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Review

Survival rate of donkey foals: Status quo and improvement methods

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The industrial improvement of donkey-hide gelatin and the development of related products, such as donkey meat, donkey milk, and donkey-hide gelatin cake, drive the upstream donkey breeding industry. However, the shortage of donkey germplasm resources seriously restricts the further development of the donkey industry. Under the biological limitations of long breeding cycle, slow breeding, low conception rate, high abortion rate, and low survival rate, lower numbers of donkey foals have become an important limiting factor in the development of this industry. This paper clarifies the ways by which the survival rate of donkey foals can be improved from five aspects: Selection and breeding of female donkeys; physiological characteristics of donkey foals; key points of nursing; prevention and control of transportation stress; and control of common diseases. These aspects are important in enhancing the economic benefits of donkey farms and breeding farmers.

Key words: Female donkeys, donkey foals, feeding, survival rate, nursing.

INTRODUCTION

Donkey breeding has a long history in China; in the heyday of the donkey industry in the country, about 12 million domestic donkeys were in stock. However, the role of donkeys in agriculture has gradually decreased because of mechanization. By 2020, the population of donkeys in the country has drastically decreased to about 2.32 million. Moreover, the shortage of germplasm resources and degradation of donkey quality hinder the development of this industry in China (China Statistical Report, 2020). The donkey breeding industry in China is gradually transitioning from the family farming model to large-scale and integrated industrial operations, which can ensure uniform product quality and stable donkey population. However, theoretical research on donkey breeding and its technical development lag far behind that of other livestock, thereby limiting its industrial development. Various technologies applied in cattle husbandry, such as artificial insemination using frozen semen, are new in donkey breeding; these technologies are worthy of promotion and application in this field (Dai et al., 2011; Yao et al., 2018).

A previous study that focused on small-scale breeders in eastern Mongolian and western Liaoning revealed that the overall reproductive period of female donkeys is 7.3 years, the average litter production is 2.8, the age of first foaling is 45.3 months, the foaling rate is 80%, and the

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foaling interval is 500.5 days (Canisso et al., 2019; Fielding, 2005). Similar issues are experienced by large-scale donkey farms in Shandong and other areas (Deng et al., 2020). The high mortality rate of newborn donkey foals not only reduces the efficiency of donkey foal output but also requires breeders to increase the number of reserve females, thereby substantially increasing the costs and seriously affecting the economic efficiency of donkey breeding. The survival rate of foals can be improved by gaining knowledge of selection and breeding of female donkeys, understanding the physiological characteristics and key points of nursing newborn foals, taking precautions during transportation, and ensuring the prevention, treatment, and control of common diseases.

Selection and breeding of female donkeys

A female donkey reaches sexual maturity at 12 to 15 months of age. However, at this age female donkeys are not yet fully developed. Female donkeys should be mated at about the age of 2.5 years or it reaches 95% of adult body height and 70% of adult body weight as mating them too soon negatively affects their skeletal development. At this age, female donkeys are still relatively small. When they become pregnant, their fetus would be too large relative to their size. Thus, the risk of difficult delivery is high, and it will also affect their subsequent pregnancy and foaling (González et al., 2018).

Donkeys in temperate regions of China are seasonal estrus animals, with a gestation period of nearly a year. Spring (late March to early June) is the peak estrus season for donkeys and the season with the highest mating success rate (Henry et al., 1991). Despite the similar climate between spring and autumn, the distribution of donkey foal births is uneven throughout the year, and fertility peaks between March and May, during which 61.7% of the total births occur. By comparison, the percentage of births in September and October is only 1.8%, and very few foals are born in November and December. Donkeys in Shandong reproduce earlier because this region has a longer photoperiod than other areas (Deng et al., 2014). By contrast, female donkeys in northeast China, the mean age at first conception time was 33.3 months and gives birth to only a single donkey. Through selective breeding, female donkeys can maintain a relatively favorable foaling rate and foaling interval until they are 15 years old (Quaresma et al., 2014; Sprayson et al., 2008). The present review seeks to provide useful information published in the literature for the targeted training of smallholder farmers, which in turn will promote the nutritional and reproductive management of donkey populations. However, further research should explore sustainable breeding programs and examine changes in male donkey semen quality during the peak of breeding season (Allen and Wilsher, 2012).

Genetic selection for female donkeys

Multiple pregnancies are considered one of the main reasons of donkey abortion (González et al., 2018). Statistically, 72.6% of twin pregnant donkeys would experience abortion or give birth to a stillborn. Among the cases of abortion, 64.5% occurs from the third month of gestation to the time of parturition. In the remaining cases, twins are born alive. However, one of the foals is usually stunted or emaciated, a condition that prevents them from surviving for more than one month after birth (Jeffcott and Whitwell, 1973). For donkeys, the total mortality rate of newborn foals within the first month of life is close to 9%, whereas the conception rate of normal twins is only about 3%, which has a mortality rate of 40% (Quaresma et al., 2014). Thus, when a pregnancy test in equine animals performed about 16 to 20 days after artificial insemination reveals the conception of twin fetuses, one side of the fertile follicle can be artificially removed and only one can be retained (Pascoe et al., 1987). Therefore, breeding programs should progressively adopt new research methods, such as the use of genetic markers and genotyping. Moreover, breeding programs should combine the latest genetic advances with relatively stable traditional traits, such as embryo testing, to select individuals that are less prone to multiple ovulations and avoid the risk of multiple pregnancies. As new perspectives on donkey breeding and conservation, these measures serve as preventive selection tools for reducing the risks associated with pregnancy (Navas et al., 2019).

Warmblood fragile foal syndrome (WFFS), an autosomal recessive, single-gene defect, is characterized by hyperelasticity of the skin and joints, vascular lesions, and cardiac and ocular defects (Burrows, 1999). In horses, the incidence of difficult births in purebred foals with WFFS is 10% higher than that in normal and healthy foals (Ginther and Williams, 1996). It is caused by fetal malposition, and the incidence of fetal malposition at birth is higher in purebred fetuses with this disease. In most cases, the fetuses of mares with a pure WFFS mutation in the *PLOD1* gene survive the entire gestation period. The foals are usually born alive, but they do not survive long after birth (Monthoux et al., 2015). Abortion in the last months of gestation is not the main manifestation caused by the WFFS genotype. Nevertheless, abnormal fetal development in early gestation due to WFFS cannot be completely excluded as the majority of WFFS pure congeners abort before the end of gestation, indicating that the purity of the WFFS allele is always incompatible with life outside the uterus, that is, the purity of WFFS is the cause of abortion or stillbirth (Aurich et al., 2019). Skin lesions are detected in most, but not all, WFFS-pure positive foals, and the nature and extent of skin

abnormalities widely vary between foals with defects. Moreover, there are WFFS-pure positive foals with undetectable skin lesions. In the absence of skin abnormalities, the WFFS purebred condition is not considered a major factor in stillbirths. Therefore, warm-blooded stallions should be genotyped and marked for WFFS carrier status, and WFFS carrier mares should not be used as stallions in production; moreover, the presence of *PLOD1* gene mutations causing WFFS disorder in donkeys must be investigated further and confirmed (Aurich et al., 2019).

Feeding of female donkeys

Donkey milk is hailed as an elixir of immortality because of its nutritional, cosmetic, and therapeutic properties. Donkey milk has been recently used for infants whose mothers have insufficient or lacking breast milk, and for infants who are allergic to cow's milk proteins because donkey milk is the closest to breast milk in terms of lactose and protein content among all animal milks (Prasad, 2020; Swar, 2011). Donkeys have a higher digestive efficiency and a lower nutrient requirement than horses. The daily nutrient intake of nonpregnant females is 2.56 kg/316±29 kg (316±29 kg is the donkey's body weight), and late pregnant females have 31% lower nutrient intake including total amount of roughage and concentrate (1.76 kg/316±29 kg) compared to the non-pregnant (Burden, 2012), which is probably due to the lower abdominal space available for feeds because of the abdominal cavity occupied by the conceptus, membranes, and fluids. A gradual transition to a higher energy diet should be planned in the last phase of pregnancy, the transition lasted 8 days and consisted of a gradual increase in concentrate (+0.25 kg/day) (Pearson et al., 2006). Donkeys breed in temperate regions, where food is relatively abundant and of good quality. In these regions, obesity is a common disease. Thus, optimal feeding is essential to prevent this condition. During pregnancy, the forage food intake of female donkeys decreases, making them susceptible to hyperlipidemia. Hence, they should gradually shift from a normal diet to a high-energy diet in the later stages of pregnancy. Female donkeys that are pregnant over 11 months and in the prodromal period should be individually fed in separate pens. The original supplemental concentrate feed should be adjusted according to the body fat status of pregnant donkeys. The amount of feed can be appropriately reduced in the case of individuals with high body fat, whereas those with low body fat should be supplemented with an appropriate amount of nutritional concentrate feed (Martin-rosset, 2018; Salari et al., 2020).

Reproduction forecast for donkey foals

Early interventions that anticipate the birth period of a pregnant mare and preparation for foaling can be very effective in improving the physical condition of the mare and foal, especially to improve the survival rate of the foal (Amorim et al., 2019). The gestation period is longer in females that have never given birth than in females that have already produced foals (Ewert et al., 2018; Morel et al., 2002). Starting at 320 days of gestation, mammary secretions can be found on both teats of female donkeys. Mammary secretions (about 5 mL) can be collected every evening (6 pm to 9 pm) and then evaluated via calcium ion titration, calcium and magnesium strip (Ca and Mg) test, pH meter, pH strip (Amorim et al., 2019). The pH value determined by pH strips is not as accurate as that determined by a pH meter, but pH strips can be tested with only a few drops of mammary secretion (the foaling rate within 24 h is 78.5% when pH value of mammary secretion ≤7.0), making it clinically convenient. Calcium titration method is the most sensitive, but it requires large amounts of mammary secretions for accurate testing and has a certain error rate for unproductive mares. Therefore, the most recommended application is the combination of calcium titration (Ousey et al., 1989) and the use of a digital pH meter (Korosue et al., 2013). The ideal diagnostic test should be both sensitive and specific. Moreover, staffing levels, competence, and costs should be considered. This combination must be implemented to be able to obtain precise information on the time of birth and alert the attendant that the pregnant donkey should be closely monitored and prepared for birth (Dascanio, 2014).

PHYSIOLOGICAL CHARACTERISTICS AND BEHAVIOR OF DONKEY FOALS

Physiological characteristics of newborn donkey foals

The Apgar scoring system was designed by Virginia Apgar in 1952 to provide a method for assessing the condition of newborn infants at specific times after birth. This system can be used to better evaluate neonatal physical condition according to various criteria, such as skin color and appearance, pulse rate, reflex irritability, muscle tone, and respiration (Apgar, 1953). The Apgar scoring system has been introduced to veterinary medicine to assess the clinical condition of animals, such as foals, puppies, calves, and piglets, and compare them with human newborn babies to assess the survival of newborns (Knottenbelt et al., 2004; Madigan, 1997).

According to the modified Apgar scoring system, which are critical for the early detection of diseases in newborn foals (the scoring process can be completed within 5 min of foal birth), newborn foals with a score of 7/8 or 8/8 have a normal respiratory rate and body temperature, indicating that they are viable. By comparison, foals with a score of 6/8 have a lower than normal respiratory rate

and body temperature, suggesting that the low respiratory rate may be associated with respiratory abnormalities due to perinatal diseases, such as hypoxic-ischemic encephalopathy, immaturity/dysplasia, and sepsis (Bonelli et al., 2019; Madigan, 1997). Diseased donkey foals may show abnormally low respiratory rate and a substantial decrease in body temperature because of central nervous system damage or depression, and this condition may be associated with a decrease in metabolic demand. The modified Apgar scoring system has been proved a simple and effective method for assessing the viability of newborn donkey foals not only for hand feeding but also under field conditions. Nevertheless, the predictive value of the Apgar score for survival rates in the short term warrants further study (Giguère et al., 2008).

The normal heart rate, respiratory rate, and rectal body temperature of a newborn donkey foal ranges from 45 to 60 heartbeats/min, 11 to 20 min^{-1}, and 37.5 to 38.6°C, respectively. Both ears of a healthy foal turn naturally and flexibly, its eyes are energetic, its body moves are coordinated, and its back hair is fluffy and not dry. The normal first standing time after birth is 62.3±25.7 min, the first suckling time is 87.1±29.15 min, and the meconium is excreted on the day of birth.

Donkey foal behavior

The birth process and early developmental stages of all domestic mammals after parturition play a vital role in the adaptation of newborn donkey foals to life outside the womb. Like other hoofed animals, donkeys are precocious mammals because their motor and sensory systems rapidly develop after birth and the mother should provide active care for the precocious newborn foal to induce intense mutual stimulation. The mother's response is stimulated by complex movements, smells, and grunts provided by the foal, and the mother will use visual, tactile, and acoustic stimuli to induce and guide the foal's activity (Crowell-Davis, 1986). The mothers can spontaneously give birth without assistance, mostly between 10:00 p.m. and 4:00 a.m., and fetal and placental expulsion times are consistent with normal births. Foals are mostly mature, healthy, and vigorous. Furthermore, their Apgar score, weight, standing time, and first suckling time are all within the normal range. The most representative behaviors of female donkeys are "observation" and "sniffing", which account for 70% of all behaviors, and these are associated with "autogrooming" during the day and "excretion" at night (Carluccio et al., 2008, 2015; Panzani et al., 2012).

In precocious animals, the neonatal period is considered a stage of intense interaction between the mother and the infant, interactions between the mother and the foal are slightly greater at night than during the day, a finding that may reflect a behavior that has been preserved from a pre-evolutionary state (Barber and Crowell-Davis, 1994; French, 1998). In the wild, nighttime is very dangerous for newborn donkey foals, and interactions with their mothers help ensure their safety and keep them calm. After birth, maternal licking increases the neuro excitability of the foal and promotes rapid motor development. Jennies provides nutrition, thermoregulation, passive immune transfer, and protection, as well as appropriate stimulation, education, and socialization for the foal. In the special social structure of donkeys, the binary relationship represents the sole and fundamental social institution. The description of neonatal donkey dichotomous behavior provides useful information for behavioral studies of early "follower" species and provides first-hand information for future behavioral descriptions of donkeys (Mazzatenta et al., 2019).

Nursing of newborn donkey foal

In winter and early spring, special attention should be given to the warmth of newborn donkey foals. Straws should be used to ensure that the foals are well rested as their thermoregulatory center is not yet fully developed. The immunity of their body decreases in the cold environment, leading to diseases caused by pathogenic invasion. When a newborn donkey foal is separated from its mother, the umbilical cord must be disinfected well to prevent infection. The correct method for severing the umbilical cord (mostly via freehand umbilical cord severing) must be adopted. Freehand umbilical cord severing quickly dries up and is not easily infected. A 5% tincture of iodine should be used to disinfect the severed end of the umbilical cord to effectively avoid many associated diseases, such as umbilitis. The midwife should observe the condition of the donkey foal after birth. The concentration of serum immunoglobulin in newborn foals is substantially lower than at other times, and the midwife should allow the newborn foal to receive colostrum as soon as possible. If the foal does not excrete feces in time, then a veterinarian should be called in to assist the foal, either by rectal instillation of soap and water to lubricate the intestines or by directly injecting a clyster into the end of the rectum after birth (Wang et al., 2020; Zhang, 2020).

NEWBORN DONKEY FOALS

Importance of colostrum for donkey foals

Donkey colostrum is the first donkey milk produced by the mammary glands of the mother donkey. It has specific components that are essential for the foal. Compared with cow's milk, donkey colostrum has a higher concentration of immunoglobulin type G (IgG) and

antimicrobial and immunomodulatory factors, such as lactoferrin, lactoperoxidase, lysozyme, oligosaccharides, and fat (Li et al., 2019a, b). The majority of passive transfer of immunity (FPT) failure in donkey foals are due to feeding of foals with low quality colostrum, delayed lactation, or lack of IgG absorption. Colostrum can be rated as of excellent quality if the IgG concentration is higher than 80 mg/mL, good if the IgG concentration is between 50 and 80 mg/mL, fair if the IgG concentration is between 28 and 50 mg/mL, and poor when the IgG concentration is below 28 mg/mL (McCue, 2014). Healthy foals usually suckle colostrum from their dams within 2 to 3 h of birth. For foals that do not successfully feed on colostrum within 2 h of birth, feeders should squeeze out the colostrum and feed it to them. During the first 12 to 24 h of life, the small intestines of donkey foals are still permeable to macromolecules, including immunoglobulins, and approximately 50% of the ingested immunoglobulins is absorbed during the first 12 h of life. By comparison, between 12 and 18 h of life, only 28% of the ingested immunoglobulins is absorbed and enters the bloodstream. After 18 h of life, the absorption efficiency continues to decrease until 36 h after birth, at which point the intestines are no longer permeable (McKenzie, 2018). The degree of passive transfer of immunity to donkey foals can be adequately evaluated by quantifying serum IgG concentrations. The circulating transfer of immune IgG from colostrum to the donkey foal is considered adequate when the serum IgG concentration is greater than 8 mg/mL. A partial failure of colostrum immune transfer is considered when the IgG concentration is between 4 and 8 mg/mL. Finally, a complete failure of colostrum immune transfer is considered when the IgG concentration is less than 4 mg/mL (Hines, 2003). Colostrum has specific antimicrobial and anti-inflammatory properties that protect donkey foals from diseases and also help to maintain a good growth rate in the first months of life. Healthy foals are more likely to gain weight than those suffering from defects in immune passive transfer. Thus, colostrum quality and the degree of immune passive transfer must be evaluated (Turini et al., 2020).

Feeding of newborn donkey foals

Supplemental feeding is required one month after birth and must be done with appropriate concentrated feed and adjusted according to the foal's appetite, the amount of its mother's milk and its health. If the foal slowly eats, then it must be individually fed. For foals with a small body size, the number of times it is fed should be increased to make it grow healthy. In addition, attention should be paid to the amount of water the foal drinks, and a water trough can be placed in the feeding pen to prevent water shortage. For 1 to 2-month-old foals, careful management is required. If the number of foals exceeds 50, then they must be separated from the females and kept in separate pens with dedicated care to prevent other females from trampling and chewing on the foals (Salari et al., 2020).

A milkless foal is a donkey foal whose mother died after giving birth or was unable to nurse after giving birth due to insufficient milk. The best way to feed milkless foals is to find a substitute mother donkey or by giving a milk substitute, which is usually made from cow and goat milk. Donkey milk has a lower fat content than cow and goat milk. When supplementing a milkless foal, the upper fat layer should be removed and diluted with water at a ratio of 1:1. A little amount of sugar should be added to make it a nutritional product close to donkey milk. Avoid feeding pure milk, pure goat's milk, or unblended cow's and goat's milk as they can cause indigestion and dehydration in newborn donkey foals, even death in serious cases (Palo et al., 2018). As the foal grows up, it needs more nutrients. Mares lose a lot of nutrients due to lactation, which will have a certain impact on the health of both the mares and their foals. As the foal grows faster in the first year after weaning, the feed should contain 1/3 of concentrate feed, which should be gradually increased with age. The amount of concentrate feed added should reach the average level given to adult donkeys when the foals reach sexual maturity at the age of 1.5 to 2 years (Martin-Rosset, 2018). The amount of concentrate feed to give to male donkey foals must be increased by 15 to 20%, and the concentrate feed should contain 30% protein feed (Wang et al., 2020).

PREVENTION AND CONTROL OF STRESS IN DONKEY FOALS DURING TRANSPORTATION

Different regions in China have different levels of economic development, environmental conditions, and breeding habits. In the south of the Changjiang River, the temperatures and humidity are high in the summer. Thus, the stock of donkeys in this area is very small, but the consumption of donkey meat is large. By comparison, there are more donkeys in stock in the north and west of this area as forage is abundant. Hence, donkeys from the north are transported to the south and from the west to the east. Long-distance transportation of donkey foals for over 10 h increased mortality and morbidity by 1 to 3% and 10 to 15%, respectively (Zhao et al., 2020). Thus, the stimulation of pregnant females and foals must be reduced during long-distance transportation to reduce abortion rate of pregnant females and improve their survival rate of foals (Liu et al., 2016).

A study that examined postpartum mares and 5-day-old foals in a trailer during a 20 km road transport experiment indicated that cortisol concentrations in both mares and foals increased after transport, with a more pronounced and sustained increase in foals than in mares. Moreover, the heart rate of both mares and foals increased during transport, with a less pronounced increase in foals than in

mares. Heart rate variability (HRV) in mares was found to increase during transport. HRV increased in mares but remained unchanged in foals. In addition, both the deceleration and the acceleration of the vehicle during transport were found to cause transient changes in the heart rate of donkeys. The recommended loading density for equine loaded in groups is $y = (54.837) \times W^{0.325}$, where y = density in kg/m^2 and W = average animal weight in kilograms (Whiting, 1999). Overcrowding (According to Scientific Opinion Concerning the Welfare of Animals during Transport, space allowance for equine should be given in terms of kg/m^2 instead of m^2/animal) during transport can also negatively affect donkeys. Various factors during transport, such as violent driving, excessive transport time, provision of food and water, presence or lack of anti-skid equipment for the vehicle and the loading and unloading platform, fit of the platform to the edge of the vehicle, enclosure of the loading and unloading platform, and many other factors, can affect the abortion rate of female donkeys and the mortality rate of donkey foals (Melchert et al., 2020).

Transport stress syndrome refers to a syndrome in which the immunity of the organism is reduced by long-distance trafficking and various stressors. Biological factors, especially pathogens, take advantage of this situation to cause respiratory and digestive system diseases and even systemic pathological reactions. Given that donkeys have a strong tolerance, the disease is already at an advanced stage when symptoms are detected. Weight loss, morbidity, and mortality due to long-distance transportation can be reduced by adding a “nutrition soup” (mainly includes oral rehydration salt, electrolytic multivitamin, vitamin C soluble powder, glucose powder, and other ingredients) to the water and let donkeys drink it before and after transportation. This step was experimentally proved to improve the biochemical index, weight, morbidity, and mortality of donkeys (Liang et al., 2020).

The transport vehicle should be meticulously disinfected before and after transportation. The donkeys being transported in the same vehicle should come from the same farm to prevent spread of diseases. During transportation, the route should be flat as much as possible. Sharp braking or sudden acceleration must be avoided during driving. The front part of the donkey’s body has a stronger weight-bearing capacity than the back part. The head of the donkey at standing direction should be oriented backward to maintain good body balance. Temperature also has a great impact on donkey foals during transport. Large differences in temperature result in greater weight loss in donkeys. Thus, donkeys should be transported at the right temperature (In the summer, transportation should take place during the cooler hours of the day or at night; while in the winter, transportation should occur during the warmer hours of the day such as midday) as much as possible to reduce morbidity (Schmidt et al., 2010; Tadich et al., 2015).

PREVENTION AND CONTROL OF COMMON DISEASES FOR DONKEY FOALS

Vaccination and deworming in donkey foals

Vaccinations are a safe and reliable method of stimulating the immune system, the system that will help your donkey fight infection and disease. They may not always prevent diseases, but they can help to significantly reduce the symptoms. We recommend that donkeys are vaccinated against Equine Influenza (Flu) and Tetanus (Cullinane and Newton, 2013; Mumford et al., 1994). However, due to the high price of equine influenza and tetanus vaccines, few donkey farms in China receive equine influenza vaccination at present. A primary course of injections must be given. These are then followed by booster vaccinations that keep the vaccinations topped up. The intervals between the injections of the primary course and boosters vary according to the type of vaccine and the disease that they protect against according to the vaccine used and the risk of disease initial course of vaccination and frequency of boosters are different (Archer et al., 2021).

Worms live in donkey’s body, draining their nutrients and sometimes causing damage to the various organs that they can be found in. Donkeys that are heavily affected by worms can fail to gain or maintain weight and may be in poor condition. However, even without these signs it is important to follow a worm control program (Matthews and Burden, 2013). Donkeys are affected by strongyles (Roundworm) and tapeworm, just like horses, but there are two other significant parasites: Lungworm and Fluke. A ‘zero tolerance’ approach should be taken to Lungworm as once established eradication can be a lengthy process (Dixon et al., 1995); donkeys grazing wet, marshy paddocks are at risk of liver fluke (Villa-Mancera and Reynoso-Palomar, 2020), and may be at particular risk if grazed with other infected livestock (e.g. sheep or cattle). As a useful method to prevent and control parasites, faecal worm egg count test (FWEC) records the number and type of worm eggs seen in a sample of your donkey’s dung. The count indicates whether your donkey is shedding a high (over 200 eggs per gram (EPG)) number of eggs in its dung (Lester and Matthews, 2014).

Enterococcus in donkey foals

Enterococcus species are a group of Gram-positive diplococcus bacteria that are emerging pathogens for sepsis in humans and animals. Over the past three decades, the prevalence of *Enterococcus* as an emerging pathogen causing sepsis in donkey foals has increased, with *E. faecalis* and *E. faecium* being the most common enterococci (Adams et al., 2016; Theelen et al., 2014). A comparative study of donkey foals with sepsis caused by

other bacterial diseases revealed that foals are more likely to be infected with *Enterococcus* through the digestive tract and umbilicus and urinary tract, similar to human infections. Enterococcal isolates are multidrug resistant and foals have a low survival rate after infection. The mortality rate for donkey foals that tested positive for enterococci is 52.1%, well outside the range of medically reported mortality rates for humans (23-50%) but slightly lower compared with that for human newborns, which have a 61% mortality rate for enterococci positivity (Billington et al., 2014; Lopes et al., 2005). Veterinarians should be aware of the relationship between enterococcal infections and umbilical infections as early as possible. Moreover, they should recognize the potential for multidrug resistance among these isolates, and they should help donkey foals choose antimicrobial drugs or specific phage preparation at an early stage. This measure emphasizes the necessity and importance of targeted use of antimicrobial drugs. The findings of previous studies supported the use of ampicillin as the initial clinical antimicrobial choice for enterococci, but chloramphenicol is a better choice when culturing enterococci in the laboratory (Willis et al., 2019).

Pneumonia in donkey foals

Respiratory disease is a major cause of mortality in donkey foals. *Rhodococcus hoagii* and *Prescotella equi* are Gram-positive parthenogenic intracellular microorganisms that cause pneumonia in foals between 1 and 6 months of age (Giguère, 2017; Giguère et al., 2011; Huber et al., 2018). Distinguishing pneumonia caused by *E. equi* from other pathogens is difficult because their external manifestations are very similar (Giguère et al., 2011). Diagnostic accuracy in the early stages of infection is critical because donkey foals tend to respond poorly to the antibiotics commonly used to treat other types of bacterial pneumonia; moreover, the use of appropriate antimicrobial agents can substantially improve the success of treating equine erythrococcal infections (Attili et al., 2006). Bacteriological culture or amplification of the Vap A gene from tracheobronchial aspirates (TBA) by PCR is a reliable method for establishing the diagnosis of equine erythrococcal pneumonia. However, TBA was abandoned by veterinarians because of the invasive nature of the technique, the disapproval of farm owners, and the costs and risks associated with the procedure. Moreover, bacterial cultures take up to 72 h to yield accurate identification results (Cohen, 2014). Bronchoalveolar lavage (BALF) is commonly used as a diagnostic test for equine respiratory diseases to diagnose noninfectious inflammatory diseases in mature horses, such as equine asthma and exercise pulmonary hemorrhage, as well as to treat pneumonia in donkey foals. Compared with TBA, the BALF method is simpler, can be performed without endoscopic guidance, less invasive, and more acceptable to farm owner. Furthermore, the analysis of BALF cellular components is instantaneous and does not require a specific laboratory. By examining the cells in the bronchoalveolar lavage fluid of donkey foals with pneumonia caused by other bacteria, possible differences can be identified and detected to help veterinarians in clinical settings to achieve an early diagnosis (Cowell and Tyler, 2002; Hostetter et al., 2017; Vitale et al., 2019).

Donkey foals born in winter and spring have an extremely high risk of pneumonia. Owing to the cold weather and the lack of vitamins in the mare's feed, the foals are negatively affected, resulting in poor resistance and a weaker constitution. The incidence is also substantially higher during sudden changes in weather. A sick donkey foal will show various symptoms, such as mental depression, runny nose, shortness of breath, and elevated body temperature. Therefore, female donkeys should be fed more vitamins and mineral-rich feed during pregnancy. Moreover, the donkeys must be kept warm in winter and spring by keeping the barn warm and dry. The staff of the farm should carefully observe the donkey foals for any abnormalities. For sick foals an immediate diagnosis should be made and treatment implemented early. Donkey foals during the treatment period should be well taken into care to ensure sufficient nutritional intake for recovery.

CONCLUSION

The survival rate of donkey foals has been gradually increasing because of the progress made in research and epidemic prevention measures. This literature review elaborated on the measures to improve the survival rate of donkey foals from five aspects: selection and breeding of female donkeys, physiological characteristics of donkey foals, key points of nursing donkey foals, prevention and control of stress of donkey foals during transportation, and prevention and control of common diseases of donkey foals. These aspects may help the donkey breeding industry in China to gradually transition from a one-family scattered breeding model to a large-scale and intensive operation. The development of new technologies and the adoption of scientifically effective measures to improve the survival rate of donkey foals can reduce breeding costs and improve the economic benefits of farm households.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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