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A Systematic Review of the Impact of Minerals on Pregnant Sheep and Goats and their Offspring in the African Continent

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ABSTRACT

The dams' physiological status (gestational stages, lactation, and dry period) is crucial in utilising minerals. The mechanisms controlling the utilisation of minerals during pregnancy are inadequately understood. Unsuitable nutrition, especially from mid to late pregnancy in ewes, affects mammary development, milk production potential, the birth weight, health and survival of the offspring. This study aimed to review knowledge from studies in Africa on mineral status intake and its impact on performance and health of pregnant ewes or does and on the health and survival of their offspring. The study aimed to establish areas where information lacks, identifying extensive management systems on minerals used to meet the needs of the pregnant dam and their offspring within African conditions. Twelve Web of Science databases were used and cohort, cross sectional, case control and analytical studies were considered. Global (4132) articles, comprising 431 African studies, were identified during the review. The number was reduced to 10, fulfilling the selection criteria indicated in a Prisma flow graph. These selected studies covered a 40-year period (1975 to 2015). The minerals investigated were: Iodine (I), selenium (Se), zinc (Zn), copper (Cu), iron (Fe), calcium (Ca), manganese (Mn), magnesium (Mg), chromium (Cr), cadmium (Cd), molybdenum (Mo) and lead (Pb). Most studies conducted globally on this topic, focused on Ca, Mg and Se, followed by Cu, I, P and Zn. Studies conducted in Africa focussed on Se and Zn. Adequate Zn, Se and Cu supplementation indicated improved survival and weight gain in the offspring. Selenium plasma levels were higher, and Zn and Cu levels were lower in pregnant ewes and does. Cu levels increased in older goats. Zn plasma levels were higher in kids, aged four to six months, than those of nine to twelve months. Supplementation of I increased lambing but not kidding rates. Half of the studies were conducted in areas with mineral deficiencies (Se and I) or holding known high soil Na levels. Previous studies investigated normal plasma levels in pregnant and lactating ewes and does. More recent studies on sheep, offered more comprehensive information, whilst those on goats mostly inclined to be significantly neglected, focussing on baseline values of minerals at various life stages. Small stock farming in Africa is mainly extensive. These African studies were predominantly conducted under intensive or semi-intensive conditions. A need for specific studies within the continent was identified. These should be based on the unique nature of each region and its influence on the dam and offspring, to adequately provide for mineral requirements in optimal growth and health of the kid and lamb. This is especially important for the significant number of goats across the African continent, as inadequate research data are available.

Key words: Pregnant, sheep, goats, minerals, offspring, deficiencies, toxic levels

LIST OF ABBREVIATIONS

AP	Alkaline phosphatase
Ca	Calcium
CAB	Commonwealth Agricultural Bureaux Abstracts
Cd	Cadmium
CK	Creatinine kinase
Cl	Chlorine
Co	Cobalt
Cu	Copper
DM	Dry Matter
ETM	Essential trace minerals
F	Fluorine
FAO/ FAOSTAT	Food and Agriculture Organization
Fe	Iron
FOA	Faostat
g/h/d	Grams/head/day
GIT	Gastro intestinal track
I	Iodine
IgG	Immunoglobulin G
K	Potassium
Mg	Magnesium
Mg/kg	Milligram per kilogram
Mn	Manganese
Mo	Molybdenum
MOD	March of Dimes
Na	Sodium
Ni	Nickel
NRC	National Research Council
P	Phosphorus
ppm	Parts per million

S	Sulphur
Se	Selenium
TMR	Total mix ration
Zn	Zinc

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1. INTRODUCTION

Sheep and goats are found globally. They are significant contributors to the economic existence of numerous low-input, small households, forming part of their social culture, specifically in developing countries (Kogsey, 2004; Kogsey, *et al.*, 2007). Africa and Asia indicate that the population of sheep and goats is increasing as they are better adapted to prevailing conditions, suitable for small-scale farmers (FAO, 2004). In the early 90s, globally, sheep comprised the second prevalent livestock category to cattle, followed by swine and then goats (Morand-Fehr *et al.*, 1999). In certain developed countries, such as Australia, New Zealand, and Argentina, sheep farming is well established compared to goats from the main small ruminants of developing countries (Morand-Fehr, *et al.*, 1999).

Figure 1 represents the global populations of sheep and goats in 2016 (OIE, 2016) where the population in Africa ranges from 1 million to over 70 million).

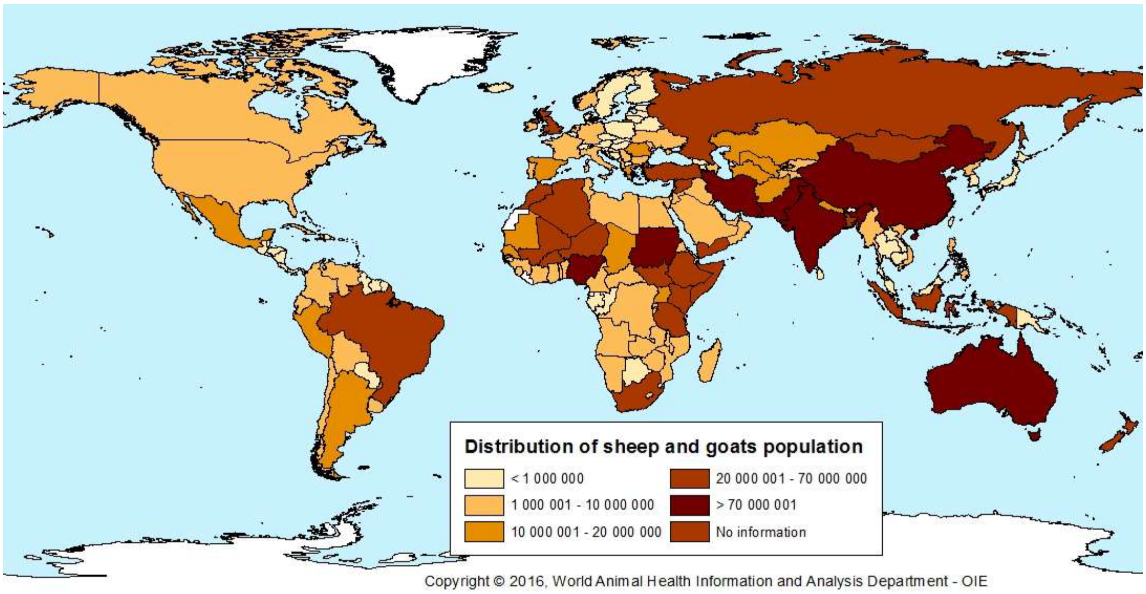

Figure 1. World distribution of sheep and goats (OIE, 2016)

The lower feed and capital needs of sheep and goats. Their shorter generation intervals, higher proficiency, and smaller size. Their enhanced utilisation of feed, including their ability to utilise crop residues. These factors render them more suitable than cattle for smallholder production systems. They would otherwise have insufficient value (Pelant, *et al.*, 1999; Devendra, 2002). Smallholder production systems refer to farmers on small land parcels, practising mixed farming (Kogsey, *et al*., 2006). Sixty-four per cent of small ruminant farming globally, are small holder production systems (De Hann, *et al*., 1996). This percentage is increasing (Skapetas *et al*., 2016). The global goat population increased by 33.79% from 2000 to 2013, whilst sheep population increased by 10.74% during the same period (Faostat, 2013). The population of goats increased by 30.23% in Asia from 2000 to 2013 and by 48.61% within the African continent (Table 1). In 2013, 59.38% and 35.00% the global goat population were in Asia and Africa, respectively (Table 1) (Faostat, 2013).

Table 1. Comparing goat population numbers in the World in 2000 and 2013 (FAOSTAT 2013).

	Goat Population		Change %	Contribution to global %
	2000	2013	2000 to 2013	2013
Asia	458 521 280	597 151 616	+30.23	59.38
Africa	236 852 594	351 978 256	+48.61	35.00
Oceania	2 396 231	3 972 060	+65.76	0.39
Europe	18 940 725	16 487 290	-12.95	1.65
E.U. (28)	14 509 183	12 411 308	-14.46	1.23
Americas	34 921 551	36 013 781	+3.13	3.58
World	751 632 381	1 005 603 003	+33.79	100

The global population estimated an increase from six billion in 1999 to over seven billion in mid-2013 and is expected to reach over eight billion in 2025 (Rosenburg, 2017). Urban living, increasing incomes and changing consumer preferences, also stimulate a need for small ruminants, such as meat, milk, skin and fibre (Kogsey, *et al.*, 2007). Goat milk is continuously recommended as a substitute for lactose intolerant patients and for babies with allergies. Goat milk has a higher protein, non-protein nitrogen and phosphate content than cows' milk, providing it with a higher buffering capacity (Park, 1994). The physicochemical properties of goats' milk also provide a higher digestibility and a healthier lipid metabolism than cows' milk (Park, 1994). The unique quality of sheep and goats' milk rendered it favourable in producing a variety of cheese and yogurt (Boyazoglu. *et al.*, 2001). Small stock also constitutes the traditional supply of locally produced mutton and goat meat in several countries (Boyazoglu, *et al.*, 2001).

The global trade in goat produce increased significantly within the Mediterranean region as the main goat milk and cheese producer (18%). India (22%) has the highest goat milk volume globally. Australia is the most significant global goat meat exporting country (60%); South Africa is the major mohair producer (50%); and China is the principal cashmere exporter (65%) (Dubeuf, *et al.*, 2004). According to Faostat (FOA) (2014) statistics, 45.4% and 28.1% of the global sheep population was established in Asia and Africa respectively, compared to only 10.8% in Europe; 8.5% and 94.4% of the total global goat population was established in Asia and Africa (Figure 2).

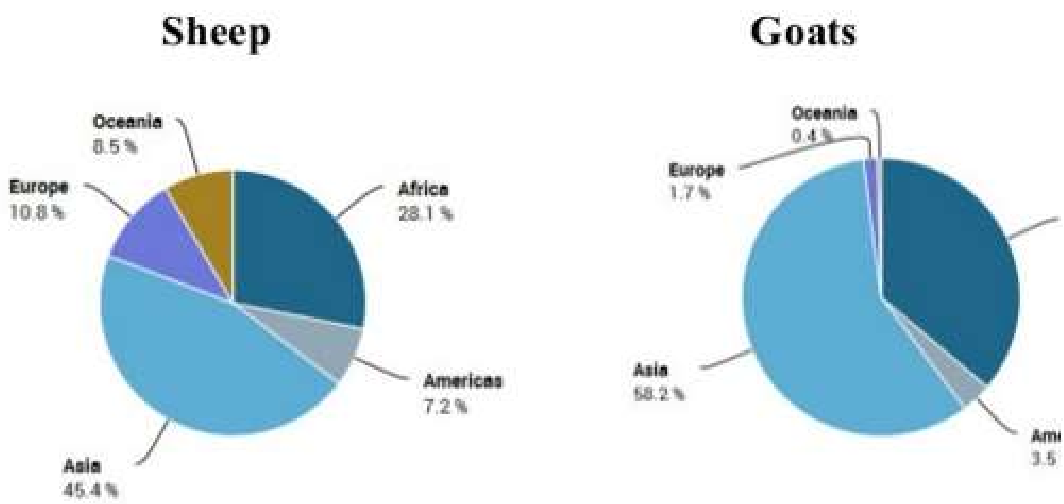

Figure 2: The world sheep and goat population in 2014. (Schoenian, 2015)

Profit in the livestock industry depends on the efficiency of production, determined by the optimal growth of animals (Redmer, *et al.*, 2004). Maternal nutrition is a main extrinsic factor affecting the growth, development and function of major foetal organs

(Wallace , *et al.*, 1999; Godfrey & Barker, 2000; Godfrey, 2002; March of Dimes, 2002; Symmonds, *et al.*, 2003; Gopalakrishnan, *et al.*, 2004)

Nutrition during conception and pregnancy in animals, contributes meaningfully to the ability of the animal to conceive and complete a successful pregnancy. It is also of major importance in the survival, growth, and development of the foetus. This includes the health and productivity of the offspring throughout its life (Godfrey, *et al*., 2000; Godfrey, 2002). According to Redmer, *et al*. (2004), maternal nutrition during pregnancy should not be underestimated, especially concerning the potential effect on the efficiency of livestock production and health.

Barker *et al*. (1997) indicate that maternal nutrition is most likely to critically influence the intra-uterine environment and hence, foetal and placental growth. Additional studies in animals indicated that malnutrition of the dam causes reduction in the placental foetal blood flow, indicating stunting foetal growth (Wu, *et al*., 2004). It was also established that nutritional deficiencies of the dam, comprising essential nutrients, such as energy, protein and micronutrients influences foetal growth (Wu, *et al.*, 2004) and the growth of specific organs in the foetus, such as the liver and skeletal muscles (Brameld, *et al.*, 2000).

Deficient nutrition of dams leads to premature births, decreased birth weight and high mortality rates from birth to the offspring's first living year (Wallace, *et al*., 2002; Belkacemi, *et al*., 2010). When foetal growth is affected, it can lead to postnatal cardiovascular and metabolic complications in the offspring (Lea , *et al.*, 2003; Greenwood & Bell, 2003). Development of the foetus depends on hormonal, nutritional, and metabolic factors, enacting on the intra-uterine environment and foetal growth (Igwebuike, 2010). Critical periods of development are present in pregnancy, such as the periods of rapid cell divisions and alteration. This stage of development in the foetus would indicate permanent consequences in the offspring (Igwebuike, 2010). Organogenesis in the foetus occurs during the early part of gestation; foetal growth is usually limited to the last third of the pregnancy (days 90 to 145 in sheep and 80 in 120 in goats) (Figure 3) (Redmer, *et al*., 2004; Smith, *et al*., 1994).

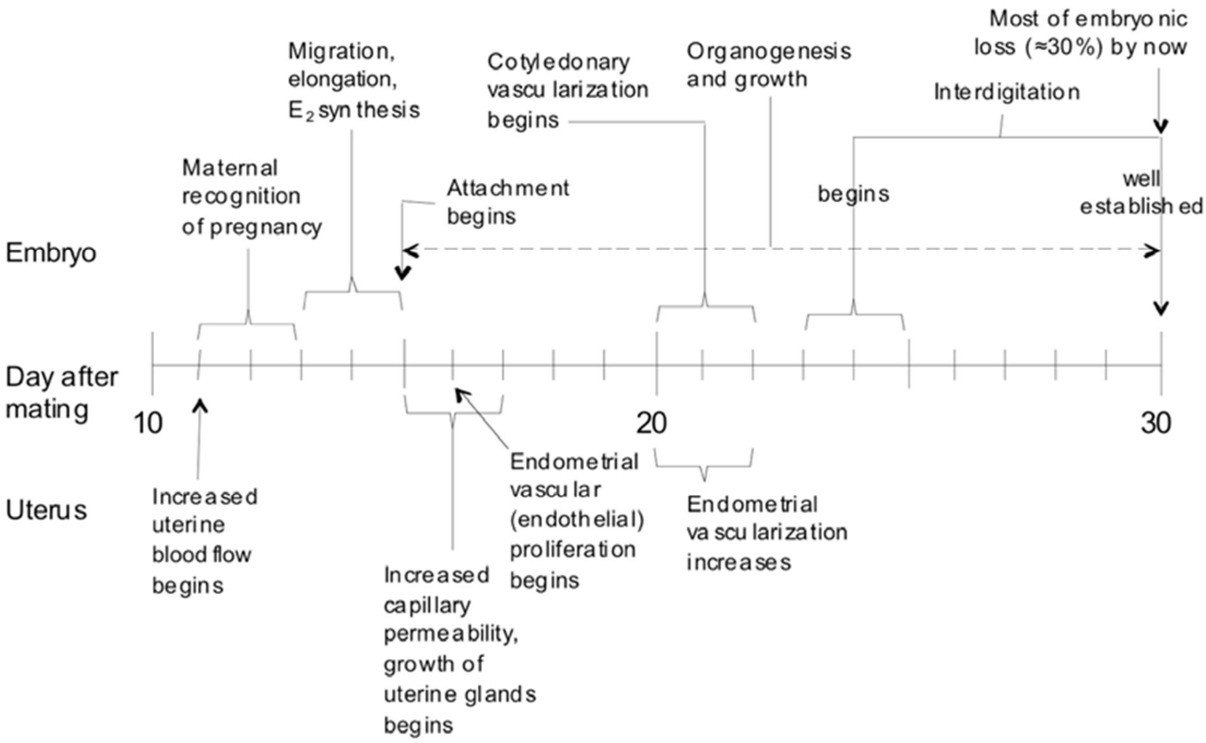

Figure 3. Timeline of placental and embryonic fetal development during early pregnancy in sheep (Reynolds, et al., 2013).

The aim of this study was to establish the impact of minerals on the health of pregnant ewes and does and their offspring, within the African continent, derived from literature of studies conducted. A systematic review was conducted on articles presenting information on studies within the African continent, investigating the effects of the mineral content of feed of the dam, with the greatest impact on the ewe or doe during all stages of pregnancy and on their offspring. The focus on Africa stems from developed countries, producing the most scientific and technological sheep and goats knowledge (Morand- Fehr, *et al*., 1999). This may be acceptable in sheep as they hold a higher global population, creating a lack of information in goats. Fifty per cent of the research conducted on goats, occurs in countries with only 5% of the world's goat population (Morand-Fehr, *et al*., 1999) (Table 2). In developed countries with intensive production systems, it is possible to formulate balanced rations for energy, nitrogen, and mineral needs (Morand- Fehr, *et al*., 1999). In tropical and subtropical environments, operating extensive management systems, it is difficult to adopt the same strategy (Morand-Fehr, *et al*., 1999).

A substantial limitation still exists in the nutritional research of small ruminants. It is difficult to define a particular feeding method for various environmental scenarios (Morand-Fehr, *et al*., 1999). In intensive management systems in developed countries, animals are fed according to their production potential, on diets with all the necessary ingredients, in controlled quantities (Lanyasunya, *et al*., 2005). These topics, under extensive management systems intake, are determined by factors, such as palatability and grazing habits. Sheep are inclined to graze on the short green leafy portion of grass, whilst goats are browsers, preferring shrubs and trees (Osoro, *et al*., 2013; Dannhauser & Jordaan, 2015). Livestock are inclined to be selective and prefer to graze palatable herbage first. This selection is based on soil and moisture differences within the camp, various species of grass and maturity of the grass strands. Certain parts on the same stem, such as young leaves, are preferred to older leaves (Dannhauser & Jordaan, 2015).

The climate conditions determine the type of vegetation found in any particular region (Oberem & Oberem , 2011). A major consideration determining vegetation is the volume of rain (Dannhauser & Jordaan, 2015). Regions characterised by high rainfall in South Africa are grass or savannah land, comprising trees and grass. Drier areas are characterised by Karoo bush and desert plants. In areas where winter rain prevails, vegetation is characterised by fynbos plants (Proteas, Ericas and restios, amongst others) (Dannhauser & Jordaan, 2015).

Additional factors affecting the vegetation type are temperature, geology, topography, burning practices and management concerning grazing (O Connnor, *et al*., 2010;

Dannhauser & Jordaan, 2015). During dry seasons, small stock is often deficient in essential nutrients when grazing relies intensely on crop residues (Minson, 1982). Most small holder farmers have limited resources available and cannot afford nutritional supplements (Lanyasunya, *et al*., 2005). The risk for mineral deficiencies in their small stock are therefore increased (Olivier, *et al.*, 2002). Small holders keep animals for multiple social and economic purposes. Unlike commercial farmers, increased productivity is not always their primary goal (Kogsey, 2004).

Morand-Fehr *et al*. (1999) indicate that an analysis to balanced rations for energy, nitrogen and mineral needs of stock, were established in developed countries, using genotypes mostly in intensive production systems. According to these authors, it may not be accurate to assume that nutritional requirements for genotypes, developed under extensive farming systems in tropical and subtropical environments, are the same. According to Baker *et al*. (2004), indigenous breeds survive better in Africa than European breeds. These breeds took generations to adapt to their environments. Indigenous breeds authenticated a range of unique adaptive traits, including disease and heat resistance, water tolerance, the ability to utilise deficient quality feed more effectively and still be productive in a tropical environment (Baker, *et al*., 1994).

Table 2: Geographic origin of general scientific articles published worldwide on studies in sheep and goats from April 1992 until April 1993

	Scientific articles (% of total)	Number of animals (% of total) (FAO, 1994)
Asia	37.0	61.2
South America	3.3	3.7
Africa	13.5	28.9
Total developing countries	53.8	93.8
North America	12.6	2.5
Oceania	4.6	0.2
Europe	30.4	2.4
Total developed countries	47.6	5.1

(Morand-Fehr & Boyazoglu, 1999).

Analytical research prevails over global systemic research (Table 3) especially regarding "viable and economically durable production systems aimed at technical-economic optimization" (Morand- Fehr, *et al*., 1999). Studies based on nutrition,

Table 3. Principal disciplines addressed in the articles based on sheep and goats published in Commonwealth Agricultural Bureaux (CAB) between April 1992 and April 1993.

: Disciplines	l articles published on the subject (%)
Pathology and Parasitology	39.7
Nutrition (including value and use of feedstuff)	21.3
Anatomy and Physiology (including reproduction physiology)	17.8
Genetics selection (including breed evaluation)	5.9
Products (including milk and including milk products, carcass meat, hair and skins)	10.8
Livestock breeding systems and monographs	4.5

(Morand-Fehr & Boyazoglu, 1999)

2. JUSTIFICATION OF LITERATURE REVIEW

Nutrients are defined as constituents of food or the products of metabolism of such constituents, released through digestion, and absorbed from the digestive tract (Mcl. Dryden, 2008). Nutrients are considered essential in providing raw materials required for body tissues and animal product synthesis, maintaining basic life processes (Mcl. Dryden, 2008). Essential nutrients are required for proper functioning of the animal's body. The body does not produce nutrients sufficiently to meet the animal essentials (Mcl. Dryden, 2008). Such nutrients comprise amino acids, certain fatty acids, minerals, and vitamins.

Most conventional foods contain sufficient essential nutrients for the requirements of the animal (McL. Dryden, 2008). When any of these nutrients are in short supply, with a serious detrimental effect, it is known as a 'limiting nutrient'. This is a nutrient, deficient in the diet. The animal responds positively when such nutrient is provided as a supplement. Customarily, supplementation of limiting nutrients provides improved health and productivity (Mcl. Dryden, 2008).

Nutrition is conceivably the most crucial determining factor involved in livestock's reproductive performance. This is attributable to the direct effect of nutrition on reproduction and its potential to moderate the effects of additional factors, such as:

- Genetic merit.
- Physical environment.
- Management (Smith, *et al*., 2000).

Nutrition can assist mediocre biological types to reach their genetic potential, alleviate negative effects of a harsh physical environment, and lower the effects of deficient management techniques. Malnutrition lowers performance and exacerbates adverse environmental effects (Smith, *et al*., 2000).

Minerals are crucial nutrients with great significance on production in ruminants (Kahn, 2012). Minerals are required in the animal body for several functions, including developing the skeleton. Minerals are constituents of the proteins and fats, structuring muscles, blood cells and internal organs. Minerals are useful in numerous enzymatic interactions in the body (Jackson, *et al*., 2000). Church *et al*., (1988) report that, "minerals are inorganic chemical elements that are actively involved in enzymatic reactions, have specific functions, and are critical to life". Minerals are divided into two classes, based on the quantity needed in the diet (Pugh, 2002).

Macro-minerals, such as calcium (Ca), phosphorus (P), sodium (Na), chlorine (Cl), magnesium (Mg), Potassium (K) and Sulphur (S) are expressed in percentages (Jackson, *et al*., 2000; Pugh, 2002; Mcl. Dryden, 2008). Micro-minerals are expressed in ppm or mg/kg; these include iodine (I), copper (Cu), molybdenum (Mo), cobalt (Co), iron (Fe), zinc (Zn), manganese (Mn), fluorine (F), nickel (Ni) and selenium (Se) (Jackson, *et al.*, 2000; Pugh, 2002).

The importance of minerals is not based on their concentration in the animal's body, but on their biological functions (Annicchiarico & Taibi, 2004). Minerals incline to have multiply interactions between each other. A lack or abundance of a mineral can render others as either deficient or toxic (Jackson, *et al*., 2000; Mcl. Dryden, 2008). Jackson *et al*. (2000) indicate that Ca, Fe, and Cu are known to interfere with the metabolism of other minerals and vitamins.

2.1 Mineral functions

McClure (2003) affirms, "trace elements are components of and cofactors for enzymes and therefore have a pivotal role in biochemical reactions. Biological functions often involve the activities of multiple enzymes. Mineral deficiency has a considerable and varied scope for limiting a range of immunological responses, either directly or [through] other physiological systems". The major minerals and trace elements, such as Fe, Cu, Zn, Mo, Se, Co and I, perform catalytic parts in enzyme systems; they are either integral components of metallic-enzymes or behave as activators within enzyme systems (McClure, 2003). They are involved in activating enzyme reactions by:

- Participating in oxygen metabolism and transport.
- Hormone biosynthesis.
- Nerve and muscle function.
- Protein synthesis.
- Catabolism.
- Energy metabolism.
- Absorption of sugars and amino acids from the digestive system.
- Synthesis of essential vitamins in the rumen (Mc Clure, 2003).

Trace minerals hold a crucial purpose in the functioning of the immune system, significantly influencing animal performance (Tomlinson *et al.*, 2008). Trace mineral deficiency affects most physiological processes, such as growth, reproduction, immunity and milk production, amongst others (Kundu, *et al.*, 2014).

Calcium and P are the two most important macro-minerals needed for bone growth and maintenance (Kumaresan, *et al*., 1984). Calcium also functions in osmoregulation and muscle contraction and blood clotting. Phosphorus is essential in various aspects of energy metabolism and absorption, contributing to skeletal tissue forming (Hafez, *et al*., 1969; Kumaresan, *et al*., 1984).

Minerals are crucial in regulating cell replication and differentiation and in their absorption and functioning. Deficiency of Cu results in a decrease in the absorption, mobilisation, and utilisation of Fe (McClure, 2003). Mineral intake in small stock depends on the availability of a mineral in the feed, its bioavailability, and the presence of antagonistic actions of other minerals in the animal's gastro intestinal track and body. Grazing sheep can consume soil, whilst grazing. This soil consumption exceeds 10% of their dry substance intake during winter, drought or in arid conditions (Suttle, 1975). High dietary iron indicated to be antagonistic, reducing copper status in sheep (Grace & Lee, 1990). High Cu levels may cause a deficiency of Mo and deplete Zn liver levels in grazing animals.

2.2 The effect of management systems in mineral intake

The availability of minerals to both the dam and offspring, depends on the intake (availability, palatability), absorption (bioavailability: organic versus inorganic) and whether antagonists are present. Organic mineral sources imply to be more available than standard inorganic sources (Ledoux & Shannon, 2005). Interactions, such as between Cu, Mo and S, influence the availability of organic Cu sources (Ward, *et al.*, 1996). Ward *et al*. (1996) indicate that Cu proteinate and Cu sulphate were effective in supplying Cu to cattle on a low dietary Mo, when higher dietary levels of Mo were fed, Cu from Cu proteinate sources became more bioavailable.

Feed and forages provided in rations, usually provide all the animals necessary mineral nutrients needed (Annicchiarico, *et al*., 2004). Certain nutrients may become limited, attributable to the type and level of production expected from the animal, and the type of digestive system involved (Mcl. Dryden, 2008). Ruminants have a higher tendency towards limiting nutrients, attributable to the synthesis of nutrients by the reticula-ruminal or large intestinal microorganisms compared to monogastric animals (Mcl. Dryden, 2008). Where nutrients are insufficient, it can be supplemented, such as with 'licks'. Seasonal differences (wet or dry) can affect the mineral status of small stock in extensive farming systems mainly, discussed in further detail below.

Animals fed on planted pastures or total mixed ration (TMR) may suffer less from nutritional deficiencies. When animals are managed in extensive conditions, deficiencies of certain elements may occur, specifically if the element is deficient in the soil (Oberem, *et al*., 2011). The mineral concentration of forages depend on soil pH, soil fertility, species of forage, maturity stage of the forage, season and climate, irrigation water and atmospheric inputs (National Research Council (NRC), 2007). Other factors include, using fertilisers in the soil and plant growing techniques and digestibility and availability of minerals dependent on the dry matter content of the feed. The vegetative phase of the plant, season of harvesting, and the palatability of the feed is also crucial in supplying essential nutrients to the animal (Annicchiarico & Taibi, 2004).

Metals occur naturally in the environment, though the rate of toxic metal concentrations in nature inclines to be increased by anthropogenic activities (Che Nde, *et al*., 2018). This occurs, attributable to the continuous discharge of waste water effluent from industrial plants, surface erosion from agricultural areas, mining and waste dump materials that may contaminate rivers (Che Nde, *et al*., 2018). The ingress of human and animal waste, discharge of domestic and industrial waste water, pesticides and fertilisers also affect the soil (Edokpayi, *et al*., 2018). These effects are observed to particularly increase in arid and semi-arid areas where fresh water resources are scarce (Che Nde, *et al*., 2018). The acidity and alkalinity of water also influence the growth of plants, benthic organisms and soil and crops when used for irrigation. The pH level could be an indication of heavy metal contamination as Cu, Zn and Cd are associated with low pH values (Edokpayi, *et al*., 2018). Areas with high rainfall with water sources close to sewages, landfills, dumpsites and agricultural run-offs (fertilisers and fungicides) are often contaminated by leachates leading to high levels of Cr, Fe and Mn in the soil (Edokpayi, *et al*., 2018). Some South African areas indicate nitrate leaching in ground water. This condition leads to oxidation and a decreased pH level, causing Fe dissolution, increasing the Fe concentration in the water (Edokpayi, *et al*., 2018).

Nutrient availability, specifically the mineral content of forage, influence reproduction and productivity (Kundu, *et al.*, 2014). In arid and semi-arid regions, feed resources are often inadequate to feed the animal throughout the year and deficiencies of Cu, Se and Zn occur in ruminants (Kundu, *et al.*, 2014). Climate conditions, such as heat and cold stress, are also crucial in the availability of these essential nutrients (Annicchiarico *et al.*, 2004). Heat stress causes a marked decrease in intake of feed, leading to nutrient deficiencies (West, 1999). Animals incline to reduce their feed intake, to decrease the heat from feed metabolism (Kadzere, *et al.*, 2002). Heat stress also directly influences the feeding centre of the hypothalamus, causing hormonal responses that decrease the metabolic rate (West, 1999; Johnson, 1985). Cold stress conversely, leads to body energy reserves being used for body heat generation instead of productive functions; this leads to decreased productivity and subsequently, decreased nutritional efficiency (Young , 1983).

In peak productivity periods, feeding supplements or exploiting integrated commercial feeds, assist to supply the needed nutrient (Annicchiarico, *et al*., 2004). Supplements can be administered as licks or it can be injected (Oberem & Oberem, 2011). Lick maintenance supplements in sheep are known to be unreliable though, as sheep incline to vary their intake, depending on the palatability of the maintenance lick, thus it may not be a good option in highly productive animals (Oberem, *et al*., 2011).

Forage comprises the main feeds for small ruminants in grazing and in several intensive systems (National Research Council, 2007). Cereals represent the main feeds in intensive finishing systems of animals. Forages are rich sources of K and Fe but incline be deficient in Na, whilst cereals are rich sources of P (National Research Council, 2007). Forages are main sources of Zn in the adult animal. The mineral content of forage varies and inadequate supply causes several deficiencies (Kundu, *et al*., 2014).

Sheep incline to survive in areas of variable agro-climatic characteristics on wide extensively managed pastures, whilst goats are commonly found in dry tropical and subtropical areas of deficient agricultural potential and marginal lands (Morand- Fehr & Boyazoglu, 1999). Sheep graze on the short green leafy portion of grass, whilst goats are browsers, preferring shrubs and trees (Osoro, *et al*., 2013; Dannhauser, *et al*., 2015).

2.3 Role of minerals in the health of the offspring and the pregnant animal

The interaction between nutrition and reproduction must be understood to minimise potential negative impacts and enhance positive impacts and to gain the full efficiency in livestock production. Production mainly depends on reproductive performance (Smith, *et al*., 2000). The physiological status of the animal, including various stages of gestation or lactation, partake in the utilisation of various minerals. Increased quantities of minerals are absorbed during gestation, allowing foetal growth and are supplementary during the first months of lactation (Annicchiarico, *et al*., 2004).

Hostleter *et al*. (2003) observed that the mechanisms controlling the utilisation of nutrients in pregnancy are not comprehended. Understanding these mechanisms, leads to an increase in the survival of viable offspring and assists to establish the period during pregnancy when these essential trace minerals are needed the most. Knowledge would assist in formulating accurate feeding plans. The mineral demand per unit of body weight of the growing animals is higher than those of adults (Kumaresan, *et al*., 1984). Improper ewe nutrition from mid to late pregnancy can reduce mammary development, alter colostrum quality, reduce colostrum quantity and birth weight of the offspring and may cause negative implications for lamb health and survival during the early postnatal period (Swanson, *et al*., 2008).

Proper nutrition of the ewe in gestation, improves lamb vigour and immunological transfer to support a successful reproductive event. A study on the effect of nutrition in reproduction of farm animals observes that maternal nutrition through its effects on foetal metabolism, growth and colostrum production, is significant in neonatal availability (Robinson, 1990). Maternal undernutrition has a detrimental influence on birth size of the offspring (Robinson, 1990). Birth size is essential to the survival of the lambs (Robinson, 1990).

Young animals absorb considerable quantities of minerals, assisting in tissue formation and skeletal development; the rate of mineral absorption inclines to decrease with the increasing age of the offspring (Annicchiarico, *et al*., 2004).

2.4 Diseases attributable to mineral deficiencies

Zinc is important in a range of metabolic and productive functions, including growth, reproduction and its effect on the humoral immune system (Prasad, *et al*., 1995; Underwood, *et al*., 1999; Abdel-Monem, *et al*., 2011). Studies on cows, by Lanyasunya *et al*., (2005), indicate that mineral deficiency was strongly associated with decreased reproductively. A decrease in P intake led to inactive ovaries, delayed sexual maturity and lowered conception rates. The effect of I on the thyroid gland was also investigated. Inadequate I reduced conception rates and ovarian activity, whilst excess I was associated with abortions and a reduced resistance to infection and disease. Deficiencies in Co, Mn and Cu were associated with impaired ovarian functions, silent oestrus and abortion (Lanyasunya, *et al*., 2005). Kumaresan *et al*. (1984), established that serum Ca, P and alkaline phosphatase increased in pregnant goats. These increases were attributed to foetal osteoblastic activities (Kumaresan, *et al*., 1984).

Calcium deficiency caused milk fever in lactating cows, whilst Se deficiency increased the retention of placentas (Lanyasunya, *et al*., 2005). Abdelrahman (2008) reports that the Ca requirements in pregnant ewes in late gestation increases rapidly, attributable to high foetal growth. A Ca deficiency could result in deficient growth and bone development in growing newborn lambs. As two-thirds of the birth weight of a developing foetus is gained in the last six weeks of gestation, balanced nutrition of the dam in late gestation is crucial for developing the foetus and the newborn's survival. An increase in the intake of K, delayed the inception of puberty and ovulation, impaired corpus luteum development and increased anoestrus in heifers (Lanyasunya, *et al*, 2005).

Adding S to licks may cause deficiencies of Cu, Mn, Mg in ewes and lambs and Zn in ewes, whilst the Zn levels remained constant in the lambs (Boyazaglou, *et al*., 1972). This was interpreted as an indication of preferential protection of lambs by ewes during lactation (Boyazaglou, *et al*., 1972). Excessive S intake in lambs decreased the circulating tocopherols and antioxidant capacity of the body, thus increasing tissue wear and tear (Boyazaglou, *et al*., 1972).

2.5 The effect of mineral nutrition on the offspring

In establishing the age of the offspring, studies indicate the neonatal period as the first week after birth when the offspring is the most vulnerable, depending upon its mother (Richet, *et al*., 1985; Mellado, *et al*., 2000; Nowak, *et al*., 2000; Castro, *et al*., 2009). Piccione *et al*., (2002) in their study of rhythmic body temperature in lambs and foals, covered a thirty-day period. It is stated though that "the efficiency of thermal homeostatic mechanisms in the offspring is confirmed by the existence of a rhythmic pattern of body temperature that emerges within the first 10 days of birth fully maturing during the first month of life" (Piccione, *et al*., 2002). Deficiencies of certain aforementioned minerals, have an adverse effect on pregnancy and the offspring (Table 6).

Inadequate nutrition of the dam can cause low body weight of the offspring and a decrease in the ratio of potential for heat exchange (body surface area) and heat production (body weight). Poor heat exchange may lead to vulnerability of the newborn that might lead to death from hypothermia in cold conditions at birth, or from dehydration or heat stress in a hot environment (Robinson, 1990).

Church (1988) established that foetal requirements are measurably significant only in the last trimester. Deficiencies of certain nutrients can be influential at any time of gestation. Trace minerals found in the offspring, depend on maternal transfer through the placenta, colostrum and milk.

Any cause of placental insufficiency leads to the retardation of foetal growth (Aitken, 2007). When undernutrition is severe some weeks prior to mating and seven days post fertilisation, it has a significant negative effect on the subsequent growth patterns of the placenta and foetus (West, *et al.*, 1991; MacLaughlin, *et al.*, 2005). Undernutrition during early pregnancy and up to 55 days of pregnancy, influences the feto-placental growth negatively, especially when multiple foetuses are present (Aitken, 2007). Overfeeding at this critical stage also decreases the chance of embryo survival as there would be an increase in the hepatic blood flow, intensifying the metabolic clearance of progesterone. Clearance of progesterone, occurring too quickly, inhibits early embryonic cell division as elevated levels of progesterone are required at this stage (Aitken, 2007).

Undernourishment of the pregnant ewe causes a decrease in producing colostrum and milk and in the composition of colostrum (Mellor, 1988). Retinol, insulin-like growth factors and their binding proteins, affect macromolecule-absorption (Aitken, 2007). It was observed that lambs from Co deficient ewes, have lower Immunoglobulin G (IgG) antibodies plasma concentrations than lambs from Co sufficient ewes (Fisher & Macpherson, 1991). When insufficient quantity and quality colostrum and milk is ingested, owing to lamb weakness, competition with other lambs and inadequate mothering or deficient colostrum production, lambs would have depleted body energy reserves and become hypoglycaemic (Aitken, 2007). This leads to cerebral compromise in warm conditions or hypothermia in cold conditions (Aitken, 2007). Inadequate intake of colostrum or milk by lambs, leads to impeded maturation of their gut and growth, impeding them. It could cause long-term deleterious effects in lambs that starved after birth (Aitken, 2007). The newborn is also deprived of its only significant source of Immunoglobulins antibodies, assisting in providing protection against infections leading to diarrhoea, pneumonia and septicaemia, amongst others (Mellor, 1988).

Deficiency of Zn in the dam could lead to a compromise in the lamb/kid's development, leading to deficient birth weight (Darnton-Hill, 2013; Kundu, *et al.*, 2014). The bioavailability of Zn is also depends on interactions with other trace minerals. Consuming Ca, Cd, Ni and phytic acid could adversely affect Zn absorption, leading to a secondary Zn deficiency (Kundu, *et al*., 2014). Deficiency of P in the mother, may produce weak or stillborn lambs (Church, 1988). In the case where pregnant sheep graze on Cu deficient soils, they can give birth to weak sway back lambs (Church, 1988). Insufficient I intake by the pregnant ewes, causes foetal hypothyroidism, resulting in increased perinatal mortality and birth of weak lambs with delayed skin and wool follicle development (Campbell, *et al*., 2012). Deficiency of I also affect the development and mineralisation of bones (Campbell, *et al*., 2012). In goats Mn deficiency leads to kids with a reduced birth weight (Church, 1988).

3. BENEFITS OF THE STUDY

A benefit of the study would be to identify areas of lacking research concerning minerals on the pregnant ewe, doe and their offspring within the African continent. The results of the study could form the basis for future research that would target the core minerals required for the ewe, doe and offspring in the African situation. Africa comprises economic, nutritional challenges and the genetics that developed under the natural selection. These factors would be considered where the findings could initiate formulating a cost-effective supplement to be used by African farmers for the animals. This study was required in partial fulfilment for an MSc degree, gaining knowledge in an aspect of a field of nutrition that could serve as a foundation for further research.

4. AIMS

The aim of the study was to investigate available studies on the effect of mineral status and intake on the ewe and doe and how this influence the health and survival of the offspring, focussing within the African continent. Another study aim was to identify areas, lacking available information on mineral needs of indigenous African breeds under extensive conditions, to meet the mineral needs of pregnant ewes, does and their offspring.

5. MATERIALS AND METHODS

5.1 Study design

A systematic literature research, based on articles relating to the effect of minerals on the pregnant ewe and doe that may affect the survival and health of their offspring, was conducted globally and within African regions. Studies of global articles, including the African continent, were observed. The study had to decide on involving pregnant animals or the offspring alone, or both pregnant animals and their offspring.

A bibliographic search was conducted according to the following topics:

- Type of articles considered, were full articles, involving scientific journals, conference papers, proceedings and agricultural reports. The inclusion of conference papers, reports and proceedings does not exclude publication bias. The research involved cohort, cross sectional, case control and analytical studies.
- Epidemiological parameters of interest considered, comprised the maternal mineral nutrition of sheep, goats and their offspring within the geographical region of Africa.

5.1.1 Data inclusions

Each selected article was broadened by obtaining the full text where possible, identifying minerals (micro and macro), affecting the pregnant ewe, doe and the offspring. Inclusion criteria were based on whether:

- A mineral was included in the study.
- An effect was observed in the offspring or pregnant animal, whether positive or negative.
- The research was based within Africa.
- The study observed the period between 1910 and 2017.

5.1.2 Data exclusions

Analyses were excluded when the sample stock was not pregnant. The study was conducted within the African diaspora. Duplicated articles and articles composed in global languages (excluding English) were also excluded.

5.1.3 Databases

The web of science (all databases) was employed. These database was chosen as it comprises a wide range of data on agricultural and medical aspects of sheep and goat.

These databases include: Web of science core collection, Biosis citation index, Cabi, current contents connect, data citation index, Derwont innovations index, Food Science and Technology Abstracts (FSTA), Food Science Resource, KCI Korean Science Database, Medline, Russian Science Citation Index, SciElo Citation Index and zoological records.

5.1.4 Search strategy

The study used search terms individually, where after combining the various search terms to obtain results:

- Caprine.
- Ovine.
- Ewe.
- Goat.
- Lamb.
- Sheep.
- Goats.
- Ewes.
- Small ruminant*.
- Kid and doe.
- Pregnant*.
- Neonat* (lamb, kid, offspring, young, newborn and foet*).

Minerals:

- Copper.
- Iron.
- Selenium.
- Calcium.
- Phosphorus.

- Sodium.
- Chlorine.
- Magnesium.
- Potassium.
- Sulphur.
- Iodine.
- Molybdenum.
- Cobalt.
- Zinc.
- Manganese.
- Fluorine.
- Nickel.

These country names were combined to establish global locations:

- West Africa, Benin, Burkina Faso, Ivory Coast, Cape Verde, Gambia, Ghana, Guinea*, Liberia, mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo.
- East Africa, Burundi, Tanzania, Kenya, Uganda, Rwanda, Djibouti, Eritrea, Ethiopia, Somalia, Madagascar, Comoros, Mauritius, Seychelles, Reunion, Mayotte, South Sudan.
- North Africa, Western Sahara, Morocco, Algeria, Libya, Egypt, Sudan, Tunisia.
- South Africa, Lesotho, Swaziland, Mozambique, Namibia, Zimbabwe, Botswana, Zambia, Malawi.
- Central Africa, Sao Tome, Central African Republic, Chad, Congo*, Rwanda, Burundi, Angola, Cameroon, Gabon, Equatorial Guinea.

Searches for global locations were subsequently combined individually with searches one to three, establishing African numbers by regions.

5.1.5 Data collection

The title and abstract established and screened all articles to eliminate duplicates and studies within the African diaspora. Each selected article was studied to identify minerals (micro or macro), affecting the pregnant ewe, doe and their offspring.

6. RESULTS

The results are based on the data gained from this study, globally and within African regions. The study Prisma (photo-editing application) flow diagram provides an indication of the results obtained through the systematic literature searches on small stock, pregnant, offspring and minerals.

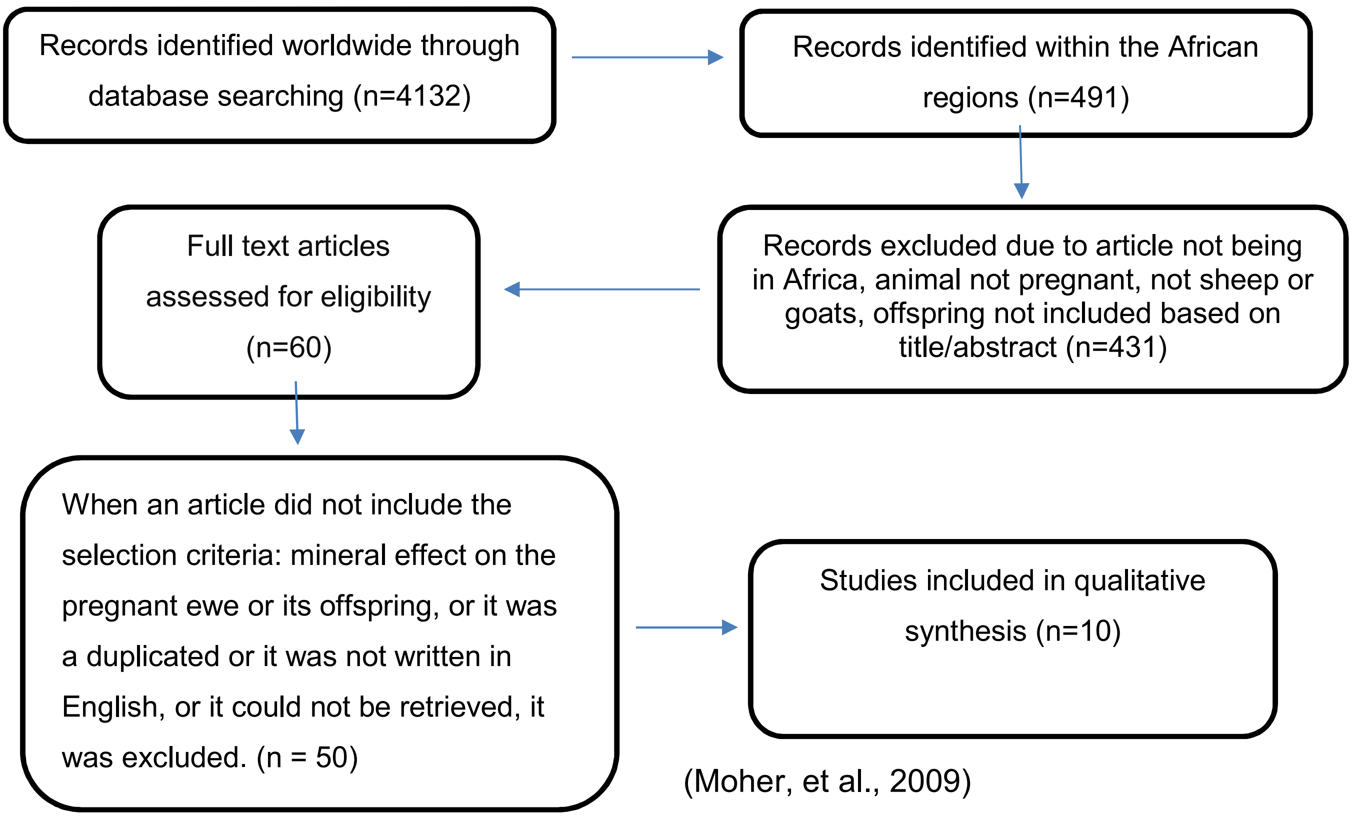

Figure 4. Prisma Flow Diagram

Twelve databases were searched on a time scale (1910-2017); 10 studies were eligible to be included in this systematic review (Figure 4). Literature on global studies established within the Web of Science databases on the topic, were compared to those established in African countries (Table 4). Results of the African search was also compared to studies conducted in Australia; Australia is considered a developed nation, having similar arid and semi-arid conditions, alike those established within the African continent. The results obtained, agreed with studies by Morand-Fehr *et al*. (1999) (Tables 2 and 3) indicating research to be more prevalent in developed than developing nations and more analytical than systematic studies conducted.

Table 4. A systematic literature search indicating the availability of studies done on the African continent and Australia on minerals in small stock

Topic searched	World	West Africa	East Africa	North Africa	South Africa	Central Africa	Australia
Small stock	3,413,504	39,942	22,038	17,845	36,037	9,589	28,505
Minerals	9,687,464	92,625	26,485	30,136	45,677	12,536	37,632
Pregnant, small stock & offspring	34,885	951	516	397	836	159	763
Pregnant, small stock & offspring & minerals	4,132	194	82	80	108	27	121

From the original 491 articles established within African continent, only 60 were available in full text. All articles where a mineral effect was not observed on both the pregnant dam and the offspring, duplicated articles, articles in other languages than English and those where the complete article could not be retrieved, were removed. The qualitative synthesis comprised a final 10 articles.

Global research performed on minerals in sheep and goats focused mainly on Ca, Mg and Se in both species. (Figure 5).

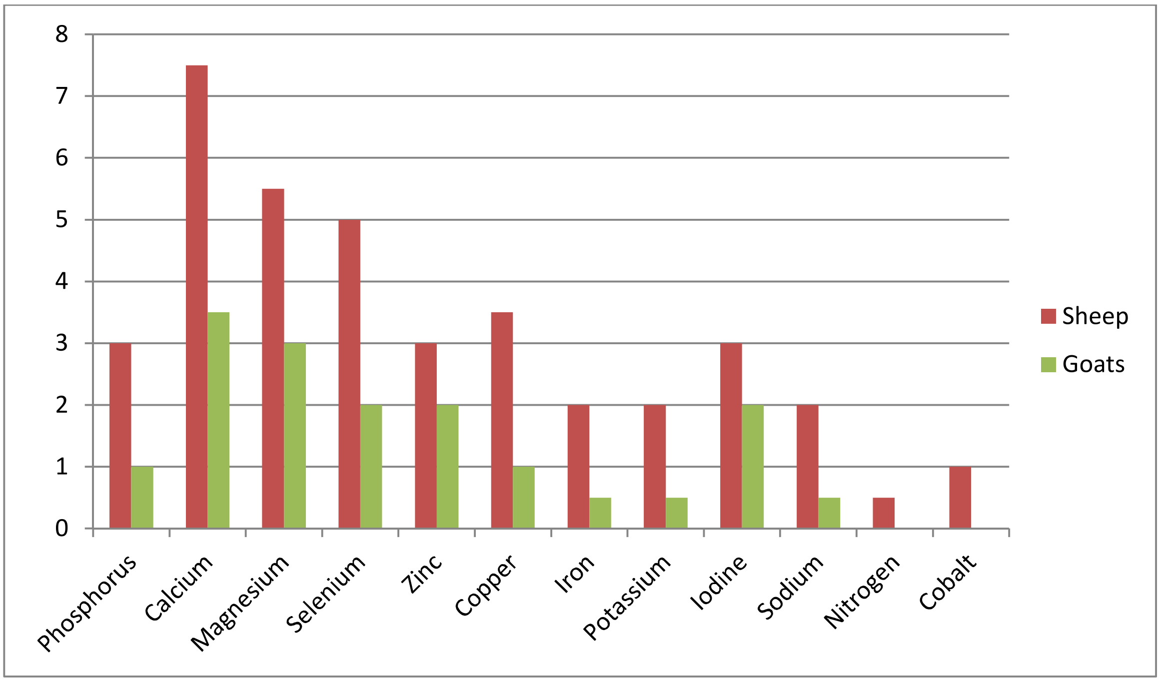

Figure 5: Number of articles cited worldwide focusing on the effects minerals have on various functions in sheep and goats.

In this study, the most frequently cited minerals researched, impacting on sheep and goats' health and production during pregnancy globally, were Ca, Mg, Se and Cu followed by P, Zn and I. Less literature was available on Fe, K and Co. Seven of these eleven aforementioned minerals were identified as affecting ewe or doe health and foetal survival (P, Ca, Mg, Se, Zn, Cu and I) (Table 5. The lack of minerals indicated to contribute to osteoporosis (P, Ca and Cu), grass tetany (Mg, K and Na), anaemia (Cu, Fe and Co) and hair loss or low quality wool (Ca, Zn and I) in sheep. Iodine deficiency in sheep was indicated as a cause of abortion and still birth, whilst Se caused white muscle disease (Table 5).

Table 5: Various mineral deficiencies that may lead to disease conditions or loss of production of the pregnant ewe/doe and /or their offspring.
(Nwosu, et al., 2017)

	CONDITIONS										
Mineral Deficiency	Abortion	Lowered immunity	Hair loss/poor	White Muscle	Still born	Rickets/ Osteoporosi	Paralysis	Ewe Health /Foetal survival	Seizures	Grass Tetany	Anaemia
Phosphorus	-	-		-	-	+	-	+	-	-	-
Calcium	-	-	+	-	-	+	+	+	-	-	-
Magnesium	-	-	-	-	-	-	-	+	+	+	-
Selenium	-	+	-	+	-	-	-	+	-	-	-
Zinc	-	+	+	-	-	-	-	+	-	-	-
Copper	-	-	-	-	-	+	+	+	-	-	+
Iron	-	-	-	-	-	-	-	-	-	-	+
Potassium	-	-	-	-	-	-	-	-	-	+	-
Iodine	+	-	+	-	+	-	-	+	-	-	-
Sodium	-	-	-	-	-	-	-	-	-	+	
Cobalt	-	-	-	-	-	-	-	-	+	-	+

"+" indicates the disease that may be caused by a deficiency in the mineral, "-" indicates no known effect.

Table 6 shows the functions of and deficiency symptoms associated with the most important minerals in sheep and goat production.

Table 6: Showing the functions and deficiency symptoms of minerals in sheep and goats. (Agmin, 2016)

MINERAL	FUNCTION	DEFICIENCY SYMPTOM
Selenium	Destruction of peroxides and protection of tissues against oxidation.	White muscle disease, muscular dystrophy, ill thrift and infertility in ewes. Poor growth rates, decreased wool production and scouring.
Cobalt	Precursor for synthesis of vitamin B12 by rumen micro-organisms	Vitamin B12 deficiency. Symptoms include ill thrift, weepy eyes, anaemia, scaly ears, and infertility and poor mothering in ewes. Cobalt / vitamin B12 deficiency is also associated with phalaris staggers
Copper	Is an essential part of several enzymes and is required for body, bone and wool growth	
Zinc	Play role in enzymes and is involvement in carbohydrate metabolism and protein synthesis	Excessive salivation, loss of wool crimp, loss of hair or wool around mouth and eyes, stiff joints, scaly and dry skin, slow wound healing and in appetence leading to reduced growth rates. Poor testicular growth and infertility
Calcium	Important for nerve function, muscle contraction, blood clotting, activation of a number of enzymes and bone formation.	Deficiency can occur on acid or sandy soils when animals are grazing forage consisting of rapidly growing grasses or cereals or when grain supplementation is high.
Phosphorus	Important for cell membranes, energy production, and muscle contraction, appetite and bone formation.	Deficiency signs include slow growth rates, decreased appetite, listlessness and poor fertility. Adequate dietary vitamin D is essential for the correct metabolism of calcium and phosphorus.
Magnesium	Activator of over 300 enzyme systems and is involved in the metabolism of carbohydrates, lipids and protein. It has roles	Deficiency symptoms often include muscular spasms, trembling and nervousness manifest in the condition known as

	in nerve conduction and muscle contraction.	hypomagnesaemia or grass tetany.
Potassium, Sodium, Chlorine	Maintaining acid: base balance and the control of body fluids.	Deficiency symptoms may include ill thrift, pica (bone chewing) and anorexia
Sulphur	Sulphur and nitrogen is essential for protein synthesis and growth of rumen microbes.	Deficiency symptoms in sheep include reduced wool production, lack of crimp and poor fleece characteristics.

From the ten final articles meeting the selection criteria for this systematic review (Table 7), the most customary mineral studied, indicated Zn (six studies) and Se (four studies), whilst additional six studies were conducted on combining minerals. The most studied mineral concerning sheep, was Se, whilst Zn was the most studied in goats. Certain studies determined only baseline values during various reproductive stages of animals, whilst most studies investigated the effect on mineral supplementation in sheep and goats (Table 7).

Table 7. Summary of the results obtained in the ten final articles in the systematic review indicating year of publication, country, management system, species and minerals investigated

First author	**Year**	**Country**	**Farming system**	**Animals studied**	**Study design (Sample size)**	**Minerals studied**	**Objective of the study**
Rudert, C.P.	1975	Rhodesia (Zimbabwe)	Natural veld with lick	Pregnant sheep	Observational	Se, I, S	Use of salt lick with I in pregnant ewes prevents goitre in the newborn lamb.
Hamliri, A.	1995	Morocco	Natural veld with lick	Pregnant & lambs	Case control (3000)	Se	Effect of Se supplementation from mating to parturition in the ewe and lamb up to 9 months.
Farrag, F.H.	2005	Egypt	Intensive	Pregnant sheep & lambs (Finnish Landrace-Rahmani)	Case control (28)	Ca, P, Mg, Cu, Zn, Co	Effect of mineral supplementation on lambs when ewe provided mineral block from late pregnancy until offspring weaned.

First author	Year	Country	Farming system	Animals studied	Study design (Sample size)	Minerals studied	Objective of the study
Abdel Monem, K.H.	2011	Egypt	Intensive	Pregnant sheep and lambs (Baladi)	Case control (48)	Inorganic Zn oxide	Effect of inorganic zinc oxide levels on ovarian activity, length to and incidence of oestrus, pregnancy and lambing rate of ewes and growth of their lambs.
El-Shahat, K.H.	2011	Egypt	Intensive	Pregnant sheep & lambs (Baladi)	Case control (48)	Se	Effect of Vit E and /or Se on fertility traits in the ewe and health of the lamb.
Katgile, J.A. *et al*.	1978	Tanzania	Natural veld & concentrate	Pregnant sheep (Black head persian) & does (Kamorai)	Case control (135 does, 185 ewes)	Iodine	Effect of I supplementation on goitre in lambs /kids and fertility parameters of ewe / does.

First author	Year	Country	Farming system	Animals studied	Study design (Sample size)	Minerals studied	Objective of the study
Nawito, M. *et al*.	2015	Egypt	Pastures	Pregnant sheep & does	Observational (142)	Se, Zn,Cu,Fe	How state of pregnancy (single or twins)/non-pregnant affects mineral levels in sheep and goats.
Kadzere, C.T. *et al*.	1996	Zimbabwe	Natural veld & concentrate	Pregnant does (Indigenous)	Observational (38)	Ca, Mg, Zn	Baseline Ca, Mg, Zn blood values for non-pregnant, pregnant & lactation does.
Ahmed, M.M.	2001	Sudan	Intensive	Pregnant does (Nubian)	Observational / 40	Zn, Cu	Baseline plasma values for Zn & Cu in pregnant & lactating does and kids of 4-6 & 9-12 months.

First author	Year	Country	Farming system	Animals studied	Study design (Sample size)	Minerals studied	Objective of the study
Donia, G.R.	2014	South Sinai, Egypt	Intensive	Pregnant does (Shami)	Case control/ 24	Ca, Mg, Zn, Na, K	Effect on blood minerals in pregnant and lactating does when feeding salt tolerant plants.

7. DISCUSSION

Sheep and goat production are of increasing importance, specifically in small holder households, within Africa (Schoenian, 2015). Twenty-eight per cent of sheep and 36.2% of goats' global population are established within the African continent (Kogsey, *et al*., 2007). Inadequate information is available from studies conducted in Africa on the importance, impact and effect of mineral deficiencies in lamb and kid health (Table 7). A significant divergence in usable knowledge was created for an improved impact on health and productivity of sheep and goats, which can improve the economic status of several households within the African continent.

The African continent has a wide diversity because of differences in soil and climate conditions within various regions (Annicchiarico, *et al*., 2004; National Research Council (NRC) 2007; Donia, *et al*., 2014; Dannhauser, *et al*., 2015). This diversity impacts on the health, nutrition and reproduction of dams and the health of their offspring. Within Africa the main management system is extensive, usually of a nomadic nature, prone to several nutritional deficiencies in all aspects of nutrition, such as protein, energy, vitamin and mineral intake (Kategile, *et al*., 1978; Hamliri, *et al*., 1995; Donia, *et al*., 2014).

It is well-established that nutrition affects reproduction and health in livestock production (Godfrey, *et al*., 2000; Redmer, *et al*., 2004; Lanyasunya, *et al*., 2005). Sheep and goats represent a growing population in ruminant production, specifically in Asia and Africa as they are more adapted to the conditions of these regions (Pelant, *et al*., 1999; Devendra, 2002).

Half of the final selection of studies comprised in this review were conducted in mineral deficient areas, and areas with high salt content soil.. All studies involved pregnant animals. The studies were inclined to investigate the effects of mineral deficiencies on the kid or lamb from birth until weaning and beyond. The age of weaning varied between studies and from four to nine months (Table 7).

7.1 Mineral requirements in sheep and goats

Mineralised salts containing Na, Cl, I, Mn, Co, Cu, Fe and Zn is supplemented in developed countries to sheep to prevent deficiencies (Pugh D. G., 2018). In urban environment, sheep relies of natural grazing. Plant leaves are high in Ca but low in P, whilst the seed or grain parts are high in P and low in Ca. Legumes incline to hold a higher Ca content than grasses. Phosphate in plants is highly influenced by the availability of the mineral in the soil (Pugh D. G., 2018). Low-quality forage inclines to be low in P especially as the forage matures, as the grain portion increases. Sheep fed on mature or low-quality forage are prone to develop P deficiencies (Pugh D. G., 2018) should be supplemented with P. As most forage is high in Ca the Ca requirements of sheep is often met when corn silage or cereal grains constitute the exclusive feed source. The diet becomes high in P and ground limestone should be provided (0.02-0.03 lb) daily (Pugh, 2018). In goats, there are no established mineral requirements at either maintenance or production levels and most research supports the assumption that mineral requirements are similar to those in sheep (Pugh D. G., 2018a). A study by Lengarite (2013), focussing on the mineral requirements of young sheep and goats in Kenya, established that forage preferred by sheep and goats varied according to season (Table 8) (Lengarite *et al.* 2013). Sheep and goats consume various plants during dry and wet seasons of the year (Tabel 8 and Table 9).

Table 8. Forage preference and daily intake by sheep in gram (g) during wet and dry seasons in Kenya

Forage	Dry season	Volume (g)	Wet season	Volume (g)
Browses	*Duosperma eremophilum*	7.5	*Crotalaria fasicularis*	3.40
	Commiphora africana	9.0	*Indigofera hochstetteri*	4.49
	Cordia sinensis	9.5	*Indigofera spinosa*	19.8
	Indigofera spinosa	25.3	*Indigofera cliffordiana*	2.63
	Sericocomopsis hildebrandtii	2.0		
Grasses/ herbs	*Aristida adscensionis*	28.5	*Commicarpus stellatus*	2.52
	Commicarpus stellatus	2.2	*Bracharia leersiodes*	14.9
	Blepharis linariifolia	3.3	*Tetrapogon cenchriformis*	20.4
	Bracharia leersiodes	4.1	*Aristida adscensionis*	9.30
	Tetrapogon cenchriformis	8.6	*Cenchrus pennisetiformis*	4.16
			Mariscus macropus	18.4

(Lengarite, et al., 2013)

Table 9. Forage preference and daily intake of goats in gram (g) during wet and dry seasons in Kenya

Forage	Dry season	Volume (g)	Wet season	Amount (g)
Browse	*Acacia tortilis*	6.28	*Bauhimia taitenis*	3.43
	Barleria acanthoides	4.27	*Commiphora africana*	3.6
	Bauhimia taitenis	7.58	*Grewia tenax*	6.72
	Combretum aculeatum	4.62	*Indigofera hochstetteri*	8.70
	Commiphora africana	8.06	*Indigofera spinosa*	19.9
	Cordia sinensis	10.1	*Lippia carviodora*	4.88
	Indigofera spinosa	25.7		
	Maerua crassifolia	3.79		
Grasses/herbs	*Aristida adscensionis*	24.2	*Bracharia leersiodes*	33.5
	Tetrapogon cenchriformis	5.40	*Cenchrus pennisetiformis*	2.80
			Mariscus macropus	5.67
			Tetrapogon cenchriformis	10.8

(Lengarite M.I., et al, 2013)

According to Lengarite *et al*. (2013), young sheep and goats' daily intake during wet and dry seasons varies. In wet seasons the intake of P, K, Fe and Mn in sheep is higher, whilst their intake of Mg, Na, and Zn is lower. Phosphate deficiencies may develop in young sheep and goats during dry seasons and Na deficiency during wet seasons (Lengarite *et al.*, 2013) (Table 10). Young sheep and goats need P and K supplements in dry seasons, Na supplements in wet seasons, whilst sheep need Zn supplements in wet seasons and goats need Mn in dry seasons (Lengarite *et al.*, 2013).

Table 10. Estimated mineral intake in dry and wet season (DM basis) and requirement in young sheep and goats

	Daily intake of Minerals					
	Sheep	Sheep	Goats	Goats	Mineral requirements[1]	
Element	Dry	Wet	Dry	Wet	Sheep	Goats
Ca, g kg^{-1}	11.4	11.5	9.8	14.6	2.0	3.5
P, g kg^{-1}	0.56	1.75	0.52	1.43	1.6	2.45
Mg, g kg^{-1}	2.18	1.52	2.13	1.77	1.2	0.8-2.5
K, g kg^{-1}	4.58k	16.2	4.1	17.1	5	5
Na, g kg^{-1}	1.34	0.39	0.88	0.49	0.9	0.8-1
Fe, mg kg^{-1}	537	681	579	456	30-50	30-100
Zn, mg kg^{-1}	72.5	15.0	63.5	11.9	20-33	>10-50
Mn, mg kg^{-1}	25.2	31.8	18.1	27.3	20-40	20-40

(Lengarite et al, 2013)

7.2 Minerals investigated in goats

The studies conducted on goats in the final selection of articles, were derived from 1978 to 2015 (Table 7). Three studies were based on extensive management systems, whilst two studies were based on intensive management systems. Three studies included supplementation, whilst two studies indicated observation on feed provided. Four studies were observational, based on various physiological states, whilst one was a case control study. Four studies analysed the mineral plasma levels, using atomic and flame atomic absorption spectrophotometry, whilst one study used an alkaline incineration technique (Kategile *et al.*, 1978). The minerals studied were Zn (4 studies), Cu and Se (2 studies each) and Fe, I, Ca, Mn, Mg, Cr, Ca Mo and P in one study each (Table 7).

Donia *et al.* (2014) conducted a study in a hyper-arid salt affected area, comparing the effect of feeding wheat hay with feeding salt tolerant plants. Sodium, K, Ca, Mg, Cd, Cr, Mo, Pb and Zn levels of the plants were determined and compared with the levels of the minerals found in the blood plasma of goats during their dry, gestation and lactation periods (Donia, *et al*., 2014). No significant difference in the plasma levels of Na and Mg for the study groups was indicated, whilst significant differences ($P<0.01$) were present in the feeding groups for K and Ca levels, with K levels being consistently higher in the treated group (Donia, *et al*., 2014). Significant differences ($P<0.01$) occurred between the two groups concerning Cd, Mo and Zn was higher in the treated group, whilst Cr and Pb indicated no significant difference between groups.

The greatest difference was present in Zn plasma levels where the level in the plasma for the salt tolerant group was 8.82ppm in the treated group, compared to 6.26ppm in the control group. Zinc indicated elevated levels in the dry period falling significantly ($P<0.01$) in the treated group until the lactation period. Between the groups salt tolerant plants indicate higher plasma levels in the treated group even though they have a lower Zn content than the control group. This was attributed to an efficiency in absorption by the group consuming the salt tolerant plants. The mineral levels in goats were higher in the groups fed salt tolerant plants. A non-significant decrease was noted at the commencement of gestation and lactation in both groups (Donia, *et al*., 2014). The NRC requirements of minerals throughout the various production stages in sheep and goats.

Regardless of the feeding group, in this study does indicate a significant ($P<0.01$) increase in Na and Ca levels during mid and late pregnancy. Potassium and Ca plasma levels were significantly lower ($P< 0.01$) in lactating compared to dry does (Donia, *et al*., 2014). The lower Na found during lactation was explained, attributable to its loss during colostrum and milk production. Similarly, the lower Ca levels were attributed to an increased demand for Ca by the foetus in late gestation and during milk synthesis. The changes in the K level, particularly during late gestation, were attributed to the plasma aldosterone levels that increased parallel to the aldosterone levels. Aldosterone increases renal excretion of K in mammals (Swenson & Reece, 1993).

Donia *et al*. (2014) established high plasma Mg levels in does during early and mid-gestation that decreased in late gestation, lactation and the dry period. The low plasma Mg concentration in the salt tolerant plant fed group was considered to be attributable to the high K concentration in the plants as K affects absorption of Mg. Chromium was lower during lactation in both groups as it is readily absorbed from the blood by bone. Chromium was significantly higher in mid and late gestation, compared with their dry period, whilst the opposite was established for Mo; high during the dry period but decreased significantly in mid-gestation. Molybdenum increased again in late gestation and during lactation (Donia, *et al*., 2014)

Nawito *et al*. (2015) compared mineral levels in pregnant and non-pregnant sheep and goats. Selenium plasma levels were higher in pregnant than non-pregnant goats, whilst Zn, Cu and Fe levels were lower in pregnant goats. The lower Zn levels in pregnant goats correlate with the study by Donia *et al*. (2014) attributing this to the increased demands of the developing foetus for Zn. Two more recent studies (Donia, *et al*., 2014; Nawito, *et al*., 2015) provide actual plasma levels, unlike the results of the study by Kadzere *et al*. (1996) that only indicate trends presented in a linear graph form.

Kadzere *et al*. (1996) indicate that the levels of Mg remained steady throughout gestation to weaning. Kadzere *et al*. (1996) explain that the consistent levels of Mg were likely because of Mg being mobilised from bone and other Mg pools in the body. This is necessary to meet the needs of the growing foetus and for milk production during the lactation period. Zn levels were the highest in mid-to late gestation; it decreased slightly at kidding and increases again during lactation. This finding does not agree with the more recent study by Nawito *et al*. (2015), indicating that Zn levels were higher in non-pregnant than in pregnant goats.

Kadzere *et al*. (1996) establish Ca levels to decrease in late gestation, reaching the highest level in lactation. The requirements for Ca were higher in pregnancy and lactation, than required for maintenance. The foetus needs Ca for skeletal formation and Ca is required for milk production during lactation. According to Donia *et al*. (2014), Ca is absorbed from the gastrointestinal tract of the goat to meet this increased demand. There was also an increase in the plasma parathyroid hormone level, causing the mobilisation of Ca from activated osteoclasts (Georgieskii, *et al*., 1982). The decrease in Ca during parturition, most likely signals the parathyroid to release parathyroid hormone to meet the increase in Ca requirements needed during lactation to meet the needs of the doe (Georgieskii, *et al*., 1982). If this response was hindered in any way and caused a lack of Ca at the tissue level, parturient paresis would arise (Underwood, 1981). Katgile *et al*. (1978) studied the effect of oral drenching of I and its effect on twinning rate, bodyweight of the newborn and incidence of goitre in newborn kids. Kids drenching with I decreased the incidence of goitre from 50% to 19.3% and 40.9% to 17.8% in two studies (Kadzere, *et al*., 1996). It was also established that the kidding rate and mean body weight of the kids were higher than values for the control group (Kadzere, *et al*., 1996).

According to Ahmed *et al*. (2001), Zn and Cu plasma levels change with the physiological state in the Nubian goats. They studied young, adult, pregnant, kidded and lactating does. There was no supplement provided, but the feed content was analysed for Zn and Cu levels. The highest level of Zn (7.38mg/l) was established in high lactating does and the lowest (2.40mg/l) in low lactating does. Studies by Ahmed *et al*. (2001), Donia *et al*. (2014) and Nawito *et al*. (2015) agree that plasma Zn levels were lower in pregnant does, compared to lactating does. The lower plasma Zn levels in the pregnant does were lower, attributable to the foetus' increased demand for Zn (Donia, *et al*., 2014). Nawito *et al*. (2015) established plasma Zn levels of 10.71 ppm in the dry period and 4.60ppm during lactation. Zn levels declined from 9.29ppm in early to 5.94ppm in late pregnancy. The Zn levels were also higher (2.56mg/l) in newly weaned offspring (four to six months) compared with nine to 12 months old kids (1.12mg/l), coping without milk (Nawito *et al*., 2015).

The highest plasma levels of Cu were established in first time pregnant goats (5.13mg/l), followed by does in second (5.11 mg/l) and third kidding (5.01 mg/l) respectively. Lactating goats had the lowest Cu plasma levels, indicating 2.70mg/l (Ahmed *et al*. 2001). Copper levels inclined to increase with age. This was associated with higher concentration levels of circulating oestrogens (Ahmed *et al.* 2001).

7.3 Minerals investigated in sheep

Studies investigating sheep in this research, ranged over four decades, commencing in 1975, to 2015. The laboratory methodology used to analyse minerals in plasma were atomic or flame atomic absorption spectrophotometry. Two of these studies based their findings on physical observations (Table 7). The minerals studied, were Se (4 studies), Zn (3 studies), I and Cu (both in two studies) and Fe, S, Ca, Mg, P and Co each in a singular study. All (excluding two) studies were conducted under intensive feeding conditions and mostly included the effect of providing a supplement, usually in the form of maintenance licks.

Studies conducted in goats mostly comprised cases of known mineral deficiencies (I and Se) or the presence of challenging soils types (soils high in salt or with presence of goitrogenic plants). Katgile *et al*. (1978) studied lambing percentages in sheep following per os administration of iodine, before breeding. Lambing percentages were higher in two from three trials. Goitre decreased from 34.7% to 21.4% and 59.1% to 34.7% in these studies. A similar study was conducted on goats. It was established that the lambing rate (more ewes lambed) was higher than the kidding rate in two from three studies, 83-75%, 86-77% (Katgile, *et al*., 1978).

Sheep had lower twinning percentages than goats; these results may be irrelevant to this study as it may not relate to the mineral under study. It may be attributable to genetics of the herd. Rudert *et al*. (1975) indicated that per os I administration decreased the rate of goitre in sheep grazing on cyanogenic glycoside pastures. Both studies corrugate the observation in the literature that I deficiency leads to goitre and foetal hypothyroidism.

Nawito *et al*. (2015) indicate that pregnant ewes had only slightly higher Se and lower Zn, Cu and Fe levels than non-pregnant ewes. This study aimed to determine baseline levels only, without supplementation of mineral in pregnant and non-pregnant ewes. A study by Hamliri *et al*. (1995) on Se supplementation in Se deficient pastures, established that Se plasma levels did not differ prior to mating, between the control and treatment groups. From mid-gestation up to parturition, Se levels in ewes receiving Se supplements, were significantly higher ($P<0.001$) than in the control group. Selenium levels also differed significantly ($P<0.001$) within the treatment group indicating the variation between individual animals. Lambs born from ewes receiving Se supplements, had increased weight gain and lower incidents of pre-weaning death. These lambs also had lower creatinine kinase (CK) activity than the control group. CK acts as an indicator for the presence of nutritional myopathy (Se deficiency) in labs. This observation agrees with findings of El-Shahat *et al*. (2011), establishing that Se and Vitamin E supplementation in pregnant ewe's increased the lambing percentage and weight gain in lambs to weaning age.

Farrag, *et al*. (2005) provided ewes from late pregnancy (fourth month) until weaning of the lambs at nine months, with a mineral block containing Ca, P, Mg, Cu, Zn and Co. The blood mineral concentrations and haemoglobin levels in the lambs and wool production and quality of the lambs were evaluated. The chemical composition of feed was noted with the levels in the mineral block (P: 4%, Ca: 5%, Mg: 5%, S: 1.2% and K: 1%, Mn: 4500ppm, Fe: 7000ppm, Cu: 2000ppm, Zn: 4500ppm, I: 3000ppm, Se: 12ppm, Co: 50ppm and Na: 22ppm) (Farrag, *et al*., 2005).

Plasma Ca levels decreased in the control group in late pregnancy and lactation. Both Farrag *et al*. (2005) and Kadzere *et al*. (1996) indicate that using Ca supplements may aid in preventing milk fever. These studies agree with a study by Abdelrahman *et al*. (2008), observing that increasing levels of calcium intake up to 1.01% as a calcium carbonate in feed of Awassi ewes at late gestation, with or without vitamin A, D and E injections, improved the Ca concentration. This is valid in both the colostrum and blood serum of ewes and their lambs, without a negative effect on their health and performance. There was an increase in inorganic P in the ewe and lamb in the treatment group but a decrease in the untreated control group. Magnesium levels increased in the treated group, whilst Zn did not increase significantly in the ewe, there was an increase in the plasma levels of the lambs (Abdelrahman, *et al*., 2008). The average daily gain of lambs receiving additional minerals was higher than those that did not. This study indicates that lambs on the supplementary diet, had a mean live body weight at puberty of 22.17 kg compared to the 20.96 kg of the control group (Abdelrahman, *et al*., 2008). Farrag *et al*. (2005) noted that the ewes consumed less maintenance lick as pregnancy and lactation progressed. The highest consumption of maintenance lick was observed in the fourth month of their pregnancy (36 g/h/d) and the lowest consumption, two months after lambing (8 g/h/d). According to Farrag *et al*. (2005), lambs consume 2 g/h/d during their first month, increasing to 10 g/h/d by the fourth month. All needs are provided for by mother's milk during the early life of the offspring, but as growth proceeds, additional intake of minerals becomes more important to prevent deficiencies. Although Farrag *et al*. (2005) conclude that mineral suplements provided an improved mineral nutritional status, the ewes and lambs were not under any severe deficiency of any element during the study.

Abdel Monem *et al*. (2011) studied the effect of inorganic Zn supplements in pregnant ewes. He established no significant difference in the body weight of lambs at birth. The lambs of ewes that received Zn had significant ($P<0.05$) higher weaning weights. This study agrees with studies by Rudert *et al*. (1975), Hamliri *et al*. (1995) and El- Shahat *et al*. (2011) indicating improved weight gain, decreased pre-weaning death and increased survival by lambs when ewes were supplemented, specifically concerning mineral deficiency.

Organic minerals are bound or chelated to organic materials, established in foods (Clark, 2015). Inorganic minerals are not bound to any substance and only contain the mineral salt. Only two studies specify the effect of inorganic forms of minerals (Farrag, *et al*., 2005; Abdel Monem, *et al.*, 2011). Farrag *et al*. (2005) observed the plasma level of inorganic P, whilst Abdel Monem *et al*. (2011) studied the effect of inorganic Zn levels. The studies in sheep offer a more comprehensive information than the studies established in goats (indicated baseline levels only). This follows global tendencies as goat studies incline to be significantly neglected, unlike cattle and sheep, considered to hold more commercial value (Morand- Fehr, *et al*., 1999; Kogsey *et al*., 2007).

The environment crucially contribute in supplying adequate minerals to the pregnant animal. Arid and semi-arid areas often hold inadequate fodders to supply forage throughout the year (Kundu, *et al.*, 2014). Dam nutrition influences lamb and kid production, prior to weaning. Balanced nutrition of the dam, especially in late gestation is crucial to foetal development and its survival after birth (Kundu, *et al*., 2014). Few later studies in Africa were conducted under extensive conditions.

From this study's results, it became evident that most studies conducted globally, included investigating Ca, Mg and Se, followed by Cu, I, P and Zn (Figure 5). Studies conducted in Africa, focused on Se and Zn (Table 7). Studies conducted within the African diaspora, investigated the impact of mineral deficiencies on health and reproduction, whilst the African studies inclined to focus on birth weight and weight gain in kids and lambs.

8. CONCLUSION

From studies within the African continent, 20% observed truly extensive conditions. Most of the reviews used in this study did not consider the actual impact of disease outcome or the effect of deficiencies (70%). The study only investigated the birth weight or weight gain of the offspring until weaning and the reproductive outcomes in the dam (lambing or kidding rates). Two studies conducted on sheep and goats did not compare differences in the outcome between these species. More studies concerning sheep, investigated the effect of Se deficiency, whilst goats' studies focussed on Zn.

From the study, it was established that oral drenching of goats with iodine in I deficient areas decreased the incidence of goitre (50% to19.3% and 40.9% to 17.8%) in kids. The kidding rate in goats and the mean body weight of kids was also higher in I treated groups than the control groups. In sheep, I supplementation was also observed to increase the lambing rate and lambing percentage, whilst decreasing the incidence of goitre in lambs (34.7% - 21.4% and 59.1% -34.7%).

Creatine Kinase (CK) in lambs was observed to be lower in treated groups than in controlled groups. Multi-mineral supplements provided to ewes in pregnancy and subsequently to lambs until weaning, caused a weight increase in lambs (22.17kg in treated lambs; 20.96kg in control lambs). Supplements of inorganic Zn to ewes, caused body weight gain, decreased pre-weaning death and increased survival in lambs, compared to the control group.

Attributable to the vast variety and nomadic nature of indigenous sheep and goats in Africa, the following factors might be inadequate for the unique nature of each region within Africa:

- A general extensive management system.
- Vast differences of soil types.
- Environmental conditions within the continent, affecting plant life.
- The influence of various physiological states on the availability of minerals within generalised animal studies on minerals, especially for intensive systems of management.

Studies related to the aforementioned factors, need to be conducted by each unique region on the dam and offspring to analyse the mineral requirements needed for optimal growth and health of the kid and lamb. This is especially important in goats, considering their substantial number within the continent, indicating a lack of data for these species.

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N.B. All asterisked articles are those of studies performed within the African Continent.

ADDENDUM 1: STAGES OF PREGNANCY IN THE GOAT: KID DEVELOPMENT

EARLY STAGE

Day 1	Two cells
Day 1 ½	Eight cells (morula stage)
Day 3 - 4	Enters uterus
Day 6 - 7	Blastula stage
Day 12	Attaches to wall of the uterus; beginning of embryonic period
Day 20	Heart begins to beat
Day 28 - 35	Limb buds become visible
MID-STAGE	
Day 42	1 ½ inches (37.5 mm) long; major tissue, organ and systems are defined; end of embryonic period; it is now a foetus
Day 42 - 49	Mammary buds/empty scrotal sac appear
Day 49 - 56	Ear canal opens
Day 56 - 63	Nostrils open
Day 60	Foetus is 4 inches (100 mm); eyes, eyelids and nostrils are identifiable
Day 77 - 84	Horn pits appear
LATE STAGE	
Day 90	Ten inches (250 mm) long; after this size varies greatly according to breed

Day 98 - 105	Hair around eyes and muzzle; tooth eruption
Day 119 - 126	Hair covering the body
Day 141	Foetus is viable (can survive outside the mother)
Day 145 - 152	Born

(Hills, 2012)