REVIEW [REVISIÓN]

TRACE ELEMENTS IN SHEEP AND GOATS REPRODUCTION: A REVIEW

[ELEMENTOS TRAZA EN LA REPRODUCCIÓN OVINA Y CAPRINA: UNA REVISIÓN]

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SUMMARY

The reproduction of small ruminants like goats and sheep managed under extensive range grazing conditions can be affected by nutrients availability and especially by the mineral content of the forages resources on the rangeland. It has been particularly demonstrated that trace elements can have equally, beneficial or detrimental effects, depending on its balance, on reproductive functions in small ruminants. Trace elements as copper, molybdenum, selenium and zinc play key role on the metabolism of carbohydrates, proteins and lipids; however, the mode of action by which these elements affect reproduction in sheep and goats are not completely understood, due to the complexity in the mode of action of the metallobiomolecules and the neuro-hormonal relationship. In this way, their absence or presence of these minerals in several organs, fluids, or tissues of the reproductive tract have allowed obtaining information on the metabolism and the role of these elements on reproduction in sheep and goats. On this regard, the objective of this document is to review the relationships and effects of some trace elements, on reproductive events in sheep and goats.

Keywords: Minerals; female reproduction; male reproduction; small ruminants.

RESUMEN

La reproducción de pequeños rumiantes, como cabras y ovejas, manejados bajo condiciones extensivas de pastoreo puede verse afectada por la disponibilidad de nutrientes y sobre todo por el contenido mineral de los recursos forrajeros presentes en el agostadero. Particularmente se ha demostrado que los elementos traza pueden tener tanto efectos beneficiosos o perjudiciales, dependiendo de su equilibrio, sobre las funciones reproductivas en pequeños rumiantes. Los elementos traza como el cobre, molibdeno, selenio y zinc juegan un papel clave en el metabolismo de los carbohidratos, proteínas y lípidos, sin embargo, el modo de acción por el cuál estos elementos afectan la reproducción en ovinos y caprinos aún no son entendidos completamente, debido a la complejidad en el modo de acción de las metalobiomoléculas y la relación neuro-hormonal. De esta manera, la ausencia o presencia de estos minerales en varios órganos, fluidos o tejidos del aparato reproductor han permitido la obtención de información sobre el metabolismo y la función de estos elementos sobre la reproducción en ovinos y caprinos. En este sentido, el objetivo de este documento fue revisar las relaciones y los efectos de algunos elementos traza sobre los eventos reproductivos en el ganado ovino y caprino.

Palabras clave: Minerales, reproducción en la hembra, reproducción en el macho, pequeños rumiantes.

INTRODUCTION

Sheep and goats are considered as prolific species, despite the fact that most breeds of both species show annual reproductive cycles (Jainudeen *et al*., 2000). During each annual reproductive cycle, there is a season of low or absent (anestrous season) and a season of high (breeding season) reproductive activity; several factors are responsible to regulate these cyclic activities (Thiéry *et al*., 2002). In high or medium latitudes: >30° (Lincoln, 1992), >35° (Malpaux *et al*., 1996) or >40° (Chemineau *et al*., 1992), the photoperiod and the annual environmental temperature cycle, are the main modulators of seasonal reproduction; whereas, in tropical regions, the annual reproductive cycle in sheep and goats is more likely regulated by annual rainfall and food availability (Figure 1) (Galina *et al*., 1995; Gündoğan *et al*., 2003; Porras *et al*., 2003).

However, reproductive functions in these species are also regulated by other extrinsic factors, such as, social and sexual interactions and nutritional status (Figure 2) (Álvarez and Zarco, 2001; Gündoğan *et al*., 2003; Bearden *et al*., 2004; Zarazaga *et al*., 2005). Reproductive functions are highly demanding, in both, nutrients quality and quantity; in this way, nutritional status is a very important modulator of reproduction in sheep and goats (Blache *et al*., 2008).

Several studies have demonstrated interaction between nutrition and reproduction in sheep and goats. For example, flushing or minerals improves has been shown to improve production and reproduction parameters (Madibela *et al*., 2002; Fernández *et al*., 2004; Almeida *et al*., 2007; Griffiths *et al*., 2007). Many studies have also confirmed the lack of a clear nutrition-reproduction interaction (i.e. lack of effect of supplementary feeding or flushing on ovulation rate, on oestrus manifestation, on fertility or prolificacy) (Ahola *et al*., 2004; Zarazaga *et al*., 2005; Rosales *et al*., 2006). Minerals such as phosphorous (P), calcium (Ca), magnesium (Mg), iodine (I), manganese (Mn), copper (Cu), selenium (Se), and zinc (Zn) are all involved in governing successful reproductive processes (Wilde, 2006). Although most sheep and goat production systems based on grazing do not provide mineral supplementation programs, the use of commercial pre-mixtures or mineral blocks is a practice that is usually performed; however, trace elements inclusion is rarely taken into account in the formulation of the supplements mentioned, so that their contribution is low or null, coupled with the deficiency of elements such as Cu and Se in some regions where the animals are grazed (McDowell, 1994). Researches on mineral concentration and interrelationship in soil, forage and blood serum of sheep and goats in Mexico have shown results that there are imbalances of minerals, with excesses of P and iron (Fe) in the sheep, with Cu deficiency associated to deficiencies of Cu and excesses of Fe in the soil and in forages (Domínguez-Vara and Huerta-Bravo, 2008). Mineral concentrations of tree leaves and grasses consumed by goats in the southern Mexico State showed that poor levels of minerals were reported for Cu and Zn, while the concentration of Ca and Mg was found in the normal range reported by NRC (2007), however, in serum of goats showed a marginal deficiency of Cu and Zn (Ramírez, 2009). Some trace elements, such as Cu, Zn, Se and Mo are involved in cellular respiration, cellular utilization of oxygen, DNA and RNA replication, maintenance of cell membrane integrity, and sequestration of free radicals (Chan *et al*., 1998). In destruction of free radicals are involved Cu, Zn, and Se through cascading enzyme systems (Chan *et al*., 1998).

Superoxide radicals are reduced to hydrogen peroxide by superoxide dismutases in the presence of Cu and Zn cofactors. Hydrogen peroxide is then reduced to water by the Se-glutathione peroxidase couple (Chan *et al*., 1998). Efficient removal of these superoxide free radicals maintains the integrity of membranes. On the other hand, excess intake of these trace elements leads to disease and toxicity; therefore, a fine balance is essential for healthy, productive, and reproductive processes (Chan *et al*., 1998). On this regard, the objective of this document is to review the relationships and effects of some trace elements, on reproductive events in sheep and goats.

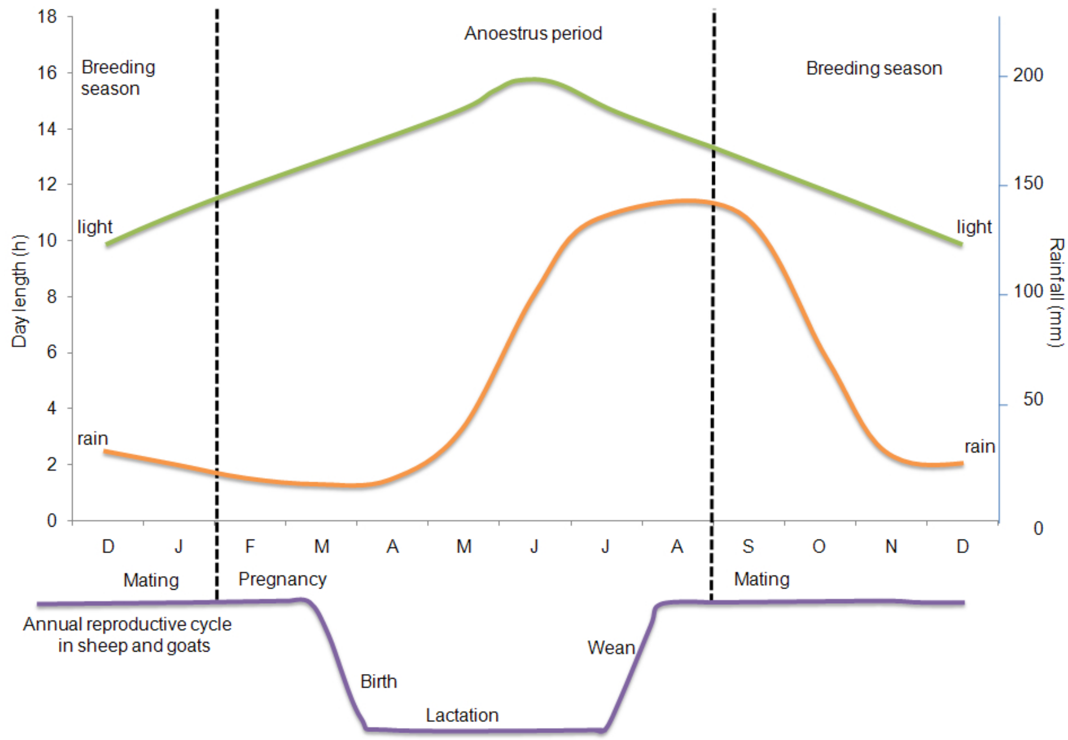

Figure 1. Model of annual reproductive cycle in sheep and goats, indicating the relationships between annual photoperiod and rainfall cycle in subtropical areas. Adapted from Arroyo *et al*. (2006).

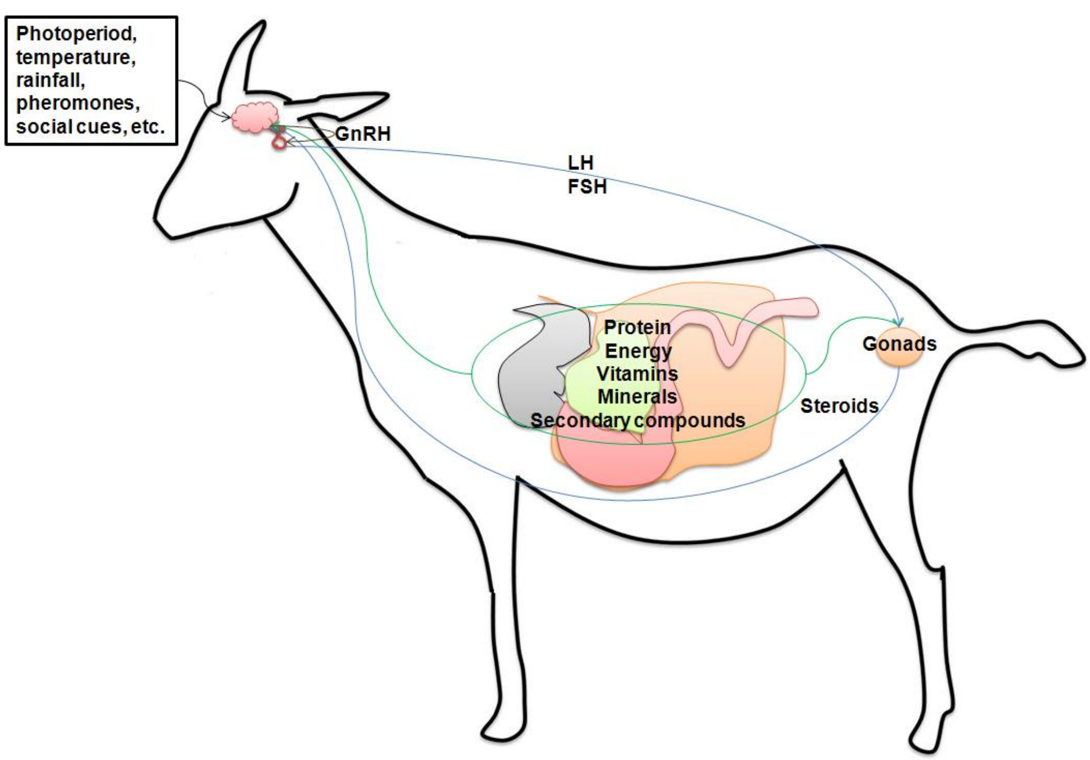

Figure 2. Relationships between external factors and nutrients in the control of the reproductive axis (hypothalamus, pituitary gland, gonads) in sheep and goats. Adapted from Wade and Jones (2004) and Blache *et al*. (2008).

MINERAL NUTRITION AND REPRODUCTION IN SHEEP AND GOATS

Diets and feedstuffs deficient in trace minerals requirements, can have deleterious effects on reproduction functions, in both males and females of both species (Table 1), thus, for feeding purposes, the mineral status of the animal should be considered in preparation of the final diets (Smith and Akinbamijo, 2000).

Moreover, cattle and goats are less susceptible to Cu toxicity than sheep, and young ruminants are more susceptible than adults because of higher absorption (NRC, 2005). Although Cu poisoning has been recorded in sheep grazing pastures fertilized with chicken litter, the inclusion of poultry litter in sheep rations is recommended by some researchers as an alternative source of protein and energy, but attention should be taken to avoid copper toxicity (Christodoulopoulos and Roubies, 2007).

In areas from southeast of the State of Tlaxcala and the mountain area of the State of Puebla, the mortality of the lambs from birth to 60 d of age was 62 percent; the lambs had symptoms of nutritional myopathy and the main finding at necropsy was nutritional muscular dystrophy, due to Se deficiency (Ramírez-Bribiesca *et al*., 2004). It is worth mentioning that Se is the most toxic essential trace element; so its supplementation should be cautious, especially in non-selenium deficient areas (Underwood and Suttle, 2003).

Table 1. Roles of some minerals on physiological functions reproductive failures and toxicity in sheep and goats.

Mineral element	Physiological functions	Deficiency	Toxicity
Calcium and Phosphorus	Intracellular messenger for transmission of nerve impulses. Release ATP/ADP and nucleic acids	Lowered milk production, milk fever by hypocalcemia in lactating ewes and does, estrus suppression and poor conception rates	Hypercalcemia and soft tissue calcification, Urinary calculi formation and skeletal softening
Magnesium	Synthesis of nucleic acids and glutathione	Tetany	Urolithiasis, lethargy, disturbance in locomotion, diarrhea, and lower feed intake
Copper and Molybdenum	Enzyme component and catalyst involved in steroidogenesis and prostaglandin synthesis	Delayed and depressed estrus, abortion, death fetuses, infertility, congenital ataxia	Haemolytic crises, haemoglobinuria, haemoglobinaemia, and jaundice; Severe diarrhea, weight loss, anorexia, and reproductive failure
Selenium	Component of selenoproteins, antioxidant function	Lamb mortality, reduced sperm motility and uterine contraction, cystic ovaries, low fertility rate, retained fetal membranes	Poor growth, abnormal gait, vomiting, dispnea, titanic spasms, labored respiration, and death
Zinc	Component of numerous metalloenzymes, influences transcription and cell replication	Impaired spermatogenesis and development of secondary sex organs in males, reduced fertility	Reduced weight gain and feed efficiency, depressed feed intake, and eventually pica

Adapted from Minatel and Carfagnini (2000), Smith and Akinbamijo (2000), Underwood and Suttle (2003), McDowell (2003), NRC (2005), NRC (2007), Blache *et al*. (2008), Hefnawy and Tórtora-Pérez (2010).

Mineral concentrations in liver are the best indicator of the endogenous mineral status of the animal (Humann-Ziehank *et al*., 2008). Nonetheless, blood analysis is more frequently used, because blood samples are easily taken and is also considered a non invasive procedure (Kincaid, 2000). Trace elements deficiencies are expressed in the animal by diverse forms, since these elements form molecule complexes of the metabolism of proteins, lipids and carbohydrates, where they play key roles as components and enzyme cofactors (Cu) or transcription factors (Zn) (McArdle and Ashworth, 1999; McDowell, 2003; Underwood and Suttle, 2003). Based on the before mentioned information, the mineral status of the animal has effects on every phase of the reproductive cycle (Bedwal and Bahuguna, 1994; Smith and Akinbamijo, 2000; Robinson *et al*., 2006). For instance, during gestation, both, the mother and fetus are very susceptible imbalances in micronutrients in the diet, during the time of rapid growth and cell differentiation (McArdle and Ashworth, 1999; Gürdoğan *et al*., 2006; Ghany-Hefnawy *et al*., 2007). Additionally, kilograms of offspring weaned per female exposed may be affected by both trace mineral supplementation and source (Ahola *et al*., 2004). However, the mechanisms of action by which these micronutrients affect reproduction in sheep and goats are not completely understood, mainly due to the complexity in the mode of action of the metallobiomolecules and the neuro-hormonal relationship (Bedwal and Bahuguna, 1994; Smith and Akinbamijo, 2000; Wilkins and Wilkins, 2002; Zatta and Frank, 2007).

COPPER (Cu) AND MOLYBDENUM (Mo)

Copper is a mineral element that activates several enzyme systems, and though in less numbers than Zn, it is considered an essential nutrient (Minatel and Carfagnini, 2007). However, sheep and goats are not tolerant to high Cu levels in their diets, and it is thus considered a toxic element (Minson, 1990; McDowell, 2003; NRC, 2005). The physiological role of Cu in the organism is related to several functions, which include cellular respiration, bone formation, connective tissue development, and essential catalytic cofactor of some metallo-enzymes, among other (McDowell, 2003; Underwood and Suttle, 2003). In addition, and contrary to a Zn deficiency, a Cu deficiency is not related to programmed cell death (Ashworth and Antipatis, 2001). Cu requirements for goats have been reported to vary between 8 to 10 mg per Kg of DM intake (Meschy, 2000). Whereas, Cu requirements for sheep have been established between 7 to 11 mg per kg of DM intake (NRC, 1985). Sheep are highly sensitive to Cu intoxication, in comparison; goats are more tolerant to such toxicity (Meschy, 2000). Nonetheless, goats are very sensitive to Cu deficiency (Draksler *et al*., 2002).

Mo is an essential trace element, but its role in metabolism is not well understood (McDowell, 2003), its role is mostly on the oxidase enzyme system (NRC, 2007). Excessive Mo intake by the animals, affects the health and the well being of the animal (McDowell, 2003). Although Mo requirements for sheep and goats have not been established, values of 0.5 and 0.1 mg/kg DM in the diet have been recommended, for use in sheep and goats, respectively (NRC, 2007).

The relationship occurring between Cu and Mo in the animal metabolism, forces researchers to approach description of its functions, in an integrated fashion (NRC, 1981; Miller *et al*., 1993). The interaction between these elements can result in a poor use of Cu, Mo since it interferes with the metabolism of Cu at the molecular level, forming chelates in the rumen which reduces its absorption, highly linked to the presence of sulfur (S) (Suttle, 1991; Aragón *et al*., 2001). In the rumen are formed, by reactions between Mo and S, thiomolybdates which ones, depending on the proportions present can be identified as follows: monothiomolybdate (MoO_3S) dithiomolybdate (MoO_2S_2) trithiomolyibdate ($MoOS_3$) and tetrathiomolybdate (MoS_4) (Whitehead, 2000; Quiroz-Rocha and Bouda, 2001). The thiomolybdates react with free Cu atoms, to form insoluble Cu complexes, thus, forming Cu-Mo-S complexes, this is a complex that affects Cu utilization, which causes Cu deficiency (Suttle, 1991; Quiroz-Rocha and Bouda, 2001). Quiroz-Rocha and Bouda (2001), recommended a Cu:Mo ratio to be between 3:1 to 6:1, in the rations for ruminants; values outside these ranges, predispose the animals to alter their Cu metabolism and status. Under practical feeding conditions, grazing ruminants are more susceptible to show Cu toxicity and/or Mo excess (Kincaid, 2000; McDowell, 2003).

In addition, low Cu content in sheep rations, causes embryo loss, inhibits embryo implantation and fetal death (Hidiroglou, 1979). Naziroğlu *et al*. (1998), reported information from 148 aborting ewes, found that the most common cause of abortion, had been low levels of micronutrients, and among them, was low Cu concentration. Likewise, Anke (1973; cited by McDowell *et al*., 1997 and Hidiroglou, 1979) fed goats with Cu deficient diets and observed low conception rates, resides, 50% of the gestating goats with Cu deficiencies aborted, mummified fetuses and hemorrhagic placentas and necrotic lesions were also found. In sheep, postnatal lordosis, detected as muscle weakness and ataxia, is also caused by Cu deficiency during gestation (McArdle and Ashworth, 1999; Ashworth and Antipatis, 2001). It thus appears that, during sheep and goat gestation, normal growth and development is affected by radical changes in Cu availability and metabolism (Hidiroglou and Knipfel, 1981; Hostetler *et al*., 2003). Du Plessis *et al*., (1999), induced a secondary Cu deficiency in ewes, by means of Mo and S supplementation, this procedure suppressed estrous behavior, however, the females continued ovulating, based on this, the results suggested that by elevating Mo and S, production and /or expression of hormones, such as estrogens and luteinizing hormone (LH) and follicle-stimulating hormone (FSH) were altered. In addition, when goats are exposed to prolonged periods of Cu deficiencies, they present nymphomaniac reproductive behavior, thus suggesting that Cu deficiency affects both, reproductive behavior and performance (Hidiroglou, 1979). Despite the above, blood Cu levels are not directly related with reproductive behavior, since, Cu concentration in rams and gestating ewes did not affect reproductive behavior and prolificacy, respectively (Hidiroglou, 1979).

In general, low fertility associated with delayed or suppressed estrus, prolonged postpartum periods, infertility associated to anoestrus, abortions and fetal losses, are reproductive disorders commonly found in Cu deficient animals, as well as in animals with excess of Mo and/or S (Smith and Akinbamijo, 2000; Underwood and Suttle, 2003).

SELENIUM (Se) AND VITAMIN E

Se poisoning occurs when grazing animals may suffer from subacute or chronic Se toxicosis in seleniferous areas (NRC, 2005). Generally, the Se-intoxicated animals show low growth performance, elevated Se concentrations in tissues, or death, in critical cases (NRC, 1983). Nonetheless, several studies supported the beneficial role of Se in human and animal nutrition (Watts, 1994; Hefnawy and Tórtora-Pérez, 2010). Se plays keyroles in several functions, mainly in those of the selenocysteine (SeCys), which is a key component of the selenoproteins (Burk, 1991; Holben and Smith, 1999) and their functions are shown in Table 2.

The glutathione peroxidase system (GPX's) prevents free radical formation and reduces the risk by oxidation damage to the tissues (NRC, 1983; Holben and Smith, 1999). In a similar fashion to the GPX's, the P and W selenoproteins have antioxidant effects; in addition, the W selenoprotein is essential for skeletal muscle functions (Beckett and Arthur, 2005; Silva *et al*., 2000). Another important selenoprotein is the sperm mitochondrial capsule (Seleno) protein, which is important for the male fertility and exerts its effects at the mitochondrial level (Silva *et al*., 2000; Holben and Smith, 1999). It could be resumed that, Se is a vital element in the animal organism, due to the several metabolic functions, where it plays key roles (Silva *et al*., 2000).

As mentioned before, Se and vitamin E play a biological role as cell antioxidant, by preventing damage by oxygen peroxide and other peroxides formed from fatty acids (Smith and Akinbamijo, 2000), both components for a very hard bond, which is involved in a wide variety of metabolic processes (Minson, 1990; Church *et al*., 2002). Even though, both clinical effects and metabolic effects of Se and vitamin E are similar, the functions on protecting tissue cell membranes, by the oxidative processes, are in independent way (Minson, 1990). Whereas, Se is required for the formation of GSH-Px, which destroys potentially toxic peroxides, and vitamin E, is presumably used to eliminate peroxides that escaped the destruction by Se (NRC, 1983; Minson, 1990). Some antioxidant enzymes activity has been shown to occur in the sheep corpus luteum (CL), these enzymes are susceptible to major changes in activity, during early gestation, which suggests that the sheep CL may be rescued from luteolysis, by increasing the antioxidant enzyme activity, thus inhibiting the apoptotic processes (Al-Gubory *et al*., 2004).

It has been shown in certain areas of Mexico, that Se is low in goats, due to low Se in the soils and the pastures (Ramírez-Bribiesca *et al*., 2001). In a study, rams were treated with a 33 g Zn, Co and Se soluble glass bolus (15.2% w/w Zn, 0.5% w/w Co and 0.15% w/w Se), and they showed improved sperm motility and viability (Kendall *et al*., 2000). Gestating sheep treated orally with Se, at monthly intervals, had greater lambing rates, than non treated ewes, this effect was attributed to embryo loss, before 30 days of gestation (McDowell *et al*., 1997). Grazing sheep in pastures with low Se and high estrogen levels, and treated with Se, increased the conception rate, from 49 to 76% (McDowell *et al*., 1997). Overall, several studies have shown that Se supplementation improves reproductive performance in sheep (Table 3). However, when goats are superovulated, they do not respond to Se treatment (*control group:* 15.5±5.1 corpora lutea, *supplemented group:* 15.9±7.2 corpora lutea) (Peña *et al*., 2005).

Table 2. Selenoproteins and their possible functions in animal metabolism

Selenoprotein (Name)	Function
GPX1 (Cytosolic glutathione peroxidase)	Se store, antioxidant in cytosol
GPX2 (Gastrointestinal glutathione peroxidase)	Antioxidant protection in gastrointestinal tract
GPX3 (Plasma or extracellular glutathione peroxidase)	Extracellular and plasma antioxidant
GPX4 (Phospholipid-hydroperoxide glutathione peroxidase)	Intracellular antioxidant
GPX5 (Sperm mitochondrial capsule selenoprotein)	Antioxidant in development of spermatic cells
D1 (Type I deiodinase)	Regulation and production $\{T_4 \rightarrow T_3\}$
D2 (Type II deiodinase)	Activating thyroid hormone
D3 (Type III deiodinase)	Converts T_4 to bioinactive rT_3
TRs (Thioredoxin Reductase)	DNA synthesis, redox regulator
Sel P (Selenoprotein P)	Antioxidant, Se transport, detoxificant
Sel W (Selenoprotein W)	Muscle metabolism, antioxidant

Silva *et al*. (2000), Underwood and Suttle (2003), Beckett and Arthur (2005), Köhrle *et al*. (2005).

Table 3. Effect of Se supplementation on reproductive performance in sheep

Reproductive parameter, %	Control	Se supplement
Estrus response	84[a], 76[b], 87[c]	88[a], 100[b]*, 100[c]*
Pregnancy	96[c]	97[c]
Lambing	72[a], 68[b], 96[c]	84[a], 100[a]**, 97[c]
Prolificacy	122[a], 100[b], 115[c]	105[a], 112[b], 131[c]**

* Indicate significant differences between means with same superscripts in the same row: *P<0.05*.
** Indicate significant differences between means with same superscripts in the same row: *P<0.01*.
[a] Adapted from Gabryszuk and Klewiec (2002) in 2-year-old ewes (Treated group: sodium selenate (0.1%) injection – Control group: no injection).
[b] Adapted from Gabryszuk and Klewiec (2002) in 3-year-old ewes (Treated group: sodium selenate (0.1%) injection – Control group: no injection).
[c] Adapted from Koyuncu and Yerlikaya (2007) (Treated group: sodium selenate (0.1%) injection – Control group: no injection).

On the other hand, McArdle and Ashworth (1999) reported that Se absorption from the diet is high (approximately 70%), although, this value is low for placental tissue, consequently, fetal growth and development, would depend on the diet and mother Se treasury. Likewise, Ghany-Hefnawy *et al*. (2007) concluded that due to the strong bond between the mother and the fetus relative to Se metabolism, in sheep and goats, the Se level in the fetus, is in direct relationship to the mother´s Se status.

As mentioned earlier, Se and vitamin E share a very close relationship, as they affect several metabolic functions, in addition, both components protect the cell membranes against oxidative degeneration (Hurley and Doane, 1989; McDowell *et al*., 1996); and they could well be involved in the prostaglandin synthesis (Hurley and Doane, 1989). The parenteral or intraruminal Se administration has shown increments in parturition rates in sheep, as it has also been increments shown in fertility, uterine contractions and greater numbers of spermatozoa adhered to the pellucid zone, this latter effect, perhaps, due to greater sperm motility (Segerson and Ganapathy, 1980; Hemingway, 2003). It has been shown that Se and vitamin E increase the percentage of ewes in estrus and prolificacy, in Karacabey Merino sheep, whereas, gestation and lambing rates did not change (Koyuncu and Yerlikaya, 2007). Other studies have shown that treatment of sheep with Se and vitamin E do not improve the reproductive parameters mentioned earlier (Gabryszuk and Klewiec, 2002). As shown, in the previous study, ewes fed with purified diets and supplemented parenterally with Se and vitamin E, did not show improvements in reproductive performance (Whanger *et al*., 1977). As sheep, goats do not always respond to Se and vitamin E treatment; in pregnant goats, the intramuscular injection of 0.31 mg Se + 4.2 IU vitamin E / kg BW increases the concentration of Se in blood, however reproductive responses to treatment, was only by increasing survivability in the kids at weaning and providing protection against white muscle disease (Ramírez-Bribiesca *et al*., 2005). The information available about the role of selenium and the effects of supplementation on reproductive activity and productivity describes that the response to Se supplementation is affected by Se source used and the severity of the deficiencies found. It should be remembered that selenium should be added in the diet carefully to avoid poisoning in livestock.

ZINC (Zn)

The need for Zn by most animals is based on its influence on enzymes and proteins and their activities, that are linked to vitamin A synthesis, carbon dioxide (CO_2) transport, collagen fiber degradation, free radical destruction, membrane stability of red blood cells, metabolism of essential fatty acids, carbohydrate metabolism, protein synthesis, metabolism of nucleic acids, among others (Powell, 2000; McCall *et al*., 2000; Stefanidou *et al*., 2006; Rubio *et al*., 2007,). Thus, the presence of Zn at the cellular level is essential, for instance, in the gonads, where cell growth and division, occurs continuously (MacDonald, 2000). Consequently, a Zn deficiency could seriously affect reproductive events in most species. For instance, in males, it could affect the espermatogenic process, as well, as primary and secondary sex organs development, and in females, it could affect them in any phase of the reproductive processes (estrus, gestation or lactation) (Smith and Akinbamijo, 2000). Zn also plays a key role in maintaining the integrity of the epithelia of the reproductive organs, which is necessary for embryo implantation (Hostetler *et al*., 2003; Robinson *et al*., 2006), besides, adequate concentrations of Zn in the serum and in the diets, are vital for uterine involution, tissue repair, after parturition, and particularly, the return to estrus (Apgar, 1985). In addition, Zn indirectly affects the reproductive process, since the deficiency of both elements, in synergism with others; favor the appearance of foot rot, in breeding animals (Enjalbert *et al*., 2006; Kiliç *et al*., 2007). Some studies in sheep, have proposed that Zn requirements are less than those for bovines, suggesting the sheep require less than 8 parts per million (ppm), than that required for calves, for normal growth (Haenlein, 1980). Consumption in goats fed rations with 6-7 ppm, do not show clinical signs of deficiencies, under this feeding regime, clinical signs of Zn deficiency are observed during the lactation, affecting only, Zn concentration in milk by 50%, but not affecting milk production. In male goats, clinical signs of Zn deficiencies appear when they are fed rations containing 4 ppm of Zn (Haenlein, 1980).

Plasma Zn levels in goats vary according to the physiological status, highest concentrations are found after parturition and during lactation (Kadzere *et al*., 1996; Ahmed *et al*., 2001). In contrast, Gürdoğan *et al*. (2006) did not find serum Zn concentration differences, in sheep with single or twin pregnancies, nor during parturition or lactation. Likewise, sheep that aborted did not show Zn plasma differences, in relation to those that carried gestation to term (Naziroğlu *et al*., 1998). Even though, results do not allow definite conclusions, since, results from others have found that sheep are highly susceptible to Zn deficiencies, during lactation (Apgar and Travis, 1979).

Sheep in Southern Australia, grazing on Zn deficient pastures, were supplemented with 140 mg of Zn weekly, increased lamb production, in relation, to the ewes that were not treated (Minson, 1990; McDowell *et al*., 1997). In Zn deficient sheep, implantation does not take place, will be this factor responsible for the low reproductive success (McDowell *et al*., 1997; Hostetler *et al*., 2003). Likewise, in goats consumption of low Zn diets, leads to low conception rates and prolificacy (McDowell *et al*., 1997). In other studies, Zn supplementation has increased prolificacy, by 14% (Minson, 1990). In rams that were fed rations with 2.4 ppm of Zn, atrophy of the seminiferous tubules and complete inhibition of spermatogenesis were observed (Minson, 1990; McDowell *et al*., 1997). However, when lambs were fed rations with 17.4 mg/kg DM, testicular development and other reproductive functions were similar to lambs fed a ration with 32.4 mg/kg DM (Minson, 1990). In male goats, a Zn deficiency causes testicular atrophy and reductions in libido and sperm production (Neathery *et al*., 1971; McDowell *et al*., 1997). Likewise, Zn, cobalt (Co) and Se treatment has resulted in increased sperm motility and viability (Kendall *et al*., 2000). Age of sire and season of year influence semen characteristics, in Damasco male goats, best semen quality was found during days of long photoperiod, during spring and season (Al-Ghalban *et al*., 2004). However, spermatogenesis requires extensive cell division and this requires large quantities of Zn, once the Zn is involved extensively in nucleic acid metabolism and protein and therefore is essential for differentiation and cell replication (Hidiroglou and Knipfel, 1984). In general, Zn affect the reproductive events in sheep and goats, directly on events as the manifestation of estrus, embryo implantation, and reduced spermatogenesis, or indirectly affecting the health of livestock. Usually little Zn is available to the body except from ingested in the diet. As the Zn must be continually supplemented.

CONCLUSIONS

Cu, Se, and Zn directly affect reproductive events on sheep and goats, they directly influence events such as, expression of estrus, embryo implantation and reduction in spermatogenesis; indirectly, they affect overall animal health. The scientific evidence so far obtained on mineral nutrition and its effects on some reproductive traits in sheep and goats can be controversial and inconclusive; however attention should be focused on the presence of these elements on the diets, since its importance on reproductive performance of these animals.

ACKNOWLEDGEMENTS

This revision was sponsored by funds from the Universidad Autónoma del Estado de México (Project UAEM 2534/ 2007) and by the Secretaría de Educación Pública-Programa de Mejoramiento del Profesorado (Project PROMEP /103.5 /07 /257219). We would like to thank Consejo Nacional de Ciencia y Tecnología (CONACYT) for the grant received by José Fernando Vázquez Armijo.

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Submitted April 15, 2010 – Accepted June 11, 2010
Revised received August 11, 2010