Optimising genetics, reproduction and nutrition of dairy sheep and goats

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by Alexander Cameron

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Foreword

Dairy sheep and goat industries in Europe are several orders of magnitude larger than in Australia and thus provide a substantial body of scientific and industrial experience for the small Australian industry to utilise. A tour of sheep and goat dairies in France and Spain highlighted some critical differences between their situation and ours. The most significant were:

- year-round milk production is of more importance in Australia
- labour is much more expensive in Australia
- both sheep and goats are genetically superior in France and Spain to those milked in Australia
- concentrates form a more substantial portion of the ration, rather than forage – one consequence of this is that replacement stock are generally milked from 12 months of age.

This project was aimed at devising strategies suitable for increasing the efficiency of milk production in dairy sheep and goats in Australia.

The key findings are:

- Artificial lighting in late lactation is a cost-effective means of increasing milk production but lighting should not commence until late April, and joining should be completed within eight weeks of lighting commencing.
- Joining goats at seven months of age is more profitable than joining at ten months of age.
- Satisfactory pregnancy rates can be achieved with a single mating following the use of CIDR and PMSG, but further work is required aimed at increasing the proportion coming into oestrus and to clarify whether reducing feed intake after mating increases pregnancy rates.
- It is probable that the benefits of delaying joining of ewe lambs beyond seven months of age or 45 kg live weight will be more than offset by the losses of delaying the onset of both the first and subsequent lactations, but more definitive evidence for this must await controlled experiments.
- Lambs in dairy ewes should be weaned within 48 hours of birth for optimum milk production.
- The Awassi breed may increase milk production by an as yet to be fully defined amount, but substantial effort will be required to turn them into an easy-care breed.
- Neutral detergent fibre of 30 per cent of the ration will prevent sub-acute ruminal acidosis. Provided this parameter is fixed (along with the per cent of protein in the ration) carbohydrate source has little measurable effect on milk production.
- There are no benefits from increasing the frequency of feeding a total mixed ration (TMR) above once daily.
- One feeder space per two animals is adequate for dairy goats fed TMR ad libitum.

This project was funded from RIRDC core funding, and industry contributions.

This report is an addition to RIRDC’s diverse range of over 2000 research publications and it forms part of our Animal Industries R&D program, which aims to conduct RD&E for new and developing animal industries that contribute to the profitability, sustainability and productivity of regional Australia.

Most of RIRDC’s publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation
About the Author

Alexander Cameron graduated as a veterinary scientist in 1981 and completed a PhD in the field of sheep reproduction at the University of Western Australia, in 1986. After several years researching on artificial breeding techniques in goats he, and his wife Julie, established Meredith Dairy in 1991. This business milks sheep and goats and processes the milk into yoghurt and cheese that is sold around Australia, and exported to Asia and the United States of America. Alexander Cameron is an Adjunct Senior Research Fellow at Monash University.

Acknowledgments

The assistance of Julie Cameron, Miranda Clarke and Fernanda Zamuner with the field work is gratefully acknowledged. The studies on photoperiod and milk production were conducted by Victoria Russo and Kathryn Logan, honours students from the Melbourne School of Land and Environment, The University of Melbourne. The assistance of their supervisors, Dr Brian Leury and Professor Frank Dunshea is gratefully acknowledged. Professors Alan Tilbrook and Iain Clarke, Monash University, arranged for hormone assays to be completed.

Abbreviations

CIDR controlled intravaginal drug release
DMI dry matter intake
LDPP long day photoperiod
ME metabolisable energy
MJ megajoules
NDF neutral detergent fibre
NFC non-fibre carbohydrate
peNDF physically effective NDF
PMSG pregnant mare serum gonadotrophin (a hormone used to stimulate ovulation)
SSC somatic cell count
TMR total mixed ration
VFA volatile fatty acid
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Executive Summary

Background

Dairy sheep and goat industries in Europe are several orders of magnitude larger than in Australia and thus provide a substantial body of scientific and industrial experience for the small Australian industry to utilise. A tour of sheep and goat dairies in France and Spain highlighted some critical differences between their situation and ours. The most significant were:

- year-round milk production is of more importance in Australia
- labour is much more expensive in Australia
- both sheep and goats are genetically better in France and Spain than those milked in Australia
- concentrates form a more substantial portion of the ration than forage – one consequence of this last point is that replacement stock are generally milked from 12 months of age.

This project was aimed at devising strategies suitable for increasing the efficiency of milk production in Australian dairy sheep and goats.

Where are the relevant industries located in Australia?

The dairy sheep industry currently has six well-established businesses, all of which are vertically integrated, processing all of their milk in their own factories. Of these, the products of one (Meredith Dairy, based in southern Victoria) are nationally distributed and three others are well established. The farm gate value from these dairies is probably about $4 million per year and probably growing at about 10 per cent per year.

The goat dairy industry has a number of nationally distributed brands that are available in independent retailers, food services and, over the past few years, supermarkets. These brands are derived from milk produced from two substantial dairies in Victoria, one of which is Meredith Dairy. There are also well-established brands in all the other states, each reliant on one or several family farms to supply their milk. The industry probably has a factory-door turnover of at least $30 million per year, and this is probably growing at 20 per cent or so, per year. Meredith Dairy is now exporting container loads of cheese to the United States, and other dairies have received genuine enquiry for powdered milk from China.

Aims/objectives

The project is aimed at establishing technologies that will enable sheep and dairy goat farmers to cost-effectively produce year-round supplies of milk.

Specific objectives include:

1. Determine how to manipulate photoperiod to increase milk production in sheep and goats.
2. Determine how to maximise the intake of energy as whole grain and conserved grass (hay and silage) while minimising the incidence of acidosis in goats.
3. Determine optimum growth curves and optimum age and weight at first joining in dairy lambs and kids.
4. Determine the optimum lactation length in goats.
5. Determine the yield penalty from suckling lambs for several weeks before weaning.
6. Evaluate the genetic merit of the Awassi breed.

Methods used

Three methods of escalating effort were made to achieve each objective:
1. A comprehensive review of the scientific literature was first undertaken to determine which objectives could be met through published knowledge obtained using controlled experimentation in other countries, or in other species. Insights obtained in this way were corroborated by changing management practices at Meredith Dairy to reflect them, and observing whether the desired change in milk production, animal health, or productivity was obtained. An example of the successful application of this process was the successful incorporation of high levels of grains in the ration through the use of total mixed ration (TMR, see glossary).

2. When a gap in the literature was discovered, we conducted retrospective studies of the lactation records, and live-weight records of Meredith Dairy. The sheep and goats at Meredith Dairy have ear tags used for radio frequency identification (RFID, see glossary) which allows milk volume to be recorded at every milking for every animal, and live weight to be obtained at all stages of the production cycle (weaning, joining, kidding etc).

3. Some objectives could only be met by conducting controlled experiments; for example to establish the effect of increased photoperiod on milk production.

**Results/key findings**

- Artificial lighting in late lactation is a cost-effective means of increasing milk production but lighting should not commence until late April, and joining should be completed within 8 weeks of lighting commencing.
- Joining goats at 7 months of age is more profitable than joining at 10 months of age.
- Satisfactory pregnancy rates can be achieved with a single mating following the use of a controlled intravaginal releasing device (CIDR, see glossary) and pregnant mare serum gonadotrophin (PMSG), but further work is required aimed at increasing the proportion coming into oestrus and to clarify whether reducing feed intake after mating increases pregnancy rates.
- It is probable that the benefits of delaying joining of ewe lambs beyond 7 months age or 45 kg live weight will be more than offset by the losses of delaying the onset of both the first and subsequent lactations, but more definitive evidence for this must await controlled experiments at which lambs are mated at pre-planned weights and ages in factorial experiments (which will be very expensive to carry out).
- Lambs in dairy ewes should be weaned within 48 hours of birth for optimum milk production.
- The Awassi breed may increase milk production by an as yet to be fully defined amount, but substantial effort will be required to turn them into an easy-care breed.
- Neutral detergent fibre of 30 per cent of the ration will prevent sub-acute ruminal acidosis. Provided this parameter is fixed (along with the per cent of protein in the ration) carbohydrate source has little measurable effect on milk production.
- There are no benefits from increasing the frequency of feeding a TMR above once daily.
- One feeder space per two animals is adequate for dairy goats fed TMR ad libitum.
- The current recommendation of 1.5 square metres of floor space does not limit milk production in milking goats.

**Implications for relevant stakeholders**

The findings can be immediately applied by sheep and goat dairy producers, and if applied will increase their production and reduce their cost of production.
Introduction

Dairy sheep and goat industries in Europe are several orders of magnitude larger than in Australia and thus provide a substantial body of scientific and industry experience for the small Australian industry to utilise. A 2007 tour to sheep and goat dairies in France and Spain highlighted some critical differences between their situation and ours. The most significant were:

1. Australian dependence on year-round milk production: The European industries are based on seasonal milking that inevitably reduces prices. Consequently the Australian industries’ competitive advantage is to produce fresh product with short shelf life for the domestic market. This necessitates year-round production, in the face of annual cycles of photoperiod that induce changes in reproduction and milk production. In a former RIRDC project, we increased June milk production in early lactation by 8.4 per cent through subjecting the ewes to 16 hours light per day throughout May and June. This study represents no more than a preliminary examination of what ought to be a systematic examination of the effects of photoperiod in sheep and goats. For example, in cattle it has been shown that increased photoperiod increases milk production in winter, yet long day photoperiod prior to calving reduces milk production in the subsequent lactation (Dahl and Petitclerc, 2003) and the administration of melatonin (the secretion of which is elevated by darkness) reduces milk production (Auldist et al, 2007) when administered during lactation in summer (which we do to advance the breeding season in goats), but does not increase milk production when administered prior to calving in summer. Understanding these effects may permit increased winter milk production, or at least minimise disruptions to milk production when melatonin is administered to advance the breeding season.

Year-round milking makes it possible to vary the interval between lactations. In our current project we established that pregnancy did not reduce milk production in lactating ewes until the third month of pregnancy, which led to us concluding that a 9-month lambing interval is optimal for sheep. We wish to undertake a similar study in goats in which we will consider whether the optimum interval between kidding is more or less than 12 months – which will depend on both the effect of pregnancy on lactation and the effect of time on milk production in goats.

2. European goats are housed and fed concentrates from weaning to puberty: This diet leads to rapid growth rates such that they readily attain 60 per cent of adult live weight at 7 months, which is the target weight for first joining. Joining at 7 months is necessary to maintain the flocks in a seasonal production system. Rations generally include more roughage and less concentrate thereafter, which may improve conception rates by reducing progesterone clearance rates. In contrast animals at Meredith Dairy are fed pasture, sometimes with concentrate supplements, from weaning to puberty. The inevitable parasite burdens reduce growth rates, and target live weights are not achieved at 7 months, so growth rates must be maintained at high rates throughout first joining and pregnancy. Of benefit though, the animals gain immunity to nematodes and coccidiosis, both of which are essential unless the animals are to be housed throughout their life. We wish to determine whether high growth rates at puberty are associated with low pregnancy rates. Further, we wish to determine the most profitable growth curves for both dairy sheep and goats in a year-round production system in which delaying puberty beyond 7 months is not necessarily disruptive. We also wish to determine whether dairy goats are most economically managed by removing all access to pasture.

3. Access to genetically improved dairy sheep: Sheep dairying in Greece, Spain and France is carried out with millions of sheep, derived from government-supported breeding programs that have led to breeds such as Lacunae, Chios and Assaf that routinely yield over 300 litres of milk, with the dairy lactation beginning after a 30-day period of the ewe suckling its new born lambs. In contrast the ewes milked at Meredith Dairy were derived by crossing the East Friesland breed, of which only 20 or so animals were ever imported from Europe, with meat breeds such as Polled Dorset. These ewes on average yield only about 200 litres of milk per lactation, provided lambs are removed at birth, and
somewhat less milk if lambs are removed several weeks after birth. The low milk production of these sheep was assumed to be at least partly due to the failure of ewes to have a milk ejection reflex when machine milked, as it was found in a previous RIRDC project that ewes had about 50 per cent residual milk (see glossary for definition) after machine milking. We wished to further evaluate the yield penalties of suckling lambs before milking of our East Friesland cross ewes.

Another dairy breed – Awassi – was imported into Australia in the 1990s, but their genetics were not made available to the sheep dairy industry for evaluation. In this project we evaluated this breed for sheep dairying.

Farm labour in Europe is cheap so Europeans tolerate ewes with pendulous udders which take substantial manual intervention to milk, without which we suspect the production of such ewes would be reduced. Probably ewes have been selected for large cisterns for many years as this is more easily estimated than the efficiency of the milk ejection reflex, which is necessary for harvesting cisternal milk. Thus Labussiere (1988) concluded that large cistern size was a prerequisite for high milk yield in ewes. Nevertheless, in dairy cows the majority of milk is retained in the alveolar portion of the mammary gland until the milk ejection reflex occurs during milking. We hypothesise that among ewes producing similar volumes of milk at first lactation, those with relatively small cisterns, and with efficient milk ejection will have higher lifetime production.

4. Concentrate feeding of lactating goats: Typical rations for lactating goats in France and Spain comprise 1 kg ryegrass hay and 1.8 kg of ‘concentrates’. The concentrates include maize, wheat, soybean meal and other pelleted feeds such as sugar-beet pulp. Invariably the ration is divided into at least four, and generally five feeds per day to reduce the risk of ruminal acidosis. This divided feeding is achieved at considerable capital expense; at the very least, the goats are housed in facilities permitting the whole herd to eat at once, and often an automated feed cart that delivers food every 3 hours is used.

We endeavour to feed as much cereal as we can as it is invariably the cheapest source of high quality metabolisable energy (ME) (see Table 1) we can source.

**Table 1.** The cost of energy sources used at Meredith Dairy. The prices are the average January price for 2006, 2007 and 2008, and in the case of silage, represent the full cost of production.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Cost ($/ton)</th>
<th>MJ ME/kg dm&lt;sup&gt;*&lt;/sup&gt;</th>
<th>Dry matter (%)</th>
<th>Cost /10 MJ ME (cents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legume hay</td>
<td>350</td>
<td>11</td>
<td>0.88</td>
<td>36</td>
</tr>
<tr>
<td>Barley</td>
<td>260</td>
<td>12</td>
<td>0.88</td>
<td>25</td>
</tr>
<tr>
<td>Pellets</td>
<td>420</td>
<td>12</td>
<td>0.88</td>
<td>38</td>
</tr>
<tr>
<td>Ryegrass hay</td>
<td>250</td>
<td>9.3</td>
<td>0.86</td>
<td>31</td>
</tr>
<tr>
<td>Silage (rolls)</td>
<td>135</td>
<td>10.5</td>
<td>0.45</td>
<td>29</td>
</tr>
</tbody>
</table>

<sup>*</sup>MJ ME/kg dm – megajoules metabolisable energy per kilogram dry matter

Cereals represent a rich source of readily fermentable carbohydrate, which in a healthy rumen is largely converted to volatile fatty acids (VFAs), which are absorbed through the rumen wall. The production of VFAs leads to a post-prandial decline in rumen pH from about 6.5 to as low as 5.6. This normal decline in rumen pH may have desirable consequences such as reduced rumen methane production, reduced protein deamination, and an increased ratio of propionate to acetate (Lana et al 1998), which in turn may increase food utilisation and yield of milk protein (Bramley et al, 2008). If rumen pH falls below 5.6, rumen function may be impaired, leading to reduced digestion, reduced food intake and lowered animal production. More severe ruminal acidosis may lead to clinical disease such as laminitis, hepatic abscesses and rumenitis. A fall in rumen pH to 5 also may lead to a proliferation of lactobacilli, leading to an accumulation of lactic acid, with consequent metabolic acidosis and death (Nagaraja and Titgemeyer, 2007). In our attempts to maximise cereal intake in
dairy goats, we have seen the full spectrum of sequelae to ruminal acidosis ranging from death through to the syndrome defined in *Veterinary Medicine 10th edition* (Radostits et al, eds) as subacute ruminal acidosis, whereby clinical signs include laminitis, intermittent diarrhoea, suboptimal appetite, a high herd culling rate and suboptimal milk production in second and subsequent lactation goats compared to first lactation goats.

The extent to which a given intake of readily fermentable carbohydrate causes ruminal acidosis depends on various factors including the extent of acclimatisation of individuals to the ration, the effectiveness of homeostatic mechanisms of the rumen, including rumen buffering and motility, feeding frequency, whether the food is part of a mixed ration that may be consumed over a long period, and social factors such as whether all animals can feed at once.

We wish to systematically optimise these factors so as to maximise the amount of cereals we can include in dairy goat rations.
Objectives

The project is aimed at establishing technologies that enable sheep and dairy goat farmers to cost effectively produce year-round supplies of milk.

Specific objectives include

1. Determine how to manipulate photoperiod to increase milk production in sheep and goats.
2. Determine how to maximise the intake of energy as whole grain and conserved grass (hay and silage) while minimising the incidence of acidosis in goats.
3. Determine optimum growth curves and optimum age and weight at first joining in dairy lambs and kids.
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Methodology

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2. When a gap in the literature was discovered, we conducted retrospective studies of the lactation records, and live-weight records of Meredith Dairy. The sheep and goats at Meredith Dairy have eartags used for radio frequency identification (RFID, see glossary) which allows milk volume to be recorded at every milking for every animal, and live weight to be obtained at all stages of the production cycle (weaning, joining, kidding etc).

3. Some objectives could only be met by conducting controlled experiments; for example to establish the effect of increased photoperiod on milk production.
Results

The effect of long day photoperiod on milk yield of dairy goats in early and late lactation

Long day photoperiod stimulates milk production in goats but limited data indicate the effects may be confined to late lactation. We tested this hypothesis on two farms by randomly allocating Saanen and Saanen-British Alpine cross goats into either a control group, housed under normal photoperiod, or a treated group, exposed to long day photoperiod (16 hours light, 8 hours dark, LDPP) for 8 weeks, commencing 29 April. Goats were in early (5 to 20 days in milk) (n=253) or late (190 to 210 days in milk) (n=289) lactation, and fed a total mixed ration (TMR) ad libitum. A total of 542 goats, all yielding at least 1.5 litres of milk per day at the start of the experiment, were studied, at two sites.

Table 2. Mean milk production in early and late lactation, goats housed under natural light (control) or under 16-hour photoperiod (LDPP), over an 8-week period commencing 29 April.

<table>
<thead>
<tr>
<th></th>
<th>Early lactation</th>
<th>Late lactation</th>
<th>SE</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>LDPP</td>
<td>Control</td>
<td>LDPP</td>
</tr>
<tr>
<td>Weekly milk</td>
<td>2.85</td>
<td>3.07</td>
<td>2.27</td>
<td>2.54</td>
</tr>
<tr>
<td>yield</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of variance showed a significant effect of light treatment and stage of lactation (see Table 2) and week of treatment for both sites. Overall the analysis could be interpreted as uniform effect of treatment over the lactation periods, as the stage of lactation by treatment interaction is not significant (0.131). But the interaction treatment*stage of lactation*time was significant (P<.001) because milk yield responded more slowly to LDPP in late lactation rather than early lactation, but the treatment had a progressively greater effect in late lactation so that by 8 weeks they were yielding nearly 500 mL more milk per day than the controls. This relationship is made clear in Fig. 1.
The maximum increase in production was attained by 4 weeks lighting, and was twice as large for goats in late lactation compared to early lactation (0.45 litres vs 0.22 litres). Fat, protein and lactose concentrations of milk were reduced by extended photoperiod compared to controls (P<0.001), for both stages of lactation (Fig 2).

Average total milk fat and protein production across the 8-week study was not significantly different between extended photoperiod and control groups, but there was an interaction between lighting treatment and stage of lactation (P<0.01) for protein production (Fig 3). Average daily yield of lactose and solids not fat were increased (P<.01 and P<.05 respectively) by extended photoperiod and for solids not fat the interaction between stage of lactation and light treatment was significant, with yield (g/day) of 142.7 and 143.5 for early lactation (control vs extended photoperiod) and 91.8 and 124.4 for late. Live weight was not influenced by light treatment.

We concluded that extended photoperiod influences milk production throughout lactation, but the main benefits are in late lactation, where both milk volume and yield of milk protein were increased.
Fig. 2. Relationships between milk fat, protein, lactose and solids-not-fat at percent and week relative to baseline (week 0), for does receiving natural lighting in early (a) or late (b) lactation and does exposed to LDPP in early (c) or late (d) lactation. The standard error of the difference for the interaction between treatment, stage of lactation and week is displayed on the data for the does receiving natural lighting during early lactation. The P-values for effects of photoperiod (P), stage of lactation (S), week (W), P × S, P × W, S × W and P × S × W were: 0.035, 0.03, 0.73, 0.20, 0.74 and 0.59 for milk fat, 0.011, 0.012, 0.008, 0.11, 0.001, 0.013 and 0.85 for milk protein, 0.010, 0.003, 0.032, 0.44, 0.44, 0.001 and 0.01 for milk lactose and 0.001, 0.005, 0.008, 0.011 and 0.30 for milk solids-not-fat.

Fig. 3. Relationships between milk fat, protein, lactose and solids-not-fat yield and week relative to baseline (week 0), for does receiving natural lighting in early (a) or late (b) lactation and does exposed to LDPP in early (c) or late (d) lactation. The standard error of the difference for the interaction between treatment, stage of lactation and week is displayed on the data for the does receiving natural lighting during early lactation. The P-values for effects of photoperiod (P), stage of lactation (S), week (W), P × S, P × W, S × W and P × S × W were: 0.035, 0.03, 0.73, 0.20, 0.74 and 0.59 for milk fat, 0.011, 0.012, 0.008, 0.11, 0.001, 0.013 and 0.85 for milk protein, 0.010, 0.003, 0.032, 0.44, 0.44, 0.001 and 0.01 for milk lactose and 0.001, 0.005, 0.008, 0.011 and 0.30 for milk solids-not-fat.
The effect of long day photoperiod on reproductive activity of goats in late lactation

Sheep have a seasonal pattern of reproduction, entrained by photoperiod, whereby regular oestrus cycles commence as day length declines in autumn. The imposition of long photoperiods can inhibit the reproductive system of ewes. Thus when ewes were exposed to alternating 12-week blocks of short and long day photoperiods, ovulatory cycles commenced towards the end of the period of short photoperiod, and ceased towards the end of the period of long photoperiod (Poulton and Robinson, 1987). Goats have a similar seasonal pattern of reproduction although the times of resumption and cessation of breeding activity have not been well defined. The photoperiodic control of reproduction in goats has received far less study than sheep, but similar mechanisms mediate the effects of day length on reproduction between the two species.

The breeding season of goats, as with some breeds of sheep, can be categorised as having a spontaneous phase, in which regular oestrus cycles occur in non pregnant females, which is preceded by a responsive phase in which the females ovulate when exposed to males (the buck effect). It is not known whether the spontaneous breeding season is also followed by a responsive phase – if so it is important when breeding goats late in the breeding season.

To achieve milk production all year round, goats are joined at four periods of the year at Meredith Dairy, including on 1 July, which we have considered to be towards the end of the spontaneous breeding season. To enhance winter milk production, goats are also housed under extended photoperiods in winter (see the experiment reported above) and we need to determine whether this reduces fertility.

The aim of the experiment was to test the hypothesis that exposure to long day length in autumn increases milk production, but shortens the breeding season.

A total of 132 lactating multiparous Saanen and Saanen-British Alpine cross dairy goats aged between two and five years, that had kidded in late November/early December (the result of a late June/early July joining) were randomly allocated into two groups: half remained under natural light and half were run under an artificial 16-hour long day photoperiod (LDPP), commencing 8 April.

For three consecutive months, commencing 1 June, half the does within each photoperiod were joined to vasectomised bucks for 3 days, following a 14-day period of administration of progesterone. The remaining goats were also administered progesterone, but were not joined. Progesterone was administered to synchronise ovulatory activity, through the application of controlled intervaginal drug release (CIDR, see glossary). Thus, four treatments were used:

i) natural light regime without exposure to a buck
ii) natural light regime with exposure to a buck
iii) LDPP regime without exposure to a buck
iv) LDPP regime with exposure to a buck.

Blood was sampled from the goats 11 days after CIDR withdrawal, and assayed for progesterone, to determine ovulatory activity.

There was a highly significant reduction (P<.001) in mean progesterone in goats under the long day photoperiod, with the effect first evident for the July joining, and more pronounced in August.

When a plasma progesterone concentration of greater than 1.5 pmol per litre was used as evidence of ovulation (established in a preliminary experiment), the results show that under natural photoperiod, ovulatory activity was largely maintained until August, whereas under extended photoperiod ovulatory activity significantly declined by July (Table 3). Exposure to males slightly alleviated this
inhibitory effect of light. In August, the proportion of does that ovulated in the buck-exposed group was significantly higher than for the non exposed does (Chi square =4.55, P<0.033), and exposure to bucks partially countered the inhibitory effect of LDPP on ovulation.

Milk yield was significantly increased by extended photoperiod (P<.023) and there was a significant interaction between time and treatment (P<0.001), because as the experiment progressed, milk production declined faster in the control than the LDPP group (Table 4).

From studies 1 and 2 we conclude that artificial lighting in late lactation is a cost-effective means of increasing milk production but lighting should not commence until late April, and joining should be completed within 8 weeks of lighting commencing.

**Table 3.** The effect of long day photoperiod (LDPP) and exposure to males on the proportion of does ovulating within 14 days of CIDR withdrawal on the first of June, July or August.

<table>
<thead>
<tr>
<th>Proportion of goats with progesterone &gt;1.5 pmol/mL (ovulating)</th>
<th>June</th>
<th>July</th>
<th>August</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPP no male</td>
<td>30/30</td>
<td>16/28</td>
<td>5/28</td>
</tr>
<tr>
<td>LDPP male</td>
<td>28/29</td>
<td>19/28</td>
<td>12/27</td>
</tr>
<tr>
<td>Total light</td>
<td>58/59</td>
<td>35/56</td>
<td>17/55</td>
</tr>
<tr>
<td>Control no male</td>
<td>25/26</td>
<td>27/28</td>
<td>28/30</td>
</tr>
<tr>
<td>Control male</td>
<td>25/27</td>
<td>26/30</td>
<td>23/28</td>
</tr>
<tr>
<td>Total dark</td>
<td>50/53</td>
<td>53/58</td>
<td>51/58</td>
</tr>
</tbody>
</table>

**Table 4.** Mean milk production for consecutive week after 9 April, for goats experiencing natural light (controls) and those experiencing 16 hours light (LDPP)

<table>
<thead>
<tr>
<th>Milk production vs time for goats with mean kidding date 15/9/2010 (early) vs non pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr-24</td>
</tr>
<tr>
<td>Pregnant (n=46)</td>
</tr>
<tr>
<td>Not pregnant (n=42)</td>
</tr>
</tbody>
</table>

**The effect of pregnancy on milk production**

To determine the optimum kidding interval in goats, a study commenced on 1 April 2010, in which 112 goats that were an average of 110 days in milk were allocated to groups that were joined on 7 April (pregnant group; 9-month kidding interval), or not joined before the end of the experiment (not pregnant group). To determine the effect of pregnancy on milk production, the milk production from the portion of the pregnant group that kidded in September was compared to the milk production of the control group (some of the control group were accidently mated, so excluded from the analysis). The results (Table 5) show that milk production fell significantly by 26 June (P<.05) which was an average of 82 days before kidding, or in other words, from mid term.

**Table 5.** Milk production in goats in 2010 that kidded in September 2009 and were joined to kid in September 2010 (mean kidding date 15/9/2010) or not joined.
The optimum age and weight at first lactation

Goats of 7 or 10 months of age, running together and fed pellets and hay, were joined in October 2008. Only 34/64 of the 7-month old goats completed pregnancy and entered the dairy, and they averaged 1.75 litres of milk per day in the first 60 days of lactation, whereas 109/136 (P<.01) of the goats joined at 10 months of age entered the dairy and they averaged 2.01 litres per day. For each age group, the goats that carried to term were heavier at joining than those that did not (34.7 kg vs 31.5 kg for 7-month old goats, and 41.1 kg vs 39.2 kg for 10-month old goats). Unfortunately a breakdown in the milk recording software precluded a full lactation being collected in this experiment.

For 151 first lactation goats that kidded in September 2010 there was no correlation between joining weight (minimum 35 kg) and subsequent 305-day milk production.

This inconsistency could be explained if it is joining age rather than live weight that is the most important influence on subsequent milk production.

We conclude that joining goats at 7 months of age is more profitable than joining at 10 months of age because a penalty of 0.25 litres per day of milk equates to only 75 litres in a 300-day lactation, whereas the goats joined at 7 months of age had produced an average of about 150 litres of milk by the time those joined at 10 months of age would have kidded.

The effect of time of PMSG administration in ovulation induction programs

At Meredith Dairy the fertility following the use of exogenous progesterone and pregnant mare serum gonadotrophin (PMSG) to induce oestrus in seasonally anoestrous goats has always been disappointing. We conducted a series of experiments aimed at improving fertility.

We administer PMSG at the time of CIDR withdrawal whereas it is common in Europe to administer it 48 before CIDR withdrawal (which is more work). An experiment was conducted to determine whether the fertility of milking goats varied according to the time of PMSG administration relative to the time CIDR withdrawal.

One hundred and ninety two lactating Saanen does were implanted with CIDRs on 12 September 2012 and randomly assigned to two groups that are administered 400 iu PMSG either 48 hours before, or at the time of CIDR withdrawal. Seven does were excluded from the experiment at the stage of CIDR removal because two were missing, one had a fractured leg, three were discovered to have recently kidded, and one had a broken leg. CIDRs were withdrawn over a 4-day period from 19 to 22 September, and goats were hand mated from 36 to 48 hours after CIDR withdrawal. The male goats used had been housed under a 16-day photoperiod from 3 to 4 months before mating, and had received melatonin implants two and one month before mating, so they were sexually active even though it was the no breeding season.

The CIDR retention rate of only 85 per cent represents a significant source of reproductive wastage (Table 6). Only 63 per cent of does came into oestrus and this was not influenced by the time of administration of PMSG (Table 6). This relatively low proportion of does coming into oestrus was surprising, but the same result occurred in another experiment conducted in October.
Table 6. The effect of time of administration of PMSG relative to CIDR withdrawal on the proportion of does detected in oestrus and mated.

<table>
<thead>
<tr>
<th>Time of PMSG administration relative to CIDR withdrawal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>minus 48 h</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>n</td>
</tr>
<tr>
<td>Number retaining CIDR</td>
</tr>
<tr>
<td>Proportion on heat</td>
</tr>
<tr>
<td>Proportion mated</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Table 7. The proportion of does that kidded after a single mating at synchronised oestrus, at which PMSG was given 0 or 48 hours before CIDR withdrawal, and half the mated does received a second CIDR 14 days after mating.

<table>
<thead>
<tr>
<th>Time of PMSG administration relative to CIDR withdrawal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>minus 48 h</td>
<td>0 h</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>No CIDR after mating</td>
<td>14/21</td>
</tr>
<tr>
<td>CIDR after mating</td>
<td>14/26</td>
</tr>
<tr>
<td>Total</td>
<td>28/45</td>
</tr>
</tbody>
</table>

The proportion of goats pregnant was significantly higher in goats treated with PMSG two days before CIDR withdrawal, and was not increased by the insertion of a second CIDR after mating (Table 7).

We conclude satisfactory pregnancy rates can be achieved with a single mating following the use of CIDR and PMSG, but further work is required aimed at increasing the proportion coming into oestrus.

The effect of nutrition after mating on plasma progesterone concentrations and pregnancy

The background to this work is that high levels of nutrition around the time of maternal recognition of pregnancy have been shown to reduce plasma concentrations of progesterone, and pregnancy rates, in sheep (Parr et al., 1987). Dairy goats are generally fed two to three times a maintenance ration and we hypothesise this may reduce fertility. The aim of the experiment was to determine whether the concentration of plasma progesterone in the late luteal phase varied according to level of nutrition, and whether this in turn affected pregnancy rates.

The experiment utilised 92 Saanen goats, aged approximately 7 months, with an average weight of 36 kg (minimum 33.5 kg) on 19 October. The goats were fed pellets and pasture ad libitum for the 5 weeks prior to this date during which they gained live weight at an average growth rate of 60 g/day. The goats were implanted with CIDRs, on 19 October, which were withdrawn on 29 October, at which time they received 400 iu PMSG. Only 78 goats retained CIDRs to withdraw. The does were hand mated 36 to 48 hours after CIDR withdrawal. Thirty-eight does were observed to be in oestrus, and mated, and these were randomly allocated to two groups, one of which received a daily ration of cereal hay (low nutrition), calculated to maintain live weight, while the other group received ad libitum pellets and pasture hay (high nutrition), for 21 days. A single blood sample was obtained by jugular venepuncture 14 days after mating.
Table 8. Growth rate of 7-month old goats in the 21 days after mating, and the proportion that subsequently kidded.

<table>
<thead>
<tr>
<th>Maintenance ration</th>
<th>Progesterone (ng/mL)</th>
<th>Empty</th>
<th>Pregnant</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.26</td>
<td>7</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Ad libitum ration</td>
<td>12.53</td>
<td>11</td>
<td>8</td>
<td>19</td>
</tr>
</tbody>
</table>

The daily live weight change was -0.02 and 0.13 kg/day respectively for the low and high nutrition groups across the 21 days of treatment (Table 8).

The difference in progesterone concentration was not significant. The animals that became pregnant had a higher average concentration of progesterone than those that did not (12.8 ng/mL vs 9.1 ng/mL respectively) which was not significant. The difference in the proportion pregnant was not statistically significant.

The experiment is worth repeating with larger numbers.

The relationship between age and weight at first lambing and milk production

Ewe lambs are first joined for milking at Meredith Dairy at the beginning of the first month at which they reach 45 kg live weight. This derives from the practice in the French sheep dairy industry in which ewe lambs are commonly joined at 7 months of age when approximately 45 kg, which is 60 per cent of mature live weight. To more fully evaluate the optimum age and weight of first joining we built a database that includes these parameters, as well as weight at lambing, and 200-day milk production at first and subsequent lactations. Analyses have involved simple correlation coefficients and show for example:

- 0.25 repeatability between first and second lactation (n=57, no sheep excluded on basis of disease, lambing difficulties etc)
- no significant correlation between live weight at first lambing and milk production (n=93, even when sheep with problems excluded) in 2009
- a correlation of 0.34 between age at first lambing and milk production (P<.01; n=68) in 2009
- no correlation between milk production and either age or live weight (minimum 210 days and 45 kg respectively) at joining in a series of 54 ewes lambing in autumn 2010, and a series of 38 ewes in autumn 2011
- a correlation between lambing weight and milk production in autumn 2011 (r=0.37, P<.01).

Collectively our results indicate that 45 kg and 210 days are below the threshold values that permit a maximum yield at first lactation, although the correlations found indicate that only about 10 per cent of yield is explained by variation in age and weight, whereas 25 per cent of variation is due to fixed causes (which importantly, include genotype).

It is probable that the benefits of delaying joining for a month or two will be more than offset by the losses of delaying the onset of both the first and subsequent lactations, but more definitive evidence for this must await controlled experiments at which lambs are mated at pre-planned weights and ages, in factorial experiments (which will be very expensive to carry out).
**Milk production in ewes in which lambs are removed one day or 3 to 4 weeks after parturition**

In the main sheep dairy countries of the world such as Greece, Spain and France, dairy ewes usually suckle their lambs for about 30 days before lambs are weaned and the ewes are milked. At Meredith Dairy ewes are usually, but not always, milked following weaning lambs one day after birth. This practice is based on our finding in a previous project that without costly supervision about 20 per cent of ewes that suckle lambs are unsuitable for milking because their lambs die or the ewes suffer teat damage. Furthermore, a US study found a 25 per cent reduction in milk yield if lambs were suckled for 30 days (McKusick et al, 2002). But analysis of our milk records showed that the average milk yield of ewes with a 3 to 4 week suckling period was the same as that for ewes from which lambs were weaned at birth. This result is not, however, based on controlled research; at Meredith Dairy lambs are most often suckled in spring when milk flow is high, so the population of ewes in the suckled group have generally been milked in spring and early summer when pasture availability, and photoperiod favour milk production.

To resolve this issue we carried out a controlled experiment using the ewes from the Meredith Dairy flock. This flock is managed so that approximately equal numbers of ewes are lambed every month of the year. This is achieved by joining ewes at a synchronised oestrus at the start of each month. The ewes joined are those that lambed 4 months previously, ewes pregnancy tested and found not pregnant to the joining period that took place two months previously and maiden ewes that attained a live weight of 45 kg during the previous month. The study used ewes mated at synchronised oestrus in early December and early January and are presumed to represent a random sample of the total dairy sheep population at Meredith Dairy.

The ewes were fed high quality pasture throughout the experiment. Pasture availability estimated to exceed 1500 kg dry matter per hectare (kg dm/ha) when the ewes suckled their lambs. While milked, ewes were supplemented with 250 g wheat at each milking. Lambing ewes were inspected twice per day, and lambing date recorded.

The ewes mated in early December (suckled group) lambed in late April and early May, and suckled their lambs for 3 to 4 weeks before lambs were weaned and ewes entered the dairy whereas the ewes joined, and lambing one month later (early weaned group) entered the milking flock 24 to 28 hours after parturition. The two treatment groups were run in the same flock throughout their time of machine milking. Ewes were joined to a synchronised oestrus 4 months after entering the dairy and milked for 200 days unless they dried off in the meantime (ewes were dried if milk production fell below 500 mL per day).

Milk production was reduced by about 25 per cent by suckling lambs for 3 to 4 weeks before milking (P<0.01) (Table 9). The reduction in milk yield is a consequence of suckled ewes drying off faster and yielding less milk for a given number of days in milk.

**Table 9.** Mean 200-day milk yield, and somatic cell counts (SSC) (obtained 4 weeks after entering the dairy) from early weaned (lambs removed at 24 hours after birth) or suckled (lambs weaned at 3 to 4 weeks).

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Total milk yield per sheep (L)</th>
<th>SSC log 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early weaned</td>
<td>117</td>
<td>173.36</td>
<td>5.37</td>
</tr>
<tr>
<td>Suckled</td>
<td>161</td>
<td>129.70</td>
<td>5.21</td>
</tr>
</tbody>
</table>
**The significance of somatic cell counts in dairy ewes**

Somatic cell counts (SSC) in dairy cattle are used as a tool for determining milk quality (and price) and identifying subclinical cases of mastitis, and there is a body of scientific literature to support this. In France and USA, for example, there are upper limits placed on the bulk cell count permitted for sheep milk delivered to processors. Nevertheless there is little empirical evidence that somatic cell counts are a useful tool in sheep dairying.

We have commenced determining somatic cell counts in individual ewes since July 2012, when ewes are approximately 30 days in milk. Microbial culture was undertaken on milk samples from 50 high cell count ewes and 50 low cell count ewes. The ewes have been retested in November 2012 to establish the coefficient of determination between the two tests.

It was found that:

- no pathogens were cultured from any of the ewes; about 50 per cent had coagulase-negative staphylococci present, but these are regarded as non pathogenic
- there was no relationship between SCC and total milk yield up to 180 days in milk
- there was no relationship between SCC in July and November.

Our provisional conclusion is that SCC are not a useful tool for sheep dairying, and that the incidence of subclinical mastitis in ewes is low.

**Evaluation of the Awassi genetics in dairy ewes**

Two recognised dairy sheep breeds have been introduced into Australia in the past 20 years: East Friesland and Awassi. The highest milk yields in the world come from the Assaf – a breed obtained with 50 per cent Awassi genetics and 37 per cent East Friesian.

East Friesland were available from 1996 and were used extensively at Meredith Dairy and cross breeding increased average yields from about 50 litres per ewe to 150 litres. Crossing the half breeds with East Friesians led to problems with pneumonia and mastitis in particular; similar problems have been encountered around the world.

The Awassi breed was introduced into Australia at a similar time – with genetic material coming in through a venture supported by the Western Australian government, and by a private venture based in Cowra, New South Wales. Neither venture made the genetics available for sale, but the Western Australian genetics were assessed by Roberta Benicini at the University of Western Australia and found to increase milk yield in crossbred ewes, but not enough to make them attractive to replace East Friesian crosses. The Cowra importers claimed to have selected sheep with ‘high milk production’ and they agreed to sell genetic material in July 2010. By this stage their flock was reduced to about 20 purebred rams and 50 purebred ewes, and they had not been milked, nor pedigrees recorded, for about 5 years at least.

We purchased 1000 doses of semen from 10 rams and inseminated about 100 East Friesian cross dairy ewes per month for the next 10 months (insemination was by laparoscopic insemination, so could only be carried out on maiden ewes, rather than lactating adults). In November 2010, six almost-purebred (15/16) Awassi rams were purchased and used to join ewes from March 2011.

Pregnancy rates averaged about 20 per cent each month following the use of frozen semen, because the semen was dilute and of poor motility. We were unable to negotiate replacement with better quality semen. The 100 or so ewe lambs have been artificially reared with their East Friesian crosses and joined when they reached 45 kg live weight.
The Awassi do not significantly affect milk yield compared to the East Friesland crossbreds (see Table 10).

**Table 10.** The 200-day yield of Awassi cross ewes (50 per cent Awassi, about 3/8 East Friesland) and East Friesland cross ewes (EF: about 5/8 East Friesland, self replacing Meredith stock), at first and second lactation, where lambs were weaned at 24 hours after lambing, or 3 to 4 weeks after lambing.

<table>
<thead>
<tr>
<th>Wean</th>
<th>Lactation</th>
<th>Breed</th>
<th>n</th>
<th>200-day yield (L)</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hours</td>
<td>1</td>
<td>Awassi</td>
<td>109</td>
<td>157</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Awassi</td>
<td>72</td>
<td>202</td>
<td>17</td>
</tr>
<tr>
<td>3 weeks</td>
<td>1</td>
<td>Awassi</td>
<td>18</td>
<td>140</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Awassi</td>
<td>39</td>
<td>156</td>
<td>21</td>
</tr>
<tr>
<td>24 hours</td>
<td>1</td>
<td>EF</td>
<td>1058</td>
<td>152</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>EF</td>
<td>1169</td>
<td>205</td>
<td>5</td>
</tr>
<tr>
<td>3 weeks</td>
<td>1</td>
<td>EF</td>
<td>268</td>
<td>112</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>EF</td>
<td>249</td>
<td>176</td>
<td>8</td>
</tr>
</tbody>
</table>

What the data do not show is the extraordinary susceptibility of the Awassi cross sheep to footrot. A strain that has been present at Meredith Dairy for many years, and is benign in the East Friesland cross ewes is virulent in the Awassi cross ewes. They also have a relatively flighty temperament and the lambs are remarkably difficult to train to drink from an automatic lamb rearing machine.

We conclude that the Awassi breed does not have a role in sheep dairying at Meredith Dairy.

The use of melatonin in dairy ewes

At Meredith Dairy ewes are induced into oestrus in the non breeding season through the administration of PMSG at the time of CIDR withdrawal. The limitation of this technique is that ewes do not return to service if they fail to conceive. We have conducted an experiment in which two months before joining half the joining group was treated with a melatonin implant. Two months later half the treated and untreated ewes are joined without PMSG treatment at CIDR withdrawal, and the other half with PMSG. Pregnancy rates were determined in January.

Melatonin has been shown to depress milk production in cows, and in a previous project we established that long photoperiod (which depresses melatonin) increases milk production. Nevertheless we found melatonin administration did not reduce milk yield when administered on 29 September (Fig. 4).

![The effect of melatonin on milk yield](image)

**Fig. 4.** The effect of melatonin on milk yield in dairy sheep.
### Table 11. The proportion of ewes pregnant when mated at synchronised oestrus, with no prior treatment (Control), or after treatment with melatonin 60 days earlier (Treat).

<table>
<thead>
<tr>
<th></th>
<th>Pregnant</th>
<th>Empty</th>
<th>Missing</th>
<th>Total</th>
<th>Percent pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14</td>
<td>12</td>
<td>1</td>
<td>27</td>
<td>53.8%</td>
</tr>
<tr>
<td>Treat</td>
<td>39</td>
<td>12</td>
<td>1</td>
<td>52</td>
<td>76.5%</td>
</tr>
</tbody>
</table>

The proportion of ewes pregnant 60 days after joining was significantly greater (P<.05, Chi square=4.1) for ewes that received melatonin implants than in untreated ewes (Table 11).

### Factors affecting ruminal acidosis in goats – a review

In our attempts to maximise cereal intake in dairy goats at Meredith Dairy we have seen the full spectrum of sequelae to ruminal acidosis ranging from death through to the syndrome defined in *Veterinary Medicine 10th edition* (Radostits et al, eds), as subacute ruminal acidosis whereby clinical signs include laminitis, intermittent diarrhoea, suboptimal appetite, a high herd culling rate and suboptimal milk production in second and subsequent lactation goats compared to first lactation goats. Acute ruminal acidosis, defined as bouts of rumen pH below 5.0, manifests as rumenitis, death or long-term health consequences such as laminitis and hepatic abscesses. Subacute ruminal acidosis is also of major concern as it is less obvious, but manifests as reduced milk fat percentage, reduced dry matter intake and milk production.

Cereals represent a rich source of readily fermentable carbohydrate, which in a healthy rumen is largely converted to volatile fatty acids (VFA), which are absorbed through the rumen wall. The production of VFA leads to a post-prandial decline in rumen pH from about 6.5 to as low as 5.6. This normal decline in rumen pH may have desirable consequences such as reduced rumen methane production, reduced protein deamination, and an increased ratio of propionate to acetate (Lana et al 1998), which in turn may increase food utilisation and yield of milk protein (Bramley et al, 2008). If rumen pH falls below 5.6, rumen function may be impaired, leading to reduced digestion, reduced food intake and lowered animal production. More severe ruminal acidosis may lead to clinical disease such as laminitis, hepatic abscesses and rumenitis. A fall in rumen pH to 5 may lead to a proliferation of lactobacilli, leading to accumulation of lactic acid, with consequent metabolic acidosis and death (Nagaraja and Titgemyeyer, 2007).

The extent to which a given intake of readily fermentable carbohydrate causes ruminal acidosis depends on various factors including the extent of acclimatisation of individuals to the ration, the effectiveness of homeostatic mechanisms of the rumen, including rumen buffering and motility, feeding frequency, whether the food is part of a mixed ration that may be consumed over a long period and social factors such as whether all animals can feed at once.

Feeding concentrates is necessary for realising productive potential of dairy cows, which has led to extensive research on factors that influence rumen pH, and these have been broadly divided into the acidogenic value of the concentrate portion of the concentrate portion of the ration and the effectiveness of the forage portion of the ration in promoting rumen buffering.

A quantitative analysis of the amount of acid produced in the rumen of a dairy cow, and its subsequent removal has been reviewed by Allen (1997). Within this review, data are presented showing that ruminal pH falls linearly from the beginning of a meal, and subsequently rises following the commencement of rumination. This rise in rumen pH is attributed to the increased salivation during rumination, with saliva containing buffers, particularly bicarbonate. In recognition of the importance of salivation in rumen buffering there have been extensive studies on the attributes of forages that
promote chewing (whether at meal time or during rumination), as salivary flow is increased during chewing (Maekawa et al, 2002). Nevertheless total daily saliva production is relatively constant (Maekawa et al, 2002) as cows that produce lees saliva due to shorter chewing time produce more saliva when at rest. This raises the possibility that the diets that promote chewing also promote movement of rumen contents which may increase the rate of absorption of volatile fatty acids from the rumen (Allen, 1997).

**Neutral detergent fibre:** An extensive review by Mertens (1997) highlighted that the neutral detergent fibre (NDF) component of the diet is important in determining rumen pH, with critical minimum levels of NDF being dependent on the forage species (for example grass hay is more effective than alfalfa), and its physical form, with shorter chop lengths reducing the effectiveness of NDF. Subsequent research has attempted to define critical fibre lengths for physically effective NDF (peNDF), and though they have failed to provide unequivocal results there is a trend for forages with a higher proportion of NDF over 8 mm in length to lead to higher ruminal pH. For example Yang and Beauchemin (2006) concluded that the proportion of particles greater than 8 mm best predicted the effectiveness of NDF, although the correlation between this measurement of peNDF and ruminal pH was marginal. Rustomo et al (2006) reduced the proportion of fibres exceeding 8 mm using a mixer wagon, and recorded a marginally lower peak in ruminal pH in consequence.

The nature of the forage component of the diet may influence rumen pH through its acid content or inherent buffering capacity, but this area has received little rigorous study. For example Dewhurst et al (2001) recorded reduced dry matter intake (DMI) when cows were fed corn silage rather than grass silage, and speculated that this was a result of the high lactic acid content of the corn silage. Wadhwa et al (2001) used an in vitro assay to rank the acid load from various diet ingredients and recorded higher acid values for corn silage than grass silage, with still lower values for clover hay. The low values for clover hay were a possible consequence of the buffering effect of excess ammonia expected to be released following its digestion. Definitive experiments aimed at determining the different buffering effects of the different forage components of the diet are difficult to construct because it is difficult to formulate rations with the same energy and protein characteristics without confounding differences in forage components with differences in concentrate components.

The effects of varying concentrates and forages in goats have received far less attention, but the principles are the same. For example dry matter intake in dairy goats increased with increased proportion of the ration as concentrates, as did milk production, but the percentage of milk fat fell (Desnoyers et al, 2008). Reducing mean particle length of forages from 3.87 mm to 2.38 mm reduced chewing activity, rumination and milk fat concentration (Lu, 1987).

**Nutrition and milk production – the importance of starch and feeder space**

For high producing dairy cattle, and sheep, achieving high levels of energy intake is seen to be prime aim of feeding systems, as, provided rations are appropriately formulated to provide adequate protein and minerals, energy intake limits milk production.

In this section of work we reviewed the key factors thought to influence energy intake, and we conducted two experiments, one looking at the most appropriate source of starch and the other at feeder space.

**The importance of starch:** There are complex interactions between carbohydrate source and milk production in cows, because of interactions between carbohydrate source and the rumen degradability of the protein source. For example Hall et al (2010) fed cows diets that were isonitrogenous, but with different levels of rumen degradability of protein, and with similar concentrations of non-fibre carbohydrate (NFC) and NDF but dependent on whether the diets were rich in corn, rather than citrus pulp or sugar and molasses the starch content ranged from 24 per cent to 12–14 per cent starch.
Increasing the proportion of rumen undegradable protein tended to improve parameters such as milk production, milk protein production and efficiency of conversion of feed to milk in diets low in starch, whereas the opposite was true for the diet high in starch. This means one can’t generalise as to whether a particular carbohydrate source is beneficial, without specifying the protein source, and until considerable extra research is undertaken to build up predictive models it is likely diets will only be optimised using field trials.

**Feeding behaviour:** Dry matter intake (DMI) changes rapidly across the transition period between late pregnancy and the first few weeks of calving, with a fall in DMI of about 30 per cent in the week before calving, following by a progressive increase such that DMI approximately doubled by 3 weeks after calving (Grant and Albright, 1995).

In formulating a ration for dairy cows and goats the primary consideration is maximising the intake of metabolisable energy. This will take the form of forage (hay and silage) and concentrates. The forage is of particular importance in providing physically effective neutral detergent fibre (peNDF), which is a critical component in maintaining rumen pH. In modern dairy rations, a target of 30 per cent NDF is typical, with two-thirds of this coming from forage. Forage intake varies with the form in which it is fed.

**Factors affecting feed intake and milk production:** Highly productive dairy goats have feed requirements up to several times maintenance requirements, and the ability of the goats to eat these requirements is doubtless an important determinant of their milk production. To maximise the energy intake of the goats, consideration must be given to formulating a ration that is as concentrated with energy as possible, while maintaining rumen health. The feeding system must be optimised to maximise the intake of this ration. Both these technical areas have been extensively, though not exhaustively researched in dairy cows (see reviews by Mertens, 1997; Grant and Albright, 1995) but almost no research has been conducted in goats.

**Starch source:** There is no evidence that the source of starch alters dry matter intake in dairy cattle. Doepel et al, (2009) fed 12 second-lactation, approximately 90 days in milk, Holstein cows diets containing different wheat components and found the treatment did not affect DMI, milk yields or milk components (fat, protein and lactose). Faldet et al, (1989), who fed lactating dairy cows 0, 21, or 33 per cent ground wheat as a percentage of dietary dry matter in place of corn, in conjunction with 45 per cent sorghum silage, reported that DMI was not different among the three treatments. Similarly, cows fed a diet consisting of 60 per cent hay and 38 per cent pelleted wheat, corn, or barley had equivalent feed intakes (Tommervik and Waldern, 1969).

**Forage preparation:** Dry matter intake was higher for pelleted hay compared to chopped or long hay (chopped was intermediate, although not significantly different from long hay). Ruminal turnover rate was increased with pelleted feed, and digestibility lowered, but despite this weight gains were increased (because of increased intake) (Quick and Dehority, 1986). Goats fed non forage diet (fibre was all in the form of by products such as cotton seeds and cassava slices) had increased DMI, reduced digestibility, but same milk production as those fed diets including about 50 per cent silage (Bava et al, 2001).

**Feeding frequency:** For wether sheep and goats fed forage once per day, over 15 per cent of ration was eaten within half an hour, more than half eaten within 6 hours of feeding, and about 85 per cent by 12 hours (Quick and Dehority, 1986). In Europe, dairy goats are always fed at least twice per day. We have been unable to find evidence that this is necessary, and in our experience, provided the ration does not deteriorate (as would be the case for rations based on silage of high moisture content) there is no penalty for feeding once per day, or even once every two days.

**Feeder space:** Adequate provision of feeder space would seem an obvious prerequisite condition for a feeding system and the author’s personal observation of modern goat dairies in France and Spain was that housing was designed so that all goats could eat from the feeder at once. Furthermore, Swiss
animal welfare legislation requires 35 cm width of feeder space per goat, i.e. one feeder space per goat (Loretz et al, 2004). There is scant evidence that such feeder space is required when rations are fed ad libitum, although studies of feeding behaviour and social interactions between goats, and other domestic animals, have provided evidence that has been used to hypothesise that it is. For example, reducing feeder space from one per goat to one per three goats increased the number of aggressive social interactions among groups of six goats, and reduced their time spent feeding, although only with some feedstuffs was intake reduced (Jorgensen et al, 2007). The effect of reduced feeder space was most obvious as the dominance rank of a goat declined (Loretz et al, 2004; Jorgensen et al, 2007), with even a reduction from two to one feeder spaces per goat sufficient to reduce feeding time in low-ranked goats within groups of horned goats (Loretz et al, 2004). Within the small pens used in the above two studies, one dominant goat can control the feed station by lying there (Jorgensen et al, 2007). In dairy cattle excessive competition for feed has been suggested as being of importance in reducing DMI and production, particularly in freshly calved primiparous cows of low social status, but no definitive evidence was available to support this (Grant and Albright, 1995). One of the few experiments in this field found that a reduction in feeder space from 0.5 m to 0.2 m per cow had no effect on time spent feeding, but a further reduction to 0.1 m per cow reduced feeding time by about 50 per cent but had no significant effect on feed intake, i.e. the cows must have eaten faster with reduced feed intake (Friend et al, 1977). This study involved only 12 cows and small, but practically important reductions in feed intake of the order of 10 per cent would not have been statistically significant. Furthermore, there was a significant correlation between dominance value of cows and the time they spent at the feed station once feeder space was reduced to 0.2 m per cow, raising the possibility that reduced feeder space would cause significant reduction in production in cows of low-dominance value.

While the effect of feeder space on feeding behaviour of goats fed a TMR has not been studied, data from other studies can be used to gain insights into possible effects of increasing competition for food. First, lactating dairy goats fed a TMR ad libitum spent on average about 3 to 5 hours per day eating, with the shorter mean feeding times recorded where forage concentration was reduced (Desnoyers et al, 2008) or finely ground (Lu, 1987) so theoretically several goats could share feeder space without restricting time to eat a full ration. On the other hand, other observations on feeding behaviour raise the possibility that competition for feeder space could affect production. First, certain individual goats within the above studies fed for longer times than average. Furthermore, individually penned goats fed ad libitum eat about 60 per cent of their ration as a main meal beginning at feeding time, followed by about six secondary meals, the number of which increased as the forage content of the ration fell (Abijaoude et al, 2000), and Desnoyers et al (2008) speculated that goats on a high concentrate diet spaced their meals apart in a manner that helped them maintain rumen pH. Perhaps competition for feeder space could interrupt this feeding behaviour. Finally, the nutritional value of the available feed changes with time, so that the animals with first access to the feed may eat a different ration to those with later access. This is because selection of the feed offered to sheep or dairy goats means the composition of food offered and consumed differs even when the feed station once feeder space was reduced to 0.2 m per cow, raising the possibility that reduced feeder space would cause significant reduction in production in cows of low-dominance value.

For large flocks of goats fed a TMR, the effect of competition for feeder space might be expected to vary for individuals within the herd depending on their dominance value, but there are few studies upon which to base predictions of any such effects. A study on the nature of the social hierarchy of a flock of 90 dairy goats was reported by Barroso et al (2000) who found that under grazing conditions they had a stable, almost linear hierarchy (of 364 relationships between pairs of goats studied, only 8 per cent were not predicted by social rank, i.e. only 8 per cent of the time did a goat of lower social rank dominate one of higher rank). There was a positive relationship between dominance value and the rate of initiation of aggression. When the flock moved from a grazing situation, where competition for food was considered slight, to a stall where competition was strong, more of the social interactions were aggressive (threats and aggressive interactions rather than displacing). Even in relatively non competitive grazing situation there was an association between social rank and production, with the most productive goats being of intermediate rank. Barroso et al (2000) speculated that this was
because such goats suffered less social pressure than goats of inferior rank, but may not have expended the energy of high ranked goats in social aggression. An alternative explanation is that older and larger animals tended to have higher social rank, but such animals are not automatically the most productive.

**The effect of source of carbohydrate on feed intake and milk production in late pregnancy and early lactation**

Nutritional management in late pregnancy and early lactation in dairy cows is regarded as being of particular importance; appetite is depressed at this time and cows have a negative energy balance. Minimising this energy imbalance is presumed to increase peak milk production, and thus increase milk production across the whole lactation.

An important factor in depressing appetite in pregnancy and early lactation is the presence of a vagal reflex, stimulated by hepatic oxidation that depresses appetite centres in the brain (Allen and Piantoni, 2013). Propionate is the most hypophagic of the volatile fatty acids absorbed from the rumen, and propionate absorption from the rumen is increased when diets are rich in highly fermentable carbohydrate, as is found in cereal grains such as barley and wheat (see Allen, 2000; Allen and Piantoni, 2013). Corn contains a less fermentable starch, which reduces propionate production from the rumen, and increases the availability of starch for digestion in the small intestine, which yields glucose, which is not a precursor of hepatic oxidation (Allen and Piantoni, 2013). A depression in intake of nearly 3 kg of dm per day (~13 per cent) was observed when fermentable grains were substituted in diets of lactating cows (Allen et al, 2009).

A slow starch releasing grain such as corn is an ideal source of starch in late pregnancy and early lactation, but in Australia is difficult to source, and is generally more expensive than wheat or barley.

BioProtect is a stable, non-volatile organic salt which slows starch breakdown rates, and thus alters the fermentation profile of wheat and barley to something akin to that obtained with corn.

We hypothesised that feeding a slower fermenting starch source (corn, or wheat treated with BioProtect) would cause an increase in DMI and therefore increase milk yield in the transition period and thereafter.

The experiment was conducted in February and March 2014, using 30 multiparous Saanen cross bred dairy goats, due to kid in March. These were individually housed in pens of 1 m x 1.4 m on a raised wooden slatted floor with ad libitum access to water and feed (Fig. 5). Plastic 32-litre feed bins were hung from the gates and feed was delivered to each feed bin once per day.
The goats were fed a pre-partum ration, ad libitum, from 20 February, which was expected to be at least 10 days before the first goat kidded, and fed a post-partum ration after kidding. The experimental period continued up until the time that each animal had been in milk for at least 14 days, and finished on 3 April 2014.

Rations were prepared by weighing ingredients with digital scales and delivered to 15-litre buckets. The forage component consisted of 2:1 lucerne to oaten hay mix, chopped and mixed in a wagon. The goats were fed daily and leftover feed from the previous day was weighed and recorded. Molofos was diluted with 1 litre of water and poured over each feed prior to feeding to increase palatability. Pre-partum rations came to 3.24 kg and post-partum rations were 4.19 kg when delivered to the animals. Post-partum rations doubled in grain content and also included 250 g of cracked peas for protein (Table 12 and Table 13). Each day the leftover/wastage feed was weighed and recorded so that feed intake could be determined.

The goats were randomly assigned to one of three treatments, each of which consisted of a different grain incorporated into the ration:

A. cracked wheat  
B. BioProtect-treated cracked wheat  
C. cracked corn.

Table 12. Diet composition of pre-partum ration.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Treatment</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td></td>
<td>700 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>700 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BioProtect wheat</td>
<td></td>
<td>700 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td></td>
<td>10 g</td>
<td>10 g</td>
<td>10 g</td>
</tr>
<tr>
<td>Forage</td>
<td></td>
<td>1.5 kg</td>
<td>1.5 kg</td>
<td>1.5 kg</td>
</tr>
<tr>
<td>Molofos</td>
<td></td>
<td>30 g</td>
<td>30 g</td>
<td>30 g</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>1 kg</td>
<td>1 kg</td>
<td>1 kg</td>
</tr>
</tbody>
</table>

Table 13. Diet composition of post-partum ration.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
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<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn</strong></td>
<td>1.4 kg</td>
<td>1.4 kg</td>
</tr>
<tr>
<td><strong>Wheat</strong></td>
<td>1.4 kg</td>
<td>1.4 kg</td>
</tr>
<tr>
<td><strong>BioProtect wheat</strong></td>
<td>1.4 kg</td>
<td>1.4 kg</td>
</tr>
<tr>
<td><strong>Sodium bicarbonate</strong></td>
<td>10 g</td>
<td>10 g</td>
</tr>
<tr>
<td><strong>Peas</strong></td>
<td>250 g</td>
<td>250 g</td>
</tr>
<tr>
<td><strong>Forage</strong></td>
<td>1.5 kg</td>
<td>1.5 kg</td>
</tr>
<tr>
<td><strong>Molofos</strong></td>
<td>30 g</td>
<td>30 g</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>1 kg</td>
<td>1 kg</td>
</tr>
</tbody>
</table>

The experiment lasted for 43 days. After animals had given birth they were taken to be milked twice daily and milk yield was recorded via the DeLaval Alpro herd recording system for both morning and afternoon milking sessions. The goats were weighed after every animal had given birth and then two weeks later.

On the second and third-last days of the experiment, milk samples were taken for fat, protein and lactose content determination in the afternoon milking session. Samples were sent to Dairy Technical Services in Melbourne and samples analysed using the ‘MilkoScan™ FT+’, a high capacity, fully automatic milk analyser.

Statistical analysis was carried out on milk yield, feed consumption and milk parameters via an analysis of variance ANOVA using GenStat™.

After the 43-day experiment, each animal had been in milk for at least 16 days and up to 32 days at most. One animal was excluded as it never gave birth and three animals were excluded because they had the following problems: lameness (1), vaginal infection (1) and production of less than 1 litre of milk due to infection/never properly coming into milk (1).

**Milk yield:** No statistical differences were found between treatment groups for milk yield over the first 14 days of lactation.

Fig. 6. Graph of predicted means for milk yield over the first 14 days of lactation, with A- untreated cracked wheat, B- BioProtect treated cracked wheat and C- untreated cracked wheat with corn. Mean SED ±0.4302.
Each group showed a gradual increase in average daily milk over the first 14 days of lactation (Fig. 6) however, we found no statistically significant differences of average daily milk between treatment groups. There was a significant difference between days in milk ($P<0.001$).

**Feed consumption:** No statistical differences were found between treatment groups for food consumption over the first 14 days of lactation.

In the first couple of days post partum, animals from each group had a reduced appetite which gradually increased and then stayed relatively constant up until day 14 however, we found no statistically significant differences between feed treatments (Fig. 7). There was a significant difference between days in milk and amount of feed eaten ($P<0.001$).

There was no statistical difference between treatment groups for milk solids, milk fat and milk protein.

Neither feed intake, nor milk production varied with treatment, meaning that wheat is suitable for feeding during the transition from pregnancy to lactation. This is satisfactory, insofar as wheat is usually the cheapest source of metabolisable energy in Australia (aside from pasture).

The similar dry matter intake and milk production for the three treatments indicate that despite the theoretical benefits of using less fermentable sources of starch (Allen and Piantoni, 2013), there are none in practice.

**The effects of feeder space and stocking rate in lactating dairy goats**

The review on feeder space (Section 13) indicates that both pen space, and feeding space, affect the behaviour of dairy goats, but the effect on milk production of increasing stocking rate above the
industry norm (generally one goat per 1.5 square metres), and of reducing feeder space below one space per goat, has not been determined for large groups of goats.

The aim of this experiment was to determine if milk yield, weight gain and feed intake are affected by altering the pen space and feeding space in fresh milking dairy goats by altering the enclosure or feeder space area and maintaining a constant group size.

The experiment utilised 356 primiparous and multiparous early lactation (30 to 60 days in milk when the experiment commenced) Saanen crossbred dairy goats, randomly allocate to one of four treatments after stratification for daily milk yield.

Two of the four treatments had goats stocked at the normal stocking density (N: 1.5 square metre per goat), and two had a high stocking density (H: 1 square metre per goat); within each stocking density, one group had one feeder space per goat (N: 30 cm per goat) and the other had one feeder space per two goats, i.e. reduced feeder space (R: 15 cm per goat) (Fig. 8).

![Experimental design diagram](image)

**Fig. 8.** Experimental design. Animals in four treatment groups: 1 – (N,N); 2 – (N,R); 3 – (H,N); and 4 – (H,R)

Goats remained in each treatment for a period of two weeks and then changed to a new treatment, such that each goat experienced all four treatments, with changes in treatments conforming to a Latin square design. The total experiment lasted 8 weeks (4 x 2 week periods).

Each group of goats remained in the same area of the goat house (the dimensions of the pens were altered with temporary fencing) lest some part of the shed provided a more favourable environment than another.
Milk volume was recorded twice daily using electronic meters. The milk volumes obtained for the last week of each treatment period were compared between periods (the first week of each treatment was considered to be an acclimatisation period).

Milk fat and protein were obtained on the last day of each treatment period.

Behaviour was monitored and recorded via the following ethogram of mutually exclusive agonistic behaviours as a modified version of that seen in Anderson et al (2008):

- biting
- frontal clashing (a behaviour where one or both individuals rear onto their hind legs with the head and torso twisted and then forcefully descends onto the front legs delivering a powerful blow forwards and downwards against the head of the receiver) or butting with the head directly towards the head of the receiver
- pushing/shoving or butting of the head towards another part of the receivers body
- chasing (quickly following) another goat that tries to escape
- threatening (pawing or rushing towards, or directing the forehead towards the opponent but without physical contact.

The mean milk production for the first two treatment periods (so 178 goats per group) was 2.23, 2.24, 2.22 and 2.33 litres per day for the HN, HR, NN and NR groups respectively (no significant difference). A preliminary analysis shows no difference in feed intake, milk composition or agonistic behaviour between the four treatments. A full ANOVA will be conducted on 27 June 2014.

A formal ANOVA is required to confirm the results but we are confident that the treatments have no effect on production. This means dairy goats can share feeder space, which will reduce the cost of goat housing by about 35 per cent. The finding that reducing pen space from 1.5 to 1 square metre per goat indicates that the current recommendation of 1.5 square metre per goat is more than adequate.
Implications

Meredith Dairy has approximately doubled its production of sheep and goat milk since this project was initiated, and increased employment by about 30 full time equivalent staff. Much of this is due to ongoing investment, but this investment has been made partly due to confidence engendered by running the above R&D program.
References


Glossary

**CIDR.** Controlled intravaginal releasing device, which releases progesterone into the animal, and is used to synchronise oestrus.

**Residual milk.** This refers the proportion of milk remaining in the udder after routine machine milking is complete. It is measured by administering a pharmacological dose of oxytocins to ewes at the completion of routine milking, which causes evacuation of alveolar milk into the cistern, from which it can be removed by re-applying cups. So, for example, a ewe with 50 per cent residual milk might be one from which 500 mL of milk was harvested by normal milking routine, and a further 500 mL harvested following the administration of oxytocins.

**RFID.** Radio frequency identification. This is achieved with an eartag that when stimulated transmits a unique signal to an antenna, thus allowing the animal to be recognised.

**TMR.** Total mixed ration, refers to feeding a mixed ration, with a mixer wagon, calculated to contain all the components needed in the ration for full production.
Optimising genetics, reproduction and nutrition of dairy sheep and goats

By Alexander Cameron

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