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MY JOURNEY TO CAMEL SCIENCE AND CAMEL INDUSTRY

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I was born into a camel - herding family. Since I was a kid, camels have been like close friends, quietly entering my life and building the most precious memories of my childhood. Camels have taught me to be tough. I've learned that even in bad situations, I can keep going steadily. Their long - term company has made sure I never feel lonely on the wide grassland. The deep friendship between me and camels has already become a part of me, leaving an unforgettable mark in my life.

At that time, camels were the primary means of transportation, freight conveyances and production facilities for people in pastoral areas. However, with the rapid development of modern transport, many important functions of camels in people's lives have gradually faded and even vanished entirely. Additionally, numerous unique biological features and economic values of camels remain undiscovered and unacknowledged. Thus, the general public is reluctant to raise camels. In just over 20 years from 1982 to 2008, the camel population in China dropped sharply from over 600,000 to over 200,000. It is precisely this severe problem that has kindled our passion for protecting camels, researching them and promoting the camel industries.

Carried out a series of studies on camel

To effectively promote the camel industry, it is imperative to conduct a series of research on the unique biological characteristics of camels and explore their potential economic value. This is to make the general public truly realise that camels are not only traditional aids in transportation and production, but more importantly, camel functional gene, camel milk, camel wool, camel blood and other aspects all contain huge development potential and commercial values.

1.1 Bactrian camel genome

While the Bactrian camel made a great contribution to transportation on the Silk Road and could be portrayed as a bridge between Eastern and Western cultures, little is known about the camel genome. After more than 5 years of unremitting efforts, the first draft of the Bactrian camel genome was successfully completed by our research team in 2012 (Jirimutu *et al*, 2012). The research results were published online as a cover article in Nature Communications. Meanwhile, the globally-recognised biological database GenBank publicly released the camel genome data worldwide.

The estimated size of the Bactrian camel genome was 2.38 Gb, containing 20,821 protein-coding genes. Rapidly evolving genes were significantly enriched in metabolic pathways, perhaps helping Bactrian camels optimise their energy storage and production in the desert. After annotation, the results also suggested that the specific cytochrome P_{450} families and unusual immune system were useful for survival in the desert. The comparative genomics analyses may also shed light on the genetic basis of the camel's remarkable salt tolerance and unusual immune system (Jirimutu *et al,* 2012; Surong Hasi *et al,* 2018).

To address the question whether Bactrian camel originated from East Asia or Central Asia, we performed whole-genome sequencing of 128 camels including both domestic and extant wild Bactrian camels from their typical habitats across Asia. Interestingly, among the domestic Bactrian camels, those from Iran exhibit the largest genetic distance and the earliest split from all others in the phylogeny, despite evident admixture between domestic Bactrian camels and dromedaries living in Central Asia. Taken together, our study support the Central Asian origin of domestic Bactrian camels, which were then immigrated eastward to Mongolia where native wild Bactrian camels inhabit (Liang Ming *et al,* 2020).

1.2 Camel milk

As Reuven Yagil said, traditionally seen as riding and pack animals, camels are hugely

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underestimated and under-exploited for their milk, even though camel milk is the most suitable for human consumption after mother's milk. In order to reveal the unique characteristics of camel milk, our research group had carried out a series of studies focusing on the main nutritional components of camel milk and its protective effects on the liver and kidneys, anti-heat stress effect and anti-oxidative stress effect of camel milk.

Compared with cow's milk, camel milk has a higher content of IgG, albumin and α - LG and does not contain β - LG. Camel milk fat content is relatively low and mainly unsaturated fatty acids, while the cow's milk mainly contains saturated fatty acids. Camel milk V_D and V_c contents are higher than cow milk especially the vitamin C content is 3-4 times more than cow milk. Camel milk iron content is 10 times higher than cow milk (Zhang *et al,* 2005; Jing *et al,* 2019).

The study demonstrated that camel whey protein (CWP) has protective effects against heat stress induced liver injury in rats. The protective effect of CWP is attributed to its ability to reduce the increase in ALT and IL-1β levels, restore core temperature and block apoptosis and histopathological changes in the liver (Donghua *et al,* 2021a, 2021b; 2022). As well as, CWP can prevent and alleviate acute heat stress-induced kidney injury in rats and its mechanism of action may be related to the up-regulation of CYP2J activity and the activation of PI3K/AKT pathway expression (Xiaoxia *et al,* 2024).

1.3 Bactrian Camel CYP Enzymes

To investigate whether the Bactrian camel's special metabolic pathways and unique detoxification capabilities are attributable to particularities of the CYP gene family, we systemically analysed and annotated the Bactrian camel's whole genome sequencing data and then, searched CYP gene family from the whole protein database and compared with CYP gene families of cattle, horse, chicken and human. The total of 63 CYP gene copies were found in Bactrian camel's whole genome and were classified into 17 families and 38 subfamilies with more CYP2J and CYP3A copies, which might be the important factors contributing to the distinct biological characteristics and metabolic pathways of Bactrian camels for adaptation to the harsh environments (Surong *et al,* 2018; Zhipeng *et al,* 2018).

In conclusion, the research work and achievements carried out on camels were rich and diverse. On the one hand, these achievements had played a role in promoting the rapid development of China's camel industry, including facilitating the rapid development in various aspects such as camel breeding, product development and comprehensive utilisation. On the other hand, we have also enhanced the overall level of the world's camel research field, making significant contributions to the sustainable development of the global camel industry.

Diversified development of camel industries in China

2.1 Deep Processing and Diversified Products of Camel Milk

Based on a systematic study of the biological characteristics of camels and camel milk, we have also explored the correlation among the camel breeding environment, feed and the quality of the milk source, optimised the breeding conditions and established a milk source traceability system. In terms of the processing technology of camel milk products, we have also carried out a series of studies, such as comparing the effects of different sterilisation technologies for fresh camel milk, optimising the drying technical parameters of camel milk powder, studying the tabletting process of camel milk tablets, screening the strains and conditions for fermented camel milk, exploring the methods for extracting and adding ingredients in camel milk cosmetics as well as the product evaluation methods. Currently, there are more than 10 modern camel milk processing enterprises in China, which produce a series of products including fresh camel milk, camel milk powder, camsel milk tablets, fermented camel milk and camel milk cosmetics.

2.2 Camel Hair Products

2.2.1 Camel Soft Hair Products

Camel soft hair is a layer of short fluff close to the body of a Bactrian camel. After washing the raw hair, removing the coarse and semi-coarse hair, combing the remaining parts, the pure camel soft hair can be obtained. Due to the fineness, softness and curliness of the fibers, the flakes made from camel soft hair have the advantages of being light, thin, fluffy, windproof, mildewproof, breathable and warm. The garments made of camel soft hair is comfortable to wear and not as bloated as a down jacket. A variety of camel hair products can be made with camel soft hair, such as quilt, trousers, sweater, coat, socks, vest, knee pads, scarf, gloves, hat, blanket, insole, back waist strap, carpet, etc.

2.2.2 Camel Coarse Hair Products

Camel coarse hair containing a large amount of coarse fibre has the advantages of keeping warm, windproof, mildewproof and breathable. However, compared with camel soft hair, the heating speed of camel coarse hair is slower. People like to use it as a filler for winter pants or camel coarse hair-padded mattress and use it also to make camel coarse hair carpets and camel hair ropes.

2.3 Camel Meat Products

Camel meat has the characteristics of high protein, low fat and low cholesterol. It is rich in amino acids, minerals and unsaturated fatty acids. On the basis of a comprehensive study of the nutritional value of camel meat, slaughter and cutting techniques and preservation techniques, our team has developed a series of products such as air-dried camel meat, camel meat pies, camel meat burgers, camel meat skewers, camel meat ham and camel paws.

Our team has also carried out studies on camel meat chemical composition and the development of high - end camel meat products (Rendalai *et al,* 2022; Liang *et al,* 2025). By using modern biotechnology, active peptides were extracted from camel meat and made into capsules or oral liquids with functions such as antioxidation and anti-fatigue. Moreover, camel meat protein powder was further purified to produce high-purity nutritional supplements, which increases the added value of camel meat products.

2.4 Camel Serum

Camelids are the only mammals that can produce functional heavy-chain antibodies (HCAbs) - the nanobodies. Nanobodies are antigen binding variable domains of heavy-chain antibodies without light-chains and these biomolecules occur naturally in the serum of Camelidae species. Nanobodies have a compact structure and low molecular weight when compared with complete antibodies. In view of their remarkable stability and manipulable characteristics, nanobodies have been incorporated into biomaterials and used as molecular recognition and tracing agents, drug delivery systems, molecular imaging tools and disease therapeutics.

Our research team had conducted systematic studies on the application of camelid serum heavy-chain antibodies in targeted drug delivery systems and drug residue detection and reaping remarkable and gratifying achievements which not only deepened the understanding of the unique properties of camelid heavy-chain antibodies but also provided new strategies and methods for improving drug treatment effects and ensuring food safety (Liu *et al,* 2023; Xinyu *et al,* 2020).

Build communication platforms and carry out a series of activities

In order to promote the research of camels and the development of the camel industry, through the active advocacy and joint efforts of our research team, the Inner Mongolia Camel Protection Association was registered and established in Inner Mongolia Autonomous Region in April 2009; the Camel Branch of the China Animal Agriculture Association was registered and established in 2012; China's first Camel Research Institute was registered and established in Alxa Right Banner in 2014. Since the establishment of the Inner Mongolia Camel Protection Association in 2009, we have organised and carried out many academic exchange meetings related to camels and Camel Culture Nadam both at home and abroad and we have actively participated in international academic exchange conferences on camel research. Among them, the representative and important activities are given below.

From June 2010 to July 2011, the Inner Mongolia Camel Protection Association organised some camel researchers and representatives of camel herders from Mongolia and China to carry out a series of international academic exchange activities of field investigations on Bactrian camels, which lasted for one year. This activity not only enhanced the mutual understanding among scholars and herders of the two countries, but also collected first-hand data on the main production areas of Bactrian camels in the two countries.

We organised and hosted the international conference "The Belt and Road: Camel Science, Industry and Culture" on September 2017 in Alxa League, Inner Mongolia Autonomous Region, China. More than 300 people participated in this grand event, including 52 internationally renowned camel experts and scholars from 26 countries such as the United States, the United Kingdom, Australia, Canada, Austria, the United Arab Emirates, Russia, Kazakhstan, Mongolia, India and Saudi Arabia, as well as Chinese camel research experts, scholars, entrepreneurs and representatives engaged in the camel industries.

Under the leadership of the Inner Mongolia Camel Protection Association and with the joint efforts of leadership and all of members over the years, the association has successfully completed all of missions such as enlivening the academic

BACTRIAN MILK PRODUCTS AS AN OUTCOME OF OUR RESEARCH

Fresh camel milk

Camel milk powder

Camel milk tablets

Camel milk cosmetics

Bactrian camel hair products

The Bactrian Camel Field Investigation Team working in Sonid Right Banner, Xilingol League (2010)

The Bactrian Camel Field Investigation Team working in Bayannuur and Alxa League (2010)

Camel research experts from all over the world are in front of the building of Inner Mongolia Camel Research Institute (2017)

The Bactrian Camel Field Investigation Team in the Ministry of Agriculture of Mongolia (2011)

The Bactrian Camel Field Investigation Team working in Bayanhongor, Mongolia (2011)

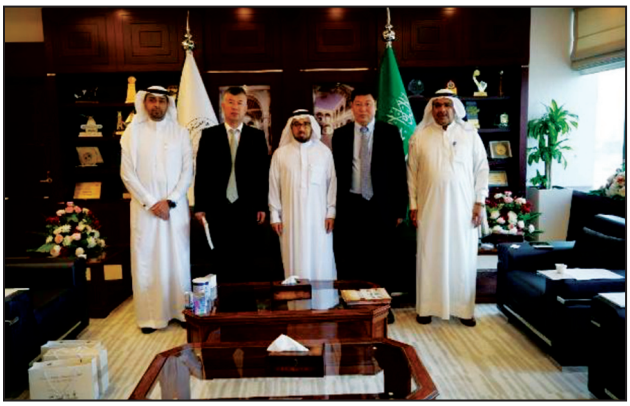
Camel researchers during the 7th China Camel Industry Development Conference (2019)

During the 4th Conference of the ISOCARD in Kazakhstan (Almaty, 2015)

During the 5th Conference of the ISOCARD in Morocco (Laayoune, 2018)

During the 7th International Veterinary Congresses (Paris, 2017)

During the 11th International Veterinary Congresses (Berlin, 2018)



Visiting the King Faisal University

atmosphere, prospering the camel industry, promoting the integration of production, education and research, building a supply-demand platform and developing the local economies. The association plays an active role in promoting the development of the camel industries. Since its establishment, the association has cooperated with relevant departments in many places to jointly hold events such as the Camel Culture Nadam, the camel industry development conference and academic conferences. It has provided detailed introductions across the country about the unique biological characteristics of camels, the nutritional value of camel milk, etc. Through in-depth discussions on academic issues of the industry, it has helped to solve the problems encountered in development and further promoted the progress of China's camel industry. In particular, in 2019, the association held the 7th China Camel Industry Development Conference in Ejina Banner and invited renowned camel research experts from countries such as the United States, Saudi Arabia, Belgium, India, Pakistan and Mongolia.

International cooperations

In our vast globalised world, camels have become a research subject of great scientific and industrial significance. The global technologies and industries related to camels are not only crucial for the livelihoods of people in arid and semi-arid regions, but also serve as the key to conducting innovative research in multiple fields. Camels have unique adaptability to the harsh desert environment. Biological characteristics of camels, such as their ability to tolerate extreme high temperatures, go without water for long periods of time and efficiently convert low-quality forage into energy, have aroused the interest of scientists around the world.

Moreover, in the fields of camel technology and industry, international cooperation is of utmost importance. Different countries possess diverse expertise. For instance, Middle Eastern countries have a centuries-old tradition of camel breeding and have in-depth knowledge of cultivating camels with specific traits. On the other hand, African countries are home to a rich variety of camel species and have unique insights into how camels adapt to different ecological environments. Central Asian countries can offer experience in large-scale camel herding and the development of camel-related handicrafts. Therefore, through extensive international cooperation, scientists

are able to integrate resources, share research findings and accelerate the pace of innovation. In addition, international academic conferences serve as a platform where researchers, industry experts and policy makers from around the world gather, it is playing a crucial role in promoting international cooperation in camel technology and industry.

In conclusion, the global camel technology and industries possess enormous potential for growth and innovation. By placing a high value on international cooperation and actively participating in international academic conferences, we can fully tap into the potential of this unique industry, bringing benefits to the camel industry, human communities and the entire scientific communities.

China has a long history of camel husbandry and is eagerly looking forward to elevating its camel industry and technological level to new heights. To achieve this goal, it is crucial to break through the limitations of national boundaries and draw on the best practices and advanced technologies of other countries. In order to bridge the knowledge gap, promote international cooperation and ultimately drive the sustainable development of China's camel industry, we actively participate in international camel-related conferences and visit countries where camel science, technology and industry are well-developed.

Our teams have successively participated in the 4th Conference of ISOCARD held in Almaty, Kazakhstan in 2015, the 5th Conference of ISOCARD held in Laayoune, Morocco in 2018, the Camelids Workshop at Plant and Animal Genome XXV held in San Diego, the United States in 2017, as well as the 7th and 11th International Veterinary Congresses held in Paris, France and Berlin, Germany.

Our international exchange trips are not only for the purpose of learning but also for contributing to the global camel industry community. We share our own scientific and technological achievements and industrial experiences and jointly explore new frontiers in camel technology and industry.

In 2018, at the invitation of Dr. Faisal Almathen, Director of the Camel Research Centre at King Faisal University in Saudi Arabia, we visited Saudi Arabia. We successively visited the Camel Research Centre of King Faisal University in Saudi Arabia, the camel breeding base and camel milk processing factory, the College of Veterinary Medicine and the College of Agriculture and Food Sciences. We also visited the camel dairy farms, camel milk processing factories, the Centre for Genetic Conservation and Improvement and the Veterinary Central Laboratory directly under the Ministry of Environment, Water and Agriculture of Saudi Arabia. Before returning to China, we also met with Dr. Mohammad, the President of King Faisal University and discussed specific cooperations. On behalf of the Inner Mongolia Camel Research Institute, Professor Jirimutu signed a memorandum of cooperation with President Mohammad. Both sides reached a consensus on exchanging scholars, jointly cultivating students and collaborating on camel genomics research, research and development of camel products and the prevention and control of camel diseases.

In 2016, during my visit to Texas A&M University in the United States, I specifically visited the Texas Camel Corps and had a detailed discussion with Mr. Doug Baum about the camel-tourism industry. We further exchanged views on how to give full play to the role of camels in the tourism and promote the development of the tourism in the future.

In the process of promoting scientific research related to camels and the development of the camel industry, the importance of international cooperation is unparalleled. Camels have unique drought tolerance mechanisms, exceptional anti-fatigue capabilities and adaptation characteristics to extreme environments, which are of great significance to disciplines such as life sciences and medicine. However, relying solely on the scientific research resources of a single country makes it difficult to comprehensively and deeply explore these values.

International cooperation has built a bridge that brings together the world's top scientific research forces. With the help of cutting-edge gene sequencing technologies and advanced molecular biology methods, it can deeply analyse the camel genome, opening up new paths for the optimisation and improvement of camel breeds and research on disease prevention and control and significantly accelerating the implementation and transformation of scientific research achievements.

From an industrial perspective, the camel industry has a wide scope, covering many fields such as breeding, processing and manufacturing and tourism. Different countries have their own strengths. Through international cooperation, the traditional camel industry can be skillfully integrated with modern science and technology to improve the quality and added value of camel products. Countries work together to explore the international market, create joint brands, expand sales channels and greatly

enhance the economic benefits and influence of the camel industry in the global market.

International cooperation also plays a positive role in the dissemination of camel culture. Through activities such as holding camel cultural festivals and art exhibitions, people from various countries can appreciate the unique charm of camel culture, promote cultural exchanges and recognition and further drive the vigorous development of the camel cultural tourism industry. Looking to the future, we should further deepen international cooperation, comprehensively tap the potential of camel resources and promote the camel industry to make greater contributions to global economic development and ecological environmental protection.

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