Strategic and effective supplementation of sheep

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New South Wales

November 2025
Nuffield Australia project number 2311

Supported by

Australian Wool Innovation Limited

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In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

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Executive Summary

This report offers global perspectives on sheep supplementation to enhance health and performance. It aims to present alternatives and strategies for Australian farmers to more efficiently and precisely provide minerals, vitamins, and/or functional nutrition additives to boost flock productivity.

This report:

- Presents insights and guidance drawn from international sheep farming practices.
- Emphasises the importance of selecting the right supplements to achieve optimum production outcomes.
- Encourages the adoption of tailored supplementation strategies to maximise sheep health and productivity.
- Highlights the need for further testing of minerals and vitamins in extensive grazing systems in Australia
- Aims to inform and improve decision-making for sheep farmers regarding supplement choice and application.

"Strategic selection of shrubs that accumulate all, or some antioxidant minerals or vitamins, and grow in arid and drought susceptible environments, offers a new opportunity to design grazing systems that provide a combination of antioxidants within a grazed system." Dr. Hayley Norman, CSIRO, Australia.

Keywords: sheep, nutrition, minerals, vitamins, supplements, health, performance

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Foreword

My career over the last 20 years has been focused on animal nutrition. I'm passionate about supporting farmers fine tune their livestock nutrition to improve animal health and performance. I love formulating rations and creating management plans to optimise efficiency and production. In 2022 I made the decision to resign from a nutritionist role with a stockfeed company to focus on our own farm, expand my consulting service for local farmers and begin the initial stages of forming a new business venture formulating and manufacturing grain balancer pellets. As I adjusted to this new career, it gave me some space in my mind to discover other opportunities and re-ignite my interest in livestock nutrition.

Figure 2: The author, Nicole Logg. (Source: Author)

For years I've watched the Nuffield Farming scholars 'from the outside', but in 2022, I thought "Why not? I should give this a go and see where it leads…". At the time I had space in my mind and life to be able to give time to this scholarship, and at the same time look at how we can provide more precise, strategic and effective nutrition to our livestock.

Sometimes you need to get out of your bubble and shake things up a bit, and being awarded a Nuffield Farming Scholarship for 2023 has given my family and I more than we could have hoped for. Always eager to learn, solve problems and be inspired, my Nuffield travel has provided me with that and more. For my first personal travel trip, my husband Rob came with me to the USA, visiting universities and sheep businesses in Montana, Wyoming and Colorado. Rob is a great conversationalist, asking many practical, relevant questions (compared to my often technical-based questions) which often opened brilliant conversations (or a good joke!) that I would not otherwise have had if travelling alone. This certainly helped us connect on a deeper level to the wonderful people who helped us along the way. More recently on our travel to Europe, we decided to take the whole family, Rob, myself, our daughter Gemma (11 years old) and son Kirby (9 years old). Our hosts were gracious and always encouraged the whole family to come along on farm visits. A fantastic experience for all and unconsciously opening the door to the wide world of agriculture to our children and opening truly endless possibilities for them. I am forever grateful for the 'Butterfly Effect' my Nuffield Farming Scholarship has had with our family.

My study topic, 'Strategic and effective supplementation of sheep' was chosen to break the monotony of many mixed farmers (us included) in using a standard macro mineral additive at various times throughout the year. Through my career as an animal nutritionist, I've been exposed to a range of supplier training and nutrition options, mostly targeted at more intensive feeding industries, so I understand there are other

options. But how do we best fit this into an extensive sheep system where pastures and soils vary from paddock to paddock within the same farm? We see the health and financial benefits of improved pastures, but focus on longevity, seed set and dry matter production – all important criteria, however, little focus on what these plants supply (or don't supply) for optimum production. It raises questions like "Do I need to supplement 'x, y, z' when grazing this type of pasture, or does it provide enough for that stage of lamb growth or reproduction?" This study is an attempt to review these questions and provide some guidance for optimum production through being more strategic and effective with the supplements we choose, with insights as to how and what sheep farmers do in other parts of the world.

Table 1. Travel itinerary

Travel date	Location	Visits/contacts
June 20th - 30th 2024	**USA:** Montana Wyoming Colorado	**Montana State University:** Brent Roeder, Sheep Extension Specialist **University of Wyoming:** Associate Professor Dr. Whit Stewart, Mineral Researcher
February 26th - 29th 2024	**Italy:** Piedmont region Lombardy region	**Virbac Animal Health:** Dr. Marco Pietro **Italmix factory:** Sergio Lanzanova, Export Manager. **University of Milan:** Associate Professor Dr. Donata Cattaneo and Professor Dr. Giovanni Savoini
March 4th - 8th 2024	**France:** Mâcon Aveyron region • Rodez	Obione – Delphine DaSilva, Export Manager Euro-phyto - Julien Cabrol, Owner Noélie Pages - Lacaune sheep dairy Laure Theron - Nuffield Scholar 2023 France Sam Sharples - farm manager at La Roque agricultural college, Rodez. Dr. Celine Pouget (Government Vet), Aveyron region, southern France.
March 13th - 24th 2024	**Spain:** Aragon region • Zaragoza Extremadura region • Monesterio	**University of Zaragoza:** Professor Dr. Alfonso Abrecia **Inzar Animal Nutrition:** Dr. Rafael Martos **Nanta Animal Nutrition:** Dr. Laura Marco **CEVA Animal Health:** Dr. Javier Acosta
June 2nd 2024	**Australia: Phone**	**DPI Cowra:** Dr. Gordon Refshauge
July 10th - 11th 2024	**Melbourne, VIC**	**Australian Society of Animal Production (ASAP) conference** **Virbac Australia:** Dr. Paula Gonzalez-Rivas, Technical Services Manager - Ruminant **ZinPro:** Dr. Chris Ashworth, Vet nutritionist

August 7th - 9th 2024	**Adelaide, SA**	**LambEx conference** **CSIRO** (**WA)**: Dr. Hayley Norman **The University of Adelaide:** Dr. William van Wettere **Agricom (DLF seeds)**: Dr. Glenn Judson, Technical Manager. Christchurch, NZ
August 21st - 22nd 2024	**Albury, NSW**	**SALRC annual conference:** **PIRSA:** Dr. Alice Weaver
September 11th - 13th 2024	**Sunshine Coast, QLD**	**Feedworks conference:** **PGG Wrightsons (DLF Seeds):** Dr Charlotte Westwood, Vet and Ruminant Nutritionist, Christchurch NZ
July 21st – 25th 2025	**Christchurch,** **New Zealand**	**Matt Iremonger** – General Manager, Willesden Farm, Ataahua, South Island, New Zealand 2021 Nuffield Scholar - New Zealand **Ben TodHunter** - Cleardale Station, Rakaia, South Island, New Zealand. 2006 Nuffield Scholar, New Zealand **Mark Wragge** - Sheep and beef farmer, Malvern Hills, South Island, New Zealand **Mark Ferguson** - neXtgen Agri **Agricom (DLF Seeds):** Glenn Judson, Technical Manager; and Kaylee Spain, Nutrition Scientist **PGG Wrightsons (DLF):** Charlotte Westwood, Vet and Ruminant Nutritionist

Acknowledgments

To the team at AWI, especially Emily King, George Lehmann and Richard Smith. You have all been wonderful to work with, providing great contacts overseas and supporting me in Australia through the '*Beyond the bale'* magazine and AWI Extension NSW webinars. I'm immensely grateful to AWI for investing in me and providing financial support to enable my Nuffield travel.

Thank you to the whole Nuffield Australia team, in particular Jodie Redcliffe, Nicola Raymond, and Carol Millar for lining up the ducks and making it all happen. A special thank you to the Nuffield NSW contingent for initially selecting me at the state interview in Dubbo. I had a wonderful time meeting you all, and I remembering thinking "If I haven't made it through, gee it's been inspiring meeting these people". A great first insight to the Nuffield family. Thank you, Stu Tait (NSW Chair), for answering my random phone calls and stepping me through the process of individual study planning and travel.

The support of my family has been imperative to making the most of my scholarship. I'm fortunate to have a husband that sees the value in a Nuffield Farming Scholarship, and I sincerely thank Rob, and our children, Gemma and Kirby, for their unconditional support over the last 18 months. My husband's response to those who asked how they were coping when I was overseas was 'we're surviving but not thriving', but surviving is ok and dare I say it builds resilience and invokes gratitude. Upon my return everyone was healthy and safe, even if sausages and chops featured heavily on the menu whilst I was away. I'm incredibly proud of my children for stepping up when needed and to Rob for seeing the huge opportunity Nuffield has provided us to improve my professional and personal development; and for juggling the demands of the farm, domestic duties, school and sport events.

Over the course of my travels, I've met some incredibly obliging, generous and knowledgeable people and I'd personally like to thank:

- Brent Roeder at Montana State University.
- Dr. Whit Stewart at The University of Wyoming.
- Dr. Donata Catanneo and Dr. Giovanni Savoini from The University of Milan.
- Virbac Animal Health: Paula Gonzalez-Rivas (Technical Services Manager-Livestock, Australia) for her help and guidance in mineral nutrition for Australian conditions, and her assistance in using the international reach of Virbac in Europe. Macro Pietro (Virbac Italy) for our wonderful time in Piedmont Italy; and Thibault Devambez (Virbac France) for connecting me with the French government Vet, Dr. Celine Pouget, who I also thank for your excellent visits and knowledge.
- Nuffield France scholars: Yolène Pages, Laure Theron, Guillame Tant. For your contacts, suggestions, farm visits, long lunches, and delicious dinners. You showcased the Aveyron region in fine form and we all felt very welcome.
- Professor Alfonso Abrecia at the University of Zaragoza. Alfonso is a tremendous wealth of knowledge and is also very kind-hearted and caring, coming to my aid and reorganising his week when my travel plans were turned upside down.
- CEVA animal health: Dr Javier Acosta who graciously took me to the depths of Spain to see Merino sheep in their homeland of the Extremadura region. Javier's

knowledge of ruminants is excellent, and he has the wonderful ability to speak to farmers on their level albeit it often took me a little while to figure out the translation!

- To the team at Feedworks Australia for inviting me to their conference, providing me with science and evidence-based information on their wonderful range of products that have been shown to improve livestock health; and especially for including me in technical discussions with the knowledgeable team at ZinPro. Their enthusiasm for livestock health makes you feel like part of a big nutrition family. It also provided me with the opportunity to connect with Dr Charlotte Westwood, Vet and Ruminant Nutritionist at PGG Wrightsons, NZ (DLF seeds), who I met up with in Christchurch for an engaging chat about mineral and vitamin nutrition in sheep.
- Dr Frank McRae from DLF seeds, for introducing me to their lovely team at LambEx, including Dr Glenn Judson from Agricom (DLF seeds) New Zealand. This provided me with the opportunity to visit the team at the Kimihia Research Centre, near Christchurch, to hear firsthand about the latest trial work on herbs and discuss the benefits of herbs in grazing systems for improved livestock nutrition.
- Andrew Glover, station manager at Pooginook for connecting me with Mark Ferguson of neXtgen Agri (based in Christchurch, New Zealand). Mark provided me with contacts for excellent farm visits with Ben Todhunter and Mark Wragge in the Canterbury region on the South Island of New Zealand, as well as finding time to chat with me in his very busy schedule. Thank you Mark.
- Sammy McIntyre: Nuffield Scholar 2023 and one of my travel mates from GFP India. A clever, level-headed lady that is also lots of fun and has been a wonderful shoulder to lean on. Thanks for your help to allow me to attend LambEx too!

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Abbreviations

ASAP	Australian Society of Animal Production
APVMA	Australian Pesticides and Veterinary Medicines Authority
AWI	Australian Wool Innovation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSU	Charles Sturt University (Wagga Wagga)
DM	Dry Matter
DMI	Dry Matter Intake
DPI	Department of Primary Industries
EU	European Union
FCE	Feed Conversion Efficiency
FCR	Feed Conversion Ratio
GFP	Global Focus Program
N	Nitrogen
NDF	Neutral Detergent Fibre
NSW	New South Wales
PIRSA	Primary Industries and Regions South Australia
ROS	Reactive Oxygen Species
SALRC	Southern Australian Livestock Research Committee
SAMM	South African Meat Merino
SRW	Standard Reference Weight
USA	United States of America

Objectives

The intentions of this scholarship are:

1. To better understand the additional mineral and vitamin requirements of sheep when sheep are exposed to stressors including environmental (heat or cold stress); metabolic (during high nutritional demand e.g. pre-lambing or fast-growing lambs); physical (behavioural changes and/or additional movement and mixing e.g. marking, weaning, crutching or shearing time)

2. To learn more about what minerals, vitamins and beneficial compounds are naturally available from the plants that sheep graze; then review commercial supplements that provide or balance these nutrients to support sheep health.

3. Identify options for measuring and assessing nutrient status to accurately assess what minerals and vitamins are needed to support livestock health.

4. Determine the most effective and efficient time/s to supplement to provide the required nutrients to be nutritionally efficient, cost-effective and labour efficient whilst improving sheep health and performance.

"Observation is key to ensure sheep health"

The consensus of the many farmers, nutritionists, professors and supplement businesses I visited during my travels

Introduction

Ruminant animals have five key nutrient requirements: crude protein, energy (fibre), fat, vitamins, and minerals. Overlooking any of these essential nutrients may lead to lower than expected performance, hence the need for supplementation at various times of the year (McGrath *et al.*, 2018). Alongside these nutrient requirements are feed additives. Feed additives are a group of feed ingredients that can cause a desired animal response in a non-nutrient role, such as a pH shift or growth (Hutjens, 1991).

In many grazing systems, there are periods when animals require nutrient supplementation because grazing does not meet their nutritional needs (Dove, 2009). In grazing enterprises, the cost of supplementary feeding is a significant discretionary expense for farmers. Therefore, improving the efficiency of supplementary feeding is economically important and can significantly impact farm income (Dove, 2009).

In a review by McGrath *et al.* (2018), it's suggested that the strategic use of feed additives offers the possibility of increasing feed efficiency and animal production, and suggested that there is ample, validated evidence to indicate dependable and cost-effective ways of optimising available feed nutrients and utilising additional feed additives to increase profitability. The review suggests this is even more important in systems utilising animals of high genetic merit, to ensure longevity and performance in their investment. Finally, the review proposed a multidisciplinary approach using a combination of micronutrients and specific feed additives to improve ruminant animal health, welfare and lifetime performance.

According to the animal health manager of a large rural retail business based in NSW, Australia, supplement blocks and loose licks make up approximately 75% of the total sales of supplements. The breakdown being a relatively even 50:50 split between blocks and loose licks. The other portions of supplement sales are grain balancer pellets (18%), followed by injectable minerals (~7%). There are very little rumen boluses or oral drenches sold (Harrison, pers.comm., 2024). Advice to aid farmers with supplement decisions is initially based on livestock requirements (i.e. stock class and reproductive or growth status), with pasture quality the final determinant of which supplement suits best.

In Australian extensive sheep production systems, pastures form the primary feed base. Research into pastures has traditionally concentrated on dry matter production, seed set, and longevity. There is an increasing desire for mixed pasture swards to aid overall pasture longevity and provide a continuous supply of feed throughout different seasons (FarmLink pasture walk, 2024). Whilst longevity is key, it would be desirable to also offer livestock a range of nutrients to better suit their requirements, and there has been new research into grazing herbs and shrubs that looks promising.

Henry *et al.* (2012) surmised that climate change will present a range of challenges for livestock production in Australia, with the effects of higher temperature on livestock and their forage base being the most certain impact. Recent research also indicates that the impact of environmental factors, such as heat stress, is quantified and offers some practical solutions for farmers.

To offer a more precise approach to feeding supplements to sheep, this report will focus on strategic and effective supplementation during the reproductive and growth phases. It will review options to supply nutrients that are nutritionally effective whilst keeping focus on what's practical in terms of cost, management and labour efficiency.

Chapter 1: The science of supplements

Feed supplements and additives are provided to sheep to improve health and productivity. Through genetic selection we are continually choosing sheep for better performance, and as improved genetics come into the flock, we should consider addressing the nutrient needs of these higher producing animals. For example, more fecund ewes, those that have a propensity to produce twins and triplets, will require more calcium to build foetal bone and produce more milk; or faster growing lambs that perhaps need elevated levels of minerals and vitamins to sustain higher growth rates. With increased focus on performance and subsequent profitability, being sharper and more precise in our supplementation program warrants investigation.

This first section will look closer at the cellular level of 'why' supplements and additives are used, to help us better understand the times when sheep are in specific need of additional nutrients.

Oxidative Stress - a little science to set the scene

Oxygen in combination with glucose is used by cells to generate energy. This process is called 'oxidation', and the end products are mostly water and carbon dioxide. The process is not quite 100% efficient, with small amounts (2-5%) of oxygen not being converted to water, resulting in the production of free radicals, also known as oxidants.

Oxidants are integral to normal cellular function and provide an important feedback loop between metabolic activity and regulation of cell function (McGrath *et al.*, 2018). Oxidative stress occurs if free radical (oxidant) production exceeds the capacity of the antioxidant system of the cell or tissue. This can occur when there is increased demand for antioxidants by the animal, when immune function is reduced, or when antioxidant capacity is impaired, as antioxidants scavenge free radicals. Oxidative stress affects metabolism and decreases productivity in farm animals (McGrath *et al.*, 2018).

There are a range of antioxidants naturally available in the body and include the fat-soluble vitamins A (including its precursor β-carotene), D and E, whilst the trace minerals selenium, copper, manganese, zinc and iron are all co-factors in antioxidant enzymes which are important for strong immune system responses. It's worth noting that fresh green forages are typically considered capable of supplying adequate level of β-carotene (a vitamin A precursor) and vitamin E.

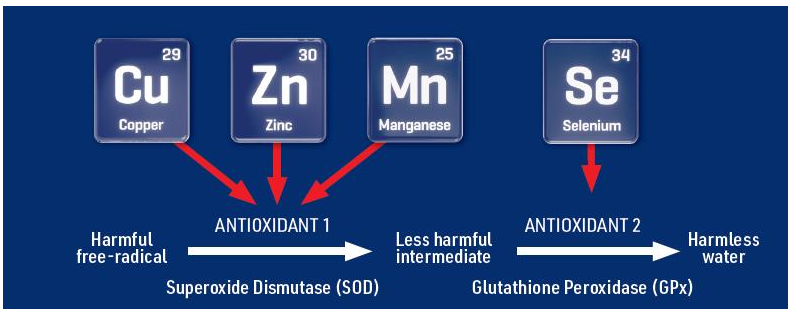


Figure 2: The trace minerals involved as co-factors in antioxidant enzymes to aid the breakdown of damaging oxidants (free radicals). (Source: Virbac 'Multimin for sheep' Flyer VIR0742)

Mitochondria are energy-producing powerhouses within cells. Primary antioxidants are required within the mitochondrion cell to reduce free radicals. If antioxidant enzymes are in short supply, the free radicals produced enter the cytoplasm. Secondary antioxidants, such as vitamin E, then play a role scavenging free radicals which will otherwise cause oxidative damage to cells.

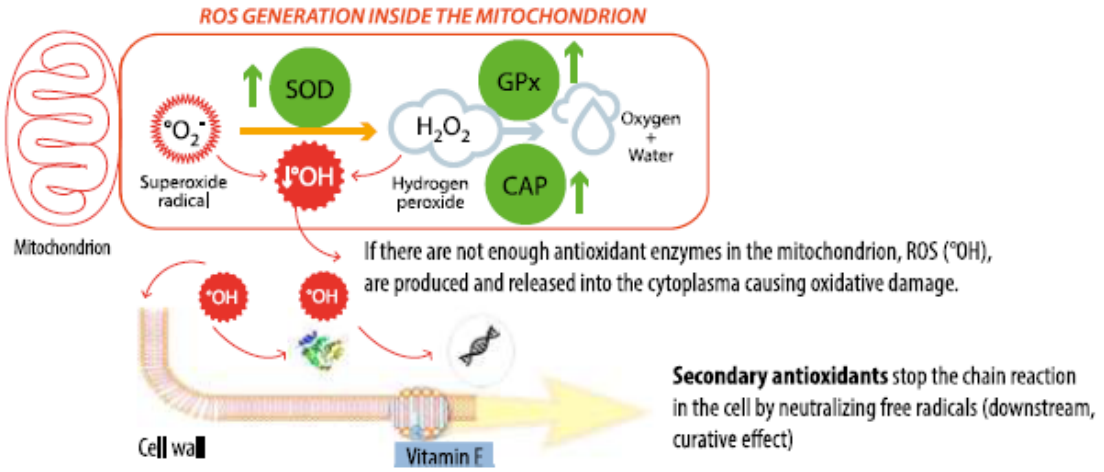


Figure 3: Pathway of endogenous reactive oxygen species (ROS) production and role of primary and secondary antioxidants at the cellular level. (Source: Lallemand Animal Nutrition White Paper 'Beyond Free Radicals: understanding the complexity of oxidative stress')

Effects of oxidative stress on reproduction

During late pregnancy and lambing, there is an elevated requirement for antioxidants. This arises from the heightened production of free radicals due to rapid fetal development, as well as the synthesis of colostrum and milk.

Other stressors that impact normal oestrus behavior and decrease ewe fertility, include poor body condition, extreme temperatures, or standard management procedures (e.g. transport or shearing) (Dobson, H. *et al.*, 2012). Stressors are cumulative; therefore, a combination of these stressors can overwhelm the antioxidant system and compound the issue of poor reproductive performance.

In Australia, a large environmental stressor is heat. Heat stress negatively affects animal performance and has been associated with oxidative stress, either through increased free radical production or decreased antioxidant defences (McGrath *et al.*, 2018).

Thermal impacts on sheep performance and wellbeing are most significant when temperatures drop below 12°C or exceed 25-31°C. However, before these temperatures are reached, physiological and behavioural responses are triggered which negatively impacts their reproduction and growth (William H.E *et al.*, 2021). It appears that both ram and ewe reproduction is affected by moderate levels of heat stress, with a decrease in semen quality and quantity in rams, and reduction in fertility and fecundity in ewes. It was also noted that sustained exposure to high temperatures (>32^{0}C) during pregnancy reduces lamb birthweight and ewe mammary gland development (William H.E *et al.*, 2021).

High environmental temperatures may also reduce pasture quality and heighten loss of β-carotene (a precursor for vitamin A production), however Vitamin A can be stored in the liver and drawn on for use for approximately 3-4 months during deficits of green feed.

Effects of oxidative stress on lamb and wool growth

Due to their faster metabolic rate, growing tissues produce large amounts of free radicals. Higher oxidative stress was observed in fast growing lambs and as such it was noted that dietary antioxidants can therefore influence growth (McGrath *et al.*, 2018).

Similarly in wool sheep, cell replication is constantly occurring in wool follicles to produce wool fibres. Healthy wool follicles and subsequent wool quality are dictated by available nutrients. For wool producers, the influence of minerals on wool growth is captured by Dove (2009) in a nice summary:

Lack of minerals can influence wool growth by:

1. Reducing feed intake and subsequent nutrition to the wool follicle. Minerals involved: sodium, potassium, sulphur, phosphorus, magnesium, cobalt, and zinc.
2. Altering rumen function and hence supply of nutrients flowing from the rumen. Minerals involved: sulphur, sodium, potassium, and cobalt.
3. Directly disrupting metabolism within the sheep and requirements for wool follicle and fibre growth. Minerals involved: zinc, copper, selenium, iodine, and cobalt.

Wool growth will still occur when the ewe is pregnant and lactating. Producers will commonly see ‘tender’ wool when there has been a deficiency of nutrients, with breaks in the wool typically occurring at lambing and/or lactation. Wool producers would also notice that a sick sheep may have a complete wool break and drop their wool before recovering. This symptom indicates a severe nutrient deficit, as the sheep shifts nutrients toward immune function and survival.

Chapter 2: The paradigm of pastures

Throughout my travels, I observed notable differences in sheep feeding systems across various regions and countries. The following section outlines these contrasts to suggest improvements for our own practices. Despite these variations, our shared goal remains: meeting sheep nutrition requirements for optimal health.

The USA: Home and health on the range

Wyoming: Rangelands grazing

In Wyoming (USA), sheep depend on rangelands and dormant forages for both their macro- and micronutrient needs (Julian *et al.*, 2021). Rangelands are defined as native grasses, forbs and shrubs that are commonly used by both livestock and wildlife, as shown in Figures 4 and 5. Approximately 85% of the land surface is considered rangelands in Wyoming (Julian *et al.*, 2021).

Figure 4 and 5: The rangelands of University of Wyoming's research site. (Source: Author, 2023)

In visiting the region, and spending time with Associate Professor Whit Stewart from the University of Wyoming, it was quickly discovered that there is a stark difference in sheep systems compared to Australia. This is primarily due to the impacts of season, namely winter and its associated snowfall. The winter snowpack provides moisture for summer forages, which also highlighted the significant variation between summer forage, and dormant winter forage. In summer, rangelands are rich with diverse plants, but over winter, with heavy snow cover, it can be difficult for sheep to access food and supplementing ewes with lucerne hay and grain (typically corn) is recommended to provide energy to meet energy and protein requirements during pregnancy.

Research from the University of Wyoming indicated that the grasses became deficient in zinc as the seed head develops and the plant matures. In the same research, they noticed that wool sheep tended to have a higher concentration of zinc in late pregnancy compared to dorpers and hair sheep. Shrubs in the rangelands tend to be adequate for manganese (Mn), zinc (Zn) and copper (Cu).

Associate Professor Whit Stewart recommended targeting mineral supplementation during the last 50 days of pregnancy (especially in twin bearing ewes), and the first 30 days of lactation. In lambs, it was recommended to provide trace minerals three weeks prior to weaning to help them cope with the stress of weaning.

The mineral status of the animal is tested via blood sampling, with selenium being tested from the whole blood - for a more accurate result, and copper and zinc being tested from the serum.

The University of Wyoming takes plant tissue tests from grasses and shrubs to identify mineral content. To determine what type of feed the sheep consume, they then take faecal samples to determine the plant DNA. Plants are then able to be identified as either grasses or shrubs also known as 'browse' and provide knowledge as to what plants the sheep choose to eat over times of the year and plant growth stage.

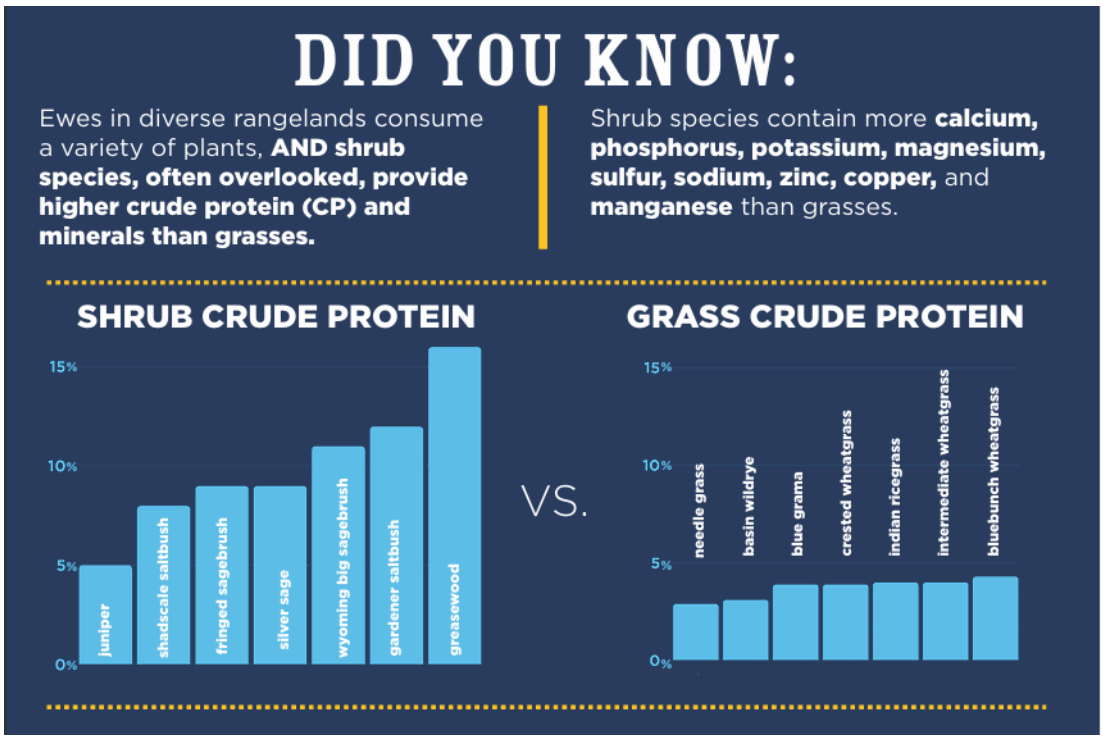


Figure 6: Shrub species are higher in crude protein, macro- and trace minerals compared to grasses in grasses in the rangelands of Wyoming. (Source: University of Wyoming, Sheep Extension Program Information sheet 'Winter care for ewes: Nutritional Considerations'.)

Interestingly, one nutrition specific issue discussed was a bone problem in lambs called 'bent leg'. This is where osteochondritis has caused improper hardening of cartilage in the legs of lambs. Vitamin D dysregulation is the primary cause due to the angle of the sun and latitude in Wyoming reducing vitamin D synthesis in lambs (Stewart, pers.comms., 2023).

There are a range of minerals naturally present in the water in Wyoming, and it is particularly high in sulphur. High sulphur content in water can bind up both copper and selenium, reducing the availability to sheep. Water quality is very similar in Montana, as noted in more detail in the next section.

Montana: Summer in the mountains, winter on the rangelands

In the southwest region of Montana, USA, they have 9 to 10-inch rainfall with a 4 to 5 month growing season. Sheep breeding season is October/November/December (late autumn/early winter), with most lambing in March/April/May (spring). Depending on sheep numbers, the breeding system is typically staggered to ensure barn capacity is not exceeded for multiple bearing ewes at lambing time.

During winter, sheep are outdoors and can typically handle the dry powder snow, as they scratch and dig through to the pasture; however, if it's wet snow, the snow melts and refreezes (as can occur at start/end of winter), or access is inhibited through large snowfall seasons, then ewes struggle to graze effectively. Poor ewe condition can be exacerbated due to sore hooves from attempting to dig through the ice, and coupled with cold stress, can quickly lead to weight loss through reduced ability to walk and access to feed. The 'Chinook' winds, aptly named "snow-eater's" cause large drifts, but in some cases blow rangeland clear of snow and open access to grasslands for grazing, which can be a fortuitous benefit for ewes during winter.

The worst weather typically occurs in mid-winter (January/February) which is also approximately mid-pregnancy. This is an important time nutritionally as brown adipose tissue is laid down in the developing lamb, which is required to keep newborn lambs warm, and in a tough winter it can be a big issue for survival of newborn lambs in the spring (Roeder, pers.comm., 2023).

During spring and late pregnancy, low protein can be an issue in pastures and require supplementation to improve ewe and lamb health. This is very similar to the rangelands of Wyoming where protein was limited on late spring pastures (Figure 7).

Post lamb marking, ewes and lambs are grouped together in 'bands' and trailed up to the high country with a sheep herder (typically Peruvian). As elevation increases, their pace and direction are dictated by snowpack depth, melt and pasture growth for the season; however, one thing is clear, all season long they consume a vast range of fresh summer forages as plant type changes with elevation. Sheep producers can access 1-month grazing allotments to rotate through different sections of mountain grazing. Often, the rancher relies on grazing the high country to be profitable (Roeder, pers.comm., 2023).

Figure 7: Peruvian herder trailing a 'band' (~1000 ewes, plus lambs) heading up into the mountains to graze lease country for the summer. (Source: Author, 2023)

In October, before winter, the sheep are required to be moved back down the range onto privately owned land where there is pasture consisting of grasses and forbs. When there are a range of plants and shrubs available, a variety of nutrients is provided naturally, however, on those pastures where there is predominantly grass

only available to graze, it is recommended that a commercial mineral mix is supplied (Roeder, pers.comm., 2023). In the region I visited, a typical commercial mix was a salt-based loose lick. The soils in Montana tend to be deficient in selenium, however with access to a range of browse and some native 'selenium- accumulator' plants, no selenium specific issues were noted. Sage brush is a typical native scrub in plentiful supply and is decent winter browse with a good protein content (Roeder, pers.comm., 2023).

Figure 8: Sage brush and shrubs in Montana. (Source: Author, 2023)

Water quality in Montana is naturally saline with higher levels of sodium, magnesium and sulphur, and tends to be alkaline (Roeder, pers comms., 2023). It was noted that some commercial loose lick supplements were tailor-made to balance water test results.

What was noticeable during my visit, is the extensive research in both Montana and Wyoming regarding pasture testing of available rangeland pasture species and knowledge of what the sheep are consuming over these rangelands, however, like Australia, most of the pasture testing has focused on energy, protein and NDF (neutral detergent fibre) content and only recently been focussed on mineral content.

The severity of the winter season and drive for improved productivity spurs this research to ensure sheep wellbeing and maximise opportunities through identifying gaps in nutrition over different seasons. Given the number of large predators in Wyoming and particularly in the mountains of Montana, any potential increase in efficiency through nutrition is tackled with gusto through the state universities.

Europe: Intensive and investigative

Feeding livestock in Europe is typically conducted indoors, with paddocks used to produce the feed. Food provenance for regions within countries is powerful, often resulting in certain rules and laws around feeding and resultant testing diagnostics to ensure food quality and the preservation of markets.

Intensive feeding systems bring precision and care to match the class of livestock - the demands of pregnancy and lactation for ewes, and growth rates and health of lambs. However, it is not without its challenges. Typical animal health issues are acidosis and respiratory disease – which are issues with see in Australia when feedlotting lambs or containment feeding ewes, albeit they are outside.

Whilst rations are well formulated for nutrients, with intensive feeding functional nutritional additives can be quite useful. A simple example of this is the use of rumen buffers to significantly reduce the risk of acidosis. However, it must be noted that the best result is the combination of well-researched and cost-effective feed additives coupled with good feeding management and observation skills.

Also important to note is the ban on ionophores (and medications) in sheep (and all ruminant) feed. Ionophores are a type of compound that have anti-microbial properties, and they are commonly used in sheep rations to improve feed conversion efficiency and aid in the reduction of coccidiosis. A typical ionophore used in Australia when feeding lambs is lasalocid sodium. It is more commonly referred to by the trade name Bovatec®. In Europe, the vet nutritionists I spoke to formulate rations using an oregano-based product, that has been well-researched and shown to provide natural anti-microbial activity using the compounds extracted from the oregano plant called carvacrol and thymol. We have a similar product here in Australia. In my experience it is working quite well in lamb feedlots but also offers the option for producers to meet market specifications for processors requiring ‘free from ionophore’ market claims.

Northern Italy: Keeping cool

Like the shepherds in Montana, the Italian native Damask sheep are herded to the mountains in summer to graze fresh native forages, then return in autumn and winter to the Lombardy region of northern Italy. Interestingly, there are extremes of weather between seasons in Northern Italy, with cold winters and particularly hot summers.

According to Giovanni Savoini, ruminant nutrition Professor the University of Milan, heat stress in northern Italy can be a particular problem for dairy cattle in the Po valley, whose milk is specifically used to produce parmesan cheese. To address heat stress and negative effects on milk production, feed formulation changes are made to the daily ration through a variety of ways, including: adding oil to increase the energy density of the ration, this is typically provided via whole cottonseed (a source of slow release fat and protein); potassium carbonate (to aid electrolyte status within cells); yeast culture (to improve fibre digestion and gut health) and organic chromium (to better regulate glucose and subsequent energy production). These measures are certainly worth considering incorporating into rations for lot-fed lambs during summer in Australia.

Southern France: The power of provenance

The Aveyron region in southern France is home to the famous Lacaune dairy sheep used specifically for Roquefort cheese production. During lambing and lactation, the sheep are housed, and the feeding infrastructure designed to reduce labour, time and improve efficiency was extraordinary. It was a real eye-opener to see the automated delivery of hay via gantry and delivery of their daily grain-based rations along conveyor belts. The delivery of the grain-based rations also provided flexibility to add or modify ingredients as required during different stages of lambing and throughout lactation.

As a supplier for Roquefort cheese production, Lacaune sheep are required to spend the summer outside on pasture. To supply a range of nutrients to the sheep, it was common to see lick pails or blocks offered to sheep whilst grazing. These supplements contained a specific range of minerals and vitamins depending on feed quality and reproductive phase. We were fortunate to be able to visit Julien Cabrol the owner of Euro-Phyto in Rodez. They supply a range of supplements and are a large supplier of pails and blocks. Julien also offered a service to clients whereby he uses forage analyses to determine if there are any specific vitamins and/or minerals required and then customises the supplement accordingly. On occasion, the tubs were also provided to housed sheep to supply nutrients depending on the farmer's infrastructure and feeding system. These typically contained the compound allicin (from garlic) to help repel flies and ticks.

Figure 9 and 10: Typical mineral and vitamin pails in southern France (Source: author, 2024)

Whilst the pails shown in Figure 10, provided a range of trace minerals and vitamins, many products also include a range of herbs and plant extracts that have natural anti-microbial properties and/or have positive benefits for improved gut health. Figure 9 is an example showing a product containing seven plant extracts. It was very common to see plant extracts added to ruminant feed in France, no doubt due to Europe's strict rules on medicated additives.

Visiting France was my first introduction to expansive diagnostic testing for a range of nutrients. Testing occurs with every milk delivery from sheep dairies to ensure food safety requirements are met for Roquefort cheese production. However, feed testing is also very common to ensure rations are optimised for cost-effectiveness and to meet sheep requirements for optimal milk or meat production.

Spain: Production pays

Many farms in Spain have multiple enterprises, for example, cropping, dairy cows, dairy goats, pigs and sheep for meat and wool may all occur on the same property. Due to the intensive nature of dairying, sheep tended to range on hilly pastures amongst the acorn trees when the Iberian pigs were not foraging in those areas.

Figure 11: Merino ewes and lambs grazing in the Extremadura region, in the southwest of Spain. (Source: Author, 2024)

Like southern France, trace mineral and vitamin supplementation was also provided in pails (and/or blocks), as shown in Figure 12, in Spain for grazing sheep.

Figure 12: Mineral and vitamin pails for extensively grazed sheep in Spain. (Source: Author, 2024)

Lambs are typically weaned early at around 45 days of age (approximately 12kg liveweight), then sent to specialised housed feedlots for a short finishing phase. The finishing period was between 15 days to 45 days (depending on entry weight) with sale/exit weights of approximately 25kg (liveweight), with a carcass weight of 12-13kg.

Due to the lambs' young age and weight there is a strong focus on immune health. It was very common for the vet nutritionist to add functional feed additives to promote rumen and gut health, whilst aiding fibre digestibility and extraction of nutrients from feed. Interestingly, at one lamb finishing site, eucalyptus powder was included in the starter ration to promote respiratory health and reduce illness, a large cause of ill health in lambs at the feedlot.

There are also heat stress issues in Spain, which were accounted for through adaptions to feeding and/or water supply. At one of the housed finishing systems I visited, electrolytes and nutrients were supplied via water during heat events, rather than through the feed. This allowed a faster response and increased flexibility to support lambs during summer.

Figure 13 and 14: Housed lamb finishing system in the Aragon region of Spain (Source: Author, 2024)

New Zealand: The pasture kings

The young soils of New Zealand naturally have a range of deficiencies due to the relatively short period of weathering, comparative to the older weathered soils we experience in Australia. The generally very high rainfall (the west coast of the South Island of New Zealand has an annual rainfall of around 1400mm), also leads to rapid leaching of minerals, with the nutritionally important minerals sodium and selenium being particularly fast moving through the soil (Westwood, pers.comm., 2025).

South Island: High country pastures and productive plains

During my visit in winter of July 2025, many stock were grazed on their 'over-wintering' forages. Winter can be exceptionally cold and as a result pasture growth of grasses and legumes slows considerably. 'Wintering' stock typically involved grazing brassicas such as kale and fodder beet, with stock being offered hay or, more commonly, baleage (silage in bale form for ease of feeding out).

Figures 15 and 16: Sheep grazing fodder beet during winter at Cleardale station, Rakaia, South Island, New Zealand. (Source: Author, 2025)

Sheep farmers on the South Island of New Zealand tend to join (tup) ewes in autumn and lamb in spring in the high country or hilly country where there is good shelter, they maintain fitness for lambing and there is less chance of ewes being cast (stuck on their side) (Todhunter, pers.comm., 2025). The high country is reliant on native pastures and shrubs to provide nutrition to lambing ewes, and whilst these regions can be accessed it is somewhat difficult to provide oral supplements such as loose licks or blocks to lambing ewes, due to paddock size and terrain.

Figure 17: Twin-bearing ewes grazing native pastures on the hilly country during winter at Cleardale station, Rakaia, South Island, New Zealand. Source: (Source: Author, 2025)

Most sheep farmers are aware of soil, plant and associated livestock nutrition deficiencies, and prepare for lambing season by providing long-acting trace minerals when conducting their pre-lambing health treatments (Turner, pers.comm., 2025). It is more labour efficient to provide these additional nutrition treatments whilst they are already in the yards. Once the ewes have lambed and lambs marked (tailed), lambs are typically moved onto purposely sown crops such as lucerne, brassica, clovers and/or grass-based pastures in late spring/early summer where there is reliable pasture growth until December (Todhunter, pers.comm., 2025).

Weaning time is another key event time for animal health treatments and it is common for lambs to be injected with short-acting (1-3 months) injections or liquid mineral and vitamin drench, or minerals that are directly added and mixed in with the deworming drench (Wragge, *pers comm,* July 2025*)*. Lambs are turned off between 32-42kg liveweight, and some may be sold at weaning or not long after, hence the strategic 'short-acting' approach (Iremonger, pers.comm., 2025).

Common mineral and vitamin deficiencies, and practical solutions from New Zealand:

Selenium:

When visiting farms in the Canterbury region on the South Island of New Zealand, sheep farmers (and the livestock nutritionists at DLF Seeds) commented that their soils are notoriously deficient in selenium. There were 3 common approaches to addressing this issue.

1. Fertiliser: Selenium prill added to fertiliser.

Prill is the term used to describe a small aggregate of powdered material. The small, aggregate form allows farmers to distribute nutrients evenly over the soil with reduced dust and handling issues. Application of selenium to soils in New Zealand is typically via plane for hilly, mountainous country, with the prill form of selenium ensuring better delivery to paddocks. The prill then dissolves into the soil for uptake by the plant which is subsequently consumed by the grazing sheep.

In my discussion with Dr Charlotte Westwood (vet and ruminant nutritionist at PGG Wrightsons/DLF seeds), it is interesting to note that there are two types of selenium prill available: sodium selenate, a shorter-acting form; and barium selenate a longer-acting form. A combination of both forms of selenium prill is now available for use by farmers.

Providing selenium via fertiliser is a longer-term approach and is typically conducted every two years, however, this may vary with rainfall and/or irrigation and the detrimental effects of leaching, with some farmers needing application yearly whilst others only need to fertilise every third year (Westwood, pers.comm., 2025).

2. Drench: Addition of selenium to deworming drench.

When stock need drenching for worms, the addition of selenium in the oral deworming drench is an effective way to ensure each sheep is treated whilst saving labour and time by tackling two issue whilst the sheep are in the yards. However, this form of supplying selenium is believed to be relatively short acting (less than a month).

3. Injections: Strategic use of selenium-only or selenium+B12 injections.

Application and timing of selenium injections is primarily based around the reproductive status of the ewe. For example, it is very common to provide a selenium injection pre-lambing along with other animal health treatments. This selenium injection will last approximately six months and is sufficient time to support the ewe through pre-lambing, lambing and lactation. Lambs tend to receive a shorter-acting injection at weaning as they are finished for sale relatively quickly.

Interestingly, selenium is not an essential mineral for plants. It is coincidentally absorbed with other nutrients for ingestion by sheep (Judson, pers.comm., 2025).

Iodine:

There are some soil types in the South Island that are naturally low or deficient in iodine, however iodine deficiencies have also been associated with grazing pregnant ewes on brassica crops – a common feed source in New Zealand. Iodine is important for fertility and for improved survival rates of the newborn lambs. Iodine plays a role in the production of thyroid hormones involved in metabolism, including the formation of brown fat which aids thermoregulation in newborn lambs. It is common practice to use long acting (3-6 month) iodine injections pre-joining (tupping) and/or pre-lambing to improve conception rates and lamb survival. Iodine may also be supplied through high-iodine based salt blocks, but intakes are likely to be quite variable.

Copper:

Grazing various types of brassica (kale, rape, leaf turnip) is very popular in the Canterbury region. In this scenario, copper deficiencies can be a concern. Brassica plants tend to naturally have a high sulphur content and coupled with additional molybdenum and sulphur contained in some fertilisers, these minerals will bind to copper making it unavailable for use by the animal. When grazing brassica, appropriate amounts of copper are typically provided via a copper wire bolus (longer acting) or potentially a loose lick with additional minerals and vitamins also included. Caution must be used when providing copper to sheep as they have a low threshold for copper, with copper toxicity a real concern.

Cobalt and vitamin B12 deficiency:

The soil is the primary source of cobalt for grazing animals, therefore, with different seasonal and pasture conditions cobalt supply may vary. Uptake of cobalt from the soil by plants is relatively poor, as is absorption from plant to animal. Cobalt is used by rumen microbes to manufacture vitamin B12. Vitamin B12 is an important vitamin required to produce energy for the animal. Cobalt is known to be highly deficient in many areas of New Zealand, and this can result in B12 deficiency, particularly in young lambs with an immature rumen (Westwood, pers.comm., 2025). Another cause of low B12 status is low rumen pH. Low rumen pH can be caused by high grain diets, or in New Zealand, is more likely to occur when feeding fodder beet or other bulbs that are very high in sugars. Fibre and potentially rumen buffers could assist in this scenario to stabilise rumen pH and aid the production of B12 when cobalt supply is not limited.

It was common for New Zealand sheep farmers to regularly provide short-acting B12 injections to lambs. For example, at Willesden Farms, the focus of B12 supplementation is directed towards hogget ewes at their pre-lambing treatments, and a large focus on B12 supplementation for weaned lambs and their finishing phase on pastures and forage. Vitamin B12 supplementation will depend on lamb weaning weight and the predicted time of sale. Any weaned lambs that are nearing the sale weight of approximately 17-20 kg carcass weights at weaning may be sold directly and not receive any additional B12. The remaining lambs will enter a finishing program and receive a vitamin B12 injection to stimulate appetite and support energy metabolism and growth. Some lambs may receive up to three vitamin B12 injections during their finishing phase. This was similar at the Wragge family farm whereby lambs were regularly ‘topped up’ with B12 (and selenium) when they came to the yards for drenching each month.

Both cobalt sulphate and copper sulphate can also be applied via fertiliser to provide a longer-term approach to increasing both cobalt and copper status in sheep (Westwood, pers.comm., 2025).

Sodium:

On multiple farms I visited near Christchurch on the South Island, it was noted that some soil types on the farm were deficient in sodium. Generally, salt was offered as loose salt or salt blocks when grazing lucerne (Iremonger, pers.comm., 2025) or paddocks known to be deficient in sodium (Todhunter, pers.comm., 2025).

Dr Charlotte Westwood described an interesting study whereby New Zealand's maritime climate of prevailing onshore winds deposited sodium and iodine along the east coast, with amounts reducing linearly as the trial moved west towards the mountains. The study found that the farmland furthest from the coast had the highest deficiencies of sodium and iodine. A similar effect occurs on the west coast but is more extreme. On some farms close to the coast and receiving the strong westerly winds, the high levels of sodium from sea spray have been excessive and burnt the leaves on pastures!

Australia: Back on home soil

Supplementing the value of lucerne

In Australia, it is typical for sheep to graze lucerne without any additional mineral or vitamin supplementation. This is primarily due to lucerne naturally providing adequate levels of calcium and magnesium, along with some trace minerals such as copper.

In discussion with Dr Gordon Refshauge, small ruminant researcher, from DPI Cowra, low sodium decreases rates of absorption of magnesium, and in some cases also reduces calcium absorption from the rumen (Refshauge, pers.comm., 2024). Soil potassium levels tend to be quite high in NSW, which can also tend to increase the risk ratio of potassium to sodium (K:Na). In trial work conducted at the DPI research site in Cowra, NSW, Dr Gordon Refshauge showed that lucerne is deficient in sodium and animals will respond to sodium supplementation when grazing lucerne. This is because absorption of magnesium across the rumen wall requires the presence of sodium. Salt is a cheap and common source of sodium for sheep, and it is recommended that loose salt be supplied to sheep grazing lucerne to assist performance.

For those with red soil types in Australian, it is also useful to know that red soils tend to be high in iron. Whilst iron is required by stock, when levels are high in the soil, iron can become antagonistic. This is where the minerals interfere with the absorption of other certain minerals, typically by binding with them and rendering the other mineral unavailable for absorption. In the case of iron, it will bind to manganese, copper and zinc (Larson, C. ZinPro, pers.comm., 2024), all of which are important trace minerals that are used as co-factors in antioxidant enzyme systems.

Native shrubs as a supplement

According to CSIRO agricultural research scientist Dr Hayley Norman, 'Anameka' a popular cultivar of 'Old Man' saltbush, offers producers an effective means of managing dry seasons by consistently supplying energy, protein, and nutrients that may help sheep cope with oxidative stress during reproduction and periods of heat stress.

Saltbush is known as a halophytic shrub. The term halophytic refers to plants that are salt tolerant. These shrubs typically accumulate sodium and chloride (salt) and can also contain higher concentrations of magnesium, potassium and sulphur compared to traditional plants; and a concentration of vitamin E and vitamin A far exceeding that of crop stubbles, dry pasture or grain (Norman, H. *et.al.,* 2019).

The important antioxidants manganese, copper, zinc, vitamin E and vitamin A are the same in plants as those in animals (Norman, H. *et.al.,* 2019). Therefore, the higher antioxidant content of halophyte shrubs such as saltbush can be a good source of minerals and vitamins for grazing animals and is of particular importance to lambing ewes and their elevated requirements for those minerals and vitamins. There is a current research focus on quantifying the potential of saltbush as an 'edible' shelter aimed at enhancing the survival rate of twin lambs.

For woolgrowers, Merino sheep grazing on saltbush systems exhibit a consistent 20–25% increase in wool growth compared to those grazing on dry pasture or stubble-based systems (Norman, pers.comm., 2024). These drought-tolerant native shrubs provide a source of green feed which is high in crude protein, sulphur and vitamin E, making them very useful complementary feed during summer and autumn when stock are grazing stubbles or dry feed (see Figures 18 and 19).

Through Dr Norman's research, it was noted that there was variation in mineral accumulation between types of saltbush, however, for many plant samples tested they were excess to sheep requirements (Norman, H. *et.al.,* 2019). This is important to note, as minerals can quickly become toxic or have antagonistic effects. While Dr Norman has shown there are notable productivity advantages associated with integrating saltbush, it is not recommended as a sole feed source due to these elevated levels of minerals present in its leaves. Offering a complementary feed source to balance the nutrients available in salt bush is a very useful option as many halophytic shrubs have low digestibility and are therefore also low in metabolisable energy (Norman, H. *et.al.,* 2019). Dr Norman suggests that saltbush is best grown in combination with high nutritive value grasses or legumes, and trial work has shown that stock will tend to include shrubs at more than 10% of their diet even when offered good quality feed.

Figures 18 and 19: Ewes grazing salt bush. Planting saltbush into crop before the pasture phase. Source: MLA CSIRO AWI publication 'Optimising establishment of saltbush-based forge systems'.

Chapter 3: Distinguishing diagnostics

The adage “measure to manage” is an important part of any successful business. In the case of mineral and vitamin nutrition, measuring mineral and vitamin status allows us to better manage livestock health and performance whilst at the same time being informed on the return on investment of the additional inputs and labour costs. It is particularly noticeable when sheep prices fluctuate. Sometimes inputs are reduced to try and maintain profitability, however we don’t always see the medium to long term effects of those reduced inputs on potential conception or weaning rates, and subsequent loss of predicted future income.

In my travels, particularly to France and New Zealand, I was amazed at how extensive testing is, that it is easy, commonly available, and affordable. In Australia, I’m only aware of the standard soil, plant, water, and feed testing; with only one lab that I’m aware of offering blood and liver sample testing.

We can essentially separate diagnostic testing into 2 categories.

1. Livestock testing. Live animal sampling and/or postmortem sampling.

The most common live animal sampling is whole blood and serum. Testing of minerals in urine and milk is less common unless they are sheep used for milk or cheese production. Mineral analysis of milk is impractical in extensive sheep production, but mineral content will also vary during lactation, so it is not typically used to evaluate whole animal mineral status of ruminants in general (Hall, 2005). It is also important to note that Hall (2005) recommends that the health status of the animal at testing should be taken into consideration as disease states can shift minerals from tissues to serum or vice versa. Stress will also alter circulating/blood concentrations of certain minerals and electrolytes.

Blood testing is specific to certain minerals. These include the enzyme glutathione peroxidase (an indicator of selenium status), vitamin B12, zinc, and iodine. Blood testing provides an indication of mineral status of the prior few days of the animal, and results can vary depending on feed type consumed (Turner, pers.comm., 2025).

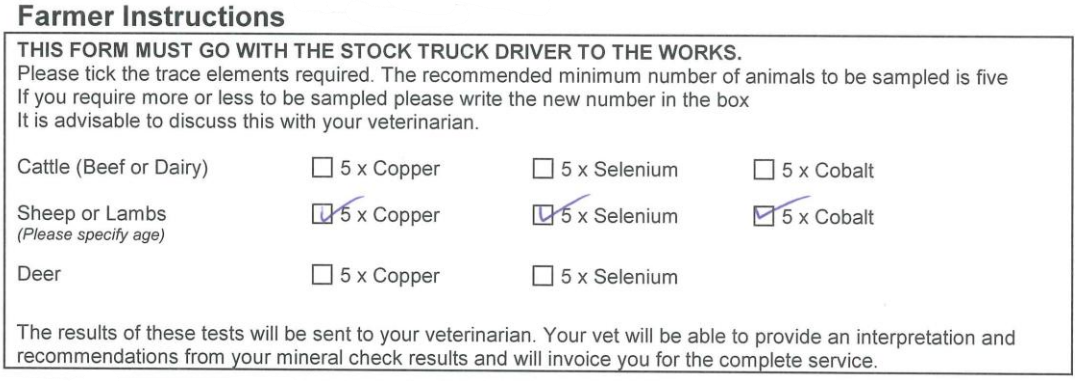
Thyroid hormones can be tested as an indicator of iodine status, but a better, more accurate test is specifically testing iodine levels in blood. Typically, test samples are ‘pooled’ together to provide an average as iodine testing is very expensive.

The timing of blood testing throughout the year needs to be considered as New Zealand nutritionist Melinda Turner shares with me that “*stock are quite often low in selenium, iodine and copper coming into winter”* therefore the time of year that blood testing occurs is important to know, as it helps put mineral status into perspective and aids in determining the best timing of supplementation.

Vets in New Zealand will also conduct live animal liver biopsies. It is a more expensive way of testing liver samples, but useful for young stock such as cattle that will benefit from improved mineral or vitamin B12 status (if required) during the longer finishing phase (compared to sheep) (Todhunter, pers.comm., 2025).

The most common postmortem sample is liver tissue, other postmortem samples include ocular fluid (magnesium and calcium), bone and urine. Liver samples can be frozen until ready for sampling which can provide an easy and practical way of collecting multiple samples before sending for testing.

In New Zealand, liver biopsy testing is readily available via the abattoir. A submission form is completed and sent with the truck driver. It is very common for sheep to be sent directly to the abattoir, which aids this 'request for sampling' process. Liver samples are taken by the abattoir vets and sent off for testing. A very easy and practical way to obtain the copper, cobalt/B12, zinc, and selenium status of your animals. A partial example of a submission form is shown in Figure 20.



Farmer Instructions

THIS FORM MUST GO WITH THE STOCK TRUCK DRIVER TO THE WORKS.
Please tick the trace elements required. The recommended minimum number of animals to be sampled is five
If you require more or less to be sampled please write the new number in the box
It is advisable to discuss this with your veterinarian.

Cattle (Beef or Dairy)	☐ 5 x Copper	☐ 5 x Selenium	☐ 5 x Cobalt
Sheep or Lambs *(Please specify age)*	☑ 5 x Copper	☑ 5 x Selenium	☑ 5 x Cobalt
Deer	☐ 5 x Copper	☐ 5 x Selenium	

The results of these tests will be sent to your veterinarian. Your vet will be able to provide an interpretation and recommendations from your mineral check results and will invoice you for the complete service.

Figure 20: Partial submission form to request liver biopsy in New Zealand. (Source: Matt Iremonger, Willesden Farms, 2025.)

2. Soil and plant testing

Soil test results in New Zealand provide information on the soil status but this needs to be linked to what stock require, and any other mineral antagonists present to provide a more informed approach to mineral and vitamin supplementation (Turner, pers.comm., 2025)

Baseline pasture testing, and subsequent follow-up tests at three and six months, is a system New Zealand ruminant nutritionist Melinda Turner employs to practically assess and understand if selenium levels are sustained in the soil and plant for use by the ewe when it's needed, for example at lambing time. Melinda also informs me that pasture growth stage will also affect the selenium status of the ewe. If the plant is growing rapidly, the selenium is simply not drawn up quickly enough through the plant to be consumed in adequate quantities; and if the feed is very mature and dry, sheep can't physically consume enough (due to high NDF) to meet requirements.

Chapter 4: Practical performance

Mineral and vitamin options for improved performance

Mineral supplementation for sheep should be straightforward and affordable. Monitoring mineral intake is crucial to meet their needs without overconsumption. Excessive intake can be costly and does not necessarily result in improved performance.

Key decision-making tips

1) Ensure the product is 'Fit for Purpose'
   It either matches the:
   a. Class of stock, for example lambing ewes or weaned lambs

   And/or

   b. Is balanced to match pasture type, for example, Brassica 'balancer' supplements contain low sulphur content and additional iodine (and possibly copper)

2) Response time and pay-out period.
   a. How quickly is the mineral or vitamin available for use by the animal?
   b. How much does it deliver daily?
   c. How long does it last for?

Options for supplementation

1) **Oral Supplementation** includes:
   - Consumption from diet, including pasture plants, loose licks, blocks
   - Rumen boluses
   - Oral drench

Pastures: Hero herbs – plantain and chicory

After spending time with Glenn Judson and Kaylee Spain from Agricom (DLF Seeds) in New Zealand, it's hard not to get excited about the potential benefits plantain and chicory. Both these herbs are great at absorbing minerals from the soil and appear to be more bio-available for the animal to absorb and use (Judson, pers.comm., 2025).

What's exciting about plantain is that it contains four times the concentration of calcium compared to ryegrass. Calcium is an extremely important macro mineral, particularly at lambing time, so much so that Glenn dubs it a 'lactation feed'. Trial work has shown that it appears to be quite palatable, as illustrated by some extraordinary lamb growth rates between birth and weaning when grazing plantain. According to AWI's 'Winning with Weaners' program, the target weaning weight for Merino lambs is 45% of your ewe's Standard Reference Weight (SRW). This is an important target to ensure optimum health for the performance of replacement ewes, wethers and/or sale lambs. The inclusion of herbs into your improved pasture paddocks could form part of a longer-term strategy to assist lamb growth rates before and after weaning.

Loose licks and blocks

There are a plethora of loose licks and blocks to choose from in Australia. Many are designed to suit various stock classes and pasture conditions. Store availability, price and consumption rates tend to dictate product choice. A review of the salt content (a regulator of intake) and content of bio-available minerals (a blend of inorganic and organic minerals is a nice balance), along with the recommended feeding rate can help guide your choice. It's a good idea to cross check your consumption rates with the recommended feeding rate to determine if they are under- or over-consuming the product. This may help guide your choice to a more cost-effective and nutritionally effective option.

It is well known that loose licks and blocks tend to have inconsistent intakes. However, they are relatively easy to administer in extensive Australian farming systems. This is not the case in New Zealand where the additive would need to be moved daily to match the strip grazing allocation.

Rumen boluses

In Australia, Coopers Animal Health supply single mineral boluses with varying pay-out periods - selenium (3 years), cobalt (1 year), and copper (1 year). New Zealand has a copper-wire bolus available for use in known copper-deficient areas.

It was noted that selenium boluses in New Zealand have a slow release rate which may be too slow to meet sheep requirements. The selenium injections provided a quicker and bigger spike in selenium for sheep (Judson, pers.comm., 2025).

Many different types of multi-mineral boluses are available in Europe, and a good variety is available in New Zealand.

In France, I visited an impressive company called Obione, who have a vast range of boluses for sheep and cattle, as shown in Figures 21 and 22, and excitingly have various payout periods to match intended use. Their product offering is backed by an expansive testing service to ensure the correct products are used at the optimum time. Very impressive!

Figure 21 and 22: Obione in France have a vast range of rumen mineral boluses for cattle and sheep to support health and performance. Cattle boluses are shown. (Source: Author, 2024)

Oral drench

Drench supplementation can be delivered via a deworming drench or as a direct multimineral drench. In delivering via a deworming drench, it can be either added by the drench supplier, typically adding selenium and/or cobalt; or as a multi-combination of minerals pre-blended on-farm and added to the deworming drench as occurs in New Zealand.

An oral multimineral drench as a separate 'stand-alone' multi-mineral and vitamin drench is also an option.

In both instances, oral drenches appear to have varying levels of longevity in the animal's system. When there is regular opportunity to bring sheep to the yards, such as drenching for worm (as happens in New Zealand) it can practically work well.

2) **Injectable Supplementation** includes:
    - Multi-mineral injectables, typically selenium, zinc, manganese +/- copper
    - Single mineral injectables, typically classified into long- or short-acting selenium, iodine, B12

Virbac animal health vet Dr Stephanie Hansen, presented an informative webinar (*'Unlocking performance"*, 24th March 2024) where trial work showed the very quick lift in body levels of copper, selenium and zinc in cattle when injected with trace minerals. The 'top-up' principle that Virbac promotes is to use injectable minerals as a strategic tool to improve trace mineral status at key event times, such as pre-joining and pre-lambing, or to support lamb growth and health. The increase in mineral status using injectables was especially useful when there are antagonists present, such as high iron content from soil.

The time taken for an increase in mineral status in both blood and liver is summarised below:

- Copper – increase in liver status (the storage site of copper) occurred two days post-injection of Multimin. Trial shows it remained in system for 45 days before liver copper level started to decline.
- Zinc – spike in zinc content in blood within eight hours, then seen to increase liver storage levels two days later.
- Manganese – similar spike in blood plasma to zinc before it enters the liver. A major antagonist is iron (typically from red soils).

The injectable trace minerals from Multimin (Se, Zn, Mn) will last for approximately three months in the sheep's system. It's important to remember that every animal receives the treatment, so whilst it is more labour intensive it removes the variability associated with consumption and optimum intake. The use of mineral and vitamin injections ensures that every animal has received their required dose.

Cost versus effectiveness

A summary of the cost and effectiveness of mineral supplements available in the UK is provided in Figure 23. Based on common feedback received during my visit to New Zealand, it appears to be very similar scenario.

Option	Cost £–£££	Effectiveness *–***	Ease of use *–***
Free choice minerals	£	*	***
In-feed minerals	£	**	***
Drenches	£	**	**
Injections	££	***	**
Boluses	££	***	*
Top dressing pasture	£££	*	**

Figure 23: A summary of the cost and effectiveness of UK mineral supplements. (Source: UK Vet Livestock - Trace elements in sheep — are they really a cure all?, 2020)

However, in New Zealand, the costs of top-dressing selenium on pasture will vary depending on terrain. Contract spreading using a tractor and spreader is far cheaper than when planes are required to spread fertiliser (containing selenium prills) over hilly, mountainous country (Wragge, pers.comm., 2025).

Conclusions

Selenium, manganese, zinc, copper, sulphur, vitamin E, and vitamin A all have an important role within the antioxidant system to help sheep manage oxidative stress.

In our extensive grazing systems in the Riverina region of NSW, typical summer and autumn feed often results in low intake of these antioxidants. It is also likely to coincide with periods of increased oxidative stress associated with the reproductive cycle (joining, lambing or lactation), or high growth rates to finish lambs for sale.

Oxidative stress is also likely to be exacerbated by factors such as heat stress and parasitic infection. Short-term oxidative stress has been shown to adversely affect growth, reproductive performance, offspring survival, and overall health (Masters, 2018).

"Strategic selection of shrubs that accumulate all, or some antioxidant minerals or vitamins, and grow in arid and drought susceptible environments, offers a new opportunity to design grazing systems that provide a combination of antioxidants within a grazed system." Dr. Hayley Norman, CSIRO, Australia.

Focusing on quality forage production and providing "functional plant diversity through mixed swards of grasses, legumes and herbs" (Judson, pers.comm., 2025), will offer a natural balance of nutrients especially when using plants suited to your environment.

"A long term solution is to supply more nutrients with every mouthful of feed consumed…" Glenn Judson, Nutritionist, DLF Seeds, New Zealand

Observation of pasture quality and diversity, combined with monitoring sheep health is key. Understanding your feed supply and the current nutritional status of your sheep, will guide you towards being able to provide supplements strategically to aid in preventing any known mineral and vitamin deficiencies and/or allow you to balance any excesses.

A strategy combining soil, plant, blood and liver analyses will provide an ideal approach for the development of customised farm nutritional programs to optimise health and production.

Yearly soil testing and quarterly (seasonally) pasture testing will help build your own sheep nutrition profile. Efficiency really revolves around tasks that can occur when sheep are in the yards. This includes sampling (blood and/or liver), and /or treatments. Consider treatment pay-out periods and measure any impacts to reflect your return on investment for example, improved lamb growth rates.

Taking the time to plan will aid your decision to use short-acting or long-acting products. Couple this with follow-up testing (soil, plant and animal) to help build your own short-, medium- and long-term approaches to improve both sheep and farm health. Being more strategic in your approach to sheep health, will help you be more cost-efficient, labour efficient and nutritionally efficient.

Recommendations

Be strategic: Planning and timing

Operational plans are imperative to a successful sheep enterprise. To become more precise in our approach to feeding mineral and vitamin supplements we need to predict the upcoming season (short-term), plan for the medium term (six months to one year), and then have a long-term strategy that improves and supports increased productivity.

The critical times to review mineral and vitamin supplementation are:

- Pre-joining: 6-7 weeks prior to joining to support ewe and ram reproductive health
- Pre-lambing: 3-4 weeks prior to lambing, and through to weaning to meet the increased demands of pregnancy, especially in higher performing ewes (bearing multiple lambs), foetal lamb development, and colostrum and milk production for the newborn lamb
- Weaning: through to sale or mating (ewe lambs/replacement ewes)

Supplementation will also depend on pasture quality, and/or crop type:

- Balance: against excesses and deficiencies in pastures and/or grazing crop

Ensuring antioxidants are supplied at critical times is important for livestock health and will help reduce reproductive wastage and ultimately improve performance.

Be effective: Time, cost and nutritionally effective

Short term: 1 to 6 months

Short-acting injectables

Macro minerals (loose licks) to balance grazing crops and high quality pastures

- Pasture testing: to aid supplement decisions
- Blood testing: for young animals

Medium term: 6 months to 1 year

Long-term injectable or rumen boluses

- Assess if the supplement/s are working with yearly blood tests/liver biopsy at key times (autumn/winter).

Long term: > 1 year

Rumen boluses

- Soil testing: +/- fertiliser
- Pasture testing: +/- different plant species.

The three-prong approach of testing soils, pastures and livestock helps to determine if there are any specific deficiencies that need to be accounted for, such as copper, selenium, and cobalt/B12. This will help determine the type of supplement required for use at the critical times above. Most often, the overlay of pasture quality will also need to be considered, for example, supplying sodium (salt) when grazing lucerne pastures.

In Australia, we certainly need to make sampling liver biopsies simpler and easier.

Ideally, this would occur via using samples sent to the abattoir, as is done in New Zealand. Similarly for blood testing, vets (government or private) should be able to easily assist in this area of testing. The results would need to be presented as an easy-to-read standardised format that would show the results and the optimum range required for sheep health. This would encourage sheep producers to review the mineral and vitamin status of their flock and provide the information to be able to make strategic, cost-effective decisions based on results. It would be a ‘measure to manage’ approach and bring more precision to sheep supplementation.

References

Dove, H. 2009. Supplementary Feeding for Wool Growth. Chapter 26, Module 4, Nutrition Management for Grazing Animals. Applied Animal Nutrition ANUT300/500. The University of New England.

Hall, Jeffery. (2005). Appropriate methods of diagnosing mineral deficiencies in Cattle.

Hutjens, M.F.,1991. Feed additives. Vet Clin. North Am. Food Admin. Pract. 7, 525-540.

Masters, David. (2018). Practical implications of mineral and vitamin imbalance in grazing sheep. Animal Production Science. 58, 1438-1450.

McGrath, J.J., *et al.* 2018 Nutritional strategies in ruminants: A lifetime approach. Research in Veterinary Science 116, 28-39.

Norman, H.C., et al 2019 Halophytic shrubs accumulate minerals associated with antioxidant pathways. Grass Forage Science. 74, 345-355

Warren, H. 2020 Microbial diversity for ruminants. All About Feed, Volume 28, No.8 p14-16