic studies have identified unique variations that enhance water conservation, metabolism and overall body weight, improving their survival in desert conditions (Ali *et al,* 2019; Joana *et al,* 2021).

Comprehensive knowledge of the species' weights, growth rates and genetic characteristics is essential for developing effective breeding programmes and conservation strategies. This supports genetic enhancement and custom breeding, securing Shami camels' sustainable future (Fraser, 2008; Balasundaram *et al,* 2023).

Genetic factors influencing growth patterns include traits like lean meat and lower fat content, with younger Shami camels producing superior meat quality (Al-Owaimer *et al,* 2014; Al-Saiady *et al,* 2015; Faraz *et al,* 2020; Suliman *et al,* 2020).

Research into camel breeding and management provides insights into optimal practices for preserving the Shami camel breed. Key considerations include improving reproduction, boosting productivity, developing fodder resources and training producers, supporting the sustainability of this valuable animal resource (Padalino *et al,* 2015; Sofiane *et al,* 2023).

Shami camel breeders' high-quality early care see faster growth and higher economic returns. Strong weight-growth rate links highlight the importance of breeding programmes for improved birth weights, herd productivity and market value. Utilising camels with high EBVs further maximises economic gains. Selective breeding and high-quality early care can significantly enhance breeder profitability. Therefore, this research was aimed to study the weights, growth rates and genetic aspects of the Shami camels.

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Materials and Methods

The herd

This research was conducted at the Deir Al-Hajar station, east of Damascus, Syria, for Shami camels adapted to semi-arid environments (Fig 1). The area receives annual rainfall between 100 to 125 mm, with coordinates at latitude: 33.5533 and longitude: 36.6339.

Camels were housed in concrete barns at night and during harsh weather for protection. They were vaccinated to prevent infectious diseases and spent 8-10 hours a day grazing on Atriplex Salty or Solsola rigid plants. Additionally, they received supplemental barley and bran (when available) and had free access to water. Breeding season occurs from November to March, with males allocated to females based on their reproductive efficiency. Both sexes can mate naturally when they reach 4-5 years old, depending on their weight. Calving happens from February to May and calves are weighed immediately after birth. Weaning occurs around 6 months of age, based on the calves' weight.

Data Analyses

The data set was covered a period from 2002 to 2007, which included 217 records of Shami camel weights that were analysed by SAS (2012).

The General Linear Model was used to analysis data weights and growth rates as following model,

$$Y_{ijk} = \mu + R_i + X_j + e_{ijk} \quad (1)$$

Where, Y_{ijk}= Birth weight (BW), Weight at 6 months old (W6), Weight at 9 months old (W9), Weight at 12 months old (W12), Growth rate from BW until W6 (BW6), Growth rates from BW until W9 (BW6), Growth rates from BW until W12 (BW12) of ijkth observations. μ= overall mean. R_i= Birth year (1= 2002, 2= 2003 … and 6= 2007). X_J= Sex of calf (1= male and 2= female). e_{ijk}= Random error of ijkth observations with mean = 0 and variance= $I\sigma^2_{\bar{e}}$.

Partial correlation coefficients were estimated from the SSCP errors matrix with their corresponding probability values denoted by (Prob.>|r|) according to equation (1).

$$Y_{ijk} = \mu + P_i + X_j + e_{ijk} \quad (2)$$

Where, Y_{ijk}= Birth weight of ijkth observations. P_i= Parity (i = 1, 2… 6). The remaining symbols are shown in the previous models.

Heritability (h^2) value was computed by paternal half-sib (Method=TYPE1) with this model:

$$Y_{ij} = \mu + S_i + e_{ij} \quad (3)$$

Where, Y_{ij}= Birth weight of ijth observations. S_i= Sire (i = 1, 2… 9). The prior models display the remaining symbols. e_{ij}= Effect of environmental and genetic deviation related to individual in a group of sire. Therefore, the h^2 value was computed in accordance to the Becker (1992).

$$h^2 = 4\,t,\ t = \frac{V_S}{V_s + V_w},\ k = \frac{1}{s-1}\left\{N - \frac{\sum N_i^2}{N}\right\},$$
$$SE(h^2) = 4\sqrt{\frac{2(1-t)^2(1+(k-1)t)^2}{k(k-1)(s-1)}} \quad (3)$$

Where, h^2= heritability value, V_S= Variance component of sire, V_W= Variance component of an individual, t and k are the constant, $SE(h^2)$= Standard

Fig 1. Female and male camles at Deir Al-Hajar station, Damascus countryside (Syria).

error of heritability, N= Total number of progeny, N_i= Number of progeny per sire. S= Number of sires.

$$EBV = \frac{N_i h^2}{4 + (N_i - 1)h^2} \ (P_{prog.} - P_{pop.}) \qquad (4)$$

Estimated breeding values (EBV) were computed in accordance to the Hardjosubroto (1994).

Where, EBV= Estimated breeding value, N_i= Number of progeny per sire, h= Root of heritability value, $P_{prog.}$= Average trait of progeny, $P_{pop.}$= Average birth weight of the population. The previous models showed the remaining symbols.

Results

Table 1 displays notable disparities in birth weight (BW), weight at 12 months old (W12) and growth rates from birth to 12 months (BW12) across different birth years. Conversely, weight at 6 months old (W6), 9 months old (W9), growth rates from birth to 6 months (BW6) and growth rates from birth to 9 months (BW9) demonstrated no significant differences. When considering calf sex, (W6), (W12), (BW6) and (BW12) exhibited significant distinctions, while (BW), (W9) and (BW9) did not show significant variations.

Table 2 shows partial correlation coefficients for weights and growth rates to evaluate the relationships between response variables after controlling for the effects of other variables. It illustrates strong positive correlations between weights at different stages of development in Shami camels, particularly between early growth (6 months) and later weight gain (9 and 12 months).

Table 3 presents mean birth weights (BW) and standard errors for Shami camels based on sex, parity and sire ID. Key findings included that male calves had a slightly higher mean BW than females, while multiparous mothers had higher BWs than primiparous mothers did. Sire ID had a notable influence, with sire 126 producing the heaviest calves and sire 243 producing the lightest. These findings highlight the importance of considering maternal parity and sire genetics to improve birth weight of calves in Shami camels.

Table 4 shows a high heritability rate (0.8) for birth weight in Shami camels suggesting a genetic influence. Sire selection in breeding programmes can improve birth weight, potentially leading to better weight outcomes for offspring.

Table 5 shows the top six sire ranked by their estimated breeding values for birth weight. The first-ranked sire (ID 126) has an estimated breeding value of +2.07 kg, indicating that his offspring tend to be heavier than average. The second-ranked sire (ID 111) has an estimated breeding value of +1.79 kg and so on. The lower-ranked sires have negative estimated breeding values, indicating that their offspring tend to be lighter than average.

Table 1. Least square means ± Standard Errors and variance of analysis of weights and growth rates of Shami camels under Semi-intensive rearing (Equation 1).

Source of variance	BW	W6	W9	W12	BW6	BW9	BW12
μ	33.6±1.07	172.2±7.60	198.1±6.85	238.0±6.35	23.1±1.28	18.2±0.75	17.0±0.53
Birth year	**	Ns	Ns	**	Ns	Ns	**
Sex	Ns	*	Ns	*	*	Ns	*
Residuals	16.388	830.352	674.448	579.630	23.750	8.162	4.052

μ= Grand mean. **BW**= Birth weight; **W6**= Weight at 6 months old; **W9**= Weight at 9 months old; **W12**= Weight at 12 months old. **BW6**= Growth rates from BW until W6; **BW9**= Growth rates from BW until W9; **BW12**= Growth rates from BW until W12. **Coefficient of Variations** for BW, W6, W9, W12, BW6, BW9 and BW12 = 11.74, 17.56, 13.21, 10.31, 22.56, 15.86, 12.1, respectively.

Table 2. Partial Correlation Coefficients for weights and growth rates of Shami camels under Semi-intensive breeding from the Error SSCP Matrix/Prob.>|r|, (Equation 1).

Variables	W6	W9	W12	BW6	BW9	BW12
BW	-0.04^{ns}	0.14^{ns}	0.06^{ns}	-0.17^{ns}	-0.01^{ns}	-0.10^{ns}
W6		0.50**	0.17^{ns}	0.99**	0.51**	0.17^{ns}
W9			0.45**	0.47**	0.90**	0.44**
W12				0.16^{ns}	0.46**	0.99**
BW6					0.51**	0.18^{ns}
BW9						0.46**

BW= Birth weight; **W6**= Weight at 6 months old; **W9**= Weight at 9 months old; **W12**= Weight at 12 months old. **BW6**= Growth rates from BW until W6; **BW9**= Growth rates from BW until W9; **BW12**= Growth rates from BW until W12.

Discussion

Table 1 reveals significant variations in birth weight (BW), weight at 12 months (W12) and growth rates from birth to 12 months (BW12) across different birth years of Shami camels reared under semi-intensive conditions. In contrast, weight at 6 months (W6), 9 months (W9), growth rates from birth to 6 months (BW6) and growth rates from birth to 9 months (BW9) did not show significant differences across birth years, suggesting stable early growth rates. In addition, significant differences in W6, W12, BW6 and BW12 were observed based on calf sex, suggesting that sex-specific management practices are necessary. These have implications for breeding strategies, nutritional and management practices and sex-specific management to improve the growth of Shami camels. Camels at birth weigh about 35 kilograms, but this can vary significantly between breeds and within breeds depending on regions (Kadim *et al,* 2008). No significant difference exists between the birth weights of male and female camels (Al-Momani and Al-Najjar, 2020). However, although the birth weight differences between sexes were minimal, male camels tended to be heavier than female camels as they grew older (Njanja and Oba, 2011). Significant weight differences emerge at 6, 12 and 18 months, with males typically being heavier (Bakheit *et al,* 2017). Camel weights increased steadily from birth until age 4 under semi-intensive care conditions (Faris *et al,* 2022) and living weights continue to increase significantly as camels age (Seid *et al,* 2016). The year of birth also affects camel weight (Al-Momani and Al-Najjar, 2020). Camel growth rates are influenced by sex, nutrition, stress and health. These rates vary between strains and are affected by growth rates before and after weaning, which in turn affect body weights (Faraz, 2022). Birth weight differences between male and female camels are minimal; various factors such as sex, nutrition, health and environmental conditions significantly influence their growth rates and weights as they age. Understanding these factors can help optimise camel breeding and care practices to promote healthier and more robust growth.

Table 2 shows strong positive correlations between weights at different stages of Shami camel development, especially between early growth (6 months) and later weight gain (6 and 12 months). This indicated that early growth significantly influenced later weight gain. Conversely, the partial correlation coefficients between birth weight and later weights and growth rates were low and not statistically significant, suggesting birth weight had little impact on later development. These findings implied that

Table 3. Means ± standard error for birth weight base on sex and parity and sire of Shami camels (Equation 2).

Trait	Parity						Sex		Sire ID					
	1st	2nd	3th	4th	5th	6th	M	F	111	118	126	230	238	243
BW (kg)	29.87±6.21	32.35±4.74	32.66±4.63	33.41±4.85	34.00±5.08	33.00±4.70	32.25±5.54	31.78±5.14	34.10±5.66	32.04±4.48	34.26±4.12	30.31±4.84	27.95±5.88	23.71±5.62

BW= Birth weight, M= Male, F= Female.

Table 4. Variance component and heritability ± standard error for birth weight of Shami camels (Equation 3).

Component	N_S	$N_{Prog.}$	V_s	V_w	k	t	h^2
Values	6	217	7.38	29.58	33	0.20	0.80 ± 0.12

Ns= Number of sire, N_{Prog}= Number of progeny, Vs= Variance component of sire, Vw= Variance component of individual within sire, k and t= Constant, h^2= Heritability.

Table 5. Estimated breeding values for body weight of Shami camel males (Equation 4).

Sire rank	Sire ID	$N_{prog.}$	BWp (kg)	EBV (kg)
1st	126	65	34.10	+2.07
2nd	111	29	32.04	+1.79
3rd	118	56	34.26	-0.02
4th	230	35	30.31	-1.57
5th	238	20	27.95	-3.43
6th	243	12	23.71	-5.31

$N_{prog.}$= Number of progeny, BWp= Average birth weight of progeny, EBV= Breeding value.

optimising early growth was crucial for effective breeding, nutrition and management practices in Shami camels. According to these results, we should evaluate birth weight from an environmental and genetic perspective. Fatih *et al* (2021) showed a strong relationship between birth weight and mature weight. Furthermore, Njanja and Oba (2011) emphasised the important relationship between dam weights and calf birth weights. These underscore the importance of understanding the interaction between birth weight and subsequent growth and highlight potential implications for management practices in animal husbandry and husbandry programmes.

Shami camel birth weight (Table 3) shows trends, i.e. males were heavier than females and multiparous mothers exceeded primiparous ones. Sire genetics matter with sire 126 excelling. This highlights the importance of maternal experience and sire selection for improving birth weight. According to Almutairi *et al* (2010), parity significantly affects the birth weight of camels, indicating the importance of understanding maternal factors in camel breeding programs. Fatih *et al* (2021), who emphasised the importance of birth weight as a critical measurement in camels, suggesting its significance in monitoring camel weight, further supported this finding. Additionally, Bene *et al* (2020) confirmed that directing attention to the she-camel and optimising the environment could enhance the calf weight at birth, providing insights into practical strategies for improving calf weights in camel farming.

The heritability value of 0.80 ± 0.12 indicates that approximately 80% of the variation in birth weight can be attributed to genetic factors. Sire selection would have an impact on improving birth weight compared to other traits (Table 4). Camel growth studies show varying genetic influences on weight. Some researchers found birth weight heritability high (Almutairi *et al,* 2010) or low (Bene *et al,* 2020). Later weight and gain showed moderate heritability (Al-Sobayil *et al,* 2006; Kaleri *et al,* 2017).

Table 5 shows sire's genetic merit for Shami camel birth weight using EBVs. Sires with positive EBVs (like 126 and 111) were predicted to have heavier offspring, while those with negative EBVs were predicted to have lighter offspring. This information helps breeders improve birth weight in future Shami camel generations. Estimating breeding values is crucial for evaluating performance and guiding breeding operations to achieve sustainable trait development using genetic models, as emphasised by Al-Mutairi *et al* (2010), who noted a gradual improvement in weights and growth rates in camel breeding. Significant differences in breeding values for birth weight were found among male camels (Bene *et al,* 2020). Al-Sobayil *et al* (2006) assessed breeding values ranging from 25.3 to 115.1 for body weight and 0.270 to 0.638 kg for daily gains. The purposes are to enhance the selection process for superior camels, leading to improved weight and growth rates, achieving better economic returns and contributing to the sustainability and efficiency of camel breeding programs.

Conclusion

This study highlights significant disparities in birth weight and growth rates across different birth years and sex-related differences were found. Strong positive correlations were found between weights at different stages, particularly between early growth and later weight gain. Maternal parity, sire genetics and breeding values play a crucial role in improving birth weight. Male calves and multiparous mothers had higher birth weights. A heritability value of 0.80 indicates that genetic factors contribute significantly to birth weight variation and breeding values of sire can improve birth weight.

Recommendations

The study recommends the importance of taking into account maternal parity and the genetic breeding values of sires to improve birth weight and growth rates in Shami camels.

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Conflict of Interest

The authors declare no conflicts of interest to disclose.

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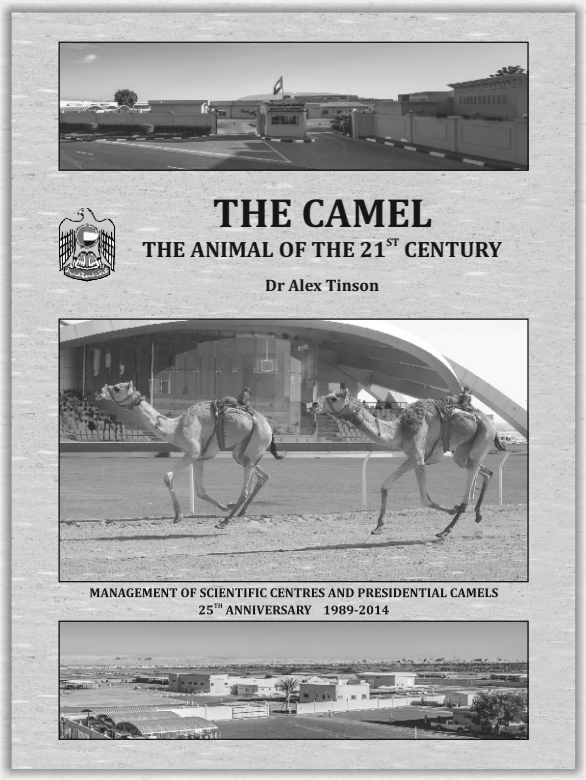
This book authored by Dr Alex Tinson is an acknowledgement to the support and inspiration that His Highness Sheikh Khalifa Bin Zayed Al Nahyan has provided to the centre and to research in general. The last 25 years has been an incredible adventure for us, the noble camel and the people of the U.A.E. Dr Tinson has been involved with many world first's since moving to Abu Dhabi 25 yrs ago. First there was the establishment of pioneering centres in exercise physiology and assisted reproduction. The establishment of the Hilli Embryo Transfer Centre led to five world firsts in reproduction. The world's first successful embryo transfer calf birth in 1990, followed by frozen embryo transfer births in 1994, twin split calves in 1999, pre-sexed embryo births in 2001 and world's first calf born from A.I. of frozen semen in 2013. The hard bound book is spread in 288 pages with 5 chapters. The first chapter involves early history of the centre, world's firsts, world press releases, history of domestication and distribution, evolution of camel racing in the U.A.E. and historical photos the early days. Second chapter comprises camel in health and disease and it involves cardiovascular, haemopoetic, digestive, musculoskeletal, reproductive, respiratory, urinary and nervous systems in addition to the description of special senses. This chapter describes infectious, parasitic and skin diseases in addition to the nutrition. The third chapter is based on Examination and Differential Diagnosis. The fourth chapter is based on special technologies bearing description of anaesthesia and pain management in camels, diagnostic ultrasound and X-Ray, assisted reproduction in camels, drug and DNA testing and surgery. The last chapter entailed future scope of current research.



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