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PERINATAL LAMB MORTALITY DISTRIBUTION WORLDWIDE AND CAUSES: REVIEW ARTICLE

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ABSTRACT

Perinatal lamb mortality constitutes an important sanitary problem affecting sheep-farm productivity and profitability. The perinatal period is the most critical period in which mortalities can occur during the prenatal period (embryonic and fetal), the day of birth, and the postnatal period (early, intermediate, and late). The risk factors that are associated with these mortalities are related to the ewe (age, body score condition, mothering behavior, and colostrum quality), to the lamb (age, weight, sex, behavior, and body temperature at birth), and to the environment (hygiene of the livestock, climate, lambing in sheepfold or outside and the breeding system) affecting the lambs' survival and thermoregulation capacities. The global distribution of perinatal mortality varied over the years with different rates: in Africa, the reported rates were as follows: in Algeria (5, 8% - 17, 2%), in Morocco (14, 35%- 25, 09%), and in Ethiopia (46.3%-51.5%), On the other hand in Europe: the noted rates were of 16 % in France, (7% -10%) in United Kingdom and (25,8%) in Scotland. Moreover, in America, the rates varied from one country to another: in the United States of America (8, 2% - 17%) and Canada (14%). In Asia, the recorded rates were (17.6%- 31.3%) in India and (1, 86% - 27, 8%) in Pakistan. Also in Australia (15%-35, 8%). The causes of these lamb losses are infectious, such as pneumonia, gastrointestinal affections, septicemia, parasitism, and abortions, incriminating numerous pathogens, and non-infectious, such as starvation, dystocia, stillbirths, birth injuries, and weakness.

Keywords: Infectious, Lamb, Non-infectious, Perinatal mortality, Risk factors.

INTRODUCTION

Sheep farming industries are very promising suppliers of red meat due to sheep's capacity to adapt to the natural climate. Currently, China, Australia, and India are the highest inputs. This makes flock productivity a fundamental parameter that should be tracked to improve the industry's profitability (Cutress, 2020). This productivity can be impacted by many factors, such as high lamb mortalities during the perinatal period, causing important wastage, and affecting animals' welfare (Dwyer *et al.*, 2016). It was reported that 50% of pre-weaning deaths are recorded during the day of birth (Nowak *et al*., 2000).

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Perinatal lamb mortality is a significant indicator of sheep-farm productivity, affecting lambs' annual yield. The occurrence of these mortalities is frequently related to various risk factors, mainly the breeding system and the hygiene of the farms, the ewes (body score condition, maternal behavior, age, parity, and colostrum quality), and the lambs (sex, age, weight, behavior, and body temperature at birth) (Gautier and Corbiere, 2011) in addition to many infectious and non-infectious causes such as pneumonia, septicemia, omphalitis, diarrhea and dystocia, hypothermia-inanition syndrome, accidents, injuries or predation (Brugère-Picoux, 2004; 2016).

Through the decades, sheep-breeding countries, such as New Zeeland and Australia (Bruce *et al.*, 2021; Jordan and Le Feuvre, 1989), Egypt (Rania *et al.*, 2021; El-Kattan *et al.*, 2018; Wassif *et al.*, 2015), Algeria (Dahmani *et al.,* 2019; Abdelhadi *et al.*, 2010), Nigeria (Ugochukwu *et al.,* 2017) France (Gautier and Corbiere, 2011., Gautier *et al.,* 2012; Prud'Hon *et al.*,1968), United Kingdom (Binns *et al.*, 2002) ….etc conducted numerous studies on these perinatal mortalities to determine their rate, associated risk factors, causes (infectious or non-infectious), and the most touched age categories and tracts (respiratory, gastrointestinal, vascular ….etc.).

This review aims to classify these perinatal lamb mortalities according to their occurrence period, risk factors associated with each period, their rates, and causes in several countries to provide a complete portrait of them worldwide.

Classification of perinatal mortalities according to their occurrence period

The perinatal period is the time just before, at, and soon after birth (Mellor and Hodgson 2007), and the neonatal period is the period after birth until the weaning of the lamb (Fragkou *et al.*, 2010). Through the years, many classifications have been used. Prud'Hon *et al.* (1986) applied a categorization with four periods, starting from the day of birth until weaning. On the other hand, in 2011, Gautier and Corbiere used a sectioning with three periods (prenatal mortality, stillbirth, and postnatal mortality) that included the perinatal period from the early embryonic life to the weaning period (Figure 1).

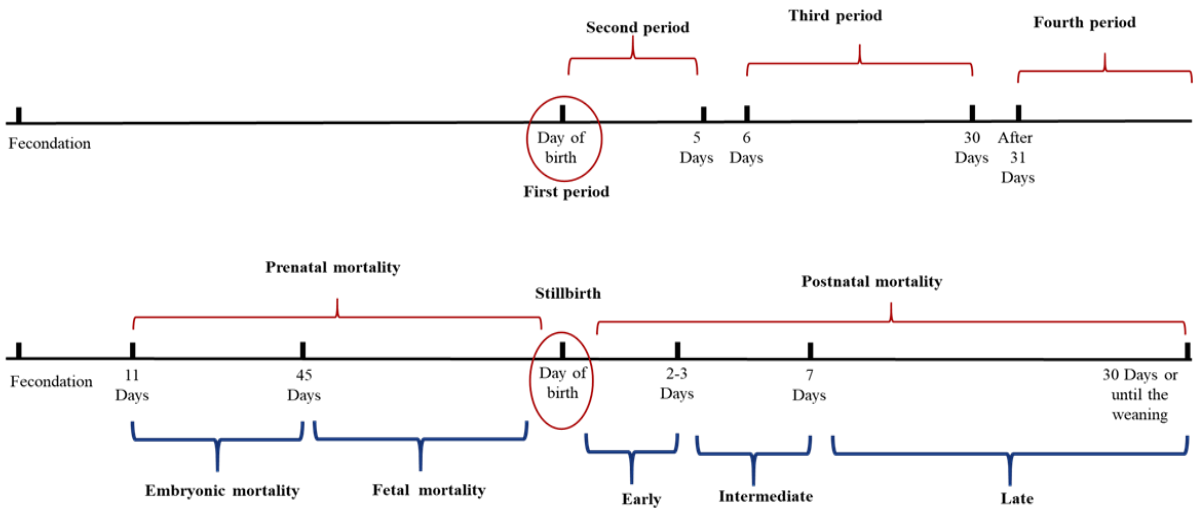

Figure 1: Classifications of perinatal mortality according to their occurrence period.

From these classifications, we see that lambs can die before birth, during the embryonic or fetal period, during the birth, and after the birth until weaning. The postnatal period is also known as the neonatal or pre-weaning period and constitutes the most important period in the lamb's life (Fragkou *et al.*, 2010).

Risk factors associated with perinatal mortality

Many risk factors can be associated with perinatal mortalities, which are related to:

- The ewe (age, body score condition, mothering behavior, and colostrum quality) mainly affects the survival capacity of the lambs during their first days of life (Southey *et al.*, 2001; Swalha *et al.*, 2007) during both embryonic, fetal periods and after birth.
- The lamb (age, weight, sex, behavior, and body temperature at birth) strongly correlated with their thermoregulation capacity (Dwyer and Morgan, 2006).
- The environment (hygiene of the livestock, climate, lambing in sheepfold or outside, and the breeding system) principally exposes the newborns to various pathogens (Gautier and Corbiere, 2011).

These risk factors have strong correlations; the environmental risk factors affect both ewes and lambs, and risk factors related to the ewe can affect the ones related to the lambs. For example, the body score condition of the ewe is crucial, especially during the last months of gestation, this factor is strongly associated with the breeding system (quantity and quality of the food given to the ewes) and can affect the weight of the lambs that determines the thermoregulation of the lamb and condition its survival during its first days of life, this example demonstrates perfectly the multifactorial character of perinatal mortalities.

In addition, risk factors can affect the lambs during several periods (embryonic, fetal, and neonatal). In embryonic and fetal periods, losses implicate several factors, mainly genetic, physiological, endocrine, and environmental (Diskin *et al.*, 2008).

Mukasa-Mugerwa *et al*. (1994) showed that in Ethiopian Menz sheep, the ewes feed supplementation in the third trimester helped to produce heavier lambs, increasing their survival and reducing the risk of death to less than 10%. Besides, the dam nutrition demonstrated that ewes that gained weight during their pregnancy had a heavier placenta with a higher number of placentomes than those that maintained or lost weight emphasizing the role of the body score condition and the importance of a balanced and well-done supplementation on the embryonic and fetal survival in ewes.

Dixon et al. (2007) reported that the breed type (black-faced ewes had greater embryonic and fetal losses than mottled-faced and white-faced ones) and concentration of progesterone, estradiol, and vascular endothelial growth factor (VEGF) were the main risk factors associated with the embryo and fetal losses. Variations in the concentration rates (high, medium, and low) of estradiol, progesterone, and VEGF are associated with partial or complete losses in the embryonic, fetal periods, or both periods (Table 1).

In 2013, Shorten *et al.* estimated that the ewe weight has a notable effect on embryo survival and that the optimal ewe weight for its survival increases with the ovulation rate. Additionally, the results of maternal heritability were significant, indicating that the ability of ewes to maintain a pregnancy has a superior effect than the embryo survival ability. This means that the maternal factor is more determining than the embryonic factor in the genetics of embryo survival. Other studies established that in some breeds, embryo survival is more notable in adult ewes than in ewe lambs. In these embryo transfer-employing studies, impaired embryo survival in ewe lambs was attributed to the inherent quality of the embryo rather than any deficiency of the uterine environment. (Diskin *et al*. 2008).

In the neonatal period, Southey *et al.* (2001) estimated that the sex of the lambs, litter

size, and the dam age affected mortality rates, indicating that male lambs had 23% greater hazard of mortality than female lambs and multiple lambs had a superior hazard than single-born lambs. Moreover, the mortality rate decreases with the dam age (younger ewes have higher mortality rates than older ones). Dwyer *et al.* (2006) concluded that lamb's survival is strongly related to their birth weight and behavior, heavy lambs were more active than lighter ones, they had better abilities to maintain their body temperature and a higher plasma concentration of thyroid hormones (T3, T4), suggesting a better heat generation, which decreases the risk of mortality. Mandal *et al.* (2007) also pointed out that improving the birth weights of lambs and ewes increases the survival rate of lambs in the postnatal period. Mustafa *et al.* (2014) revealed that the breed, the year, and the season of birth had a considerable effect on mortality rates due to a lack of care, nourishment, and milk feeding.

Table 1: Association between steroids (progesterone, estradiol-17β) and VEGF (vascular endothelial growth factor) concentration rates and the embryonic and fetal mortalities.

Steroids and VEGF	Concentration rate	Type of losses
Progesterone	Low	Complete embryonic and fetal losses.
	Medium	Complete and partial embryonic and fetal losses.
	High	Partial embryonic losses.
Estradiol-17β	Low	Complete and partial fetal losses.
	High	Partial embryonic losses.
Vascular endothelial growth factor (VEGF)	Low	Partial embryonic and fetal losses.
	Medium	Partial fetal losses.
	High	Partial embryonic and fetal losses.

Perinatal mortality rates worldwide

The distribution worldwide of perinatal mortality rate studies varied from country to country (Figure 2).

In Africa, lamb mortality has increased from 4, 35% to 25, 09% in Algeria (Abdelhadi *et al.*, 2010; Douh *et al*., 2018; Gani and Niar, 2021) and from 17.6% to 31.3% in Morocco (Chaarani *et al.*, 1991), and above that in Ethiopia (46.3%-51.5%) (Bekele *et al.,* 1992).

In the United States of America, the mortality rate goes up by 8,2% to 17 % (Huffman *et al.*, 1985; Rook *et al.*, 1990; Rowland *et al.*, 1992; Nash *et al.*, 1997; Kott *et al.*, 1998; Southey *et al.,* 2001). In Australia, mortality rates vary from 15% to 35,8% (Dennis *et al.*, 1974; Fowler, 2007; Geenty *et al.*, 2014; Kopp *et al.*, 2020; Clune *et al.,* 2021a). Also, in Canada and Scotland, studies showed that the rate varies from 14% to 25,8% (Johnston *et al.*, 1980; Wiener *et al.*, 1983; Bélanger *et al.*, 2001; Girard et Arsenault, 2003). In India and Pakistan, the rate was lower, between (1, 86%- 27, 8%) and (5, 8% - 17, 2%) respectively (Mandal *et al.*, 2007; Rastogi, 2001; Swarnkar *et al.*, 2021; Mustafa *et al.*, 2014). The recorded mortality rates in France and the United Kingdom were from 16 % to 18, 4% (Gautier and Corbiere, 2011; Lepeltier, 2010) and 7%- 10% respectively. (Green and Morgane, 1993; Binns *et al.*, 2002) (Table 2).

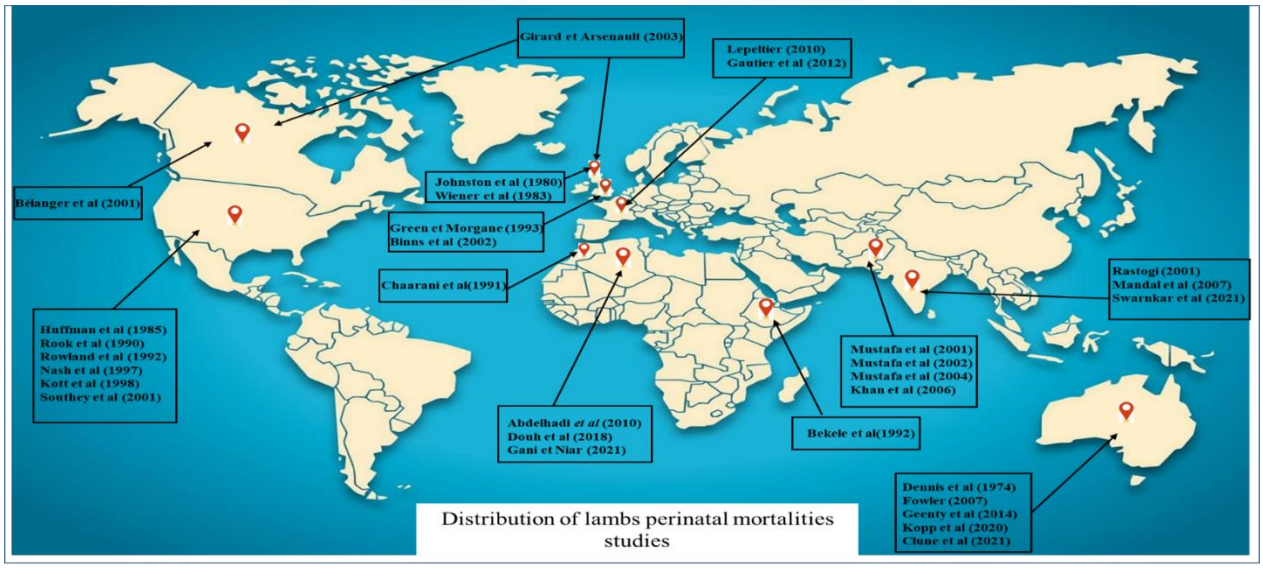

Figure 2: Distribution of perinatal lamb mortality worldwide.

Table 2: Recorded perinatal mortality rates by countries.

Authors	Years of study	Mortality rate	Country
Huffman *et al.* (1985)	1979	14.3%	**United states of America**
Rook *et al.* (1990)	1986-1988	15%-20%	
Rowland *et al.* (1992)	1984	8.2 to 12.2%	
Nash *et al.* (1997)	1986-1991	15.5%	
Kott *et al.* (1998)	1994-1996	17%	
Southey *et al.* (2001)	1983-1999	15.2%	
Dennis *et al.* (1974)	1963-1965	22.8%	**Australia**
Fowler (2007)	2006-2007	31.5%	
Geenty *et al.* (2014)	2007-2011	15%-22%	
Kopp *et al.* (2020)	2019	20-25%	
Clune *et al.* (2021)	2018-2022	35.8%	
Bélanger *et al.* (2001)	1999-2001	15.8%	**Canada**
Girard et Arsenault (2003)	2003	14%	**Scotland and Canada**
Johnston *et al.* (1980)	1978-1980	14.2%	**Scotland**
Wiener *et al.* (1983)	1966-1971	25.8%	
Green et Morgane (1993)	1989-1991	9.7%	**United kingdom**
Binns *et al.* (2002)	1997	7%-10%	
Lepeltier (2010)	2010	18.4	**France**
Gautier *et al.* (2012)	2010-2011	16%	
Mustafa *et al.* (2001)	2001	17.2%	**Pakistan**
Mustafa *et al.* (2002)	2002	16.6%	
Mustafa *et al.* (2004)	2004	5.8%	
Khan *et al.* (2006)	1998–1999	9%- 12%	
Rastogi (2001)	1982-1985	8.8 %-27.8%	**India**
Mandal *et al.* (2007)	1978-2002	6.6%	
Swarnkar *et al.* (2021)	2021	1.86%- 5.12%	
Abdelhadi *et al.* (2010)	2004-2006	25,09%	**Algeria**
Douh *et al.* (2018)	2015-2016	24±6%	
Gani et Niar (2021)	2020	14.35%	
Chaarani *et al.* (1991)	1984–1986	17.6%- 31.3%	**Morocco**
Bekele *et al.* (1992)	1989-1990	46.3%-51.5%	**Ethiopia**

Perinatal lamb mortality causes worldwide

Perinatal mortalities can be attributed to many causes classified according to the aetiology into two categories (infectious, non-infectious). The infectious causes are due to several agents, such as bacteria, viruses, parasites, and fungi, causing lesions in numerous tracts (respiratory, digestive, vascular, etc.), which cause abortion, pneumonia, septicemia, diarrhoea, and omphalitis. Non-infectious causes are mainly due to dystocia, injuries, hypothermia, starvation syndrome, predation...etc. (Brugère-Picoux, 2016; 2004; Gautier and Corbiere, 2011; Henderson, 2007).

Rook *et al.* (1990) reported that lamb loss is frequently due to abortion, hypothermia, starvation, exposure, pneumonia, stillbirths, and dystocia, which represents 50% to 75% of all documented perinatal losses. In several countries (the United Kingdom, New Zealand, Australia, Ethiopia, and India), studies on abortion show that

In Australia and New Zealand, studies from 1970 to 2022 concluded that the leading causes of lamb losses were non-infectious, including dystocia, starvation-mismothering, stillbirth, trauma, cold exposure, and predation in addition to congenital abnormalities, death in utero-prematurity and the implication of infectious agents (*Corynebacterium spp,* Unidentified fungus, *Escherichia coli, Spherophorus necrophorus, Pasteurella hemolytica, Pasteurella multocida*) (Dennis *et al.*, 1970; 1974; Jordan and Le Feuvre, 1989; Refshauge *et al.*, 2015; Ridler *et al.*, 2022). In 2021, Bruce *et al.* used a classification of death due to dystocia based on the lamb necropsy (McFarlane, 1965; Holst, 2004) as follows:

• A born dead lamb (Subcutaneous oedema around the head and neck) due to fetal-pelvic disproportion or bad presentation (Dystocia A).

bacterial agents such as *Chlamydophila spp, Coxiella burnetti, Toxoplasma gondii*, and *Brucella melitensis* cause premature birth, low-weight lambs, late abortion, fetal resorption, infertility, and stillbirths (Green and Morgane, 1993; Renukaradhya *et al.*, 2002; Verma *et al.*, 2017; Gebretensay *et al.*, 2019; Clune *et al.*, 2021a, 2021b). In France, besides the previous pathogens, *Salmonella abortusovis* was responsible for an increase in abortion, mainly during the last six weeks of gestation or fatal septicemia in newborns (Gautier and Corbiere, 2011). In North America, *Campylobacter spp.* is the most important cause of sporadic or recurrent abortion, stillbirths, or the birth of weak lambs (Menzies, 2007; Mobini *et al.*, 2002). Meanwhile, viral agents such as the blue tongue virus and akabane virus cause abortion, fetal mummification, or congenital deformities (Givens and Marley, 2008). The major challenge confronting veterinarians in these cases is the availability of the placenta to perform etiological diagnosis (Clune *et al.*, 2021a).

• Stillborn lambs with significant lesion scores or could have breathed and walked without metabolizing perirenal or pericardial fat (Dystocia B) (Refshauge *et al.*, 2015).

• Dead lambs, due to birth injury, breathed and metabolized perirenal and pericardial fat reserves (Dystocia C).

These lambs died at any time up to 5 days after their birth. In some cases, there is milk ingestion, but the significant lesion score defines this death category (Holst *et al.*, 2002; Refshauge *et al.*, 2015). This classification offers a subcategorization of the dystocia into proper dystocia (fetus presentation problems), stillbirths, and birth injuries and is wildly used (Behrendt *et al.*, 2019; Lockwood *et al.,* 2019a, b; Kerslake *et al.*, 2005).

In Canada, lamb losses were attributed to birth injuries, lack of adaptation to postnatal life, thermoregulation, weakness, mis-

mothering, infections like pneumonia (*Pasteurella spp*) and diarrhoea (*Escherichia coli*), functional disorders, and predation (Dohoo *et al.*, 1985; Dwyer, 2008). In Perou, Ameghino *et al.* (1984) demonstrated that starvation and infections (Pneumonia, Enterotoxaemia, and septicemia), accidents, predation, stillbirths, and congenital malformations induce lamb mortalities (Ameghino *et al.*, 1984).

In the United States of America and Morocco, the leading cause of lamb death is starvation, followed by infections (Colisepticemia, enterotoxaemia, Pasteurellosis, peritonitis, and salmonellosis) (Huffman *et al.*, 1985), pneumonia, trauma, and gastrointestinal problems (Yapi *et al.*, 1990), dystocia, stillbirth, and infections (Enteritis, in utero infection, pneumonia) (Rowland *et al.*, 1992) and infections (enteritis, septicemia, and pneumonia) in Morocco (Chaarani *et al.*, 1991). Thus, mortalities in Turkey are due to premature birth, birth stress, trauma, trichobezoar, starvation, septicemia, omphalitis, clostridial infection, and white muscular disease (Gökçe and Erdoğan, 2009).

In Norway, India, Pakistan, Brazil, and Ethiopia, infections are the most significant cause of mortality in the perinatal period, classified as follows:
Pneumonia (bacterial and verminous), gastrointestinal affections (enteritis, abomasal impaction, and parasitism), septicemia, toxemia, pleurisy, worm infection, white scour, tympany, heat stroke, starvation, trauma, severe congenital malformations, accidents, and mismothering with various distributions (Swarnkar et Sonawane, 2024; Holmøy *et al.*, 2017; Mustafa *et al.*, 2014; Mandal *et al.,* 2007; Nóbrega *et al.*, 2005; Bekele *et al.*, 1992).

In Algeria, studies demonstrated a significant prevalence of dystocia due to bad presentations, cervical problems (atony, a lack of dilation, and cervical atresia), uterine torsion, and neonatal diarrhoea implicating *Cryptosporidium parvum*, *Escherichia coli* K99, rotavirus, and coronavirus (Dahmani *et al.*, 2019; 2020). On the other hand, French farmers reported problems of dystocia, drowned lambs, weak lambs at birth and enterotoxaemia, watery mouth disease (*Escherichia coli*), diarrhoea mainly caused by *Escherichia coli, Salmonella spp* and *Cryptosporidium parvum* and respiratory tract disease caused by *Mannheimia haemolytica, Pasteurella multocida* and *Mycoplasma ovipneumoniae* ….ect. However, omphalitis can cause septicemia, permitting pathogens penetration (staphylococci, streptococci, *Actinomyces pyogenes, Escherichia coli*) via the umbilical cord (Gautier and Corbiere*,* 2011; Gautier *et al.,* 2012). Furthermore, in Spain, the principal cause of high mortality rates is neonatal diarrhoea attributed to various infectious agents (*Escherichia coli* and *Cryptosporidium spp*) (Munoz *et al.*, 1996; Andres *et al*., 2007).

CONCLUSION

This review concludes that perinatal lamb mortality is a multifactorial entity that depends on the breeding system and management, as well as the ewes and the lambs. The associated risk factors and rates are widely spread worldwide and have various origins (infectious, non-infectious), implicating numerous pathogens (bacteria, viruses, fungi, and parasites) affecting lambs during the embryonic and fetal period or the neonatal period, which makes investigations quite relevant to describe the epidemiological status of the sheep farms, estimate these mortality rates and determine their causes.

To avoid dystocia and birth injuries, it is imperative to establish adequate management strategies such as assisted lambing, ensuring expulsion of the placenta, and providing appropriate care to mothers during their gestation (food supplementation during the third trimester)

and to newborn lambs in the first days of their life (standing, sucking the udder, taking colostrum, etc.) and the hygiene of floors and livestock buildings (disinfecting lambing pens, lamb nurseries, etc.). These practices help to minimize the risk of exposure to pathogens that can cause several diseases, affect the survival capacities of lambs, and increase both mortality and morbidity rates. Furthermore, their application can limit the impact of these perinatal mortalities on sheep production and the industry's profitability, especially in sheep farming countries.

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توزيع وفيات الحملان في الفترة المحيطة بالولادة حول العالم وأسبابها: مقال مراجعة

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تشكل وفيات الحملان في الفترة المحيطة بالولادة مشكلة صحية هامة تؤثر على إنتاجية وربحية مزارع الأغنام لأن هذه الفترة تشكل الفترة الأكثر حرجًا التي يمكن أن تحدث فيها الوفيات خلال الفترة السابقة للولادة (خلال الفترات الجنينية) و يوم الولادة وفترة ما بعد الولادة (المبكرة، المتوسطة، والمتأخرة). عوامل الخطر المرتبطة بهذه الوفيات تتعلق بالنعجة (العمر، الحالة الجسمية، سلوك الأم، وجودة اللبأ)، وبالخروف (العمر، الوزن، الجنس، السلوك، ودرجة حرارة الجسم عند الولادة)، وبالبيئة (نظافة الماشية، المناخ، الولادة في الحظيرة أو خارجها ونظام التربية) التي تؤثر على بقاء بقاء الحملان على قيد الحياة وقدراتها على تنظيم و الحفاظ على درجة حرارة جسمها. سجل توزيع معدل وفيات الحملان في الفترة المحيطة بالولادة حول العالم نسب متفاوتة على مر السنين بمعدلات مختلفة: في أفريقيا، كانت المعدلات المبلغ عنها كما يلي: في الجزائر (5.8% - 17.2%)، في المغرب وفي إثيوبيا (46.3% - 51.5%)، من ناحية أخرى، في أوروبا: كانت المعدلات المسجلة ،(14.35% - 25.09%) في فرنسا، (7% - 10%) في المملكة المتحدة و(25.8%) في اسكتلندا. علاوة على ذلك، في أمريكا، تفاوتت 16% المعدلات من بلد إلى آخر: في الولايات المتحدة الأمريكية (8.2% - 17%) وكندا (14%). في آسيا، كانت المعدلات المسجلة (17.6% - 31.3%) في الهند و(1.86% - 27.8%) في باكستان. أيضًا في أستراليا (15% -35, 8%). أسباب هذه الخسائر في الحملان هي أسباب معدية، مثل الالتهاب الرئوي، والاضطرابات المعوية، والتسمم الدموي، والطفيليات، والإجهاضات، التي تتهم العديد من العوامل الممرضة، وأسباب غير معدية، مثل الجوع، وصعوبة الولادة، والموت عند الولادة، وإصابات الولادة، والضعف

الكلمات المفتاحية: حمل، عوامل الخطر، غير معدي، معدي، وفيات الحملان في الفترة المحيطة بالولادة