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**Rural Industries Research and  
Development Corporation**

# **Increase in Autumn and Winter milk production in dairy goats**

**A report for the Rural Industries Research  
and Development Corporation**

by Alexander Cameron

September, 2003

RIRDC Publication No 03/105  
RIRDC Project No UMO-24A...

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ISBN 0 642 58671 3  
ISSN 1440-6845

*June 8, 2003*  
*Publication No. 03/105*  
*Project No. umo-24A*

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Published in September 2003  
Printed on environmentally friendly paper by Canprint

# Foreword

Goat milk manufactures with the highest profit margin have short shelf lives necessitating a relatively constant supply of milk. Unfortunately, goat milk production is seasonal, being greatest in spring and summer, then declining to a nadir in winter. Given adequate nutrition, this seasonal pattern of milk production is a direct reflection of the seasonal pattern of reproduction in goats, as they normally commence regular oestrous cycles in autumn, and thus kid in late winter and early spring.

The objective of this project was to develop management options for advancing the breeding season of goats.

The research indicates that satisfactory pregnancy rates can be obtained in August and January, as well as in autumn. The use of these 3 joining periods should spread kidding dates sufficiently to permit relatively uniform year round milk production.

This project was funded from RIRDC Core Funds which are provided by the Australian Government.

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# Contents

Foreword .....	iii
Executive Summary .....	v
1. Introduction .....	1
2. Experiments.....	3
The effect of age, stage of lactation and milk yield on the buck effect.....	3
Definition of the breeding season of dairy goats.....	3
Experiment 1. ....	3
Experiment 2. ....	4
Strategies for improving fertility in spring .....	5
Experiment 1. ....	5
Experiment 2. ....	6
Experiment 3 .....	6
The use of melatonin to advance the breeding season in does .....	7
Discussion of results and their implications for industry .....	7
Implications .....	8
3. Recommendations .....	9

# Executive Summary

Goat milk manufactures with the highest profit margin have short shelf lives necessitating a relatively constant supply of milk. Unfortunately, goat milk production is seasonal, being greatest in spring and summer, then declining to a nadir in winter. Given adequate nutrition, this seasonal pattern of milk production is a direct reflection of the seasonal pattern of reproduction in goats, as they normally commence regular oestrous cycles in autumn, and thus kid in late winter and early spring.

The objective of this project was to increase the production of goat milk in autumn and winter by overcoming the seasonal pattern of reproduction in goats.

A series of experiments were conducted to determine how far the breeding season extended into late winter. We discovered that does continue to show oestrus until early September, when the proportion ovulating abruptly fell. Nevertheless fertility in early September was poor (11/35), perhaps, because the bucks were relatively infertile. Ovulation was induced with PMSG in November, but fertility was again poor.

Artificial insemination was used in an attempt to overcome the poor fertility obtained in does in which ovulation was induced in spring. Unfortunately pregnancy rates were relatively low in both autumn and spring (10/16 vs 10/17 for adults; 5/12 and 5/14 for maidens), but indicate that fertility is similar in the two seasons if semen quality is uniform.

The annual change in hours of daylight is the environmental cue that entrains the breeding season of goats. Declining day length initiates regular oestrus cycles in autumn. This effect of day length is mediated by melatonin; a hormone released by the pineal gland during the hours of darkness. Plasma melatonin concentrations are thus elevated for longer in autumn than in summer. Implants that continuously release melatonin (thus mimicking 24 h darkness) for 4 weeks are available. A single implant of melatonin in summer did not advance the breeding season of goats, whereas prolonged treatment (two or more implants administered sequentially) initiates oestrous cycles in Spring, provided the goats are first exposed to artificially extended day lengths for the preceding 2 months. We examined the effect of administering 2 consecutive implants, in goats exposed only to natural lighting, before joining in December or January. The resultant pregnancy rate was 50% for those joined in December and 91% for those joined in January.

Bucks were also treated with 2 sequential melatonin implants following 9 weeks exposure to 17 hours light per day, that commenced in mid July. The treated bucks were much more sexually active than untreated controls in November, and when mated achieved a 55% (22/44) pregnancy rate, compared to 18% with untreated bucks.

This research indicates that satisfactory pregnancy rates can be obtained in August and January, as well as in autumn. The use of these 3 joining periods should spread kidding dates sufficiently to permit relatively uniform year round milk production.

# 1. Introduction

A relatively constant supply of goat milk confers several financial benefits to goat milk processors. First, the goat milk manufactures with the highest profit margins, such as mould ripened cheeses, fresh milk, yoghurt and fresh curd cheeses, have short shelf lives, necessitating a relatively constant supply of milk if shelf space is to be maintained. When product is not available, hard won shelf space is often lost for good. Further, for efficient utilization of both equipment and staff, a steady supply of milk is required, even when longer life products such as feta are produced. The need for relatively expensive cold storage of finished product is also minimised when production closely matches demand, as is the requirement for capital to finance any stockpile.

Unfortunately the production of goat milk has historically been highly seasonal, being greatest in spring and summer, then declining to a nadir in winter. In 1995, before we initiated an R&D program at Meredith Dairy to tackle this problem, milk production in June was less than 25% of that obtained in December, and in most other dairies production ceased entirely in winter.

In 1995, three causes of seasonal variation in milk production were identified:

Nutrition. The quantity of pasture available in autumn and winter cannot sustain peak levels of milk production. Experiments revealed that a ration of ad lib silage and whole wheat sustained higher milk yields than did spring pasture and wheat. The silage based ration is cheap and has eliminated nutritional constraints at Meredith.

Lighting. Day length has been shown to effect milk production in sheep, but the situation in goats remains unclear.

Seasonal reproduction. Goats have a highly seasonal pattern of reproduction, normally commencing regular oestrus cycles in autumn. Thus few goats kid before August. At Meredith this seasonal kidding pattern is of overriding importance. When goats were treated so as to kid in May their peak daily production in winter averaged 83% of that obtained in the previous spring following an August kidding.

To summarise, late autumn and winter milk production is directly related to the number of goats kidding in autumn and early winter, and thus the number impregnated in spring and early summer. In this project we investigated several strategies for mating goats in spring and early summer. To understand the rationale for the strategies employed involves some understanding of the breeding season of goats.

Goats are short day breeders; they commence oestrus cycles in autumn, in response to declining day length, and experience seasonal anoestrus in spring, when day length is increasing. At some point between spring, when all does are in anoestrus, and about mid April, when all does experience regular oestrus cycles, there is a period in which provided does have been isolated from bucks, the introduction of bucks induces ovulation within about 48 hours of the introduction of bucks. Most often this ovulation is not accompanied by oestrus. Often the corpus luteum that develops from this ovulation is short-lived, and the does ovulate a second time about 8 days after the introduction of bucks, at which time they display oestrus (heat), and are thus mated. In other does, the initial corpus luteum is normal, so the does display heat, and ovulate about 21 days after the introduction of bucks. Generally the does then return to anoestrus (unless pregnant), so next ovulate in April. This phenomenon whereby the introduction of bucks induces ovulation is referred to as the buck effect. The annual change in hours of daylight is the environmental cue that entrains the breeding season of goats. Declining day length initiates regular oestrus cycles in autumn. Under experimental conditions reducing day length in summer, by placing animals in darkrooms has advanced the onset of the breeding season. But in time the animals become refractory to the effects of reduced day length; eventually they return to anoestrus. To become sensitive to the effect of reduced day length

the animals must be first exposed to long day lengths, if not by experiencing naturally increasing day length, as occurs in spring, then by using artificial lighting. It is not known at what point in spring does become sensitive to reduced day length once more, but 2 months of artificial lighting (16 hours light per day will re-sensitise goats.

This effect of day length is mediated by melatonin; a hormone released by the pineal gland during the hours of darkness. Plasma melatonin concentrations are thus elevated for longer in autumn than in summer. Implants that continuously release melatonin (thus mimicking 24 h darkness) for 4 weeks are available. The ability of melatonin implants to advance the onset of the breeding season is probably dependent on an interaction between the duration of melatonin treatment and the day length the goats have experienced before being treated with melatonin but practical recommendations have not been developed for all situations. We have previously found that a single implant of melatonin in summer did not advance the breeding season of goats, whereas prolonged treatment (two or more implants administered sequentially) initiates oestrous cycles in spring, provided the goats are first exposed to artificially extended day lengths for the preceding 2 months (Chemineau et al 1986). We found that exposure to 24 h light per day throughout September and October, before reverting to natural lighting in November did not advance the onset of breeding.

Pharmacological methods have also been used to advance the onset of the breeding season. The various protocols used involve administering a progestagen, using intravaginal sponges or CIDR's followed by the administration of PMSG (pregnant mare serum gonadotrophin). At Meredith, fertility from such treatments had been poor prior to the current project.

The objective of this project was to increase the production of goat milk in autumn and winter by overcoming the seasonal pattern of reproduction in goats, which dictates that they mate in autumn, and so commence lactation in spring. The experimental program involved investigation in 4 main areas.

Defining the breeding season in terms of when does respond to the buck effect, and when they exhibit regular oestrous cycles.

Determine the efficacy of PMSG in inducing ovulation, measured as the proportion of goats ovulating, and the proportion impregnated.

Compare buck fertility between the breeding season and the non breeding season.

Define protocols for using melatonin to advance the breeding season.

## 2. Experiments

### **The effect of age, stage of lactation and milk yield on the buck effect**

A group of first and second lactation does that had kidded in June or September were isolated from bucks by at least 600 meters between June and January, at which stage they were joined to bucks and several does in which oestrous was induced with PMSG. Bucks remained with the does for 6 weeks.

None of the does were observed in oestrus, or became pregnant. This negative result, which contrasts with the previous year when 75% of first lactation goats became pregnant following a January joining, highlights the risk of relying on the buck effect for inducing early breeding. We had joined ewes to rams across the fence line from where the does were run, in December, and wonder whether rams could have desensitised does to the buck effect.

### **Definition of the breeding season of dairy goats.**

Goats are short day breeders; they commence oestrus cycles in autumn, in response to declining day length, and experience seasonal anoestrus in spring, when day length is increasing. Regular oestrous cycles commence in April when does are continuously run with bucks. The season in which the buck effect first occurs has not been defined, although in previous work we obtained 70% kidding following a January joining, and about 50% of does showed oestrus in early December (RIRDC project UMO-18a). The extent of the breeding season into late winter and spring is unknown and was the subject of the following series of experiments. The ovulatory response was compared to that obtained with PMSG.

#### **Experiment 1.**

Sixty six goats were randomly assigned to be joined on July 5, September 6 or November 9, meaning 22 goats were joined at each date. Joining was preceded by 2 weeks treatment with progesterone, administered by CIDRs, and half the goats in each group received 400 i.u. PMSG on the day of joining. The ovaries were examined by laparoscopy 8 days after joining began to count the number of corpora lutea present, and to determine whether the corpora lutea had regressed prematurely. This premature luteal regression is a phenomenon which we noted when carrying out embryo transfer in the autumn of 1999, whereby corpora lutea regress within 5 days of ovulation (so within 7 days of sponge withdrawal). It thus precludes pregnancy, and might explain the low fertility we obtained in goats treated with PMSG (see project UMO-18a).

Pregnancy was determined by ultrasound 60 days after joining.

The results are shown in table 1. Unfortunately a number of the animals in the first joining groups were found on laparoscopic examination to be freemartins, and 3 were pregnant, leading to reduced group sizes. This led to the remaining groups being examined, and pregnant animals and freemartins were replaced.

**Table 1. The number of goats with a particular number of ovulations after joining at 3 different times, at which they received 0 or 400 i.u. PMSG.**

Joining Date	Dose of PMSG	Goats per group	Number of ovulation points					Regressed	Ovulations per goat	
			0	1	2	3	4			5
5 July	0	6		4	1				1	1.2
	400	10	2	3	1			4		2.0
6 Sept	0	11		7	4					1.4
	400	11		7	2	1	1			1.5
9 Nov	0	11	1							
	400	11	1	5	1	3			1	1.7
			1							

The key findings are that all goats joined in September ovulated, meaning the breeding season continues into early spring, and the buck effect does not occur in November. Another important finding is that 400 iu PMSG induced physiologically normal ovulation rates at all joinings, including November, when the goats were seasonally anoestrus. The low incidence of regressed corpora lutea in November, rules out premature regression as a cause of poor fertility when using PMSG in the non breeding season.

Pregnancy rates were similar in all groups with 15 of the 49 goats that ovulated pregnant.

## Experiment 2.

The previous experiment showed that the breeding season extends to at least September, which would result in a February kidding. A further experiment was conducted to define just when the breeding season ended, and whether this depended on does having been isolated from bucks. Further, we wished to determine whether the cause of the low fertility in the previous year was due to does not being mated.

Ninety, 9 to 15 month old maiden does were randomly allocated to 3 groups that were joined to entire bucks on September 1 (36 does), September 18 (18 does) or September 30 (36 does).

Within the groups mated on September 1 and September 30, half were joined with teaser males (castrate males, treated with testosterone so as to induce normal male sexual behaviour), for the 3 weeks preceding joining to entire males, while all the remaining does were isolated from males for the 3 months preceding joining. All does were administered progesterone, using CIDRs, for 14 days preceding joining to entire males.

It was intended to determine which does came on heat using direct behavioural observations twice per day for the 5 days following the commencement of joining, but the sexual activity of the bucks was too low to determine whether oestrus was absent in some does, or merely unobserved. Therefore the ovaries of does not observed in oestrus were examined for the presence of corpora lutea (CL) 8 days after joining commenced. Laparoscopy revealed the presence of 4 freemartins, which reduced group sizes to those shown in table 1.

**Table 2. The proportion of goats ovulating (determined by the detection of oestrus, or the presence of a CL at laparoscopy), and pregnant following joining at three dates.**

<b>Joining date</b>	<b>Ovulated</b>	<b>Pregnant</b>
1 September	35/35	11/35
18 September	4/16	1/16
30 September	3/35	2/35

For the group mated on the first of September, oestrus was only observed in 17 of the 35 goats. These 17 goats were observed to be mated, yet only 4 became pregnant. Seven of the 18 goats in which oestrus was not observed also became pregnant. Subsequent observation of kidding dates indicated that all of the goats that became pregnant did so within several days of CIDR withdrawal i.e. no goats returned to service. This, together with the small proportion of goats ovulating in the groups mated on September 18 or 30 demonstrates that the breeding season ended rather abruptly during September.

The low fertility of mated goats suggests that buck fertility is reduced by the end of the breeding season. This might be exacerbated by the use of CIDRs, as sperm transport is diminished by the use of progestagen treatments.

There was no evidence that previous exposure to teaser bucks varied the proportion of goats ovulating, compared to those isolated from bucks.

## **Strategies for improving fertility in spring**

In the previous chapter we showed that PMSG reliably induced ovulation in spring, but fertility following natural mating was poor. Similarly fertility was poor following natural oestrus in September. Both low sexual activity of bucks, and reduced sperm production and semen quality in spring are the likely cause, as all these parameters reach a seasonal nadir in spring.

### **Experiment 1.**

To test the hypothesis that differences in pregnancy rates between seasons were caused variation in buck fertility, semen, frozen in autumn, was used to inseminate does in autumn, or in the non breeding season. The quality of the frozen semen was evaluated through comparison with the fertility obtained with fresh semen in autumn. One batch of semen was used to inseminate lactating does, 4 to 6 months post parturition, and another using maiden does, aged 10 to 13 months. The lactating does were inseminated by passing a catheter through the cervix, and the maiden does by laparoscopy. Oestrus was synchronized using CIDRs, with 400 i.u. PMSG administered when CIDRs were withdrawn.

In autumn, some does (10/40 lactating does and 13/40 maiden does) were observed in oestrus 4 to 6 days after insemination. This indicates they had undergone premature CL regression, so were excluded from the analysis.

**Table 2. Pregnancy rates following insemination with fresh or frozen semen in the breeding and non-breeding season.**

Season	Breeding Season	Breeding Season	Non Breeding Season
	Fresh Semen	Frozen Semen	Frozen Semen
Lactating does	10/14	10/16	10/17
Maiden does	5/15	5/12	5/14

The fertility of does induced to ovulate in the non breeding season did not differ significantly from that obtained in the breeding season when differences in male fertility are removed. The reason for the uniformly poor results obtained with laparoscopic insemination is not known.

## Experiment 2.

Being dissatisfied with the pregnancy rate obtained in the first experiment we again attempted to compare the fertility obtained using frozen semen in autumn and spring. Several treatments were compared in the initial round of insemination in autumn with a view to reducing the rate of CL regression, and lifting pregnancy rates by improving the time of insemination.

Thus 48 goats were treated with 400 i.u. PMSG either 48 h before, or at the time of withdrawal of CIDRS. Of those treated with PMSG 48 h before CIDR withdrawal, half received GNRH 24 h after CIDR withdrawal, while for those treated with PMSG at CIDR withdrawal, half were treated with GNRH 36 h later. It was thought these treatments with GnRH would coincide with the median time of the LH surge within each treatment, and would serve to prevent any late ovulations. In the event, when A.I. commenced 48 h after CIDR withdrawal it was found that all but 3 goats had ovulated, indicating our usual time of A.I.(55 h after CIDR withdrawal) is perhaps too late (conventional wisdom is that oocytes remain fertilizable for about 12 h after ovulation, so artificial insemination is thought to be best timed to coincide with, or slightly precede ovulation; there are, however no experimental results to support this in goats). The goats were inseminated with fresh or frozen semen, and half received 2 I.M. treatments with finadyne (a prostaglandin inhibitor, found previously to prevent, or at least delay CL regression when administered 12 hourly for several days).

Fully 21 of the 48 goats had premature CL regression, regardless of treatment, which once more prevented meaningful data on fertility. This was compounded by a high incidence of abortion, of unknown aetiology, that occurred at about mid pregnancy (it was noticed when the goats were scanned for pregnancy).

Subsequently we artificially inseminated 70 goats with frozen semen in October, of which 20 became pregnant. Semen from this same batch is to be used in June, 2003 in goats synchronised with CIDRS, but not treated with PMSG (so as to not cause premature CL regression).

## Experiment 3

Although the above experiments are not entirely convincing, experiment 1 indicates that the reduced fertility in spring is attributable to does not receiving adequate sperm. We attempted to stimulate the reproductive system of bucks in spring by exposing them to 17 h light per day for 9 weeks, commencing July 13, and then administered 2 consecutive melatonin implants. The treated bucks were demonstrably more sexually active than untreated bucks when joined in late November. They achieved a 55% pregnancy rate when mated to 40 does that were treated with CIDRs and 400 i.u PMSG in November, compared to 18% in those mated to control bucks. The fertility rates would probably be greater were they not obtained in goats that failed to kid the previous year, and were the bucks adults rather than 12 month old.

## **The use of melatonin to advance the breeding season in does**

In a previous project (UMO-18a) we demonstrated the effectiveness of a technique pioneered by Deveson et al (1992), in which does were exposed to 17 h light for 9 weeks, commencing in mid June, and then received 2 sequential implants of melatonin (to mimic short day lengths). All does commenced cycling in late October and early November and became pregnant.

A major advantage of this treatment, rather than the use of PMSG, is that does that fail to conceive at their first mating return to service, so pregnancy rates per goat treated are high.

For several years melatonin was not sold in Australia, but it became available in 2002. We have begun the task of defining a regimen of melatonin treatment that induces spontaneous oestrous cycles in goats in spring or early summer, without a prerequisite period of artificial lighting. Two consecutive melatonin implants were administered to 2 groups of 90 goats, with treatment commencing in early October in one group, and November in the other, with bucks joined in early December and January respectively. The two groups of does were not arrived at by random allocation, so we cannot compare the results obtained by statistical analysis.

Spontaneous cycles began in some does in the first group before joining commenced in early December, and 40 of 82 became pregnant. From the kidding dates it was concluded that all goats that became pregnant did so in the first cycle of joining. In other words the goats appeared to commence cycling when, or even before joining began, but quickly lapsed into anoestrus.

The group joined in January experienced a 92% pregnancy rate. Kidding is proceeding at the time of writing this report but it seems likely that some goats showed oestrus more than once before being impregnated.

## **Discussion of results and their implications for industry**

The experimental series described above has not been as conclusive as expected, for several reasons. First, little of the physiology of goats is understood compared to sheep and cattle, with the consequence that procedures that are routine in for example sheep turn out to be inappropriate in goats. For example we inseminated does in spring and autumn with the same batch of semen to control for semen quality. Unfortunately fertility was low even in autumn, compared to that which we obtain in sheep (usually 70 to 80 % pregnancy rates). This was partly a consequence of premature regression of corpora lutea, which is rarely seen in sheep, perhaps also because the does were found to ovulate earlier than expected on the basis of sheep work, and perhaps for reasons we still do not understand.

The importance of isolating does from bucks before experiments involving the buck effect was also a constraint. It was difficult to carry out more than one experiment each year, especially with lactating goats which had to be located near the dairy. This led to the unsatisfactory situation where the effectiveness of melatonin before joining in December and January was compared, but only one of the groups could be lactating does.

Dealing with valuable commercial animals led to compromising integrity of some experiments. For example in first year we did not join kids, as is our usual commercial practice, so as to have subjects for first spring. This reduced our milk production by at least 30,000 litres. As the project proceeded we became ever more anxious about the use of control groups that were expected to have poor fertility. This led to the situation where the maiden does joined in December last year were all treated with melatonin, rather than having some untreated controls.

Nevertheless, there were three key findings from the project that should permit us to achieve our objective of producing milk year round:

1. Bucks are relatively infertile from September through to December, and this can be overcome using lighting and melatonin. This is evidenced by the low pregnancy rates obtained in does that were mated and ovulated in September. It was also apparent that fertility was similar in does inseminated with frozen semen in autumn and spring, indicating that semen, not some factor associated with the does, was the cause of the low fertility following induced oestrus in spring. Finally, stimulating the bucks' reproductive axis by exposing them to 17 h light in winter, and then implants of melatonin, increased their fertility.
2. The spontaneous breeding season continues until early September. Thus kidding can be delayed until January, providing relatively early lactation does in autumn.
3. PMSG reliably induces ovulation in spring. Fertility is acceptable provided bucks have been treated with lights and melatonin. Hopefully artificial insemination can be developed for this time of year as well.
4. The breeding season can be advanced to January, and perhaps December using sequential melatonin implants in does. In January does will return to service if they are not pregnant after their first oestrus.

## **Implications**

Relatively uniform milk production requires at least 3 joining groups, at about 4 month intervals. From this project we have shown we can expect high pregnancy rates in January, April and August. We need to confirm that pregnancy rates are satisfactory in August; we have shown that the does show oestrus at this time.

### 3. Recommendations

The ability to control reproduction is a central management tool for dairying, because lactation follows reproduction. This project provides hope that reproduction can be controlled for much of the year, but also highlights gaps in our knowledge that preclude dogmatic recommendations on how to control reproduction. For example when applying for this grant we noted that in a previous project we had achieved a 75% pregnancy rate using the buck effect in January, yet in this project achieved a nil pregnancy rate from the same joining. We postulate that pheromones from nearby rams may have sensitized the does to the buck effect, but do not know this. In fact little is known of what constitutes 'isolation from bucks' in the context of using the buck effect. Another gap in our knowledge relates to premature regression of corpora lutea. This phenomenon may be a major impediment to artificial insemination in autumn, which in turn has implications for developing progeny testing programs. Another surprising result was that following treatment with melatonin for 8 weeks prior to a December joining, at least 2 does had commenced oestrus without the presence of bucks (they were in oestrus when the bucks were joined), yet none of the does returned to service. We were perhaps close to achieving a high pregnancy rate, but a lack of knowledge of the best time to join bucks relative to the administration of melatonin may have prevented this. We therefore recommend that the RIRDC continues to support research on reproduction in goats.