DOI : 10.5958/2277-8934.2025.00037.0 *Vol 32 No 3, p 293-299*

MY JOURNEY TO CAMEL SCIENCE: FROM FOUNDATIONAL FIELD WORK TO HIGHLY SPECIALISED MOLECULAR RESEARCH

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ABSTRACT

My journey into camel science began in September 1990 when I joined a field mission to eastern Sudan to investigate an outbreak of a skin disease in camels. I worked in a French Sudanese Camel Research Project and studied the husbandry and production parameters of camels in the Butana area of eastern Sudan. I was awarded a research grant from the International Foundation for Science (IFS) to fund my Ph.D. research on pox and pox-like diseases in camels. Later in my post-doctoral training,with Alexander von Humboldt Fellowship in Germany from 2001 to 2003 under the guidance of Professor Matthias Buetner, I learnt molecular techniques. In January 2010, I accepted a new position in ACSAD in Syria. This role expanded my expertise in the field of camel development, including production and marketing in Sudan, Algeria, and Morocco. Later, I joined King Faisal University (KFU) in Saudi Arabia in July 2012 and established a research laboratory at the Camel Research Centre that focused on using advanced molecular techniques to diagnose and differentiate camel diseases. Our research aimed to develop multiplex PCR for rapid disease diagnosis, detect MERS-CoV, phylogenetic analysis of camel contagious ecthyma virus, and identify pathogens associated with reproductive health issues in both male and female camels. In July 2016, I moved to the Abu Dhabi Agriculture and Food Safety Authority (ADAFSA), where I established a virology laboratory with a BSL-3 facility and implemented specialised diagnostic tests for camels. One of my significant accomplishments at ADAFSA was leading capacity-building and research activities that led to the World Organisation for Animal Health (WOAH) designating our veterinary laboratories as a Collaborating Centre for Quality Management in Veterinary Laboratories in 2020 and as a collaborating centre for camel diseases in 2021. Our center's mission remained to monitor emerging infectious diseases affecting camel health and their zoonotic potential throughout camel-raising countries. The culmination of my decades of work is showcased in the 2021 book- Infectious Diseases of Dromedary Camels, which I co-authored with the late Professor Mansour Hussein. My journey exemplifies how a scholar's work can expand in scope while deepening in scientific merit, ultimately leaving a lasting legacy in the field of camel science. International leadership I have taken on a prominent leadership role in international scientific Organisations, utilising my extensive expertise to influence global policy and advance research in veterinary medicine. My contributions span some key Organisations, with a particular focus on animal health, disease control, and the study of camelids. I have demonstrated my leadership skills by progressing to a key position within the PPR Global Research and Expertise Network (PPR-GREN), a collaborative initiative of the FAO and WOAH, and I was first elected as a bureau member in 2021. I served as Secretary-General of ISOCARD from 2009 to 2012 and later as Chairman from 2012 to 2015, during which I played a crucial role in advancing the scientific understanding of camelids.

Key words: Camel science, diseases, molecular diagnostic techniques

After graduation, I earned a master's degree in virology from the Faculty of Veterinary Medicine, University of Khartoum. I began my career as a veterinary officer in northern Sudan in November 1986. Three years later, in May 1989, I moved to the Central Veterinary Research Laboratories (CVRL) in Khartoum, where I focused on diagnosing animal diseases. During this time, I gained practical experience in essential laboratory techniques, including histopathology, electron microscopy, serological diagnosis, and cell culture, which are fundamental to traditional laboratory methodologies.

My journey into camel science began in September 1990 when I joined a field mission to eastern Sudan to investigate an outbreak of a skin disease in camels. This was my first time working with these remarkable animals. When we returned to the lab, we analysed the samples and diagnosed the disease as contagious ecthyma. The diagnosis was confirmed by detecting the characteristic viral

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particles under an electron microscope, and the results of our findings were published in my first contribution to camel health research (Khalafalla *et al,* 1984). Yet, it wasn't just the science that captivated me; it was the profound experience of working with these gentle creatures and their generous herders that truly inspired my future path.

Diving deeper into camel research

At that time, a collaborative research project was underway between the Faculty of Veterinary Medicine at the University of Khartoum and the French agricultural research and international cooperation Organisation, CIRAD. This initiative was known as the French Sudanese Camel Research Project. Al Showak city, located at 14°03′ N and 35°08′ E, approximately 480 km east of Khartoum, served as the project's field station. The project was aimed to study the husbandry and production parameters of camels in the Butana area of eastern Sudan (Agab, 1993). From 1991 to 1993, we visited fifteen camel herds monthly as part of this initiative. During this period, I was awarded a research grant from the International Foundation for Science (IFS) to fund my Ph.D. research on pox and pox-like diseases in camels.

The series of papers extracted from the PhD thesis was groundbreaking because it marked the first formal isolation and characterisation of the camelpox virus in Sudan. It established a crucial diagnostic baseline using classical virological techniques and provided the first field-based epidemiological study of pox and pox-like diseases in camels (Khalafalla and Mohamed, 1996; Khalafalla *et al,* 1998a; Khalafalla *et al,* 1998b; Khalafalla and Mohamed 1998c; Khalafalla *et al,* 1998d; Khalafalla and Mohamed, 1997).

The ongoing citations of this seminal work in contemporary literature, along with its impact on advancing the lead author's career in the study of emerging zoonoses, highlight its lasting influence. The true value of this research lies in its historical significance and the catalytic effect it has had on subsequent scientific inquiry and professional development.

A Teaching Career and International Collaboration

Upon completing my Ph.D. in 1997, I began a new chapter as a lecturer at the Faculty of Veterinary Medicine at the University of Khartoum. Over the next decade, I advanced from Assistant Professor to Associate and finally to Full Professor in 2004. During this time, I also took on leadership roles, serving as the Head of the Department from 2004 to 2009 and as the Director of the Camel Research Centre at the university.

A pivotal experience in my career was my Alexander von Humboldt Fellowship in Germany from 2001 to 2003. This post-doctoral training, under the guidance of Professor Matthias Buetner, equipped me with essential molecular techniques that would become central to my research.

My time at the university wasn't limited to teaching. My postgraduate students and I conducted groundbreaking research on viral respiratory infections in camels, leading to the first laboratory identification of several viruses, including parainfluenza virus 3 (Intisar *et al,* 2009), respiratory syncytial virus (RSV) (Intisar *et al,* 2010a), pestivirus (Intisar *et al,* 2010b), and adenovirus type 3 (Intisar *et al,* 2010c). This work spurred further scientific inquiry in the field.

From research to global development and policy

In January 2010, I accepted a new position as a camel development and health expert at the Arab Centre for Studies on Arid Zones and Dry Lands (ACSAD) in Syria. This role expanded my expertise beyond animal health to the broader field of camel development, including production and marketing. I conducted feasibility studies for camel ranches and led a project to improve camel milk production in Sudan, Algeria, and Morocco. I also oversaw animal health and transboundary disease projects, establishing health programs and conducting routine examinations of livestock.

Due to the civil conflict that began in Syria in 2011, I relocated to King Faisal University (KFU) in Saudi Arabia in July 2012. At KFU, I established a research laboratory at the Camel Research Centre that focused on using advanced molecular techniques to diagnose and differentiate camel diseases. Our research aimed to develop multiplex PCR for rapid disease diagnosis (Khalafalla *et al,* 2015a), detect MERS-CoV (Khalafalla *et al,* 2015b), phylogenetic analysis of camel contagious ecthyma virus (Khalafalla *et al,* 2015c), and identify pathogens associated with reproductive health issues in both male and female camels (Al-Busadah *et al,* 2017; Khalafalla *et al,* 2017).

Moving to Abu Dhabi

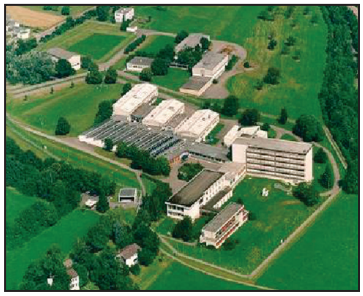
In July 2016, I moved to the Abu Dhabi Agriculture and Food Safety Authority (ADAFSA), where I played a vital role in enhancing their diagnostic capabilities. With the support of the

Our Land Cruiser got stuck in the mud close to Kasamor Mountain, August 1992.

Crossing the Atbara River to meet a herd of camels; from Ieft: I, the vet technician (Abdelrahman), and two camel herders.

CVRL, Khartoum, Sudan, 1989-1995

FVM, University of Khartoum, 1995-2010



BFVA, Tubingen, Germany, 2000-2001

ACSAD, Damascus, Syria, 2010-2012

CRC, KFU, KSA, 2012-2016

ADAFSA, Abu Dhabi, UAE, 2016-2025

Fig 1. Countries and workplaces where I worked from 1989 to 2025.

ADAFSA Director General, I established a virology laboratory with a BSL-3 facility and implemented specialised diagnostic tests for camels.

One of my significant accomplishments at ADAFSA was leading capacity-building and research activities that led to the World Organisation for Animal Health (WOAH) designating our veterinary laboratories as a Collaborating Centre for Quality Management in Veterinary Laboratories in 2020 and as a collaborating centre for camel diseases in 2021.

The recent findings of the Wesselsbron Virus Disease in camels in Ethiopia (Ishag *et al,* 2025) align with our center's mission to monitor emerging infectious diseases affecting camel health and their zoonotic potential throughout camel-raising countries.

In addition to viral diseases, our recent publications have concentrated on bacterial and parasitic infectious diseases affecting camels. These include studies on Salmonella and Theileria co-infection (Abdelwahab *et al,* 2020), tick-borne hemoparasites and *Coxiella burnetii* (El Tigani-Asil *et al,* 2021), caseous lymphadenitis (Terab *et al,* 2021), and paratuberculosis (El Tigani-Asil *et al,* 2023). Furthermore, a recent review on zoonotic diseases transmitted by camels (Khalafalla *et al,* 2023) discusses

Delivering a lecture in September 1997 at the Fac. of Vet. Medicine, U of Khartoum

Working in the safety cabinet at the Camel Research Centre, King Faisal University, December 2014

At the camel barn of the Camel Research Centre, King Faisal University, February 2013

Injecting a camel during an experiment at ADAFSA animal house, October 2021

Fig 2. Images showcasing university teaching, laboratory activities, camel barn operations, and experimental infection.

ARASCO camel workshop, December 2014, Riyadh, KSA

The 4th Conference of ISOCARD, 2015, Almaty, Kazakhstan

First International Camel Salon, Ouargla, Algeria, November 2022

Neonatal Camel Calf Diarrhoea Workshop, Al Salam Vet Group, Al Qassim, December 2024

Fig 3. Photographs depicting the delivery of opening speeches and presentations at camel workshops and conferences.

Fig 4. Photographs of ADAFSA scientists conducting a field investigation into an unknown camel disease in the Borana region of Ethiopia, July 2024.

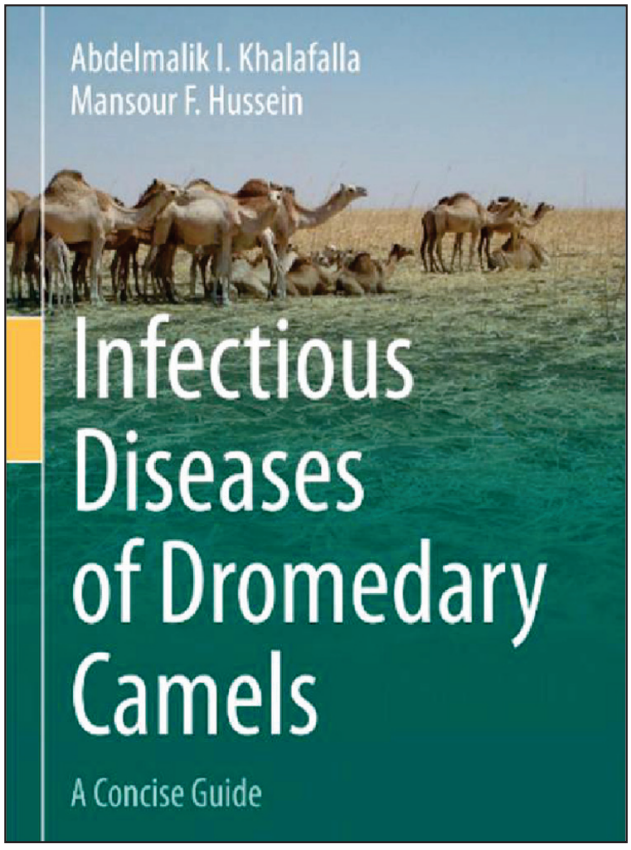


Fig 5. Cover page of our book, Infectious Diseases of Dromedary Camels, Springer Nature, 2021.

various zoonoses associated with camels, highlighting public health risks and prevention strategies that are essential for One Health approaches, which integrate epidemiology, microbiology, and public health.

From local observations to broader expertise

Throughout my career, I've seen my research evolve from studying endemic diseases in camels to exploring emerging transboundary diseases and global zoonotic threats. I began as a dedicated field researcher, documenting and characterizing diseases in underserved regions using classical methods and then advanced my work by skillfully integrating modern molecular tools. My later work on the Peste des petits ruminants virus (PPRV) in camels (Khalafalla *et al,* 2010), Middle East respiratory syndrome coronavirus (MERS-CoV) (Khalafalla *et al,* 2015b; Yusof *et al,* 2017; Paden *et al,* 2018; Khudhair *et al,* 2019; Khalafalla *et al,* 2023; Ali *et al,* 2024), and Crimean-Congo hemorrhagic fever virus (CCHFV) (Khalafalla *et al,* 2020) has directly linked camel health to public health, highlighting the enduring relevance of my foundational work. Furthermore, a recent review on zoonotic diseases transmitted by camels (Khalafalla *et al,* 2023) discusses various zoonoses associated with camels, highlighting public health risks and prevention strategies that are

essential for One Health approaches, which integrate epidemiology, microbiology, and public health.

The culmination of my decades of work is showcased in the 2021 book Infectious Diseases of Dromedary Camels, which I co-authored with the late Professor Mansour Hussein. This comprehensive volume consolidates my extensive research and that of others, serving as a definitive source of knowledge on the subject. My journey exemplifies how a scholar's work can expand in scope while deepening in scientific merit, ultimately leaving a lasting legacy in the field of camel science.

International leadership

I have taken on a prominent leadership role in international scientific Organisations, utilising my extensive expertise to influence global policy and advance research in veterinary medicine. My contributions span some key Organisations, with a particular focus on animal health, disease control, and the study of camelids. My involvement with the World Organisation for Animal Health (WOAH), formerly known as the OIE, highlights this commitment. I have served as a member of several critical ad hoc groups, including 1) Camelid Diseases, addressing the unique health challenges faced by these animals, 2) MERS-CoV, guiding effective management and control strategies for this emerging zoonotic disease and 3) Peste des Petits Ruminants (PPR) Status of Countries, advising on the management and control of this highly contagious viral disease affecting small ruminants. Additionally, I have demonstrated my leadership skills by progressing to a key position within the PPR Global Research and Expertise Network (PPR-GREN), a collaborative initiative of the FAO and WOAH aimed at eradicating this disease by 2030. I was first elected as a bureau member in 2021, and my contributions led to my election as Chair of the PPR-GREN Bureau in 2023. In addition to my work with WOAH, I have been a central figure in the International Society of Camelids Research and Development (ISOCARD). I served as Secretary-General from 2009 to 2012 and later as Chairman from 2012 to 2015, during which I played a crucial role in advancing the scientific understanding of camelids.

Appreciation words

Looking back on my journey, I am grateful to my family, mentors, supervisors, and colleagues who have supported me along the way. I began as a field researcher, documenting camel diseases in underserved regions using traditional methods. Over time, I integrated modern molecular tools into my work, allowing me to address both local animal health issues and global public health threats. My sincere gratitude goes to Prof. T.K. Gahlot for publishing this series about the paths of camel scientists in JCPR.

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