LUPINS IN SHEEP NUTRITION

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ABSTRACT

The use of lupins for feeding sheep is reviewed. The paper concentrates on the use of sweet *Lupinus angustifolius* (in Australia) as a source of supplementary summer feed for sheep which normally graze dry pasture or cereal crop residues of poor nutritional value.

MODERN DOMESTICATION AND USE OF LUPINS

Gladstones described the modern domestication of lupins by Frederick the Great of Prussia in the late 18th century. Lupins were the foundation of the Merino wool industry of Saxony until lupinosis and cheap nitrogen fertilizer caused the popularity of the crop to decline.

The breeding of sweet cultivars of *Lupinus angustifolius* and *L. luteus* in Germany, in the late 1920s, led to a resurgence in the use of lupins for animal feeding. In Germany it was found that sweet lupin seed could replace oil seed meal in lamb rations. Sweet lupin (60%), barley (*Hordeum vulgare*) meal (30%) and herring meal (10%) fed at 250-300 g/day produced lambs of excellent carcass quality. The digestibility of sweet *L. angustifolius* and *L. luteus* seed for sheep was determined. All components of the seed were highly digestible.

In New Zealand, in the late 1930s, bitter *L. angustifolius* was recommended for ewe feeding. The crop was used as a green feed. Lupins, in conjunction with Italian ryegrass (*Lolium multiflorum*), carried 20 to 22 dry sheep/ha for 3 months in winter. The effect of growth stage of the plant on nutritional quality of lupins for ewes was determined. Over 2 months, ewes at 24/ha. gained 10 kg when lupins were grazed pre-flowering, but lost > 1 kg when the crop was grazed at the green pod stage. The birth weight of lambs was higher from ewes on the younger lupins (5 kg compared with 4 kg). By 1942 sweet lupins had reached New Zealand and their use was being recommended for fattening lambs. Animals grazed on lupins for 4 weeks, at 72 lambs/ha. gained 193 g/day, compared with controls fed on rape (*Brassica napus*), at 48 lambs/ha. which only gained 158 g/day. The two together produced 30% more dry matter and fattened 20% more lambs than lupins alone. Lambs fed on the lupin/rape combination grew faster than lambs raised on rape alone.

During the early 1940s experiments were conducted in England with sweet *L. luteus* forage for sheep, also in combination with rape.

In South Africa lupins were used as a supplement to poor quality feed. When lupins were compared with maize (*Zea mays*) grain. as a supplement for Merino wethers animals grew best on a combination of 50% maize and 50% bitter blue lupin seed. Animals supplemented with
155 g/day of the mixture gained 10.6 kg compared with a 7.3 kg gain in control animals\textsuperscript{10}. Lupins were also shown to be a satisfactory substitute for lucerne (\textit{Medicago sativa}) hay in rations for Merino weaners\textsuperscript{11}. Nutritionally, a mixture of 100 kg of chaff and 25 kg of lupin seed was equivalent to 100 kg of lucerne hay. Animals lost weight on chaff and lupins but made satisfactory weight gains on rations containing 15 to 20\% bitter blue lupin seed, chaff and lucerne. However, 35\% lupin seed and 67\% chaff was not suitable feed for ewes with lambs at foot\textsuperscript{12}. Over 30 days the ewes lost 12.7 kg and their lambs gained only 4.1 kg compared with controls fed on lucerne hay and oats (\textit{Avena sativa}) which gained 8.2 kg.

In Western Australia \textit{L. cosentinii} had become naturalised on the Swan Coastal Plain\textsuperscript{1}. It was used extensively to raise sheep and grow wheat (\textit{Triticum aestivum}) in the development of the Western Australian light lands. As the plants were bitter they were not grazed while green, and sheep ate the seed and stems after the crop dried off\textsuperscript{13,14}.

**THE IMPACT OF SWEET, NON-SHATTERING \textit{L. angustifolius}**

The breeding in Australia of alkaloid-free, non-shattering \textit{L. angustifolius} cultivars, commencing with Uniwhite in 1967\textsuperscript{15}, lead to increased production of lupins, initially in Western Australia, and then in all of the southern states of Australia. By 1986 the Australian lupin crop was worth $A64 million\textsuperscript{16}. In the same year the area sown to lupins in Australia was nearly 600,000 ha\textsuperscript{17}. The availability of high protein lupin seed to feed sheep, which normally grazed poor quality dry pasture and crop residues during the dry Australian summer, has lead to considerable research into the integration of lupins into the farming system in southern Australia.

The increased use of lupins on farms has not been without problems. Feeding of lupins, infected with \textit{Phomopsis leptostromiformis}, has frequently been responsible for outbreaks of lupinosis. Lupinosis has recently been extensively reviewed\textsuperscript{18} and is beyond the scope of this review, which will concentrate on the effects of feeding uninfected lupins to sheep.

**FEEDING OF WEANERS AND WETHERS**

\textit{Liveweight gain:} European workers evaluated lupin seed as a substitute for soya bean (\textit{Glycine max}) meal in lamb rations. In Spain, Merino lambs fed on \textit{L. albus} cv. Neuland, gained more weight (14.2 kg compared with 13.7 kg) at a higher feed conversion efficiency ratio (4.00 compared with 4.22) than soya-fed animals\textsuperscript{19}. In France, also with \textit{L. albus}, workers were unable to show significant differences, for lamb feeding, between soya and lupin based rations using cvs Kalina and Blanca\textsuperscript{20}. There was little difference in liveweight gain of lambs fed either whole, or ground. Kalina as a supplement to maize or barley\textsuperscript{21}. A comparison of Kalina with soya meal, field beans (\textit{Vicia faba}) and peas (\textit{Pisum sativum}) as a supplement to a barley-based ration, found no significant difference in any measured parameter among the four protein sources. Lambs on lupins gained 264 g/day and had a final carcass weight gain of 6.7 kg compared with soya-fed controls which gained 227 g/day for a final carcass weight gain of 6.8 kg\textsuperscript{22}. 

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In a series of Victorian experiments, 6-week-old weaner lambs were fed \textit{ad lib.} for 11 weeks on rations of wheat, oats or barley grain with or without \textit{L. angustifolius}, or on lupins alone. Lambs fed on rations based on wheat, barley or oats supplemented with lupins could be weaned early to dress out at 14-16 kg, with 4-9 mm of fat cover. Oats required the most supplementation (30%) and wheat (14.9% protein) the least (0%). A comparison of three \textit{L. angustifolius} cultivars, differing in their alkaloid content, showed that lambs which consumed 4,480 mg of alkaloid did not differ in their final weight, or total weight gain, from lambs which consumed only 2,240 mg of alkaloid (41.9 kg and 42.7 kg; 21.9 kg and 22.8 kg). However, lambs fed a high dose of alkaloids consumed more energy and protein per kg of weight gain.

In 1972 the first of a series of papers appeared which reported the use of standing crops of dry lupins as high quality feed for young and mature sheep, in summer, after pasture had dried off and was of poor nutritional quality.

When weaners were stocked at 50 sheep/ha and wethers at 25 sheep/ha respectively, animals which ate significant amounts of lupin seed gained weight. Sheep were extremely efficient at picking up fallen lupin seed from the ground. By the end of the experiment there was little difference in the weight of animals which had been fed back seed, or had grazed the standing crop. Weaners gained 4 kg compared with a loss of about the same amount on lupin stubble. The wethers gained 9 kg on seed treatments but lost 5 kg on stubble.

Farmlet experiments compared the value of lupins with oats for summer feed: pasture, or pasture supplemented with lupins, at different stocking rates; and the optimum time of lupin feeding to weaners. The oats and lupins were stocked at 7.5 and 12.5 sheep/ha.

In the stocking rate trial, sheep grazing lupins, at both low and high stocking rates, were heaviest when lupins were grazed for 20% of the year. Sheep made greater liveweight gains when lupin seed was fed in early summer. Sheep grazed on pasture early in summer and then fed on lupins were lighter than those given lupins at the start of summer. A comparison of lupins, peas and vetches (\textit{Vicia sativa}) showed that there was little difference in liveweight gain of Merino weaners on lupins or peas. Vetches gave considerably lower liveweight gains. Although liveweight gain, at 140g/day, was the same on lupins and peas, more lambs (73%) reached slaughter weight on lupins than on peas (60%).

Comparison of the nutritive value of \textit{L. albus} (WB1) with \textit{L. angustifolius} cvs Borre, Uniharvest and New Zealand Blue (bitter), \textit{L. cosentinii} cvs Chapman and Box (both bitter) and \textit{L. luteus} cv Weiko III showed that Merino weaners, at 50 sheep/ha, gained up to 10 kg in 80 days. Sheep tended to do better on sweet cultivars. However, seed production was also a determinant of final weight gain. Results on Weiko III and \textit{L. albus} were disappointing.

Workers in South Australia and Victoria also commenced work on the value of lupins for sheep. As with the French work with \textit{L. albus}, when whole or hammermilled,
L. angustifolius seed was fed as a supplement to Phalaris aquatica/Trifolium fragiferum hay there was no difference in liveweight gain of lambs. Animals fed 40% lupins for a period of 27 to 55 days gained 77 g/day. When given free choice of lupins or hay, lambs selected a diet of 85% lupin seed and gained 160 g/day over 42 days\(^{31}\).

A comparison of the effect of 100 g/day of lupin seed with urea, or urea and sulphur, using 4-year-old wethers grazing dry, weed-free wheat stubble, showed that, at the end of 3 months, sheep fed lupins lost 0.5 kg but were 3.8 kg heavier than controls fed on wheat straw, and 1.6 kg heavier than the urea-supplemented sheep. Lupins increased straw intake by 129 g/day, but did not increase its digestibility\(^{32}\).

The potential of lupins as a grain supplement for live sheep export were compared with oats and wheat. Merino wethers (18 months) were offered pasture (9% protein, 47% digestible) and oats, wheat or lupins at 0 to 540 g/head per day or ad lib. In a second experiment, oats or wheat were offered ad lib. and supplemented with 0 to 270 g/head per day of lupins. The experiment lasted 9 weeks. Liveweight gain was directly related to grain intake. Intake on the two cereals was low and animals only maintained their liveweight. On ad lib. lupins, sheep consumed 650 g/head per day, and gained 4.0 kg liveweight and 3.8 kg carcass weight. Adding 180 g/head per day of lupins to the cereals increased ad lib. intake of the cereals, and animals gained 1.0 kg on wheat and 4.5 kg on oats. It was concluded that any ration which contained more than 10% lupins showed promise for fattening wethers\(^{33}\).

Similar experiments compared lupins with oats, and soya bean meal, as a supplement for young Merino weaners grazing dry Lolium perenne/Trifolium subterraneum pasture from January to April. There was no significant difference among the supplements of oats, lupins, soya bean meal alone, or in combination with lupins. Animals supplemented with lupins at 240 g/head per day weighed 24.6 kg at the end of the feeding period compared with controls at 20.5 kg. When lupins were offered, in 50 g increments, at from 0-350 g/head per day, as a supplement to hay, there was no increase in liveweight gain above 200 g lupins/day. Supplemented animals weighed 5 kg more than controls at the end of the experiment. The difference in body weight was still apparent the following November. Weaners readily consumed lupin seed but often took up to two weeks before they commenced to eat oats\(^{34}\).

Butler and McDonald\(^{38}\) also found that young Merino wethers grew better on a combination of oats and lupins, than on oats alone. Animals fed on oats and lupins gained up to 150 g/day, compared with gains of 75 g/day on oats, and weight losses on straw stubble.

When lupin seed and barley was fed to mature ewes, the maximum ad lib. intake of lupins was 1.3 kg/day compared with 1.0 kg/day for barley\(^{39}\). It was suggested that the animals' capacity to consume significantly more lupins was related to the low amount of starch in lupin seed.
In Western Australia, a barley/lupin mixture (15% crude protein) fed *ad lib.* to Merino weaners was tested as a supplement to dry subterranean clover pasture. Supplemented lambs weighed more than unsupplemented animals. Differences in body weight varied between years, but at times were as high as 15.3 kg between the high and low nutrition (stocked at 32.5 sheep/ha) groups and 10.4 kg between the supplemented and normal nutrition groups (16.4 sheep/ha). When animals were placed onto the same nutritional regime the effect of the early nutritional differences lasted 24-30 months.

When oats or triticale (64%) were mixed with *L. angustifolius* seed (27%) and hay (9%), and fed *ad lib.* to one-year-old Merino wethers on poor pasture for 8 weeks, cereal/lupin supplemented animals had a heavier mean liveweight (39.8 kg) than control animals (30.4 kg). Supplemented animals also had a higher condition score, carcass weight, depth of fat cover and eye muscle area than controls. The lupin/triticale combination produced better results than the lupin/oat mixture. The same cereals, lupin seed and sunflower meal were compared to see if frequency of supplementation was important. It was found that, while best results were obtained from giving cereal supplements every 3 days, there was no difference in the results when lupins and sunflowers were offered daily, or every 3 days.

In some parts of Australia it is possible to grow pasture in the summer. Kenny and Reed compared the *ad lib.* feeding of hay, supplemented with 300 g of lupin seed/day with a range of pasture grasses and legumes, for 3 years during summer and autumn, on a range of soil types. Generally, animals lost weight on grass, but tended to gain weight on pasture legumes. Sheep grazed on strawberry clover did best and gained 100 g/day over the three seasons. The lupin/hay mixture gave the next highest average liveweight gain at 75 g/day. Animals gained weight in all years on lupins. On pasture legumes, in some years animals lost weight due to dry seasonal conditions.

Finally, the value of lupin seed as a supplement to ensiled apple (*Malus pumila*) pomace was investigated. Two-tooth Merino weaners were offered 300 g/day of meadow hay and were fed *ad lib.* on rations based on apple pomace which contained from 3-16.9% lupins and varying amounts of urea or gypsum. Without lupins animals gained 124 g/day. The most efficient ration contained 6.7% lupin, 0.65% urea and 0.15% gypsum. Animals gained 238 g/day and had a final carcass weight of 19.5 kg. However, there was no significant difference in any measured parameter between these animals and those fed a ration which contained 16.9% lupin. It would seem that where there is a cider industry, lupin seed provides an effective way of disposing of crushing residues.

**WOOL PRODUCTION**

Besides its effect on body weight, lupin seed can have major effects on wool production and fleece characteristics. Animals which grazed...
standing lupins for 100 days produced significantly more wool (weaners, 12.6 g/day; wethers 17.5 g/day) than animals on lupin stubble (weaners 8.7 g/day; wethers 14.8 g/day). When grazed over summer, different lupin species differed in their value for wool production. On *L. angustifolius* mean wool production ranged from 10.6 to 12.1 g/day. Sweet cultivars tended to produce more wool but this was not consistent over years. Mean production on *L. albus* was 7.5 g/day. *L. cosentini* produced 7.7 g/day while *L. luteus* produced 9.6 g/day. As with body weight, differences in production were probably related to total dry matter production rather than differences in nutritional quality. In a comparison of lupin (*L. angustifolius*), pea and vetch seed as supplements, fed at 160 g/day, there was no difference in wool production between peas and lupins (14.0 and 13.9 g/day) but vetches were significantly inferior (12.6 g/day).

Sheep grazing weed-free wheat stubble for 90 days were fed 100 g/day of lupin seed. They produced 9.4 g/day of wool. Control animals produced 8.5 g/day. Similarly, on dry annual pasture, over 60 days, as lupin supplementation increased from 0 to 600 g/day wool growth increased from 3 to 8 g/day. Again on dry pasture, over summer and autumn, supplementation of weaners with 240 g/day of lupins gave 13.6 g/day of wool compared with controls at 10.3 g/day. Maximum wool production was obtained from a lupin/soya mixture (100 g soya/80 g lupin/day) at 14.5 g/day. When animals were fed on hay and given lupins from 0 to 350 g/day, wool growth rate increased from 8.5 g/day to 12.0 g/day (300 g/day lupin seed). At the end of the season there was a significant difference in greasy fleece weight between control (3.2 kg) and lupin-fed (350 g/day) animals (3.9 kg). In a comparison of different pastures grazed over summer and autumn, with lupins (300 g/day) and hay (*ad lib.*), lupin-fed sheep produced from 11.8 to 13.6 g/day of clean wool. Only animals grazed on lucerne (14.6 g/day) and strawberry clover (15.4 g/day) produced more wool.

Over two seasons, differences in wool growth between animals supplemented with oats (9.1% crude protein), or mixtures of oats and lupins (12% and 15% crude protein), were significantly different. Sheep fed oats produced 12 g/day of wool. Both oat/lupin mixtures produced an average of 14 g/day while controls fed on cereal stubble and some weeds produced only 5 g/day. A comparison of lupin seed, lucerne, wheat or wheat and urea as a supplement to 19-21 month ewes, grazing pastures of *Lolium rigidum*, *Hordeum leporinum* and *Trifolium subterraneum* from February 7 (one week before joining) to April 1, showed that ewes fed on lupins produced 19% more wool than controls for every 170 g/day of lupin seed eaten. In a further comparison of oats and lupins, or a mixture of oats and lupins (30%), as the sole energy source, animals fed on the mixture produced significantly heavier fleeces (2.75 kg) than animals fed on oats (2.39 kg) or lupins (2.44 kg). The results were the same, irrespective of whether the ration was offered daily or twice weekly. When oats and wheat were compared with lupins at 270 g/head per day, as a supplement to poor quality hay, offered from 2 weeks before lambing,
until 6 weeks after lambing, lupins produced heavier fleeces (2.99 kg) than controls (2.76 kg). There was little difference in fleece weight between animals fed on lupins or oats\textsuperscript{46}. Under simulated drought conditions where ewes were fed either wheat or oats, with 0-60% added lupins fleece weight increased from 3.33 to 3.72 kg as the proportion of lupin in the diet increased to 45\%\textsuperscript{48}.

Improved nutrition of Merino wethers, during their first summer, grazed at 16.4 sheep/ha and supplemented, \textit{ad lib.}, with a barley/lupin mix (15\% crude protein), produced significantly heavier fleeces at the end of the first year (4.0 kg compared with 3.2 kg). Supplemented animals tended to produce heavier fleeces for the following three years, but the differences were not significant\textsuperscript{40}.

Breeding ewes which were pen-fed, from 4 weeks pre-tupping until lambs were 100 days old, on a commercial ration, or on rations formulated from \textit{L. angustifolius} genotypes which varied in their alkaloid content, produced the same amount of wool on the commercial ration and on the two bitter genotypes (Ignis and Mirela) (mean, 8.25 g/100 cm\textsuperscript{2} in 150 days). Sheep fed cv. Remik produced only 7.49 g/100 cm\textsuperscript{2} \textsuperscript{45}.

The effect of lupin supplementation on fleece quality varies, although some workers reported little difference in clean wool yield in response to lupin supplementation\textsuperscript{43,44}. In Western Australia, when lupins were grazed, mean yield declined from 70.0\% to 67.8\%\textsuperscript{47}. Effect on mean fibre diameter also varied: some workers found no response\textsuperscript{43,44,47} while others found significant variation in response to lupin supplementation\textsuperscript{48}. A consistent reported response to lupin supplementation was a marked reduction in the proportion of tender fleeces\textsuperscript{46,47}.

As these trials show lupin supplementation can increase wool production. Its value in modification of fleece quality is less clear.

**VALUE OF LUPIN STUBBLES**

The growing of large areas of lupins has produced large amounts of lupin crop residues available for feeding animals after crop harvest\textsuperscript{47,50}. Early work showed that both wethers and wethers lost weight when fed on lupin stubble\textsuperscript{25}. Lupin stubble had a low digestibility (30\%) but a higher nitrogen concentration (1.4\%) than cereal stubble (0.77\%). At 11.25 sheep/ha, animals gained some weight on lupin stubble from mid-January to late-April. At 22.5 sheep/ha the sheep lost about 8 kg in bodyweight. Sheep fed on pea stubble performed similarly. In all treatments the sheep ate little of the stubble and preferentially grazed green weeds. Compared with peas and vetch, lupin stubble contained slightly more nitrogen (1.5\%) than the other two species (peas, 1.2\%; vetch 1.4\%). When animals were offered the three stubbles \textit{ad lib.}, and were given 160 g seed/day of each of the three species the mean digestibility of diets based on lupin stubble was 70.8\%. There was no significant difference in liveweight gain among the treatments which ranged from 37 g/day to 131 g/day\textsuperscript{30}.
In a comparison among species and genotypes of lupins, stubble was grazed with weaners at 50 animals/ha for 63 days from mid-December. There was no difference in the amount of stubble among the 6 genotypes \( (L.\text{albus} [1]; L.\text{angustifolius} [3]; L.\text{cosentinii} [1]; L.\text{luteus} [1]) \) (mean 8.281 kg/ha). There were marked differences in weight gain during the feeding period. Animals grazed on \( L.\text{cosentinii}, L.\text{luteus} \) and \( L.\text{angustifolius} \) ( cvs Uniharvest and Uniharvest) stubble gained 5 kg. Weaners grazed on \( L.\text{albus} \) and \( L.\text{angustifolius} \) cv. Fest only gained about 3 kg. A similar experiment with dry ewes, at 66 sheep/ha, compared 3 \( L.\text{angustifolius} \) cultivars with wheat stubble over 55 days. On lupin stubble maximum weight loss was 2 kg compared with a loss of 6 kg on wheat stubble. Similar results were obtained by Croker et al.\(^51\). On \( L.\text{angustifolius} \) cv. Uniharvest stubble, Merino sheep at 25 sheep/ha gained weight for 80 days. At 50 or 75 sheep/ha, although sheep still gained weight, the weight gain was less and it was not maintained for as long\(^51\).

It appears that the ability of sheep to gain weight on lupin stubble may be related to the amount of lupin seed that is left on the ground after harvest\(^52\). The amount of grain on the ground after harvest was about 364 kg/ha. After 79 days on the stubble, sheep had picked up nearly all of the grain (mean residue 38.1 kg/ha). The addition of a further 350 kg seed/ha to the stubble considerably improved animal performance at both 25 (8 kg bodyweight gain) and 50 sheep/ha (5 kg gain). However, even without the extra seed, animals did gain weight. It appears that lupin stubble is of higher nutritional quality than the normally available cereal straw. Its value is increased by the fallen lupin seed which the animals pick up from the ground.

**FEEDING OF EWES**

**Ovulation rate**. Many workers have reported increases in the ovulation rate of ewes fed lupins, for varying periods, at around mating\(^42,53-77\). Responses have mainly been observed in Merinos\(^53,54,59,62,66,68-73,75-77\). However increases have also been obtained from Border Leicester x Merino\(^42,57,58,67\), Corriedale\(^55\) and Romney\(^65\) ewes. Increased ovulation rates have been shown in sheep in eastern\(^42,57-59,61,62,64,66,67,70,72\) and Western Australia\(^53-56,60,68,70,71,73-76\) and New Zealand\(^65\).

Increases in ovulation rate to lupin supplementation are highest from animals on poor quality feed. Ewes grazing wheat straw had an ovulation rate of 1.08. Animals supplemented with lupins at 500 g/day ovulated at 1.50. On dry subterranean clover, control ewes produced 1.25 ova, while lupin-supplemented ewes produced 1.61\(^53\). Increased amounts of lupin, from 170 to 510 g/day, increased ovulations from 1.23 to 1.47 (controls, 1.13 ova)\(^42\). Oat stubble-fed ewes produced 1.09 ova. Lupin stubble was superior in quality and produced 1.50 ova. A comparison between lupins at 500 g/day for 14 or 35 days, pre-joining, showed no difference in ovulation rate \((1.48)\)^\(^54\).
Not all experiments have shown marked responses. In an experiment in New South Wales, increased ovulation was only obtained in 2 out of 4 seasons. Ewe age affects the response, and maiden and young ewes respond less than mature animals. Marshall et al. found no response to supplementation in 1.5-year-old ewes (1.00), but a marked increase in ovulation rate as ewes aged (1.27 at 4.5 years). Other workers obtained similar low response rates from young ewes. Although responses have mainly been obtained from *L. angustifolius* seed, *L. albus* cv. Ultra, at 0-500 g/day for 7 or 14 days, significantly increased ovulation rate.

Reported feeding durations range in length from 4 weeks before joining until lambs were 100 days, to as short as 4 days. However it has now been shown that feeding ewes 750 g/day of lupins, from days -8 to -5 of the ovulatory cycle, increased ovulations from 1.29 to 1.43.

Whether increased ovulation is due to improved protein nutrition, or increased energy supply, is still not clear. However it has been suggested that a response to the protein in lupin seed will only be obtained when the initial ration is low in both protein and energy. Similarly, the amount of extra supplement fed has varied considerably, from as little as 170 g/day, to 750 g/day. When the effect of increasing the plane of nutrition of ewes by supplementing every 6 weeks for 9 days at 750 g/day, was compared with a single supplementation of 9 days it was found that the same ovulation rate could be produced from a single supplementation (1.24) as from repeated supplementation (1.25) with controls (1.08). Response to the single supplementation increased between December and March.

**Lambing percentage.** In spite of increases in ovulation rate in response to feeding lupins, increases in lambing percentage have not always been consistent and have ranged from -14% to +38%. Increased embryo abortion in supplemented animals has been observed and it has been suggested that this is caused by lower plasma progesterone levels. In all cases where lupins have given major responses there have been increases in the number of twin lambs.

In a major Western Australian trial with 22,800 ewes there was only a weak correlation between lupin supplementation at 250 g/day and the number of lambs born (R² = 0.281, P < 0.01). More recently Croker has suggested that the cause of the variable responses may be subterranean clover pasture. Ewes fed lupins at 250 or 500 g/head per day produced 10 to 19% more lambs on subterranean clover pasture. In the absence of the clover the response to the lupins was -4 to +13%.

**Supplementation in late pregnancy.** Supplementation of ewes with lupin seed in late pregnancy and early lactation can lead to larger lambs and to ewes ending the season in better condition. Feeding of ewes, on dry pasture, on 0 to 600 g/day of lupin seed, for 10 weeks from 4
weeks before lambing gave a significant linear increase in milk production of 0.17 ml/4 hours per g of lupin. Lamb birth, weaning and rate of growth to 50 days were also increased. Supplemented ewes at weaning were 3-6 kg heavier than controls. Beeton obtained similar results when ewes were fed a mixture of oats and barley (2:1) with 250 g of lupin seed added per 1 kg of the cereals for 106 days from 4 weeks pre-lambing, as did Kenney and Roberts when they compared oats, wheat or lupin seed, at 270 g/day for 8 weeks, from 2 weeks pre-lambing. In the following season only 6% of lupin-fed ewes were barren, compared with 25% in other treatments.

In eastern Australia it was suggested that responses to supplementation could not be expected if more than 300 kg/ha of green material was on offer. In south-west Western Australia and much of South Australia, this amount would almost never be present in summer. Under simulated drought conditions feeding of lupins to provide 0-60% of the diet for 11 weeks gave 3 kg heavier ewes, reduced ewe deaths, and increased lamb survival by 24% and lamb growth rate by 41 g/day. Lupin seed was also as good as roughage pellets (15.7% crude protein) in producing fast rates of growth and heavier ewes at the end of the season. However, although impressive results have been obtained, it has been suggested that, provided ewes are in good condition, they may be able to make compensatory growth to overcome problems caused by autumn lambing. Therefore, the amount of lupin seed to be fed to ewes during and after pregnancy will depend on ewe condition and the amount of dry feed on offer, but should probably be between 200 and 400 g/day.

**FEEDING OF RAMS**

Reproductive potential in rams can be improved by feeding with lupin seed prior to the start of the breeding season. However, notwithstanding reports of considerable increases in testicular volume and spermatozoa production from lupin supplementation, only one paper reports the effect of supplementation on conception rate. When rams were allocated to ewes on the basis of testicular volume the number of rams to the ewe could be reduced from 2.3% to 1.3% without an increase in returns to service. However, when unsupplemented rams were put out at 1.3% they were just as effective. In all treatment groups there was a linear decline in testicular volume from the start of the breeding season. Supplemented animals, allocated at 2.3%, had a testicular volume at the end of the breeding season of 500 ml which was greater than unsupplemented animals at the start of mating. Further, supplemented animals ended the breeding season in better condition. All animals lost weight at a constant rate and supplemented animals were 10 kg heavier prior to mating.

Addition of 500 g of *L. angustifolius* seed to 2 kg/day of hay (5.6% crude protein) increased testicular volume during a 9 week feeding period by 250 ml (400 ml to 650 ml). Body weight increased by 16 kg. Sperm production per g of testicular tissue rose from 18.0 x 10^6 to...
g to 26.4 x 10^6 per g per day. On a per animal basis, supplemented rams produced nearly twice as much sperm per day. It is suggested that increased testicular volume is caused by increases in the peak frequency of luteinizing hormone and testosterone within 5 days of lupin feeding. At the end of a 6 weeks, blood from animals supplemented with 750 g of lupin seed/day contained 4.06 ng/ml of testosterone compared with 2.47 ng/ml in controls. There was no significant difference in the level of luteinizing hormone (0.80 ng/ml compared with 0.66 ng/ml). These effects are not constant. Martin et al. in a comparison between Booroola and Merino rams supplemented at the same rate for 9 weeks, found no difference in plasma luteinizing hormone or testosterone levels. However, the intervals between pulses of the two hormones were shorter in supplemented animals. As in the previous work there were marked responses to supplementation in both body weight and testicular volume.

When lupins and other supplements were compared for their effect on testicular volume to try to determine if it was energy or protein which was responsible for the changes, only lupins increased volume in comparison with casein and glucose, fed to provide the same level of protein. When lupins were compared with a synthetic ration of equivalent energy and protein, or with barley fed at the same energy level, there was no statistical difference in testicular volume or in body weight among treatments. The relationship between body weight gain and testicular volume was asymptotic, with little increase in testicular volume at weight gains above 200 g/day. It was suggested that changes in testicular volume were related to metabolisable energy intake rather than protein per se. Cumming et al. in Victoria, supplemented rams with 750 g/day of L. angustifolius seed and produced major changes in body weight but no change in testicular volume, testosterone, luteinizing hormone or libido. Diet quality may have been involved in the lack of response. In the first experiment, control animals were fed on an isocaloric ration of lucerne/barley pellets. Energy was therefore probably not limiting, and given the lucerne, protein was also probably adequate.

The major effect of supplementing rams with lupin seed is to improve their nutritional status so they commence the breeding season with better body weight, and with greater reserves of testicular tissue. Whether in the long run this will produce more lambs remains to be proved.

USE IN SHIPPING RATIONS

Australia currently exports about 7 million live sheep a year to the Middle East. Aboard ship the animals are fed on pellets. The current demand for pellets is 150,000 t/annum. Recent trials have tested lupins as a possible component in shipboard sheep rations. An initial experiment did not give promising results. Lupin seed was added to the pellets at 0 to 39%. There was no difference in liveweight change (-1.55 kg to -0.54 kg), or feed intake (814 to 827 g/head per day) over a 20 day feeding period. Sheep fed a ration high in lupins consumed their food significantly faster than other animals. In a comparison of a mixture of
75% oats/25% lupin seed with cubed lucerne or commercial pellets, sheep fed on the lupin/oat mix lost 1.85 kg in 11 days compared with no change or a slight weight gain from animals fed lucerne or pellets. Sheep consumed significantly less of the mixture (471 g/day) than lucerne (959 g) or pellets (906 g). A possible small advantage for the shippers of the lupin/oat mixture was that faecal volume was only 25 to 33% of that from sheep on pellets or lucerne.

Western Australian work\(^9\) showed that feeding whole lupin seed leads to excessive ammonia production by sheep. A solution appears to have been found by the inclusion of lupin testas, a by-product of lupin kernel production, which are low in protein. Pellets were formulated using lupin testas to which variable amounts of whole lupin seed were added. The pellets were 12 to 13% crude protein. An initial trial showed that sheep adapted quickly to the pellets and at the end of 5 weeks the sheep performed better on lupin pellets than on standard commercial pellets.

In a further trial\(^9\) with pellets comprising 66% lupin testa and 33% kernel, it was shown that sheep adapted rapidly to the lupin pellets and consumed virtually all pellets from the start of the trial. Because of initial refusal there was a marked loss of weight in animals fed commercial pellets over the first 2 weeks. Although the weight differences between the two rations were not significant, at the end of 5 weeks sheep fed on lupin pellets were more than 2 kg (52.2 kg) heavier than those fed commercial pellets (50 kg).\(^9\) It appears that pellets of lupin testas combined with whole seed or kernel can be used as a concentrate feed for sheep without the waste of protein that occurs with the feeding of whole lupin seed.

**CONCLUSIONS**

This review of the use of lupins for feeding sheep has shown that lupins can increase body weight in young and mature animals, promote wool growth, increase ovulation rates, and in some circumstances lambing percentages, and promote both testicular volume and sperm productions in rams. The economics of the reported responses will depend upon the cost structure of farming, and the returns from sheep production in individual countries.

**REFERENCES**