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Review

Breeding of Camels in Europe: Between Continuity and Innovation

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Abstract: Camel breeding in Europe has undergone significant changes, intertwining historical continuity with modern innovation. Historically, dromedaries (*Camelus dromedarius*) and Bactrian camels (*Camelus bactrianus*), played essential roles in Roman logistics, medieval rituals, and agriculture, leaving archeological and cultural footprints across Europe. Following a decline during the Middle Ages, camels were largely confined to exotic collections. However, the past few decades have witnessed a resurgence in camel farming, primarily driven by tourism and the demand for camel milk, with an estimated 5000–6000 camels now present in Europe. Despite their adaptability to harsh climates and nutritional advantages, the sector faces challenges such as small population sizes, fragmented breeding efforts, and the absence of regulatory frameworks tailored to camels. Advances in genomic tools, including genome-wide association studies and SNP genotyping, have created opportunities for the genetic management of camels in Europe, yet also reveal concerns about low genetic diversity stemming from founder effects. Addressing these issues requires coordinated international efforts, standardized phenotype recording, and enhanced welfare guidelines. With climate change highlighting the resilience of camels to arid environments, their potential as sustainable livestock remains promising. This review underscores the balance between preserving the historical legacy of camels in Europe and fostering their integration into contemporary agricultural systems.

Keywords: *Camelus* spp.; history; breeding systems; regulatory frameworks; genetic diversity

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1. Camels in Europe Are Not a Recent Phenomenon

The *Camelidae* family traces its origins to North America during the Middle Eocene, approximately 46–42 million years ago. This family was highly diverse, with up to 13 genera, now extinct, present during the Miocene. Both paleontological and mitochondrial DNA evidence indicate that two major tribes within this family began to diverge in North America during the late Early Miocene, around 17.5–16 million years ago. The tribe *Camelini*, genus *Camelus*, cameloids or Old World camelids migrated across the Bering Strait, eventually spreading throughout Asia, the Middle East, and Eastern Europe, while the tribe *Aucheniini*, genus *Lama*, lamoids or New World camelids moved southward to South America [1].

Within the genus *Camelus*, two species of domesticated camels are recognized: the one-humped or dromedary camel (*Camelus dromedarius*) and the two-humped or Bactrian camel (*Camelus bactrianus*). The dromedary was domesticated in Southeast Arabia, while

the Bactrian camel was domesticated in Central Asia between the fourth and first millennia B.C.E. [2]. These domesticated species, including their hybrids (*Camelus dromedarius* x *Camelus bactrianus*), which are known to be fertile [3], were subsequently spread to various regions for diverse utilitarian purposes, such as packing, draught, and riding activities [4]. Dromedaries are traditionally found in African, Near and Middle Eastern, and Southern Asian countries, while Bactrian camels are restricted to Central Asia. However, the two species coexist in only a few regions, primarily Kazakhstan [5].

In Africa, dromedaries appeared around the seventh century B.C.E., introduced through Egypt during trade expeditions from the Arabian Peninsula. Their adaptability to harsh environments and functional versatility led to their widespread distribution across the Sahara by the fifth century B.C.E. [6]. Bactrian camels, on the other hand, expanded to regions such as Mongolia and Western China by the 3rd and 1st centuries B.C.E., respectively [7]. By the beginning of the Common Era, both camel species had reached most arid and semi-arid regions of Africa and Asia. Their introduction to Europe began during the Low Roman Empire (284–476 C.E.), when two-humped camels first arrived. They were initially incorporated into the Roman army due to their superior speed and endurance compared to horses. Beyond military uses, camels played roles in public games, imperial logistics, and as symbols of wealth and social status [8–10] (Figure 1). Ancient literature and iconographic evidence provide insights into using camels in the Roman Empire [11–13]. Camels were primarily bred as beasts of burden, serving military and trade purposes [13]. During the Late Roman period, the State maintained a substantial number of camels to transport supplies required by the Roman army during campaigns. Additionally, camels were utilized as riding animals and played a role in agricultural activities in southern regions, such as plowing. Historical records also document camel fighting and racing in public spectacles. Furthermore, written sources reference the consumption of camel milk and meat [11,14].

Figure 1. Camels in Roman Europe and the Roman Mediterranean. (**a**) A fragment of the 'Mosaic of Silenus' of Thysdrus depicting a dromedary camel (El Djem, Tunisia, 3rd century C.E.) (© Wikimedia); (**b**) a fragment of a mosaic floor showing a camel carrying a wine amphora (Kissufim, Israel, 6th century C.E.) (© Wikimedia); (**c**) 'Adoration of the Magi' featuring three camels from a fourth-century C.E. Roman sarcophagus at Rome (Photographer: Jastrow/© Wikimedia Commons); (**d**) a Roman statuette of a dromedary dated to approximately 1–300 C.E. (© Museum of Fine Arts of Budapest, Hungary); (**e**) the obverse of a silver denarius featuring Nabatean King Aretas kneeling with a camel (M. Aemilius Scaurus and Pub. Plautius Hypsaeus, 58 B.C.E., Rome mint) (© CNG Coins).

Archeological evidence of camel remains has been found in Roman sites across Central and Southeastern Europe, including France, Belgium, Germany, Italy, Austria, England, Hungary, and Switzerland [15–22] (Figure 2). However, more data are needed regarding the specific camel species present in this region. Pigière and Henrotay [23] provided an inventory of camel bones found at twenty-two sites across the former northern provinces of the Roman Empire, particularly highlighting the site in Arlon, Belgium, where at least one adult camel was identified, concluding that dromedaries, Bactrian camels, and their hybrids were present throughout the Roman period, suggesting their use as pack animals and possibly for meat. This study was supported by Tomczyk [21], which highlights that the remains predominantly represent adult camels; however, limited quantitative data are available concerning the estimated numbers, ages, or sexes of the animals [23]. Tomczyk [21] also mention, in their study, the citations by Aristotle and Diodorus Siculus in *Historia Animalum* (published in 343 AC) and in *Bibliotheca historica* (first century BC), respectively, about the consumption of camel meat and milk. However, other research has suggested that the discovery of camel bones in the Roman provinces of Belgica, Germania, Pannonia, and Raetia is often associated with military activities [9,12,19].

Figure 2. The geographical distribution of Roman-era and Middle Ages finds of camel remains across Europe.

The introduction of camels in the Iberian Peninsula occurred relatively synchronously with other European regions and is primarily associated with civilian sites, such as villas and cities. However, some authors suggest that camel bones found mainly along the Iberian Peninsula were directly imported from North Africa [9,24]. Tomczyk [21] further noted that the taxonomic classification of camel bone remains indicates a relatively higher prevalence of dromedaries in Western Europe, whereas Bactrian camels are more commonly found in Central and Eastern European countries. However, the split was not entirely strict. Some exceptions include an almost complete skeleton of a Bactrian camel found in a Roman urban setting at Saintes (France), and a dromedary remains unearthed at Kompolt-Kistér (Hungary).

In early medieval Western Europe, camels played a multifaceted role. Even after the fall of the Roman Empire, camels continued to be employed as pack animals, with records of their use in religious and noble contexts (Figure 3). They appear notably in

many coats of arms in several Italian municipalities [25]. However, beyond their utilitarian purposes, camels were also used in public rituals of humiliation, inspired by Late Roman and Byzantine practices. A striking example of the use of camels in public rituals of humiliation is the execution of Queen Brunhilda (who ruled the eastern Frankish kingdoms of Austrasia and Burgundy) in 613, who was paraded on a camel before being brutally executed. Similarly, King Wamba of the Visigoths humiliated his rebellious enemies in 673 by parading them on camels through the streets, a public display meant to degrade and shame. The act of humiliating adversaries by forcing them to ride on a camel's hump persisted in both the Byzantine Empire and Western Europe up until the 12th century. The final documented case occurred in 1185 AD when the ousted emperor Andronicus I Comnenus (Andronikos) was subjected to this form of degradation [26,27].

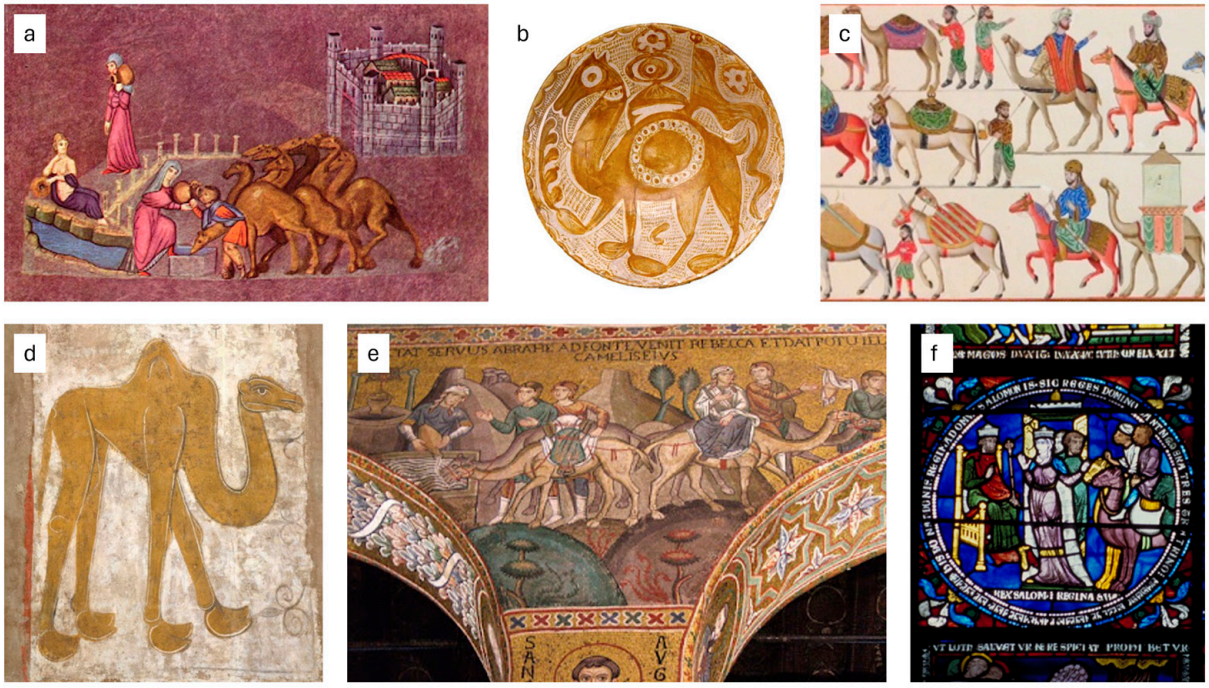

Figure 3. Camels in medieval Europe. (**a**) Dromedaries as depicted in an illustration of the 'Story of Rebecca' (6th century C.E. Vienna Genesis (Genesis 24)) (© Wikimedia Commons); (**b**) a golden reflection ataifor decorated with a dromedary figure (Al-Andalus period) (© Detroit Institute of Arts, Founders Society Purchase, General Membership Fund, 25.44); (**c**) a fragment of the paintings from the Casa del Partal in Alhambra (Granada, Spain). Reproduction by M. López Vázquez (© Marinetto, 2020, p. 28. Archive and Library of the Patronato de la Alhambra and Generalife); (**d**) a fragment of a twelfth-century Spanish fresco of a camel from the hermitage of San Baudelio de Berlanga (Soria, Spain) (© The Met); (**e**) a twelfth-century mosaic of camels, illustrating the 'Story of Rebecca' (Genesis 24), from the Palatine Chapel (Palermo, Italy) (© Andrew & Suzanne, Flickr CC BY-NC); (**f**) Solomon and the Queen of Sheba, detail from the stained-glass window in the northern aisle of Canterbury Cathedral (Canterbury, United Kingdom) (12th century) (© University of Michigan Library Digital Collections).

The act of forcing adversaries to ride on camels not only served as a means of public shaming but also conveyed deeper moral messages about hypocrisy and justice. In the case of emperor Andronikos, the camels were laden with symbolic meaning, as highlighted by references to biblical imagery, such as the camel passing through the eye of a needle, the vengefulness attributed to camels by Early Church Fathers, and the comparison of a camel to a gnat from the Gospel of Matthew. These three biblical references involving camels in the humiliation of Andronikos highlight important themes. First, the saying about a camel passing through the eye of a needle illustrates the difficulty for rich individuals to

be humble, reflecting Andronikos' arrogance. Second, camels symbolize vengefulness, indicating the people's resentment toward him for his past actions. Lastly, comparing a camel to a gnat emphasizes hypocrisy, as it points out how Andronikos criticized others while usurping power himself. The camels, therefore, became a poignant vehicle for conveying moral lessons to the audience, emphasizing the consequences of one's actions. Moreover, the camel's exotic nature captured attention and enhanced the spectacle of Andronikos' humiliation, allowing the scene to resonate on multiple levels. This suggests that while camels were visually striking, the broader implications of their use in punishment highlight the interplay between justice, retribution, and moral critique in Byzantine society. The potential significance of more commonly encountered animals, like donkeys and mules, also hints at the varying connotations that different animals could carry in similar contexts of public humiliation [28].

Camels were also regularly present on the Iberian Peninsula throughout the Middle Ages (476–1492 C.E.), as confirmed by bone discoveries, written records, and/or artistic depictions from the Islamic period [29]. Archaeofaunal evidence shows that dromedaries arrived during the Caliphate period (632–1258 C.E.) and remained until the fall of the Nasrid Kingdom in 1492 [30]. Notably, two significant periods of high dromedary populations occurred: Al-Mansur's large-scale importation of camels from North Africa around 1002 C.E. and the Almoravid and Almohad invasions (1090–1146 C.E.), during which camels were integrated into local economies [31,32]. Archeological findings suggest that camels were consumed for meat, and their bones were repurposed into tools during this period [30,33].

Around 1405 C.E., dromedaries were also introduced to the Canary Islands (Spain), where they adapted quickly and became vital to the region's socio-economic development [34]. The islands' dry climate and sodium-rich vegetation, combined with the absence of natural predators, favored the rapid growth of camel populations. Camels played a vital role in agriculture, grain milling, and transportation, shaping the local landscape, such as through the construction of terraced fields. Socially, camels became symbols of prosperity and status, further embedding them into the cultural heritage of the Canary Islands [35].

Despite their historical significance, camels eventually became rare in mainland Europe at the end of the 15th century, primarily limited to exotic collections by European aristocracy from the Renaissance onward [36] rather than with battles or trade caravans connecting the Orient and Europe [15,20,37]. For example, in the Iberian Peninsula, upon the completion of the Reconquista, camels had become an exotic rarity that only occasionally reached the Peninsula as spoils from the raids and forays conducted by the Christian troops from the garrisons of North Africa [9,38] (Figure 4).

Juan Antonio Álvarez de Quindós, in the early 19th century, emphasized the long-standing tradition of sovereigns showcasing their grandeur by housing exotic and rare animals, plants, and fruits from foreign lands within their palaces. In his *Descripción histórica de Aranjuez*, he details the presence of several unusual animals at the royal site during the reign of Charles III, including a bison, zebras, elephants, Tafilete rams, Chilean guanacos, and the now-extinct camels. These collections were a testament to the prestige and influence of the monarchy [39]. The association of exotic-animal collections with the display of royal majesty dates back to medieval times. Still, it gained significant prominence during the Renaissance, when the practice became widespread among European princes and rulers. Francesco Matarazzo, an Italian humanist, emphasized this idea in the early 16th century, stating that "the magnificence of a great lord should also be seen in his horses, dogs, falcons, and other birds, as well as in his jesters, musicians, and the exotic animals he possesses". This reflects the increasing importance of exotic animals as symbols of power and prestige during this period [40]. From the 16th to the 18th centuries, European aristocrats, emulating the great leaders and emperors of antiquity, developed a strong

interest in collecting exotic animals and wild beasts. This passion, often limited to monarchs due to the high costs involved, reflected the animals' status as prestigious luxury items. Like art, precious objects, or antiques, these animals symbolized the nobility's natural distinction and expressed the owners' reputation and grandeur [41]. In Spain, camels adapted well to the climate of Aranjuez, successfully reproducing and growing in number from about ten in 1583 to around two hundred by the late 17th century. They became a notable attraction for travelers, grazing freely on the royal estate and surviving various challenges, including poaching and military plundering. While some camels were used for hauling, most were admired for their exotic presence. Visitors such as Antoine de Brunel and François Bertaut documented their presence, although some, like the Marquise of Villars, found the collection less impressive than Louis XIV's menagerie at Versailles [42]. Bactrian camels were essential to the Turkish conquests in the Balkans and supported Suleiman the Magnificent's army during the 1529 Siege of Vienna. They also played a key role in long-distance trade across North Africa, with regular transport of camels from Asia to Europe through the port of Constantinople [43].

Figure 4. Camels as part of the exotic-animal collections of European potentates. (**a**) 'Royal Site of Aranjuez: Viewed from the Arca del Agua along the Camino de Ocaña' (Aranjuez, Madrid, Spain) (1773; illustrator: Domingo de Aguirre; engraver: Juan Moreno de Tejada) (© Mingo Salamanca-Estampas de Aranjuez); (**b**) 'Arrival of the Moroccan ambassador at San Ildefonso in 1766' (Segovia, Spain) (exact date unknown; illustrator: Antonio González Velázquez; engraver: Manuel Salvador Carmona) (© Centro de Estudios del Madrid Islámico); (**c**) 'Journey of Cosimo de' Medici through Spain and Portugal (1668–1669)' (Pier María Baldi, exact date unknown) (© Mingo Salamanca-Estampas de Aranjuez); (**d**) an illustration of two Bactrian camels (1976–1977; illustrator: Hans Savery). Part of the collection 'Le Cabinet d'un Amateur: Dessins flamands et hollandais des XVIe et XVIIe siècles d'une collection privée d'Amsterdam, 1976-77, no. 118, pl. 32'. This Bactrian is probably one of the many curiosities and rarities which Hans was able to study during their time in Prague, in the celebrated menagerie of the Emperor Rudolf II (© Christie's); (**e**) an illustration of a dromedary camel (exact date unknown; illustrator: Anselmus Boetius de Boodt). Part of the second album with drawings of four-legged friends. The second of twelve albums with drawings of animals, birds, and plants known around 1600, commissioned by Emperor Rudolf II (© Rawpixel).

2. Camels Are Gaining New Momentum in Europe

Camelids have served humans in various capacities for centuries, providing milk, meat, draft power, fiber, and recreation, particularly in arid and semi-arid regions where their resilience to harsh climates is invaluable. For example, dromedaries can yield between 1000 and 12,000 L of milk during an 8 to 18 month lactation period, with significant variations observed depending on the geographical region [44]. This significantly exceeds the milk production of Bactrian camels, which may yield between 514 and 1525 kg milk per 305 day lactation period [45]. The disparity highlights the dromedary's specialization as a dairy animal, particularly in arid and semi-arid regions. Conversely, Bactrian camels are often regarded as multipurpose animals, valued for their meat, wool, and as pack animals, especially in the colder climates of Central Asia.

Although camels were historically present in Europe during the Roman Empire and the Middle Ages, they were mostly confined to zoological gardens and circuses after that [9]. Despite a significant decline in their numbers after the Middle Ages, camels continued to hold socioeconomic and cultural significance in the Canary Islands well into the 20th century [46]. Over the past three decades, however, camel farming in Western Europe has experienced a resurgence, particularly with an emphasis on tourism, sport, and milk production. According to FAOSTAT, the FAO's global statistical database, about 6000 camels are estimated to be currently present in Europe, representing 0.02% of the global camel population, with the Canary Islands (Spain) hosting the most notable group. These populations are primarily composed of dromedaries, although Bactrian camels and hybrids may also be found in some settings. Despite this modest figure, Europe's camel numbers are comparable to those in smaller Central Asian republics and recognized "camel countries" such as Lebanon [5].

During this period, camel dairy farms have been established across several European countries, including Spain, France, Switzerland, Germany, Poland, Sweden and the Netherlands [47,48]. In these farms, milking is conducted using machine milking systems. This resurgence not only represents a diversification of agricultural activities but also introduces camel milk production to the European market, where this luxury food was previously only available in the form of pasteurized milk and derived dairy products, through import from Middle Eastern countries, notably from UAE [49,50]. As stated by Smits, Joosten, Faye, and Burger [48], over the past decade, the rise in demand for camel milk in Europe has been largely driven by a growing number of international consumers from countries where camel milk is a traditional product, as well as its growing popularity due to perceived health benefits. However, the price of dromedary milk remains higher than that of cow's milk due to the fact that dromedaries produce significantly less milk per day compared to cows. This is further compounded by the fact that there is substantial lack of knowledge regarding the influence of environmental factors (e.g., photoperiod and nutrition) in both the quantity and quality of milk, which could impact the processing characteristics of raw camel milk more than its price at the market. In addition, dromedaries require specialized training to be milked properly, ensuring that the milking machine and routine function optimally. The machine milking of dromedaries is still in its early stages and requires further research to optimize the technology and improve milk ejection [44,51]. Regarding other camel-derived products, such as camel meat, to the best of our knowledge, it is not an established functional niche in Europe due to the lack of authorized slaughterhouses for these animals, among other factors.

Additionally, in regions like the Canary Islands, dromedary camels are still primarily utilized for leisure-oriented activities (e.g., camelback riding) following mass tourism development in the 60s, further contributing to the growing interest in camel farming. Establishing a European Camel Federation reflects the increasing enthusiasm and investment

for camel farming in Europe, highlighting its potential for sustainable livestock production and local tourism development [5].

Determining the exact global population of camels remains challenging, largely due to the nomadic nature of camel owners, the absence of health programs such as compulsory vaccinations, and the lack of comprehensive registry database [5]. Discrepancies between FAO (Food and Agriculture Organization) estimates and national statistics, as well as inconsistencies within countries, further complicate the reliability of population data. Additionally, many countries do not conduct regular or accurate censuses, leading to camels being overlooked even in regions where livestock registration is systematic. Addressing these issues requires a standardized global camel census that distinguishes between species to achieve a clearer understanding of their current status in domestic herds [5].

An interactive, freely accessible map has been created specifically for this study, displaying the exact location and basic information of camel farms and breeding centers currently existing in Europe. The map is available through the link in reference [52]. This resource is designed to facilitate the visualization and access to relevant data on camel production in the region. Furthermore, the map is continuously updated to reflect the most recent and accurate information available. Contrary to the global scenario of camel rearing, which typically follows nomadic, pastoralist systems [53], camel farming in Europe primarily takes place in semi-extensive and semi-intensive farm systems.

Although the primary functions of camels in Europe are, as mentioned earlier, leisure-oriented activities and milk production, some general geographic trends can be observed. In Southeastern Europe (i.e., Spain, Italy, Cyprus, and Bulgaria), camel farms are primarily tourism-oriented, with the Canary Islands (Spain) serving as the primary source of camels for live animal sales in Europe. These farms tend to be semi-extensive, with camels often raised in more open, less-intensive systems. Camels in Spain are also used for representation in movies and socio-cultural acts. Although there is an emerging interest in camel milk production for human consumption, the milk produced on these farms is currently primarily used in cosmetic products (e.g., creams, lotions, and soaps).

In contrast, in Northern and Central Europe, camel farms predominantly focus on breeding camels for milk production and milk-derived products (e.g., milk powder, cheese, ice cream, yogurt, chocolate, and cosmetics), with a smaller, but still significant, emphasis on educational activities, camel riding, and camel training. Due to climatic conditions, these farms are typically more intensive, with camels often housed in more controlled environments (loose housing systems) especially at night and in the cold winter. However, most of these farms also allow the animals to graze freely for part of the day.

These distinct farming systems reflect the unique environmental and socio-economic factors across Europe, where farming practices are tailored to different climatic conditions and market demands. This variety of farming systems also highlights the adaptability of camels to a wide range of environments and breeding systems. Despite their remarkable resilience, this should not lead, however, to overlooking their behavioral and welfare needs. The well-being of camels must remain a priority, ensuring that their specific needs are met in all types of farming systems.

3. Challenges for a Modern European Camel-Breeding System

Camel breeding in Europe is a small niche sector, still suffering some limitations arising, among others, from a generalized perception of camels as exotic, circus, and zoo-confined animals. A number of regulatory and management aspects are still adopted from the major livestock species, not taking into account the peculiar features and needs of camels. In what follows, we try to provide a non-exhaustive overview of regulatory

frames and management issues, highlighting missing or weak points, as well as recent opportunities, for what concerns the emerging camel-breeding sector.

3.1. Identification Systems of Camels in Europe

Overall, EU regulations and guidelines, specifically regarding the identification and registration of camels, are lacking. However, we managed to find some information by personally contacting the respective Animal Health and Welfare Departments of the following EU countries.

A unified and comprehensive identification system for camelids across all EU countries is essential to ensure consistency, traceability, and compliance with health and welfare standards. Current systems, such as those in France, Italy, and Spain, operate under a mix of national and EU regulations, with variations in databases and procedures, leading to inefficiencies and inconsistencies in managing camelid health and traceability. A standardized EU-wide system would streamline the identification process, enhance disease prevention, and support better data management, benefiting not only animal health and welfare and animal genetic improvement but also facilitating trade and research. Implementing such a system would ensure that all EU countries adhere to the same high standards, promoting better coordination and oversight across Member States.

3.1.1. France

In France, the identification and registration of camelids have been governed by European Union regulations and national laws, with oversight from two primary organizations: the Institut Français du Cheval et de l'Équitation (IFCE) and the Ministry of Ecological Transition. The IFCE managed the SIRECam database, which served as the primary registry for domestic camelids, while the Wildlife Database, under the Ministry of Ecology, focused on zoo and non-domestic species. SIRECam collected detailed information on each animal, including species, birth details, identification date, and physical characteristics, ensuring compliance with regulatory frameworks like Decree n° 2016-119 of 5 February 2016.

Camelids were identified using transponders implanted by veterinarians or ear tags applied by breeders. The data were subsequently registered in eSIRECam to support zootechnical monitoring and ensure adherence to animal welfare standards. Collaboration between public and private entities facilitated the management of these records, although the databases remain inaccessible to the public. However, recently, IFCE announced that it will no longer manage the identification and registration of camelids, such as dromedaries, camels, llamas, and alpacas. Consequently, the eSIRECam database, previously used for these purposes, was permanently closed on January 6, 2025. Despite this change, identifying camelids remains a legal requirement. Owners must document identifications in their personal registers, as Article 102 of EU Regulation 2016/429 mandates. Non-domestic species like guanacos and vicuñas should now be registered with the I-FAP database, dedicated to protected wildlife identification. The IFCE advises owners to download their registration certificates from eSIRECam before 28 February 2025, to maintain proper records. The registration of camelid keepers is temporarily suspended and will resume under the forthcoming National Operators Database, currently being developed by the Ministry of Agriculture. Information previously recorded in eSIRECam will be transferred to the relevant authorities: the Ministry of Agriculture for domestic camelids and the Ministry of Ecology for non-domestic species. Despite the cessation of IFCE's management of camelid registration in 2025, this system exemplified a structured approach to animal identification, integrating regulatory compliance with zootechnical oversight.

3.1.2. Italy

The identification and registration of camelids in Italy are regulated by a comprehensive framework that includes European Union and national legislation. Key EU regulations consist of EU Regulation 2016/429, which sets forth the fundamental principles for animal health and identification, as well as Delegated Regulation (EU) 2019/2035 and Implementing Regulation (EU) 2021/520, which offer specific guidelines for the identification and registration processes. At the national level, Legislative Decree 134/22 establishes the requirements for animal identification and registration, while the Ministerial Decree of 7 March 2023 provides the operational manual for the identification and registration (I&R) system. This system, which covers various animal species, including camelids, is managed by the Ministry of Health and will become fully operational for camelids in January 2025. Through the Ministry's online platforms related to general health and animal health matters, farmers and operators can access essential information on legislation, organizational structure, and the identification process. Additionally, vetinfo.it offers aggregated data on the number of establishments, farms, and animals categorized by species and location while maintaining confidentiality. This regulatory framework, combined with accessible online resources, aims to enhance traceability, health management, and the sustainable development of camelid farming in Italy, thereby improving animal welfare in the sector.

3.1.3. Spain

In Spain, the identification and registration of camelids are governed by Royal Decree 787/2023, enacted on 17 October 2023. This legislation ensures the traceability, identification, and registration of terrestrial species in captivity, including camels, dromedaries, llamas, alpacas, vicuñas, and guanacos. Camelid farms must be registered in the General Registry of Farms (REGA) as regulated by Royal Decree 479/2004, while individual camelids are recorded in the General Registry of Individual Identification of Animals (RIIA). Additionally, their movements are tracked in the General Registry of Livestock Movements (REMO) under Royal Decree 728/2007. Camelid identification involves conventional ear tags or injectable transponders implanted aseptically in the upper third of the left side of the neck. Each animal is assigned a unique identification code that includes a country code (724 for electronic or ES for visual identification), a two-digit code for the identification type, two digits for the region, and an eight-digit individual identifier. Camelids in Spain must be identified within nine months of birth, which aids in maintaining accurate records and effective health management. The RIIA database records key information for each camelid, including its identification code, re-identification history, identification date, species, sex, birth date, farm code, and, if applicable, death date. Health data are also recorded following regulatory requirements, ensuring thorough documentation. Access to the RIIA, REGA, and REMO databases is limited to competent authorities safeguarding sensitive information and ensuring proper management. This regulatory framework strengthens camelid health and traceability management, ensuring compliance with both national and EU animal welfare and identification standards.

3.2. Movement and Traceability of Live Animals

The movement and traceability of camels within the European Union (EU) are governed by a comprehensive regulatory framework designed to mitigate the risk of animal disease transmission (Table 1) and ensure the health status of these animals [54]. A comprehensive list of EU regulations is provided below.

Table 1. Diseases of interest for camels, as updated at the second meeting of the OIE (World Organisation for Animal Health) Ad Hoc Group on Diseases of Camelids (May 2010).

Disease Category	Group *	Dromedary Camel	Bactrian Camel
Viral diseases	I	Camelpox, Contagious ecthyma, Papillomatosis, Rabies and Rift Valley Fever	Camelpox, Contagious ecthyma, Foot and mouth disease, Influenza A infections and Rabies
	II	African horse sickness, Bluetongue, Bovine viral diarrhea, and Peste des petits ruminants	Bovine viral diarrhea
	III	Crimean–Congo haemorrhagic fever, Herpesvirus infections and West Nile Fever	Bluetongue, Crimean–Congo haemorrhagic fever and Herpesvirus infections
Bacterial diseases	I	Anthrax, Brucellosis (*B. melitensis*), Clostridia infections, Colibacilosis, Dermatophilosis (*Dermatophilus congolensis*), Haemorrhagic septicaemia (*Pasteurella multocida* or *Mannheimia hemolytica*), Johne's disease, Pyogenic diseases (Caseous lymphadenitis) and Salmonellosis	Anthrax, Brucellosis (*B. abortus* and *B. melitensis*), Clostridia infections, Colibacilosis, Johne's disease, Plague (Yersiniosis), Pyogenic diseases (Caseous lymphadenitis), Salmonellosis and Tuberculosis
	II	Leptospirosis, Q fever, and Tuberculosis	Leptospirosis and Q fever
	III	Chlamydiosis, Glanders (Melioidosis) and Plague (Yersiniosis)	Chlamydiosis, Glanders (Melioidosis) and Haemorrhagic septicaemia (*Pasteurella multocida* or *Mannheimia hemolytica*)
Parasitic and fungal diseases	I	Cephalopina infestation, Coccidiosis, Gastrointestinal parasitosis, Hydatidosis/Echinoccosis, Mange (*Sarcoptes scabiei*), Ring Worm (Dermatophytosis), Tick infestations, and Trypanosomosis	
	III	Myasis other than Cephalopina, Neosporosis, and Toxoplasmosis	

* Group I: known to produce significant diseases; Group II: diseases for which camelids are potential pathogen carriers; Group III: minor diseases.

3.2.1. EU Regulations

The main EU regulations governing animal health focus on the entry of animals into the EU, their movement within the Union, and compliance with health certification and biosecurity measures (Table 2). The regulations ensure disease prevention, traceability, and the regulation of trade involving animals within EU Member States and from non-EU countries. Except for the Implementing Regulation (EU) 2021/404, which concerns camelid and cervid animals from non-EU countries, all other regulations generally deal with animals. The first introduction of trypanosomiasis (*Trypanosoma evansi*) in French territory, a common hemoparasitosis affecting camels, through the import of contaminated camel from the Canary Islands, is an emblematic example of the health risk linked to the camel trade within the European Union [55].

Table 2. Overview of key EU animal health regulations.

Regulation	Description
2016/429 (Animal Health Law)	Establishes general health requirements for the entry of animals into the EU to prevent the spread of diseases
2020/692	Sets specific animal health requirements for non-EU countries, including health certification
2021/404	Details conditions for importing camelid and cervid animals from non-EU countries, including health certificate requirements
2021/620	Lists Member States and regions declared free of certain diseases or under eradication programs, facilitating trade
2019/2130	Provides rules for official controls at Border Control Posts for animals entering the EU, ensuring compliance with health requirements
2020/688	Outlines health requirements for the movement of terrestrial animals within the EU, emphasizing traceability and biosecurity
2017/625	Focuses on official controls to ensure compliance with food and feed law, animal health, and welfare rules
2021/403	Establishes the model for animal health certificates required for the movement of animals within the EU and imports from non-EU countries
2019/2035	Lays down rules for establishments keeping terrestrial animals and for the traceability of those animals within the Union
2020/689	Provides specific provisions for animal health and movement requirements to disease-free zones

3.2.2. Regulatory Framework for Movement

The movement of camels is primarily regulated by Regulation (EU) 2016/429, known as the Animal Health Law, which establishes general health requirements for the entry of animals into the EU. Supplementary regulations, such as Regulation (EU) 2020/688 (Section 5, Article 23), provide specific guidelines for the health requirements associated with intra-EU movements of camelids. Establishments and transporters must be registered with the competent authority to ensure traceability. A fundamental principle of this framework is that only camelids originating from registered or approved establishments may be transported to another Member State, ensuring that these animals are sourced from facilities that adhere to stringent health and safety standards.

Transport protocols dictate that camelids should be moved directly from their establishment of origin to their destination. However, under certain derogations, assembly in approved establishments is permitted. Accompanying these movements, an animal health certificate is required, which must be signed by an official veterinarian. This certificate attests to the animals' compliance with health requirements and must be presented at the EU entry point (Implementing Regulation (EU) 2021/403).

3.2.3. Traceability Systems

The EU employs advanced technical systems, such as the Trade Control and Expert System (TRACES NT), to facilitate the traceability of camelids. This system enables the creation and management of health certificates and the tracking of animal movements throughout the supply chain. The animal health certificate contains essential information regarding the non-EU country of origin, the destination, and the identification of the animals, along with attestations concerning their health status and the conditions of their holdings (Commission Implementing Regulation (EU) 2021/404).

Despite the absence of border controls for movements between Member States, non-discriminatory spot checks are conducted en route and at the destination to ensure compliance with the health guarantees provided in the animal health certificate (Implementing

Regulation (EU) 2021/403). These measures are crucial for maintaining the integrity of the EU's animal health standards.

3.2.4. Considerations Before Entry

Camelid and cervid animals entering the EU must comply with specific animal health requirements outlined in Regulation (EU) 2016/429, including the acquisition of an animal health certificate issued by an official veterinarian in the exporting non-EU country. This certificate verifies the prevalence of animal diseases and the adequacy of the country's veterinary services. It must accompany the animals during their transport and be presented at the EU Border Control Post. As mandated by Implementing Regulation (EU) 2021/403, the CAM-CER model serves as the essential health certificate for camelid and cervid animals entering the EU. It contains critical information, including the animals' country of origin, destination, and identification.

The CAM-CER certificate ensures that camelid and cervid animals entering the EU meet stringent health standards. It verifies that the animals originate from farms free of diseases such as brucellosis, anthrax, and rabies, and confirms that they have not been treated with certain pharmaceuticals or hormones. An official veterinarian from the exporting country must sign the certificate, attesting that all health requirements are fulfilled. This certification is essential for maintaining animal and public health within the EU. Upon arrival, live animals are inspected at Border Control Posts to confirm compliance with health regulations (Implementing Regulation (EU) 2021/403), and animals failing to meet these standards are denied entry, protecting both livestock and human health.

3.2.5. Considerations After Entry

Once camelids have entered the EU, operators at the destination must conduct thorough checks to verify the correct identification of the animals and the completeness of their documentation. Any discrepancies must be reported to the competent authority, and affected animals must be isolated until further instructions are provided. Biosecurity measures are strictly enforced to prevent animal escapes and excrement spillage during transport. Transport vehicles are mandated to be promptly cleaned and disinfected after use. Furthermore, camelids must continue to comply with the health requirements established in the Animal Health Law (Regulation (EU) 2016/429 of the European Parliament and of the Council), which includes ongoing monitoring for diseases that could pose risks to livestock and human health.

3.2.6. Stakeholders and Responsibilities

Operators are responsible for registering their establishments, ensuring compliance with health regulations, and verifying animal identification and documentation before transport (Regulation (EU) 2017/625). Upon receiving animals, they must check for discrepancies and report them to authorities. Transporters must follow biosecurity rules to prevent animal escape and contamination during transport and are responsible for cleaning and disinfecting vehicles. Veterinarians in non-EU exporting countries and EU Member States certify animals' health and ensure compliance with health regulations through inspections and signing health certificates. Competent authorities oversee the registration process, conduct inspections, ensure compliance, and handle irregularities (Regulation (EU) 2021/403, Regulation (EU) 2019/2035).

3.3. Movement and Traceability of Animal Products

3.3.1. Personal Imports

The regulations and requirements for the movement of animal products within the EU and their entry into the Union emphasize the importance of animal health to prevent

disease transmission [56]. Although the EU regulations do not specify the personal import of camelid products, the general key points include:

- General requirements: Under Regulation (EU) 2016/429, the EU has established harmonized animal health requirements for the movement of products of animal origin between Member States and their entry into the EU. Products must be produced in registered or approved establishments, and checks may occur at the final destination.
- Specific requirements: Specific animal health certificates may be required for certain products during evolving disease situations.
- Entry into the Union: Animal products entering the EU require accompanying health certificates signed by an official veterinarian from the exporting country. Upon entry, products are inspected at designated Border Control Posts.
- Brexit considerations: Brexit has significantly impacted the movement of animal products between the EU and the UK, particularly regarding food law and travel. Post-Brexit, travelers from Great Britain face stringent regulations on importing animal and food products into the EU. Meat and dairy imports are largely prohibited, except for small quantities of powdered infant milk and special pet food. Personal consignments are subject to strict weight limits, while larger quantities must comply with commercial regulations. These rules aim to protect public health and prevent disease [57].

After Brexit, UK food products must comply with EU labeling and safety standards. This includes mandatory origin labeling and the identification of EU importers. Authorization applications must be submitted through EU Member states to ensure food safety and quality for imports from the UK [58]. The Windsor Framework, established post-Brexit, addresses trade challenges between Great Britain and Northern Ireland while maintaining the integrity of the EU's Single Market. It promotes stakeholder engagement, ensuring that Northern Irish citizens' perspectives are considered in decision-making. Ultimately, the framework aims to promote economic stability and uphold the principles of the Good Friday Agreement [59].

3.3.2. Imports for Human Consumption

The European Union's regulatory framework for products of animal origin is primarily governed by Regulation (EU) 2016/429, which addresses transmissible animal diseases [60]. This regulation specifies health requirements for both terrestrial and aquatic animal products. For terrestrial products, movement within the EU generally does not require health certificates, except for those from restricted disease zones, as outlined in Commission Delegated Regulation (EU) 2020/2154. Aquatic products are regulated under similar health standards, supplemented by Commission Delegated Regulation (EU) 2020/990. Additionally, the Commission Implementing Regulation (EU) 2020/2236 provides model certificates for the entry of these products into the EU.

Compliance with these regulations is crucial for producers and exporters seeking access to the EU market. Adherence to health certification and hygiene standards is necessary to ensure the safety and quality of animal products. Table 3 provides an overview of significant EU regulations governing food safety and animal health, including rules for hygiene, pesticide residue levels, contaminant limits, official controls, and animal health certifications. These regulations ensure the prevention of diseases, compliance with food and feed laws, and the safe entry and movement of animals and animal products within the European Union.

Table 3. Key EU regulations on food safety and animal health.

Regulation	Description
(EC) No 999/2001	Rules for preventing, controlling, and eradicating certain transmissible spongiform encephalopathies (TSEs)
(EC) No 178/2002	General principles and requirements of food law, establishing the European Food Safety Authority (EFSA)
(EC) No 852/2004	Hygiene of foodstuffs, setting general hygiene requirements for food businesses
(EC) No 853/2004	Specific hygiene rules for food of animal origin
(EC) No 396/2005	Maximum residue levels of pesticides in food and feed
(EU) 2023/915	Maximum levels for certain contaminants in food
(EU) 2017/625	Official controls and activities to ensure compliance with food and feed law
(EU) 2019/624	Official controls on the production of meat and live bivalve mollusks
(EU) 2022/2292	Requirements for the entry into the Union of consignments of food-producing animals
(EU) 2019/627	Uniform arrangements for official controls on products of animal origin
(EU) 2020/2235	Rules for model animal health certificates for entry into the Union
(EU) 2016/429	Animal Health Law for preventing and controlling transmissible animal diseases
(EU) 2020/692	Specific rules for entering the Union of certain animals and products
(EU) 2021/404	Lists of third countries from which entry into the Union is permitted
(EU) 2021/405	Lists of third countries authorized for entry into the Union of certain animals and goods
(EU) 2020/2154	Additional rules for products from restricted zones
(EU) 2020/990	Additional rules for products of animal origin from aquatic animals
(EU) 2020/2236	Model certificates for entering aquatic animal products into the EU

Chapters 5 and 6 of Annex III in Commission Implementing Regulation (EU) 2020/2235 outline the requirements for importing camelid meat into the EU, covering both domesticated and wild camelid sources. These chapters specify the necessary animal health certificates for fresh meat intended for human consumption, ensuring compliance with EU health standards while excluding offal, minced meat, and mechanically separated meat to safeguard public health. However, despite the comprehensive framework for animal product imports, there is a notable gap in EU legislation addressing other camelid-based products such as milk, fibers, and derivatives. This absence of targeted regulations could lead to inconsistencies and confusion, potentially compromising animal health and product safety. As the camelid sector grows in the EU, developing specific regulations for camelid products is crucial to ensure clear guidelines and maintain high safety standards.

3.3.3. Camelid Germplasm Movement

The movement and traceability of animal products, specifically germplasm, within the European Union, are governed by a comprehensive legal framework to ensure animal health and prevent the spread of transmissible diseases. The key legislation in this area is the Delegated Regulation (EU) 2020/686, commonly referred to as Reg. 686, which outlines the rules and requirements for the movement of germinal products, including those from the *Camelidae* family [61]. The authors listed the important EU Regulations governing animal products below. Some regulations are specific to the camelids, whereas others apply to animal products imported into the EU. Table 4 outlines important EU regulations concerning animal health, focusing on the prevention and control of transmissible diseases, the movement of germinal products, and the entry and transfer of camelid animals within the EU. The regulations ensure traceability, the categorization of diseases, and the implementation of necessary health requirements across member states.

Table 4. EU regulations for camelid product movement across the EU member countries.

Regulation	Description
2016/429	The Animal Health Law (AHL) establishes rules on transmissible animal diseases and related health requirements
2020/686	Specifically, it governs the movement of germinal products, including those from camelids, and outlines traceability and animal health requirements
2020/688	Concerns about the approval of germinal products and their traceability
1629/2018	Updates the AHL and includes measures for the prevention and eradication of diseases transmissible to animals
1882/2018	Subdivides diseases into different categories based on management measures and their potential impact on health and the economy
2021/403	Pertains to the entry of camelid animals into the EU
2021/404	Relates to the movement of camelid animals between member states

3.3.4. Regulatory Framework and Traceability

The movement of camelid germplasm is primarily governed by Delegated Regulation (EU) 2020/686, which establishes rules for traceability and animal health requirements. This regulation aims to ensure the safe movement of germinal products, including semen, oocytes, and embryos while preventing the spread of transmissible diseases. Article 38 of Regulation 2020/686 outlines specific animal health requirements for moving camelid germinal material. Article 11 specifies traceability requirements, ensuring that all movements of germinal products are documented and can be tracked throughout the supply chain. Articles 39 and 40 detail the rules concerning animal health certification for germinal products. Articles 41, 42, and 43 outline the rules for notification of movements, ensuring that relevant authorities are informed of any transfers.

3.3.5. Technical Systems

The TRACES (Trade Control and Expert System) notifies movements of germinal products between member states. It is integrated with an Information Management System for Official Controls (IMSOC), which manages data and documents related to official controls and activities.

The regulation also includes emergency procedures for notifying movements in case of system failures, ensuring that stakeholders can still communicate necessary information to authorities.

3.3.6. Stakeholders' Responsibilities

In the movement of camelid germinal material, operators are responsible for ensuring compliance with animal health standards, maintaining traceability, and providing necessary product certifications. Veterinary services play a crucial role in enforcing health regulations, validating health certifications, and monitoring the health status of the animals from which the germinal products are derived. Competent authorities oversee the implementation of regulations, ensuring accurate documentation of movements and compliance with established health and traceability standards. Additionally, establishments that process germinal material must adhere to biosecurity standards and maintain separate storage for different types of germ products to prevent cross-contamination.

3.4. Genetic Management

For the major livestock species, the main regulatory frame is represented by the Regulation (EU) 2016/1012 on zootechnical and genealogical conditions for the breeding, trade-in, and entry into the Union of purebred breeding animals, hybrid breeding pigs, and

the germinal products. This regulation only applies to bovine, porcine, ovine, caprine, and equine species and no mention is provided within the text for camels or camelids.

The modern genetic management and improvement of livestock species rely on an articulated system of practices and procedures implemented by the various stakeholders of the breeding sector (breeders, breed societies, competent authorities, etc). Given the limited size and fragmented nature of camel breeding in Europe, together with issues related to interspecific hybridization between one and two hump camels, as well as the absence of registered breeds within the two camel species, setting up a well-organized and managed breeding framework for camels in Europe de novo represents a real challenge. However, new technical opportunities offered by the advent of massive DNA genotyping at the genome-wide level and the consequent shift from traditional genetic improvement schemes relying on genetic evaluation testing through statistical inference from phenotypic data toward the selection of reproducing animals using genomic-estimated breeding values (gEBVs) currently offer alternative strategies for the tailored development of breeding schemes specifically suited for camels in Europe.

One of the main limitations in developing modern breeding systems for European camels is currently represented by the small census size and the scattered distributions of animals throughout Europe. The availability of a small base population, coupled with the fact that different farms may have different selection goals depending on the single or multiple uses of camels (e.g., leisure activities, milk production, etc.), may hamper efficient genetic progress unless a strong emphasis is given to supranational organizations that may promote interaction among breeders, and breeder associations (still mainly lacking for camels in Europe), in different countries, and boost harmonization in the genetic evaluation and selection of reproducing animals at the international level. For example, in the case of purebred breeding animals of the bovine species, those tasks are carried out by the Interbull Centre, a permanent subcommittee of the International Committee for Animal Recording (ICAR), which is the European Union Reference Centre designated by the Council Decision 96/463/EC.

Furthermore, most of the dromedaries in Europe may have a common origin in the Canary Islands, the only European territories where dromedaries have a longstanding history of breeding and from where import into other EU countries may result easier than from non-EU countries. This flux of animals into Europe from a relatively isolated and small population, the so-called “Camello Canario” (Canarian Camel), represents, from a population genetics point of view, a sort of “founder effect” and may contribute to the poor genetic diversity expected in European dromedaries, also based on the low genetic differentiation observed at the intercontinental scale for this species [62] and the paleontological and molecular evidence, suggesting that the distribution and population size (hence, levels of genetic diversity) of wild dromedaries were already restricted prior to domestication compared with the ancestors of other livestock species [63]. The above elements also suggest the possible need for cautious genetic improvement actions and specific genetic conservation strategies and measures for European camels. Assessing and monitoring genetic diversity status represent one of the pillars of the FAO Global Plan of Action for Animal Genetic Resources adopted in 2007 [64]. A strategic role in this direction for camels could be played in the future by the European Regional Focal Point for Animal Genetic Resources (ERFP), which has been established in the framework of the FAO Global Plan of Action in Europe for more effective management of endangered livestock resources. Indeed, so far, the only studies addressing genetic variation in European dromedaries by using morphometric and/or molecular markers have been focusing on Canary Islands camel populations [34,65]. In addition to the analysis of neutral genetic diversity, a recent study also investigated possible functional genetic loci affecting morphometrics, biomechanics, and behavior traits

in Canarian camels by genome-wide association studies [66]. The recent availability of medium-density genome-wide genotyping tools for a fast, cheap, and reproducible analysis of Single Nucleotide Polymorphisms (SNPs) in camels from the Illumina® [67] and the Affymetrix® [66] biotech companies is expected to boost genetic studies in camels at the worldwide level, including European camels. A first step toward the goal of assessing the genetic diversity of camels using medium-density SNP genotyping tools (SNP arrays), including at the European level, is represented by the EU-funded PRIMA (Partnership for Research and Innovation in the Mediterranean Area) project CAMEL-SHIELD (Camel-breeding systems: actors in the sustainable economic development of the northern Sahara territories through innovative strategies for natural resource management and marketing) where biological samples from about 300 dromedaries from France, Spain, Cyprus, and The Netherlands, also in collaboration with Generatio GmbH®—Center for Animal Genetics in Heidelberg (Germany), have been collected, and will contribute (i) to better understanding genetic diversity and relationships among European dromedaries, (ii) to monitoring inbreeding phenomena, (iii) to giving support to breeders regarding genealogical information, and (iv) to checking for detectable interspecific hybridization with Bactrian camels.

Systematically extending the genotyping of the current dromedary population in Europe would be extremely beneficial, as it would allow for a routine validation of genealogical information, parentage inference in cases where multiple sires are used, the definition of mating plans based on the minimization of breeding animals' relationships to control for inbreeding-related problems, and DNA-based individual traceability and the trackability of live animals and their products, thus representing a valuable tool to support the establishment of breeding societies and breeding registers. Moreover, the enlargement of the mentioned initial population of SNP-array genotyped European dromedaries may contribute to establishing the first reference population for the genome-based genetic evaluation of breeding animals. To this aim, a major constraint is still represented by the lack of national or international initiatives and organizations responsible for the collection of phenotypic records for the main traits of interest in this species, as well as the lack of standardization in phenotype recording in camels. An attempt in this direction is represented by the integration of a small group of scientists with expertise on camels within the Sheep, Goats, and Camelids Working Group of The International Committee for Animal Recording (ICAR), but larger efforts are needed by the international scientific community and the involved stakeholders. Developing more effective reproduction management techniques for camels will be crucial to boosting genetic progress in species that present clear biological constraints (low reproduction efficiency) compared to other major livestock species.

Artificial insemination in domestic animals is an important tool to maximize the use of genetically superior males and ensure rapid genetic progress [68]. Moreover, it may minimize the transmission of venereal and zoonotic disease among animals and herds [69]. The application of AI in camelids has been hindered by a number of difficulties, mainly involved in collecting as well as handling semen [68]. Semen-processing methods should, therefore, be optimized, together with aspects related to animal welfare, nutrition, and the control of seasonality. Semen collection centers may play a significant role in addressing all the above aspects comprehensively [69]. Notably, improving protocols for the long-term storage (cryopreservation) of dromedary sperm may significantly contribute to attenuating the negative impacts on the genetic diversity of the European dromedary population, due to its fragmentation and the poor gene flow among distant farms. Indeed, frozen semen can more easily be transported within and between countries, thus possibly contributing to strengthening the genetic connectivity of European dromedary herds and limiting genetic erosion due to random drift phenomena in a highly fragmented population. This aligns with the concept of "One Conservation" [70], which highlights the value of reproductive

biotechnologies as essential tools for effective biodiversity conservation. This framework also underscores the need for coordinated efforts across various sectors, including public, private, third, and agricultural stakeholders, to address biodiversity loss and ensure the success of conservation initiatives.

Another critical aspect of genetic management that requires attention is the indiscriminate castration of male camels to manage their behavior for interactive experiences, such as those in tourism activities. While castration may be employed to reduce aggression and enhance trainability, its widespread application poses significant risks in terms of the further restriction of the already small male breeding population and consequent erosion of extant genetic variability, as it eliminates valuable breeding males from the gene pool. Consequently, this practice can hinder efforts to maintain genetic quality and adaptability within camel populations, ultimately compromising the long-term sustainability of camel management in Europe.

3.5. Camel Welfare

Another critical issue for modern camel breeding in Europe and other countries is the lack of welfare guidelines specific to camels [71,72]. Currently, the World Organization for Animal Health (OIE) offers only general guidelines for camels, mainly focusing on transportation and slaughter, indicating a significant gap in the welfare standards for camels compared to other animals [48,73]. Although Europe's high level of animal welfare awareness has led to the "automatic" transfer of measures commonly used for other livestock species to dromedaries, this approach has notable limitations. The unique behavioral and physiological needs of camels are often neglected, and practices tailored for ruminants such as cattle or sheep may not adequately address the specific requirements of camels, potentially leading to welfare compromises.

Given the growing consumer concern about animal welfare, there is a critical need for evidence-based guidelines tailored to the specific needs of camels in various rearing systems. Considering Europe's progress in setting better welfare standards for other livestock species, it is reasonable to expect increased emphasis on implementing welfare surveillance and promotion measures for camels in the near future. Although there are no welfare standards for camels due to the lack of sufficient empirical data to define them, some basic recommendations can still be cited to guide practices in this field. Welfare assessment requires a comprehensive approach that includes animal-, resource-, and management-based measures. Protocols like the AWIN have been adapted for camels to assess welfare at different levels, including caretaker, herd, and individual animals [74].

Effective camel welfare practices are essential for ensuring the health and productivity of camels, particularly in the context of their increasing use in intensive and semi-intensive systems. These practices encompass a range of management strategies and welfare assessment protocols that address the unique needs of camels. The most effective welfare practices focus on good feeding, housing, health, and behavior. Below are the key aspects of effective camel welfare practices:

A. 'Good Feeding' practices: Effective feeding practices are crucial for maintaining a healthy body condition score (BCS) and managing thirst (Thirst Index). Poor feeding and water management negatively impact these indices. At the caretaker level, feeding management involves ensuring feed availability, quality, and appropriate feeding behavior [74].
B. 'Good Housing' practices: Adequate space allowance and shaded areas are critical for camel welfare. Limited space and exposure to the sun can lead to stress and discomfort. In addition, maintaining clean bedding and water sources is essential to prevent diseases and promote comfort [75].

C. 'Good Health' practices: Effective health practices include the prevention and management of diseases, injuries, and pain. This involves regular health checks and the use of a camel composite pain scale for assessing discomfort [76]. Experienced caretakers are better equipped to manage health issues and ensure proper handling, which reduces the risk of injury and stress [77].
D. 'Appropriate Behavior': Assessing camel behavior, such as response to handling and social interactions, is important for identifying stressors and improving welfare. Limited space and poor management practices can lead to aggressive behavior and stereotypes [78]. Furthermore, providing a social environment that allows for natural behaviors is crucial, especially in intensive systems where camels may be more isolated [79].

While these practices are effective, challenges remain in implementing them across diverse camel-rearing systems. The transition from traditional extensive systems to more intensive ones presents unique welfare challenges, such as the need for more structured management and health practices. Developing comprehensive welfare standards and regulations is still in progress, requiring further research and collaboration among stakeholders [76]. For an in-depth exploration of camel welfare management, the book "Dromedary Camel Behavior and Welfare" offers valuable insights [72]. Additionally, the CAMELI-Dynamics methodology [80] provides a comprehensive framework for understanding the principles of handling and training camelids. The EU Reference Centre for Animal Welfare focusing on the welfare of ruminants and equines (as established by Commission Implementing Decision (EU) 2021/755), is well-placed to lead the necessary advancements for promoting and ensuring the welfare of domestic camels in Europe. Although the work program of this Centre primarily includes ruminants (such as cattle, sheep, goats, and deer) and equines (horses, donkeys, and their crossings), relatively recent developments have extended its activities to cover domestic camelids.

Reference Centres aim to enhance the enforcement of animal welfare legislation by supporting EU Member States in conducting official welfare controls. They provide technical and scientific assistance, conduct studies, develop methods to assess and improve animal welfare, and promote the dissemination of best practices. Additionally, they share research findings and offer training to competent authorities within the EU and experts from non-EU countries. Given their mandate, these Centres are well-positioned to lead efforts on camel welfare, thus fostering a sustainable future for camel farming in Europe and globally. Furthermore, these efforts could help resolve debates regarding the domestication status of camels, recently contested by the Dutch government [81].

4. Final Remarks

Camels in Europe have an attested long-standing niche presence in Europe since antiquity. They have undergone an evolution of census size and socio-economic and cultural perception over centuries. The recent renowned interest in camel farming in Europe faces several challenges, including the lack of specific regulatory frameworks and guidelines, the regulatory constraints in animal restocking from non-EU countries, the limited number of animals, and the fragmented and scattered geographical distribution of farmers in European countries, often pursuing different camel uses and attitudes, as well as the lack of breeding organizations, breeding registries, and genetic evaluation schemes, together with a number of challenges related to the low reproduction efficiency and poor reproduction management of these species. However, climate change and increasing desertification issues within Europe are likely to make camels' adaptive abilities to arid environments, as well as their peculiar behavioral features and their milk composition and functional properties, more and more appreciated. Camel farming in Europe, while

not expected to gain relevance comparable to the major livestock species in the next few decades, may still offer interesting opportunities for farm diversification and viability.

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