Cold Stress in Lambs

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Cold stress in the newly born lamb can be a major concern in the sheep industry. When the lamb is born it goes quickly from a very warm, controlled environment to an unstable lower ambient temperature. This can have adverse effects. It has been reported to represent 20-30% of all born lambs with in 3 days of life (1) and 50% of perinatal lamb death by cold or cold induced starvation (Encinias et al. 2004).

Cold Stress

Animals have a lower critical temperature. This is the temperature at which the body must generate heat through active biological processes to survive. Cold stress results when the animal undergoes long periods at ambient temperatures lower than its lower critical temperature tolerance. The lamb depletes its body reserves of resources needed to produce heat and may lose the ability to thermoregulate.

Thermoregulation: biological response

Thermoregulation is the production of heat. There are two mechanisms for producing heat; shivering and non-shivering thermogenesis (2). Shivering thermogenesis is controlled by a portion of the hypothalamus called the primary motor center for shivering (3). This area becomes excited by cold stimuli arising from skin and the spinal cord, and activates the shivering response (3). Very small muscles located around each hair follicle act to increase the boundary barrier of the animal providing a blanket of air for insulation (2). The skeletal muscle system is responsible for the shivering response (2).

Non-shivering thermoregulation is a mechanism of heat production which occurs immediately after a meal (heat of digestion) or in brown adipose tissues (4). Brown adipose tissue is very important for neonatal and hibernating mammals (3). The focus here is on brown fat thermogenesis in lambs. Brown adipocytes have many mitochondria which express mitochondrial uncoupling protein 1 (4). During cold stress situations the uncoupling protein in brown adipocytes has the ability to uncouple the "oxidative phosphorylation from ATP synthesis" and generate heat from substrates instead of ATP (Gate et al. 1999).

Mechanisms of cold tolerance in lambs

Immediately after birth lambs are exposed to colder temperatures than that of the uterine environment. This can elicit a cold stress response from the sympathetic nervous system (Doubek et al. 2003). Cold causes sympathetic stimulation of beta-adrenergic receptors on brown adipocytes (4) and an increase in metabolic rate (Doubek et al. 2003). This in turn stimulates the brown adipocytes to activate hydrolysis of triglycerides and release fatty acids (4). These fatty acids are immediately oxidized in the mitochondria with heat being produced instead of ATP, a process dependant on mitochondrial uncoupling protein (4).

Catecholamines (epinephrine and norepinephrine) and thyroidal hormones (triiodothyronine and thyroxine) are also involved in non-shivering thermogenesis (Doubek et al. 2003, Budge et al. 2000, Symonds and Clarke 1998). Fetal glucose supply promotes adipose tissue development (Gates et al. 1999). It has also been suggested by McFadin et al. that leptin concentrations in the ewe's milk can assist the lamb in thermoregulating (2002). They found elevated leptin concentrations in the ewe's colostrum as well as in the plasma of the neonate and since leptin regulates appetite and body temperature it was suggested that it is a mechanism of thermogenesis regulation in the neonate (McFadin et al.2002). Leptin has also been shown to activate the sympathetic nervous system (McFadin et al. 2002). The lamb would be able to absorb this leptin during the first few days post partum before gut closure occurs (McFadin et al. 2002). "In order to maximize thermoregulatory adaptation after birth, new born lambs must possess sufficient energy reserves to provide the energy required for the initiation of non-shivering thermogenesis in brown adipose tissue" (Gate et al. 1999). These reserves also include hepatic glycogen stores (Budge et al. 2000).

Cold tolerance and cold stress are important issues for the sheep industry in that it represents a major portion of lost lambs before weaning. As mentioned, up to 50% of lamb fatalities can be accounted for by cold stress and related problems like cold induced starvation and pneumonia (Encinias et al. 2004). There can also be some health concerns associated with the ewe, like pregnancy toxemia (Fisher 2002). Optimal management practices can ensure higher productivity. Healthy animals produce more so it is beneficial to increase the welfare of the herd to a standard that promotes productivity. Some welfare discussion and management suggestions will be further explored as well, lambing condition recommendations will be given.

Problem manifestation

Newborn lambs have a low cold tolerance (Wassmuth 2003) and are an unusual mammal as they are born with almost 100% brown fat where others have both brown fat and white fat (Encinias et al. 2004). During parturition the change in temperatures between the uterine and the extra-uterine environments is such that the lambs have the threat of succumbing to cold stress. Inadequate brown fat stores in conjunction with starvation and cold exposure is a significant cause of premature death in lambs (Gate et al. 1999). "Lambs produce 50-60% of there heat through shivering and 40-50% through non –shivering thermogenesis (Encinias et al. 2004). Non-shivering thermogenesis is essential for lamb survival. Low temperatures cause a sympathetic nervous system activated stress response that activates shivering and non-shivering brown adipose mediated thermogenesis (Encinias et al. 2004). There is evidence that good management practices can alleviate cold threats to neonatal lambs even in extensive practices (Fisher 2001).

Problems of cold stress in lambs

In extensive operations lamb core body temperatures immediately after birth can fall up to 4.5ºC (Faurie et al. 2004). It has been found that despite the higher surface area to body volume ratio in lambs compared to adults (Doubek et al. 2003) lambs keep their body temp higher than the ewes for the first 2 weeks of life (Faurie et al. 2004). Not until the second month postpartum do lamb core temperatures resemble that of the adults (Faurie et al. 2004). Some physiological symptoms of cold stress include; vasoconstriction, respiratory failure, cold induced starvation, hypothermia, and pneumonia. Respiratory failure causes hypoxia which prevents thermoregulation and therefore causes hypothermia (Symonds and Clarke 1998). There are also some behavioural symptoms which are; failure of suckling behaviour (results in cold induced starvation) (Faurie et al. 2004), shivering, failure to walk (due to hyperthermia) and clumsiness. The immediate suckling reflex right after birth is a thermoregulatory mechanism which activates digestive and metabolic processes responsible for maintaining body heat (Faurie et al. 2004).

Research into management practices: improving lamb thermogenesis

There is a link between the amount and quality of brown adipose tissue a lamb has and the condition of the ewe. A lamb having more brown adipose tissue weight may not be at an advantage (Budge et al. 2000). The higher weight could be due to hypertrophy of adipocytes or an increase in size of the brown fat cells. The thermogenic mechanism is the mitochondrial uncoupling protein in brown adipose tissues (Doubek et al. 2003). Therefore the amount of non-shivering thermogenesis is dependant on the amount of uncoupled protein-1 that is present in and not on the number of perirenal (brown) adipocytes (Budge et al. 2000). Literature has shown that many factors during pregnancy play a role in the thermoregulation capabilities of lambs. These factors can include; maternal body weight, ewe nutritional status, ewe nutritional supplementation, chronic cold stress in the ewe induced by shearing during pregnancy and more.

Ewe body weight before conception has been shown to affect a ewe's ability to sustain placenta weight after dietary insufficiency before and after conception (Clarke et al 1997). Clarke et al. 1997 found that light weight ewes gave birth to lambs with less brown adipose tissue, smaller livers, hearts, kidneys, brains, adrenals and thyroids. They found that nutritionally compromised ewes had mobilized fat reserves during early-mid gestation and as a result had smaller placentas (Clarke et al 1997). This was thought to have contributed to their offspring being less able to thermoregulate upon a caesarean section delivery thermoregulatory test (Clarke et al. 1997). Caesarean section delivery as cited by Clark et al 1997, is known to severely impair a lamb's ability to thermoregulate and was viewed as a suitable test for thermal regulation Caesarean section can severely compromise a lambs ability to thermoregulate due to impaired non-shivering thermogenesis (Symonds and Clarke 1998).

Clarke et al. 1997 used ewes of a 20% body weight variation which yielded significant offspring differences showing that a slight size difference in ewes can greatly affect the performance of their lambs. It can be extrapolated from this research that body weight differences and nutritional inadequacy can lead to decreased lamb endogenous energy reserves and can limit survival due to an inability to thermoregulate.

The nutritional status of the ewe can effect the lambs thermoregulation. Severe nutrient restriction in late pregnancy is known to cause a drop in maternal and fetal plasma insulin-like growth factor (IGF-I) concentrations and lowered fetal body and liver weights (Heasman et al. 2000). IGF-I is a major growth promoter for fetal organs, endocrine glands and skeleton as cited by Heasman et al. 2000 and the IGF-I axis may be affected if the ewe is nutrient restricted during early to mid gestation. The lambs born to ewes who were nutritionally supplemented after being restricted showed an increase in body length and weight (Heasman et al. 2000). The major finding of this research was that the increase in fetal size with out an increase in IGF-I plasma levels shows a "loss in the relationship between fetal weight and plasma IGF-I "(Heasman et al 2000). Here it can be deduced that larger lambs, whether a result of increased plasma IGF-I or simply due to adequate ewe nutrition can lead to higher thermoregulatory capabilities. As the lamb is larger the surface to body volume ratio decreases and the mechanisms by which heat are lost are also decreased (Doubek et al. 2003).

Another study showed that well fed ewes gave birth to lambs with less total brown adipose tissue but that had higher thermogenic activity than controls (Budge et al. 2000). This research was done to "investigate the influence of maternal nutritional enhancement during the second half of gestation on prolactin receptor abundance in fetal brown adipose tissue and liver close to term" (Budge et al. 2000). Budge et al. found that the brown adipose tissue of lambs born to well fed ewes had more prolactin receptors (2000). The mechanism behind this is as yet not known but there is a positive correlation between increased ewe nutrition and prolactin receptor content. The higher thermogenic activity was due to more uncoupled protein-1 (Budge et al. 2000). According to Budge et al. high quality of feed in late gestation can lead to increased uncoupled protein content in conjunction with a higher amount of the 15-kD isoform of the prolactin receptor, "the combination of which is likely to enhance neonatal survival" (2000).

Nutritional supplements during pregnancy can alter the brown adipose reserves of a neonatal lamb. Encinias et al. did a study to determine if feeding high linoleic safflower seed to pregnant ewes could increase thermoregulation and survival in lambs (2004). They also wanted to see if adipose deposition was affected by safflower seed supplementation (Encinias et al. 2004). It was discovered that linoleic and linolenic supplementation lead to increased uncoupling protein-1 content by two fold and a 74% increase in brown fat thermogenic capacity (Encinias et al. 2004). Further ewe body weight and condition remained unchanged during supplementation which Encinias et al. suggest is an economic benefit (2004). This is only one of many nutritional supplementations that could be used. Others have included giving about one pound of corn or barley a day during the last 6 weeks of pregnancy due to smaller rumenal space.

Shearing during pregnancy was thought to have positive affects on increasing birth weights of lambs (Kenyon et al. 2002). However it was suggested that these results were inconclusive and that previous studies yielded variable results (Kenyon et al. 2002). In 1999, Gate et al. thought that the actual affect could be due to shearing plus sub-optimal feeding and not shearing alone. Kenyon et al. in 2004 found that pregnancy shearing caused changes in lamb fleece characteristics due mainly to "elevated maternal thyroid hormone levels in mid-pregnancy. The enhanced fleece of lambs born to shorn ewes could aid them in thermoregulation, but only on the boundary level which is not very effective. Gate et al. found no difference in birth weights of lambs born to shorn versus not shorn ewes (1999). However, the plasma growth hormone concentration was lower and insulin higher in lambs born to shorn ewes (Gate et al. 1999). They also suggested that this ratio could enhance postnatal growth of the lamb (Gate et al. 1999). There was no affect on brown adipose tissue thermogenic properties between shorn and unshorn ewe-lambs (Gate et a. 1999). Overall the research in this area seems to be quite variable however some producers see this pregnancy shearing as an unnecessary handling of heavily pregnant ewes and regard it as too stressful (1).

Genetics can lead to more thermoregulatory capacity. For example the Rhonschaf breed is shown to produce lambs which are more cold resistant than the German Blackface (Wassmuth et al. 2001). Wassmuth et al. noticed that the breed of ewe had an effect on lamb vigor (2001). In genetics the breeding of pure-breeds gives an offspring that is called a crossbred. The more cross breeding the more the chances for obtaining a homozygous deleterious effect is reduced and this is called hybrid vigor. Wassmuth et al. demonstrate this in the crossbred German Blackface and Charmoise ram with a

Rhonschaf ewe being the most able to survive outdoor winter lambing (2001). There are many other sheep breeds which are considered to be hardy in winter conditions like the Rambouillet and the Scottish Blackface.

Conclusion

From a welfare perspective it is important to provide for your herd. Through good management practices and raised welfare standards production will be high. Whether housing sheep free range or indoors the welfare of the herd "does not appear to be poorer during some seasons than during others" (Fisher 2002). Management needs to be optimal in order to avoid underfeeding during low grass growth in winter months (Fisher 2002). There are different management issues with regard to cold stress when housing indoors verses outdoors.

Indoors there is little threat of cold stress as long as the building is draft free. Sufficient ventilation and lumination should be provided. Care should be taken that all ewes receive adequate nutrition and not just dominant animals as this will have a negative effect on subordinate ewe's offspring. Ewes should not be nutritionally restricted during pregnancy as this will ensure lambs are born viable with the ability to under go shivering and non-shivering thermogenesis. However over-nutrition should be avoided as this can lead to large lambs and dystocia (Fisher 2002). A lambing cubicle could be provided as ewes prefer to separate themselves from the group during parturition (1) and this could also prevent miss-mothering (the steeling of a ewe's offspring from a hormonally, motherly, expectant ewe).

Housing sheep outdoors may be more economic for the producer however it is probably more labour intensive. Lambing in winter conditions can cause many loses in lambs as has been discussed however the provision of a shelter can halve these losses (1). Management should try to be sure all ewes can access the shelter or more than one could be provided. Types of outdoor shelters include; wind breaks, phalaris stands, natural undulating paddocks, tree belts, and forested paddocks (1). Proper nutrition and water should always be provided for expecting ewes to prevent pregnancy toxemia (1). Autumn can lead to periods of "feeding deficit, fly strike, intestinal parasites, injury from barely grass seeds including blindness, facial eczema and ryegrass staggers" (1). Lambing in the spring months requires a very different management strategy. Spring time can mean rain storms and a need for shelter is just as important. The type of shelter can be a factor in how effective it is. The more it covers from the elements the more beneficial it will be in protecting lambs from cold stress.

Through nutrition of the ewe, maintenance of the ewe's body condition, nutritional supplementation, clean, dry lambing environments and good management practices, the lamb's ability to thermo regulate will take care of itself. Proper herd health and welfare will ensure thermogenically active lambs and a reduction in losses associate with cold stress in neonates. Any problems should be addressed as management problems (1).