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Graham Centre Sheep Forum

7 July 2017 -
CSU Convention Centre, Wagga Wagga

8.30-8.55am  Registration and Coffee
8.55-9.00am  Welcome and outline of the day
Toni Nugent (Industry Partnerships & Communications Manager, Graham Centre)
9.00-9.40am  Production management on-farm and its effects on meat quality
Bruce Hancock (Rural Solutions SA:PIRSA/Sheep CRC)
9.40-10.00am  The use of technologies for lamb carcase assessment
Steph Fowler (NSW Department of Primary Industries)
10.00-10.20am  Minerals in pastures: calcium and magnesium levels and implications for supplementation
Shawn McGrath (Fred Morley Centre, Charles Sturt University)
10.20-10.40am  Fully sick grazing cereals – common sheep diseases to watch out for
Gordon Refshauge (NSW Department of Primary Industries)
10.40-11.15am  MORNING TEA
11.15-11.35am  Manipulating fatty acids in sheep and cattle: implications for animal and human health
Edward Clayton (NSW Department of Primary Industries)
11.35-11.55am  Drones as tools in agriculture
Ben Watts (Bralca Consultancy)
11.55-12.15pm  Are acid soils under control? Legumes tell us we could do better
Helen Burns (NSW Department of Primary Industries)
12.15-12.45pm  Panel session (all session speakers)
12.45-1.00pm  Forum summary, wrap up and evaluation -
Toni Nugent (Industry Partnerships & Communications Manager, Graham Centre) and
Michael Friend (Director, Graham Centre)
1.00pm  LUNCH
Supporters

awi | sheep connect new south wales | Rabobank

Charles Sturt University | MLA MEAT & LIVESTOCK AUSTRALIA

NSW Government Local Land Services Riverina | NSW Government Department of Primary Industries
Welcome to our 2017 Sheep Forum

Strong meat and wool prices, combined with good seasons in most areas, have underpinned yet another good year for the industry. The industry is a very positive, forward looking industry at present, which is investing in innovation to secure its future.

Demand for sheepmeat in the future will be dependent on the product we produce meeting consumer expectations. The quality of meat we produce is heavily dependent on our practices on-farm, so Bruce Hancock will kick our forum off with what we know about how on-farm practices affect meat quality. Equitable returns to the producer for producing quality is then dependent on an accurate assessment of the carcase, and Steph Fowler will provide an update on technology development to assess lamb carcases. Ed Clayton will discuss strategies to alter the fatty acid content of diets to improve both animal and human health, which may provide opportunities for health claimable meat that attracts premiums.

The increased use of grazing crops in our systems has provided significant opportunities to overcome the traditional winter feed gap. But using such crops brings new challenges, especially in the management of metabolic issues. Gordon Refshauge will cover off on the major issues to be aware of, while Shawn McGrath will focus on the importance of having adequate calcium and magnesium levels for grazing stock.

Technology is advancing at a rapid pace, but we need to stop and ask what value technology provides before we adopt. Drones are a perfect example of this. Much hype exists around their potential, but realistic assessment is needed. Ben Watts will discuss how useful they can be as a tool.

Finally, attention to our resource base is essential if we are to run profitable farming businesses. Soil acidity is a well-recognised constraint in our region, and there are well established strategies to manage soil acidity. But how well are we doing? Helen Burns will round our day off with an assessment of how well we are doing managing soil acidity.

We look forward to some robust discussion about the opportunities, challenges and research needs facing our sheep industry.

Regards

Professor Michael Friend,
Director, Graham Centre for Agricultural Innovation
Ms Helen Burns

Helen Burns is currently NSW DPI Pasture Development Officer based in Wagga Wagga. The majority of her career has been involved in agricultural development and extension in south-eastern NSW. Previous roles include NSW DPI district agronomist based at Lockhart and various industry funded projects including, being part of the TopFodder Silage team that produced the Successful Silage manual and workshops, and leading an MLA review of soil phosphorus status and the use of phosphorus fertiliser in livestock production systems of southern Australia.

More recently Helen has been working on two GRDC projects addressing the ongoing challenges of soil acidity in south eastern Australia. This takes her almost full circle and back to some early extension work in the 1980s when liming and soil acidity were new to broadacre agriculture. The two projects Helen is currently involved in are:

1. Innovative approaches to managing subsoil acidity in southern Australia (2015-2020).

Dr Edward Clayton

Ed Clayton completed a Bachelor of Rural Science (Hons) and a PhD in ruminant nutrition at the University of New England before commencing work with the then NSW Department of Agriculture in 1999. He has been involved with industry-based commercial research as well as research examining the effects of omega-3 fatty acids on a range of disease models in humans, including risk factors for cardiovascular disease. Since taking up the position of Livestock Research Officer with NSW Department of Primary Industries, Ed has worked in several areas related to forage conservation and omega-3 fatty acids, including forage quality and the effects of nutrition on reproduction as well as the impacts of diet on the health attributes of meat.

Dr Stephanie Fowler

Stephanie Fowler joined the NSW DPI meat research team at Cowra while completing her PhD (graduated 2015), which focused on the development and validation of a Raman spectroscopic handheld device to measure lamb quality. This has contributed to experience in carcase assessment, quantification of meat quality and fatty acid composition of meat, as well as the development of technologies to measure meat and carcase qualities.

Stephanie is currently working on several projects as part of the Sheep CRC including the validation of NitFOM and NIR technologies to predict intramuscular fat levels in sheep and lamb meat, the development of technologies to measure the GR depth of lambs and improving the utilisation of cuts of heavy lambs (fabrication costs, new cuts and nutritive value). Stephanie is also engaged with other technology based projects including the preservation of fresh lamb shelf life using hypobaric chambers and the development of Raman spectroscopy to predict beef meat and sensory traits. She has currently published 10+ papers/reports and is an adjunct research associate with the Graham Centre of Agricultural Innovation.

Dr Bruce Hancock

Bruce Hancock is a Rural Solutions SA:PIRSA senior livestock consultant and has been the Sheep CRC/MLA National Lamb Supply Chain Coordinator since 2009. With over 37 years’ experience in agricultural development, industry empowerment and capacity building, he has worked with businesses along the meat sheep supply chain, from Research Development Corporations managers, researchers and adoption agents, ram breeders who supply the genetics, sheep producers, marketers and processors and retailers and exporters. The essential ingredient has been the development of a shared vision of a consumer focus with clear market specifications, feedback and benchmarking on their performance to initiate review and continuous improvement.
Dr Shawn McGrath

Shawn McGrath grew up on a beef/wool property near Tumbarumba. He completed a Bachelor of Science in Agriculture at the University of Sydney in 2001, before commencing work in corporate agriculture for Elders Ltd (2002-2009), predominantly in the beef supply chain with production and marketing of domestic beef and export Wagyu, and then in rural finance. In 2010 he returned to southern NSW and changed his career focus to research, with a wool industry-sponsored PhD, into the utilisation of dual-purpose wheat, followed by an MLA-sponsored project comparing Dorper and Merino production in mixed-farming systems at Wagga Wagga. In August 2015 he commenced in his current position as Lecturer in Whole Farm Management (McCaughey) in the Fred Morley Unit at CSU, with a focus on applied research and undergraduate and postgraduate teaching in livestock production and consultancy.

Dr Gordon Refshauge

Gordon Refshauge is a Livestock Research Officer with NSW DPI, based at the Cowra Agricultural Research Station. His PhD studied the relationships between fat and muscle depths in ewes selected for high and low bodyweight and clean fleece weight. In 2008 he commenced work in his current position, overseeing the management of the Cowra sites’ Information Nucleus Flock - a Sheep CRC genetics resource flock. Gordon has strong interests in sheep reproduction and is involved in studies involving mineral nutrition affecting ewe health, nutrition or heat stress effects on ewe fertility and other studies examining cause of death in neonatal lambs.

Mr Ben Watts

Ben Watts is Australia’s leading independent drone specialist, developing innovative solutions for commercial agriculture.
Production management on-farm and its effects on meat quality

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Take home messages:
• Seek feedback on carcase compliance to specification of lean meat yield percentage and eating quality to ‘Measure - Monitor - Manage’
• Utilise a mix of decision support tools and service provider offerings
• On-farm effects on eating quality include breed, age, finishing growth, carcase specification and pre-slaughter handling.

Background
The Australian lamb/sheepmeat industry is strongly consumer focused, and responds to the meat quality market signals/feedback sent back down the supply chain. Key eating quality traits include:
• Lean = fat
• Convenient / fast (new, more cuts)
• Juicy / tender
• Innovative / modern (larger carcase)
• Colour stability
• Healthy and integrity
• Overall liking
• Provenance

In Australia, through hard work by all across the supply chain, an excellent balance of market destinations has been developed to ensure it is not exposed to any one particular market. The share exported is steadily increasing year on year to 70+ countries in chilled, frozen and live form, along with numerous and important co-products, and domestic food service and retail volume holds firm.

Sheepmeat consumption is subject to a range of historical, economic and geographical factors. Increasing demand due to population growth, urbanisation and increasing incomes, especially in developing countries, continues to challenge the supply. Most would feel the time is right to invest in the platforms for growth, sustainability and human capacity and capability building on-farm (MLA, 2017).

Lamb is one of few industries that has shown positive growth over the past 30 years, and has been on a 2.7 per annum rising real price since 1990 (Figure 1).

Figure 1. Australian real commodity prices.

The Sheep Industry Strategic Plan (SISP 2015-20) sets a direction for continued growth via a focus on on-farm production management for good eating quality outcomes (Table 1).

Table 1. Linkages between production efficiency, optimising product quality and animal wellbeing.

<table>
<thead>
<tr>
<th>Production efficiency</th>
<th>Product quality optimisation</th>
<th>Animal wellbeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking rate – NRM, feedbase utilisation, within climate variability</td>
<td>Lean Meat Yield (LMY%), while maintaining or improving Eating Quality (EQ)</td>
<td>Animal health diagnostics and control of endemic and exotic diseases</td>
</tr>
<tr>
<td>Reproduction rates</td>
<td>Objective measures of hard to measure EQ traits such as LMY %, Shearforce (SF5) and intramuscular fat (IMF %)</td>
<td>Animal Health and Biosecurity – NVD and NSHS, MRL’s, WHP, ESI.</td>
</tr>
<tr>
<td>Genetic gain</td>
<td>Welfare risk assessment – LTEM, BWFW, ASKBILL</td>
<td></td>
</tr>
<tr>
<td>Liveweight gain</td>
<td>Farm Assurance</td>
<td></td>
</tr>
<tr>
<td>Human capability building</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enterprise structure and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Production / margin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: The Sheep Industry Strategic Plan (SISP 2015-20).
**Key Profit Drivers**

Key profit drivers were recently summarised in the 2015 - 2016 Holmes Sackett Benchmarking dataset of prime lamb producers in 600 - 700mm country. Producers ran on average, 2500 ewes over numerous years where the average profit for benchmarking participants was $10 / DSE, and the top 20 per cent of prime lamb enterprises achieved a profit of $25 / dry sheep equivalent (DSE). The was two and a half times more than the average.

The four key benchmarks of the top 20% were:
- One ewe joined / hectare / 100 mm of rainfall.
- 24 kg of lamb (dressed weight) sold / ewe joined (e.g. 120 % NLW @ 20 kg in spring).
- 250 g / day growth rate to sale.
- Cost of production: $78 / ewe joined (comprising $22 for labour, $14 pasture, $7 animal health, $9 shearing and crutching, $10 selling costs and $16 overheads).

**Market specification signals for the producer**

The value based pricing journey is ramping up via more objective carcase measurement (OCM) and feedback systems (Table 2).

**Table 2. Meat and Livestock Australia’s Livestock Data Link (LDL).**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MSA - Sheepmeat</td>
<td>LMY% (LDL) (HSCW + GR Knife)</td>
<td>LMY% (DEXA) “In an overlay grid”</td>
<td>LMY (ICT Scan?) EQ Index</td>
</tr>
<tr>
<td>HSCW + GR</td>
<td>HSCW + GR</td>
<td>HSCW + GR</td>
<td>HSCW + GR</td>
</tr>
</tbody>
</table>

The Sheep CRC and its collaborating supply chain partners (i.e. ram breeders right through to processors, and retail - domestic, export and food service), have been working on future customer requirements and specifications. The Nucleus and MLA Resource flocks aim to measure genotype, phenotype and slaughter characteristics of 2400 lambs per annum of known genetics, with a focus on hard to measure eating quality traits such as LMY %, and IMF %. These measurements have supported the development of genomic assisted Australian Sheep Breeding Values.

Activity along the supply chain has included, but is not limited to, that shown in Table 3.

**Table 3. Activity measured in the lamb supply chain.**

<table>
<thead>
<tr>
<th>Consumers</th>
<th>Processing</th>
<th>Lamb Producers</th>
<th>Ram Breeders</th>
</tr>
</thead>
<tbody>
<tr>
<td>New cuts, larger carcase</td>
<td>OCM</td>
<td>Enterprise structure Cost of Production</td>
<td>Yearly genetic gain</td>
</tr>
<tr>
<td>Packaging</td>
<td>Robotics</td>
<td>Feedbase ? NRM / Stocking Rate</td>
<td>Wool - easy care Animal health</td>
</tr>
<tr>
<td>Display</td>
<td>RFID - Hook tracking (not EID)</td>
<td>Liveweighting gain</td>
<td>Carcase - PTW, PEMD, PFAT</td>
</tr>
<tr>
<td>Marketing: Fine dine to Fast food</td>
<td>Feedback systems New, transparent</td>
<td>Genetic gain</td>
<td>EQ traits and indexes</td>
</tr>
<tr>
<td>Branding - True Aussie Australian National Icon</td>
<td></td>
<td>IMF%, LMY%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MSAA Mk 2</td>
<td>Reproduction rates</td>
<td>Reproduce</td>
</tr>
</tbody>
</table>

There are a number of ‘supporting technologies’ in development including:
- Hook tracking – RFID (not EID) to enable carcase measurement feedback.
- MSA Mk 2- is developing an ‘Eating Quality Index’, which includes:
  - Breed
  - LMY %
  - GR Fat
  - IMF % - “hopeful in 2017”
  - Carcase / cut

There are also a number of decision support tools available for producers’ on-farm including:
- Cost of Production / business and enterprise structure
- Carcase feedback: Benchmarking carcase specifications within property; year on year, region or supply chain (e.g. MLA LDL, or proprietary services)
- Building relationships with processors and key personnel in the supply chain
- Sheep genetics workshop (e.g. RAMSELECT, APP, Bred Well - Fed Well)
- Lamb biology - Muscle:Bone:Fat from varying diet energy sources and lamb age
- Fat score - lamb assessment (get the hands on the back of every lamb)
- MSA - accreditation and pathways; get ready for the MSA Eating Quality Index.
Service providers

Service providers / consultants operate across a number of disciplines and areas. They are there to help support best on-farm practice and adoption. It is good practice to review your current service, identify their role, mode of operation and service offering that supports you and your business in a profitable and sustainable direction.

Action plan for production management on-farm

A useful tool for producers is to develop an action plan for production management on-farm, and to look at the effects management practices have on meat quality. Table 4 below shows a template producers can use to develop an action plan for their business.

Table 4. Action plan for on-farm production management.

<table>
<thead>
<tr>
<th>Action Area</th>
<th>Target</th>
<th>My action plan / Notes to self</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoP / Business and enterprise structure</td>
<td>$3.50 /kg DW labour</td>
<td>LMY % (DEXA) In an overlay grid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MSA Mk2 / EQ Index</td>
</tr>
<tr>
<td>Feedback : Benchmark</td>
<td>hSCW, GR Fat, LMY %</td>
<td></td>
</tr>
<tr>
<td>Genetics</td>
<td>Carcase ASBVs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carcase indexes</td>
<td></td>
</tr>
<tr>
<td>Growth Pathway</td>
<td>350 g / day to weaning</td>
<td></td>
</tr>
<tr>
<td>Live animal assessment</td>
<td>Fat score 2-4</td>
<td></td>
</tr>
<tr>
<td>MSA Sheepmeat</td>
<td>Accreditation and NVD</td>
<td></td>
</tr>
<tr>
<td>MSA Mk 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Providers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

References and further reading


The use of technologies for lamb carcase assessment

**Stephanie Fowler**¹² and **David Hopkins**¹²

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**Take home messages:**
- Technologies are being assessed for their ability to accurately predict yield and meat quality traits of lamb carcases
- Development of technologies will provide the means for objective carcase assessment that will be utilised by all sectors of the supply chain.

**Background**

Innovation in the Australian red meat processing industry is being driven by the increasing global demand for high-quality, safe meat products for consumers. However, the development of technologies that provide information on the safety and quality of meat and meat products will soon be required for meat supply chains to become value based chains. Processors will be able to objectively measure the characteristics that create product value and pass this information through the supply chain to both consumers and producers.

Assessment of lamb carcases is one area that has the potential to benefit from the development of technologies for carcase assessment, given that carcases are currently traded on weight and a palpated fat score that are poor indicators of carcase yield and eating quality. Therefore, industry requires more robust methods capable of measuring carcase traits that are more indicative of yield and meat quality including GR tissue depth, intramuscular fat, metabolic related meat quality traits including pH and purge, as well as sensory traits. Consequently, several technologies including a dual GR / Impedance probe and spectroscopic technologies including Raman and Near Infrared are being assessed to determine their potential to predict carcase and meat quality traits.

**GR tissue depth**

GR tissue depth is defined as the tissue depth at the GR site, 110 millimetres from the mid-line of the carcase over the 12th rib; a measurement used as an indicator of carcase yield. There are currently two methods that are commonly used to determine the fat depth of lamb carcases; (1) palpated fat scores where scores are assigned to carcases from 1 being the leanest to 5 being the fattest. These represent GR knife scores of approximately 0 - 5 mm, 6 - 10 mm, 11 - 15 mm, 16 - 20 mm and 20 + mm for fat scores 1 - 5 respectively; and (2) measurement using a GR (Greville) knife. However, the measurement of GR completed by palpation has a low ability to predict lean meat yield and a GR knife is unable to be accurately used at fast chain speeds.

During the 1980s and 1990s, the AUS-MEAT Sheep Probe (ASP) was developed to measure GR tissue depth under commercial conditions (Hopkins et al., 1995). The ASP has since become unavailable for use by lamb processors as parts became unavailable and servicing of equipment was not possible. A dual purpose GR / Impedance probe that electronically measures the depth via displacement of a perspex plate has been trialled to determine its potential for measuring GR tissue depth in commercial situations (Figure 1).

**Figure 1. Measurement of the GR tissue depth site using the dual GR / Impedance probe.**
Trial of the dual purpose probe measured 1016 randomly selected carcases in three abattoirs, which demonstrated the variability of lamb carcase conformation is a challenge for the probe that was developed to measure fat depth of pork carcases (Fowler et al., 2017). As a result, the large perspex plate of the probe does not sit flat against the rounded ribs of lamb carcases resulting in poor accuracy of measurements, an effect that was more pronounced in fatter carcases. Even though this probe was unable to provide the measurements required by industry, this study identified several modifications including miniaturisation of components that will aid further research.

Given the importance of GR tissue measurements in yield calculations, research will continue into the development of a technology to measure GR tissue depth as smaller lamb plants, which are not likely to invest in Dual Energy X-ray Absorptiometry (DEXA) units, will still require a reliable objective indicator of yield. Consequently, trials of the Icemeat Probe that has been developed and adopted to objectively measure fat depth of Icelandic lambs will begin in mid-2017 to determine whether it is suitable for use by Australian processors.

**Intramuscular fat**

The accurate measurement of intramuscular fat (IMF) is important to lamb carcase assessment as it is indicative of the eating quality traits, tenderness, juiciness and flavour. As lamb carcases are not split by processors for grading and visual assessment of IMF content (marbling), wet chemistry methods are required that are destructive and not suitable for use in commercial situations. Given that Near Infrared (NIR) spectroscopic methods, which measure the chemical composition of matter by recording the absorption of light, have been developed for the assessment of IMF content of freeze dried meat in laboratory conditions, it is possible that miniaturised, handheld units are capable of measuring NIR of muscles in the carcase. Subsequently, several devices including a Carometec NitFom NIR device and two ASD® NIR devices – the fibre optic TerraSpec® and the handheld Halo® – have been investigated.

The Carometec NitFom NIR device has been trialled on loins from 486 carcases and topsides from 287 carcases. The probe was inserted into each muscle in situ and measured through the depth of the muscle. The NIR data obtained was then used to predict the value of the NIR data obtained in the laboratory on the freeze dried muscle. While the NitFom demonstrated no ability to predict IMF, the limitations identified in the study have been used to direct the subsequent work using the ASD® devices.

To date, data has been collected from the loins of 260 carcases and topsides of 379 carcases using both the Halo® handheld device and the TerraSpec® fibre optic NIR device. Measurements were conducted on the cuts in situ (Figure 2) at various time periods post slaughter, including 25 min and 24 hours, while 100 of these were also measured and boned out at five days post slaughter. While this study is currently ongoing, it is hoped this data will allow the prediction of the IMF of the muscle determined by the laboratory using wet chemistry methods.

**Figure 2. Measurement of IMF using a handheld Halo® NIR device.**

**Metabolic related meat quality traits**

There are several meat quality traits that are related to the metabolic processes that occur during the conversion from muscle to meat in the early post slaughter period, particularly pH and water holding capacity, which affect consumer acceptance of meat as they are related to tenderness, juiciness and colour characteristics. While it is possible to use an electrode attached to a probe to measure pH, the build-up of fat and protein on the surface of the electrode and the invasive nature of the measurement are seen as negative consequences of using the probe to measure pH in commercial situations. Yet, ultimate pH (pHu) and pH decline are important factors in determining eating quality as they relate to quality defects including dark cutting and pale soft and exudative meat.

Several investigations have been conducted into the use of a prototype Raman spectroscopic technology (Figure 3) to measure meat quality traits of lamb as it is able to provide a ‘chemical fingerprint’ of muscle, by measuring the scattering of light that is directed into the muscle. These studies have demonstrated the potential to measure pH values at 24 hours post slaughter (pH24) and pHu, as well as muscle lightness and purge (fluid removed from the muscle during vacuum packaging) (Fowler et al., 2015). But the results using the handheld device need to be verified over time to ensure they are repeatable and subsequent research will need to address this.
Since these initial studies, further advancements in Raman spectroscopic equipment have been made and handheld Raman devices are now commercially available, and are better suited to the measurement of meat quality attributes in the carcase. For example, the MIRA® portable handheld Raman device is a similar size to a smart phone and is capable of real time measurements (Figure 4). Trials have begun to determine the potential of this handheld unit to predict the pH of the loin and topside collected from 60 carcases. The initial stages of data collection have been completed for this trial and it is hoped that continuing research with this device will determine its potential to supplement visual grading procedures such as Meat Standards Australia.

Conclusions

Significant research is currently being conducted on lamb carcases to determine the potential to use technologies for carcase assessment and prediction of yield. The measurement of GR tissue depth and IMF will continue to be key areas of focus for ongoing research, while future research will consider the potential of emerging devices to complement existing systems such as MSA, providing more objective information for consumers and producers.

Acknowledgements

The authors would like to thank Janelle Hocking-Edwards, Graham Gardner and David Pethick for their assistance with the NitFom research. The authors would also like to thank the Sheep CRC for funding the GR probe and NIR research.

References


Minerals in pastures: calcium and magnesium levels and implications for supplementation

Shawn McGrath\textsuperscript{1,2} and Michael Friend\textsuperscript{2}  
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\textsuperscript{2}Graham Centre for Agricultural Innovation, Wagga Wagga  
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Take home messages:  
\begin{itemize}  
  \item A CSU-led project is investigating the link between calcium and magnesium deficiencies and lamb survival  
  \item On-farm surveys in 2016 identified a possible link  
  \item A review of the literature has identified a number of mechanisms by which low calcium and magnesium status in ewes could be implicated in low lamb survival.  
\end{itemize}

Background  
A research project commenced in 2016 to consider the question, ‘Are deficiencies in calcium and magnesium implicated in lamb mortalities in sheep flocks in Australia?’ The research was sponsored by AWI and was headed by the Graham Centre, with collaborators in New South Wales, Victoria, South Australia and Western Australia.  
In 2016 ewe flocks were monitored during the lambing period, including collection of soil and pasture samples between 30 days prior to lambing and lamb marking, and blood and urine samples from ewes just before lambing and at lamb marking. Survival was monitored on a flock basis. In the local area participating flocks were located at Holbrook, Wagga Wagga and Junee. The preliminary results indicate there may be some relationship between lamb survival and the calcium and magnesium status of ewe flocks.  

It is well known that clinical hypocalcaemia (low calcium levels in blood) and hypomagnesaemia (low magnesium levels in blood) can compromise ewe health and result in death. A subsequent literature review has identified mechanisms by which subclinical hypocalcaemia and hypomagnesaemia could have a role in poor survival in new born lambs, or conversely, how supplementation with calcium and magnesium may improve lamb survival. On the basis of this a new experiment will be run in 2017 that will include a comparison of supplementation with calcium and magnesium compared to no supplementation, to see if the possible benefits to lamb survival identified from the literature can be demonstrated on farm.
Fully sick grazing cereals - common diseases to watch out for

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Take home messages:

• The best minimum standard for mineral supplementation of sheep grazing cereals (wheat, triticale and barley) is to provide a source of calcium, in addition to magnesium and salt. When grazing oats, provide calcium and use salt as an attractant or with sugar
• In some cases, a vitamin D3 injection may act as a prophylactic preventative measure when administered to young sheep about to graze these crops
• Providing mineral supplements to sheep grazing cereals is the cheapest form of insurance.

Background

The practice of grazing cereal crops has a long history, but only in the last nearly 20 years has it become widespread and common. The rate of this practice adoption has been quite remarkable, particularly compared to the rate of adoption for pregnancy scanning. The development of winter wheats critically underpinned this practice and its adoption.

The rapid forage growth of cereals fills the winter feed gap with good quality nutrition that supports weight gain and sustains high stocking rates. About 40 per cent of the net benefit arises from the rest afforded to the pasture base. Sowing more than one crop, or several paddocks, further increases the net benefit. The cessation of grazing at jointing (Z31) leads to full grain recovery. The more leaf left on the plant at Z31, the better the grain recovery. If a bob-tail spring (Z31) leads to full grain recovery. The more leaf left on the pasture base.

Most recently, a series of experiments have been undertaken to examine the mineral health aspects of twin bearing ewes on a range of grazing crop species, across wide ranging environments in Southern Australia (Masters et al., 2017). From these most recent studies we are learning about the complexity of factors affecting the mineral health status of twin bearing ewes grazing cereal crops.

Grazing cereals - an issue of mineral balance

Dual purpose cereal crops include wheat, triticale, barley and oats. These grass crops contain levels of potassium (K) excessive for all classes of livestock, magnesium (Mg) levels are in the adequate range, sodium (Na) levels can be adequate or very low and calcium (Ca) levels are low for animals with high calcium demands (e.g. twin bearing ewes).

The mineral content available in the forage needs to be absorbed across the rumen. A high ratio of K : Na lowers the absorption of Mg and Ca.

Other important ratios include K : Ca +Mg and K : Na + Mg and the dietary cation anion difference (DCAD), that is (K + Na) : (Sulphur + Chloride). The DCAD affects the acidity of the animal, where low DCAD values acidify animals. Grazing cereals have a high DCAD, in particular wheat, triticale and oats. High DCAD leads to high blood and urine pH, low blood calcium and an impaired ability of the kidney to make the best biological form of vitamin D (calcitriol, D3). Low DCAD diets enhance renal production of 1, 25(OH) vitamin D3 and increased responsiveness of target tissues to vitamin D3, associated with increased Ca absorption from the intestinal tract (Lean et al., 2014).

Together these mineral balance ratios can indicate the riskiness of forage crops. Supplementation with calcium and magnesium is required irrespective of the mineral form.

Sheep mineral requirements

Mineral requirements are dependent on a number of factors including age, mature weight, growth rate, physiological state and stress (CSIRO, 2007; NRC, 2007). Older ewes require higher levels of dietary calcium as their bones are not as good at providing Ca when required, while fast growing young sheep require large amounts of minerals. Twin bearing ewes require more than single and dry ewes, and their requirements increase as gestation advances. Stressors such as mustering, adverse weather or being held off pasture for prolonged time periods will also affect an animal’s mineral requirements.

For sheep with high mineral demands that are grazing cereal crops for prolonged periods of time, the risk of disease increases because forage Ca can be low, its absorption impaired, and the forage increases the animal’s blood pH, impairing the formation of vitamin D3.
Common sheep diseases observed on grazing cereals

Diseases associated with grazing cereal crops include dystocia and lazy lambers (difficulty birthing), pregnancy toxaemia (lambing sickness), grass tetany (low Mg), foot abscess, milk fever (low Ca), nitrate poisoning, parasitism, mastitis and uterine prolapse. The forage mineral balance of grazing cereals is implicated in part or in full with five of these sheep diseases (underlined). Milk fever and rickets are discussed below, and are the two diseases considered as the most prevalent reason for District Veterinarian call-outs to properties where sheep health problems have occurred on grazing cereal crops (Dr Belinda Edmonstone, pers. comm.).

Milk fever (Hypocalcaemia)

Milk fever is a disease of low blood calcium levels. In hypocalcaemia, the body’s calcium balance mechanisms fail, principally because of target-organ insensitivity to the hormones calcitriol, parathyroid hormone (PTH) and vitamin D3 (Suttle, 2010). Calcium, phosphorus and magnesium levels fall. In ewes, the corresponding changes begin before lambing, particularly in twin bearing ewes, because the demand for Ca in the foetus in late pregnancy becomes greater than for lactation. It can also occur when calcium supply is excessive, calcium is passively absorbed and homeostatic mechanisms are reversed, which inhibit the intestinal hydroxylation of vitamin D3 (Suttle, 2010; Watt, 2006).

An animal’s ability to absorb and use calcium depends on its vitamin D3 status. Grazing livestock are dependent on UV irradiation of the skin to convert dietary D2 to D3. Hypocalcaemia on grazing cereals is commonly observed and may be due to low forage Ca content and / or impaired Ca absorption or high forage DCAD levels, each contributing to low vitamin D3, leading to an impairment of bone Ca resorption.

A recent estimation of the cost to the sheep industry is $11.2M (Lane et al., 2015), of which $4.4 M is attributed to prevention, $1 M is attributed to treatment and the remainder to production loss ($5.7 M).

Rickets

Rickets is a disease of growing bones that is caused by a failure of bone calcification in growing animals, leading to thinning bone shafts and swollen joints, lumps in the ribs, hypocalcaemia and broken legs. Affected mobs may have 1 - 2 animals ‘down’ per 40 head (Edmonstone, 2011; Watt, 2007; Watt, 2012). The cause is most likely a result of interactions between Vitamin D, Ca : P ratio and the factors regulating the homeostasis of these nutrients in the animal’s plasma. In general, lambs that are deficient in Vitamin D, particularly in overcast weather on lush green feed or cereal crops such as oats, are known to be at risk of developing rickets. Rickets has been diagnosed on grazing wheat and triticale. These cases may be due to low sunlight, high forage vitamin A content or high forage DCAD levels each contributing to low vitamin D3.

The cost to the sheep industry was not quantified in the most recent review of priority diseases for the red meat industries (Lane et al., 2015).

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Increasing omega-3 in meat through dietary manipulation

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Take home messages:

• Omega-3 fatty acids may have several health benefits for humans, including decreasing the risk of cardiovascular disease and treating a number of inflammatory conditions such as eczema and arthritis.

• Omega-3s are commonly found in high concentrations in oily fish, but are also found in red meat. The amount of omega-3 in meat is influenced by the diet consumed by animals and, in turn, the amount of omega-3 in feed can be altered by a number of factors including feed type, species and stage of growth.

• The current review summarises the effect of diet on the amount of omega-3 in red meat and ways in which this can be manipulated.

Introduction

Many people have heard of omega-3 fatty acids and that the consumption of these are thought to prevent or cure a range of diseases and illnesses. What many people might not know is, what role these omega-3s have in the body, how much do we actually eat in an everyday diet, and how the amount can be increased if it is likely to improve health. Omega-3s are available in a range of food sources, including fish, eggs and red meat. Although researchers know some of the factors contributing to altering the concentration of omega-3 in red meat, the variation in the content seen across different production systems in Australia and the extent to which these can be altered is largely unknown.

Why is omega-3 healthy?

The most important omega-3 fatty acids from a human health point of view are the long-chain omega-3s eicosapentaenoic acid (EPA, C20 : 5n-3) and docosahexaenoic acid (DHA, C22 : 6n-3), that are found in very high quantities in oily fish. The short-chain omega-3-linolenic acid (ALA, C18 : 3n-3) is only found in plant material. The other most common fatty acid people will have heard about is omega-6 fatty acids, where the first double bond occurs six bonds from the end. Human nutritionists are increasingly focussing on the importance of omega-3, in terms of both absolute intake and the ratio of omega-6 : omega-3 (n-6 : n-3 ratio) in human food sources. The major health benefits associated with fatty acid intake from red meat are likely to be associated with an increase in the concentration of omega-3 or a reduction in omega-6.

Long-chain omega-3 may have a number of beneficial effects in humans, including lowering blood triglycerides and reducing the risk of cardiovascular disease (CVD, for review, see Howe et al., 2007). Omega-3s are important for two main reasons: (1) they are metabolised to prostaglandins that are either pro-inflammatory or anti-inflammatory and, (2) they are integral components of cell membranes and cell function.

Long-chain fatty acids are the precursors for prostaglandins (PG), which act like hormones as cell signalers in the body. The PGs are involved in many normal functions, such as causing the demise of the corpus luteum leading to the onset of oestrus in sheep and cattle and parturition, and some abnormal inflammatory states (Peet and Stokes, 2005). Omega-3 and omega-6 fatty acids have opposing biological effects and, in general, omega-6 are pro-inflammatory while omega-3 are anti-inflammatory (Horrobin and Bennett, 1999).

Normal brain growth and development in infants and children also requires dietary intake of omega-3 as the major structural components of neural cell membranes (Innis and Elias, 2003) and appears to be involved in the development of cognition in infants (Willatts and Forsyth, 2000). Omega-3 intake has also been linked with several other illnesses including asthma, eczema and several mental health disorders including depression and bipolar disorder (Clayton et al., 2007).
How much omega-3 do we need?

There are several different recommendations for intakes of omega-3 from different organisations in Australia and internationally. The recommended intake (Adequate Intake, (AI)) of long-chain omega-3 for the Australian population is 160 milligrams / day for men, 90 mg / day for women and lower for adolescents (Table 1). Higher Suggested Dietary Targets (SDT) to prevent chronic disease are recommended for adults, but not adolescents.

Table 1. Australian guidelines for recommended daily intakes of long-chain omega-3 for different populations (Nutrient Reference Values, NRVs).

<table>
<thead>
<tr>
<th>Recommend Daily Intake for Omega-3 (mg/day)</th>
<th>Adolescents (14-18yrs)</th>
<th>Adults (19+ yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>Adequate Intake (AI)</td>
<td>125</td>
<td>85</td>
</tr>
<tr>
<td>Suggested Dietary Target (SDT)</td>
<td>NI</td>
<td>NI</td>
</tr>
</tbody>
</table>

1Omega-3 = eicosapentaenoic acid (EPA) + docosapentaenoic acid (DPA) + docosahexaenoic acid (DHA).NI = not indicated in NRVs. Data adapted from: Australian Nutrient Reference Values (NHMRC and Health, 2006)

International guidelines recommend intakes of EPA + DHA between 200 - 650 mg /day for the general population and 1000 mg / day for people at risk of CVD. The American Heart Association recommends two fatty fish meals per week or 400 - 500 mg / day EPA + DHA for the general population (Murphy et al., 2007).

Meat consumption in Australia

Meat, other than fish, is an important contributor to omega-3 intake in the Australian population (Howe et al., 2006). Meat contributes approximately 42 per cent of the total intake of long-chain omega-3 in Australian adults and 54.4 % in children and adolescents. In general, the amount of beef and lamb consumed in Australia has declined since the 1980s, while the intake of poultry and pork has increased (Figure 1). This pattern is somewhat related to the price of these meat products, with poultry and pork being cheaper than beef and lamb.

Figure 1. Apparent Consumption (kg / person / year) of beef + veal, lamb + mutton, pig meat and poultry in Australia (1973 – 2013).

Altering the amount of omega-3 in meat

The amount of omega-3 in red meat is influenced by a number of factors including breed and fatness of the animal. As animals mature and the total fat content of meat increases, the concentration of saturated fatty acids (SFA) in meat increase, but the relative proportion of omega-3 decreases (De Smet et al., 2004). So, breeds that are fatter and, older animals at slaughter, tend to have higher proportions of SFA and lower proportions of omega-3 in their meat.

But the largest influence on omega-3 content in meat is diet, especially in the 6 - 12 weeks prior to slaughter. Dietary manipulation can involve a number of different feeding strategies, including changing the amount of grain or forage or feeding supplements high in omega-3 such as linseed or algae.

There is little published data available comparing omega-3 concentrations in the meat of lambs fed pasture versus grain in Australia. Most research examining omega-3 in lamb involves supplementation with linseed, canola, fish oil or algae (Ponnampalam et al., 2001; Ponnampalam et al., 2002). However, research in France showed the concentration of omega-3 in meat was lower when lambs were fed a diet based on barley, wheat and sugarbeet pulp compared with grass (Aurousseau et al., 2004; Aurousseau et al., 2007). In cattle in Australia, the amount of omega-3 in meat was also lower when animals were fed grain compared with pasture prior to slaughter (Figure 2).
Figure 3. Concentration of omega-3 in meat when lambs were fed a control diet based on grain or a control diet with the addition of high omega-3 algae and their dams were fed either silage high in omega-3 or oats / CSM high in omega-6 at the time of joining.

Source: Hopkins et al., 2014.

Altering the amount of omega-3 in feed

The amount of omega-3 in animal feed depends on the type of feed (forage versus grain), plant species, fertiliser status, and growth stage. The amount of omega-3 is higher in fresh forage versus grain and can be influenced by soil fertility (Table 2). Total omega-3 is influenced by the nutritional status of the plant and is positively correlated with the amount of protein in pasture (Figure 4).

Feeding algae high in omega-3

The total concentration of omega-3 in meat was higher when lambs were fed algae in addition to a grain-based diet, compared with grain alone (Hopkins et al., 2014; Clayton et al., 2015). When algae was included in the diet, the lamb meat could be considered a ‘source’ of omega-3 according to Australian guidelines (Figure 3). The total amount of omega-3 in meat was also influenced by the diet fed to the dams of these wethers at the time of joining. The accumulation of omega-3 was lower when their dams were fed oats and cottonseed meal compared with silage around joining.
**Figure 4.** Relationship between the amount of protein in pasture (CP) and the amount of omega-3 as a proportion of total fatty acids.

Source: Clayton (2014) unpublished data.

The amount of omega-3 in pasture is also strongly influenced by the stage of growth. As the plant matures, the amount of total fat and omega-3 declines (Table 3). So, in order to maximise the amount of omega-3 available for meat, it is important to have high nutrient availability, especially nitrogen and graze or harvest the plants at an earlier stage of maturity when quality is higher, which is also favourable for animal production.

**Table 3.** Concentration of fatty acids in Timothy hay cut at different stages of development.

<table>
<thead>
<tr>
<th>Stage of Growth</th>
<th>Total</th>
<th>C18:3n-3</th>
<th>C18:2n-6</th>
<th>n-6:n-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem elongation</td>
<td>18.01</td>
<td>8.71</td>
<td>3.97</td>
<td>0.46</td>
</tr>
<tr>
<td>Early head</td>
<td>15.09</td>
<td>6.86</td>
<td>3.51</td>
<td>0.51</td>
</tr>
<tr>
<td>Late head</td>
<td>14.42</td>
<td>6.37</td>
<td>3.39</td>
<td>0.53</td>
</tr>
<tr>
<td>Early flowering</td>
<td>13.72</td>
<td>5.96</td>
<td>3.19</td>
<td>0.54</td>
</tr>
<tr>
<td>Sem2</td>
<td>0.447</td>
<td>0.255</td>
<td>0.093</td>
<td>NI</td>
</tr>
</tbody>
</table>

C18:3n-3 = α-linolenic acid and C18:2n-6 = linoleic acid.

Conclusions

Omega-3 fatty acids are seen as an important component of the human diet and red meat consumption contributes significantly to omega-3 intake in Australia. The amount of omega-3 in beef and lamb can be altered considerably through dietary manipulation. In particular, the consumption of high quality forage by sheep and cattle will maximise the amount of omega-3 available. While there are several studies available from overseas indicating the extent to which omega-3 in beef and lamb can be altered through dietary manipulation, there is little evidence currently available for Australian production systems. In particular, the variability in omega-3 in beef and lamb produced under feedlot or grass-fed situations in Australia is largely unknown and is worthy of future research.

Acknowledgments

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Drones increasing information in agriculture

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Take home messages:
• Practice flying drones before using them for work - this is key!
• Good telemetry and contact is essential for longer range flights
• Farmers will create their own solutions to get more out of drones.

Introduction

New generation Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are creating solutions in agriculture to age-old challenges. The growing of crops and livestock has always required a trained eye in the field, paired with a solid understanding of soils and climate, to be ready to act when unplanned issues present causing stress such as disease or nutrient deficiencies.

Standard quad copter drones fly for around 20 - 25 minutes and can fly a path of up to eight kilometres. Basic ‘off the shelf’ units can cover around 50 hectares of pasture or stock map per battery on autonomous flight.

At a cost of $2000 - $3500 for a basic quad copter, these are units that can be used as a day-to-day unit for monitoring or to assist with spotting stock for mustering. But remember, CASA rules require us to keep a drone in flight within line of sight unless we have a full CASA REPL license with specific beyond line of sight approvals.

For longer distance stock or water monitoring, winged drones or hybrid Xcraft equipment can be used. These units provide flight times up to 1.5 hours and can cover up to 160 km with directional antennas providing live feed video footage, as well as recording points of interest to an sd card.

This long range equipment flies using free open source software ‘Mission Planner’ that increases flight accuracy and safety.

Additional safety features include ADS-B transmitters that lift the units to the level of commercial aircraft on air traffic control and aircraft radars. These units cost $5000 - $30,000.

Drones in cropping systems

Whilst early developments of in situ cameras were a step forward in mapping single plants, commercial agriculture continued to operate on vast areas with the responsibility of millions of dollars in resources across land, water infrastructure, crops, livestock and environmental areas.

All these resources can be monitored using drones fitted with purpose built sensors. A standard camera to collect either flight video or high quality still photos of points of interest is the starting point for monitoring. Capturing imagery at key times including crop emergence, tillering and flowering, can assist farmers to more accurately monitor crop density and health, allowing yield variability predictions to be made.

There is significant variation in any paddock when viewed from above. Standard digital cameras known as RGB (Red, Green, Blue) paired with the right software can provide accurate information on features not visible by the human eye. These features can include biomass, nitrogen variance and early stage disease infection.

Mounting a camera fitted with filters to collect near infrared imagery provides detailed information that can be represented through a Normalised Difference Vegetation Index (NDVI) map. This index provides a live snapshot of which plants are actively photosynthesizing. Whilst NDVI maps are available from satellites, these are often on a weekly or fortnightly basis and can be affected by cloud. Satellite maps are generally on 50-250 metre pixel size.

Drone mounted systems can generate NDVI maps on any given day (exception is rain) at an accuracy of 1-5 centimetre pixels. This provides up-to-date information on individual plants across a field that would not be visible for another 10 days if farmers had to wait on traditional visual assessment.

Early identification of plant stress allows for timely treatments to prevent disease spread and early treatment of deficient nutrients before significant yield losses are caused.

Using high definition maps throughout the growing period rather than looking at a yield map post-harvest, allows for a proactive approach, matching inputs where required with the aim of maintaining input costs whilst increasing yields. The result being reduced cost of production.

 Whilst the technology has been developed around the cropping industry, recent research has applied the technology to pastures in grazing systems, providing further benefits to the traditional grazing industry.

Monitoring livestock in their grazing environment often requires accessing rugged, difficult to access areas. Drones provide a solution to quickly covering such areas without the costs or risks involved in ground based monitoring. Aerial monitoring also provides imagery of livestock in their natural state where their grazing, social and movement behavior can be observed to better understand and manage animal production.
NDVI mapping with UAVs

While UAVs or drones represent excellent tools for gathering images to identify problems and supplement crop scouting in agriculture, a consensus has not been reached on how to extract the most valuable information from these images.

So what is NDVI? NDVI is simply a ratio of near infrared (NIR) reflectivity minus red reflectivity (VIS) over NIR plus VIS.

\[
\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}
\]

Plants reflect strongly in the near infrared due to a spongy layer found on the bottom surface of the leaf, but do not reflect strongly in the red (plants reflect green light). Soil, on the other hand, reflects both. But when a plant becomes dehydrated, the spongy layer collapses and the plant ceases to reflect as much NIR light. So, a linear combination of the NIR reflectivity and red reflectivity should provide excellent contrast between plant and soil, and also between healthy plants and sick plants.

The value of regular non-destructive pasture monitoring to livestock businesses is well understood, but existing field assessment techniques used by farmers are labour intensive, qualitative and do not effectively capture the spatial heterogeneity of grazed swards.

Existing cost effective remote sensing platforms provide guidance, but at a resolution (250 m² or 30 m², at fortnightly or monthly frequency) that does not capture the interaction between livestock and the pasture sward, particularly to support accurate assessment of forage quality required by producers.

UAVs have considerable potential to address these shortfalls and provide farmers with a relatively cheap, non-destructive and high resolution pasture assessment, where they govern the frequency of measurement to suit their management needs.

As part of the FarmDecisionTECH® program, trials from Germany and Sweden were successfully repeated at a research plot (alpha site) and commercial scale (beta site) near Orange, New South Wales during spring 2016 and autumn 2017. Commercially available low cost UAV systems collected overlapping RGB imagery. Modelling produced 3D Grass Surface Models (Biomass) and vegetation indices (quality), with a moderate to high correlation (0.7 - 0.9) with field measured pasture height, biomass cuts, botanical quality assessment and laboratory forage analysis (Figure 1).

Similar to other trials, these techniques had difficulty tracking small (1 cm) changes in grazed pastures under extreme resource limitations (below grass residuals of 2 cm). While these results reinforce the potential identified for using UAVs in grazing businesses, they also identify a number of barriers for farmer adoption including flight autonomy and safety, the requirement for ground control, processing large payloads in broadband limited environments, trade-offs between cost and alternatives to RGB cameras, workflow automation and interoperability with other farm planning tools.

Figure 1. Grass Surface Models at the alpha site (Orange Agricultural Institute) and pasture quality estimates at the beta site (Waidup Homestead).
Take home messages

- Rhizobia survival, plant root growth and the nodulation process are all disrupted at pH\(_{Ca}\) < 5
- Severely acidic layers at depths of 5 - 15 cm (pH\(_{Ca}\) < 4.5) were detected in some of the most productive soils across the mixed farming zone of central and southern NSW
- Sample for pH at 0 - 5, 5 - 10, 10 - 15, 15 - 20 cm depths to better inform paddock selection and liming programs
- Current lime rates are insufficient to neutralise acidity in the surface 0 - 10 cm layer and the soil profile below continues to acidify.

Introduction

The medium and high rainfall zones of central and southern New South Wales are dominated by acidic soils (pH\(_{Ca}\) < 6). The use of lime to manage acidity of surface layers has enabled the expansion of acid-sensitive crops and pastures (e.g. wheat, canola and lucerne) onto soils that were once considered unsuitable. These species are now significant contributors to the annual feedbase and productivity of the livestock systems in the mixed farming zone.

Numerous studies since the 1970s have highlighted the production benefits of lime application to manage soil acidity. The research links poor growth of many acid-sensitive species to low pH (pH\(_{Ca}\) < 5), particularly in soils where low pH coincided with toxic levels of soluble aluminium (Al). Recommendations arising from the Acid Soil Action program encouraged incorporation of lime to 10 centimetres at rates sufficient to lift pH\(_{Ca}\) of the top 10 cm to 5.5, in order to avoid acidification at levels below 10 cm (Upjohn et al., 2005).

Lime application is now a standard practice but the guidelines have been modified. Management of soil acidity is usually informed by 0 - 10 and 10 - 20 cm soil tests and broad guidelines for sensitivity / tolerance of species (or varieties) to levels of exchangeable Al and pH. Typically lime is applied immediately prior to sowing sensitive species, about every 10 years at a standard rate of 2 - 2.5 tonnes per hectare. Widespread adoption of minimum disturbance tillage systems means that most applied lime is not incorporated. Many producers are now in the second or third round of lime applications and there is a general belief that soil acidity is ‘under control’.

An extensive survey of over 4500 paddocks in the southern Slopes and Plains region of New South Wales from 1997 to 2003 (Scott et al., 2007) concluded that rates of lime used were generally insufficient to maintain desirable soil pH levels in the top 20 cm (pH\(_{Ca}\) > 5). Over 50 percent of soils in rainfall zones above 550 millimetres were severely acidic (pH\(_{Ca}\) < 4.5) in both the surface (0 - 10 cm) and subsurface (10 - 20 cm) layers.

A 2015 survey of subterranean clover based pastures in the Slopes and Plains of southern NSW indicated that 97 % of paddocks had poor nodule formation (Jenkins, 2016). Factors causing low rhizobia growth rates and nodule formation included low pH\(_{Ca}\) (< 5.2) and toxic levels of exchangeable Al (> 5 %). Only 41 % of the paddocks surveyed had received lime in the last 10 years.

Project background

This paper presents results from a NSW Department of Primary Industries project, supported by GRDC, investigating constraints to legume crop and pasture ‘performance’ on acidi soils of south eastern Australia. Poor nodulation and severe nitrogen deficiency symptoms were observed across a range of seasons and soil types in commercial faba bean crops surveyed as part of the project. Both the plant and Group F rhizobia (specific to faba bean) are sensitive to pH\(_{Ca}\) <5.

Survey process

In 2015 and 2016, a total of 41 commercial legume crops and pastures were monitored in NSW, Victoria, South Australia and Tasmania. This included 26 faba bean crops grown mainly on Sodosol and Chromosol soil types.

Soil and plant samples were collected from a uniform, one hectare area of crop at each site. Soils were sampled at depths of 0 - 10 cm and 10 - 20 cm, with crops assessed 2 - 3 months post-emergence and scored for nodulation. Scores were allocated for; (1) plant growth and vigour, (2) nodule number, (3) nodule position; (4) nodule colour, and (5) nodule appearance for a maximum possible score of 25 (Anon 1991).

In 2015, crops with nodulation scores below 18 were revisited. Root growth was assessed and soil samples were collected at 2.5 cm intervals to a depth of 15 cm, and tested for pH using a Manutec® Soil pH Test Kit. In 2016 root growth was also assessed on poorly nodulated crops. Soil samples were collected at increments of 2.5 cm to a depth of 10 cm, and at 5 cm increments from 10 - 20 cm. These were tested in the laboratory for pH, using the calcium chloride method (pH\(_{Ca}\)).
Results and discussion

Soil acidity and nodulation

Analysis of nodulation scores and soil pH of the monitored paddocks indicated that nodulation of faba bean reduces when soil pH<sub>Ca</sub> falls below 5 (Figure 1). The inoculant used (e.g. peat slurry, freeze dried or granular) did not have a significant effect on nodulation score.

The faba bean crops fell into two distinct categories; (1) vigorous, well nodulated crops, and (2) those showing symptoms of nitrogen deficiency within 2 - 3 months of emergence. In Figure 1, note the poorly nodulated crops at Holbrook (Hb), Junee (J2), and Kybybolite (Kb). These crops had nodulation scores of 17, 16.6 and 15, respectively, with 0 - 10 cm pH<sub>Ca</sub> readings of 4.6, 4.4 and 4.5, respectively.

Although percentage of exchangeable Al at the Holbrook site was 8 % in the 0 - 10 cm and 35 % at 10 - 20 cm, the percentage of exchangeable Al at the Kybybolite site was < 2 %, suggesting that low pH alone disrupts the nodulation process.

Figure 1. The effect of surface soil pH<sub>Ca</sub> (0 - 10cm) on nodulation of faba bean in the high rainfall zone of SE Australia.

Soil pH stratification

All sites shown in Figure 1, with the exception of Kybybolite, had received applications of lime within the last five years. Lime was applied at a rate of 2 t/ha to the Holbrook site in 2010 and again in 2015. The Junee sites (J1 and J2) were within the same paddock and received a blanket rate of lime (1.13 t/ha) in 2011, based on a bulked 0 - 10 cm soil test from the whole paddock (pH<sub>Ca</sub> of 5.2). The lime was not incorporated.

The soil test results shown in Table 1 demonstrate the failure of bulked soil samples taken at depths of 0 - 10 cm and 10 - 20 cm to detect pH stratification, and the sharp drop in soil pH below 5 cm at the Holbrook and J2 sites detected by finer 2.5 cm soil samples.

Although Howieson and Ballard, (2004) noted that the focus is often on the impact of low pH<sub>Ca</sub> < 5 being detrimental to rhizobia survival and performance, the nodulation process also requires pH conditions favourable to the host plant. Rhizobia infection for many legume species, including faba bean, clovers and lucerne, occurs via root hairs, and anything that affects normal root hair development will affect nodulation (Drew et al., 2012). The roots of plants at both Holbrook and Junee were stunted with low root hair density. The hostile pH and Al levels detected in the finer soil samples, drives home the impact of the ‘acid throttle’ encountered on the emerging seedling.

Despite the Holbrook site receiving 4 t/ha of lime since 2010, incorporation with a Speedtiller® was ineffective in mixing the lime below 5 cm. The crop showed symptoms of severe nitrogen deficiency within three months of emergence. Poor root development (Figure 2), reflects the toxic conditions of the subsurface layers. Root hair density and nodulation was poor, roots were stunted and did not penetrate far into the severely acidic layers below 6 cm (pH<sub>Ca</sub> < 4.4).
Table 1. pH\textsubscript{Ca} measurements of 0 - 10 and 10 - 20 cm bulked soil samples underestimate the pH stratification in the soil profile at the Holbrook and Junee sites, compared with tests from finer sampling increments.

*Sub samples were not collected from the same location as bulked samples. The pH\textsubscript{Ca} for the Hb sub samples were estimated using a Manutec® Soil pH Test Kit, and pH\textsubscript{Water} was converted to pH\textsubscript{Ca}.

Table 1. pH\textsubscript{Ca} measurements of 0 - 10 and 10 - 20 cm bulked soil samples underestimate the pH stratification in the soil profile at the Holbrook and Junee sites, compared with tests from finer sampling increments.

<table>
<thead>
<tr>
<th>Soil Depth (cm)</th>
<th>Holbrook site - 2015</th>
<th>Junee 1 site - 2016</th>
<th>Junee 2 site - 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodulation score</td>
<td>17</td>
<td>20.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Soil pH\textsubscript{Ca}</td>
<td>Exch Al (%)</td>
<td>Soil pH\textsubscript{Ca}</td>
<td>Exch Al (%)</td>
</tr>
<tr>
<td>Bulked Sample*</td>
<td>Sub Sample</td>
<td>Bulked Sample</td>
<td>Sub Sample</td>
</tr>
<tr>
<td>----------------</td>
<td>------------</td>
<td>----------------</td>
<td>------------</td>
</tr>
<tr>
<td>0-2.5</td>
<td>4.6</td>
<td>6.5</td>
<td>5.2</td>
</tr>
<tr>
<td>2.5-5.0</td>
<td></td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>5.0-7.5</td>
<td>4.4</td>
<td></td>
<td>5.2</td>
</tr>
<tr>
<td>7.5-10.0</td>
<td>4.2</td>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td>10.0-15.0</td>
<td>4.2</td>
<td>4.3</td>
<td>35</td>
</tr>
<tr>
<td>15.0-20.0</td>
<td>4.1</td>
<td></td>
<td>5.0</td>
</tr>
</tbody>
</table>

*Sub samples were not collected from the same location as bulked samples. The pH\textsubscript{Ca} for the Hb sub samples were estimated using a Manutec® Soil pH Test Kit, and pH\textsubscript{Water} was converted to pH\textsubscript{Ca}.

Figure 2. Faba bean plants collected at early flowering stage from the Holbrook (NSW) crop were poorly nodulated. Roots were stunted and concentrated in the top 6 cm with root growth restricted by acidic layers below 5 cm. (see photo below)
The Junee sites were from lower slope (J1) and mid slope (J2) areas within the same paddock. The soil tests from J1 indicate slight acidity ($\text{pH}_{\text{ca}} > 5$) from 0 - 7.5 cm, tending toward moderately acid ($\text{pH}_{\text{ca}} > 4.6$) from 7.5 - 15 cm. Plant roots from this site were vigorous and well nodulated (nodulation score of 20.6).

The J2 site was moderately acidic in the surface 2.5 cm ($\text{pH}_{\text{ca}}$ of 4.9), tending to severe acidity from 5 – 15 cm, with pH$_{\text{ca}}$ ranging from 4.6 at 2.5 cm, to as low as 4.1 at 7.5 - 10 cm, corresponding to exchangeable Al levels of 7 % and 17 %, respectively. The J2 plants were stunted and showed symptoms of severe nitrogen deficiency two months after sowing. Root growth was restricted to the surface layers (0 - 4 cm), root hair development was considerably less in J2 plants, and plants were poorly nodulated (score of 16.6).

The severe pH stratification identified by testing at 2.5 cm intervals at the Holbrook and Junee sites was also detected at a number of other sites. The surface applied lime was not effectively incorporated under minimum tillage systems operating at both sites and had very little effect in raising pH below 5 cm.

**Is pH stratification affecting livestock production?**

The detrimental effect of intense pH stratification and severely acidic layers at 5 - 15 cm on nodulation and growth of faba bean crops reported here should concern all livestock producers operating on moderate to severely acidic soils of southern NSW. Faba bean (Group F) rhizobia are more sensitive to low pH than Group C (clover) rhizobia and more tolerant than Group AL (Lucerne) rhizobia (Drew et al., 2012).

Numerous studies have shown that nodulation, nitrogen fixation and production of subterranean clover is reduced at pH$_{\text{ca}} < 5$. A review of subterranean clover responses to pH 4.5 layers were detected at depths of 5 - 15 cm across a range of soil types, including those with a high rainfall zone (> 600 mm) are naturally acidic to depth, the severe acidity ($\text{pH}_{\text{ca}} < 4.4$) detected in layers at 5 - 10 cm following 4 t/ha of lime application, was surprising. But the severity of the acidic layers ($\text{pH}_{\text{ca}} < 4.2$) from 5 - 15 cm on the Chromosol soils at Junee was unexpected.

The results highlight that in order to sustain production levels in the highly productive agricultural regions of southern NSW, there is an urgent need to revise soil sampling methods, lime application rates and incorporation methods, and paddock selection processes and preparation, particularly prior to sowing acid sensitive species.
Recommended reading


References


