Development of Speciality Sheep Milk Dairy Products

Increasing the Market Scope (UWA-23A)

A report for the Rural Industries Research and Development Corporation

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Foreword

Sheep milking in Australia was started in the 60s by farmers seeking to diversify from the traditional productions of wool and prime lambs and provide import substitution sheep milk products.

Since then, many enterprises in most states have initiated sheep milking ventures with mixed fortunes. So far, the Australian sheep milking industry is far from being established despite improved breeding and management, high farm gate prices for the milk, and potential markets.

This report identifies, through consultation with industry, issues crucial for the development of a sheep milking industry in Australia and reports on results obtained by the University of Western Australia investigating these issues.

This report, a new addition to RIRDCs diverse range of almost 400 research publications, forms part of our New Plant Products R&D program, to address the main problems faced by the industry with the aim of facilitating the establishment of a viable sheep milking industry in Australia.

Most of our publications are available for viewing, downloading or purchasing online through our website:
- downloads at www.rirdc.gov.au/reports/Index.htm

Peter Core
Managing Director
Rural Industries Research and Development Corporation
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Executive Summary

This project addressed the three main problems faced by the emerging sheep milking industry in Australia. These were identified as:

1) The fact that Australia did not have specialised breeds of dairy sheep.
2) A lack of typical Australian sheep milk products.
3) The lack of traditional markets for young milk-fed lambs.

Only a holistic approach to all the problems faced by the industry could ultimately result in the establishment of sheep milking as a viable industry.

Thanks to funding from the RIRDC and The Faculty of Agriculture at The University of Western Australia, we established a fully functional sheep dairy and a dairy products laboratory to conduct research on the three main areas of concern.

1) The fact that Australia did not have specialised breeds of dairy sheep.

The local breeds of sheep produce less than 100 litres of milk per lactation, a level of production that is not economically viable in the average sheep milking enterprise (Bencini and Dawe, 1998). The Awassi and the East Friesian sheep have been imported recently and they are reported to be the highest producers of milk in the world (Epstein, 1985; Anifantakis, 1986), so they have the potential to make sheep milking profitable. However, in both cases, only small numbers of animals were actually imported, and farmers are likely to milk the crosses of these breeds with local sheep. Our project aimed at evaluating the dairy potential of the Awassi sheep and its crosses with local breeds to establish which cross had the best potential for dairy production.

Throughout the course of three lactations, we compared first cross Awassi x Merino Ewes and 3/4, 7/8 and 15/16 Awassi x Merino ewes with control Merino ewes. Our experimental results indicated that Awassi cross ewes produced up to three times as much milk as the controls and had longer lactations than Merino ewes. However, the amount of milk produced by first cross Awassi x Merino Ewes was less than half a litre per day and only some of the higher Awassi crosses (3/4 and above) produced economically viable amounts of milk of a litre per day and above. The validity of these results was partially impaired by an outbreak of virulent footrot in 1996 that obliged us to suspend our research work to dedicate ourselves to the health of the animals in our care. It is not surprising that Awassi cross ewes did not produce much milk as the footrot probably affected their ability to forage. Now that we have overcome the footrot problem, we are milking 3/4 Awassi crosses that produce around or above a litre of milk/day. Nevertheless, selection for dairy production will be necessary even within the imported dairy breeds to ensure that economically sustainable yields are achieved.

2) A lack of typical Australian sheep milk products.

So far, manufacturers venturing into the processing of sheep milk have attempted to reproduce famous overseas cheeses such as the Pecorino and the Fetta. This was probably due to a desire to replace imports of these products, which are currently imported for the ethnic communities. However, these cheeses are either protected by DOC trademarks, or suffer from serious competition from cheap cow's milk imitations.
To establish a viable sheep milking industry it is essential to follow the example of other successful new industries, such as the wine industry, and develop local specialty Australian products. Australian consumers also have developed a taste for mild products rather than the strong flavours typical of the imported sheep milk cheeses.

Most of the sheep milk produced throughout the world is transformed into cheese, as cheese making is an ancient tradition (<biblio>). However, modern consumers are also attracted by novelty products, fresh products, and healthy and low fat products.

Our project addressed the lack of specialised dairy products made with sheep milk by developing new sheep milk products that were initially tested on small groups of people to assess their acceptability to Australian consumers. This resulted in the development of methodologies for the production of two new cheeses. One of these is a soft spreadable cream cheese that has virtually no maturation time. It was developed to respond to the need of manufacturers for a fresh product that would provide the 'cash flow' for the enterprise. The other is a semi mature cheese that has to be aged for about one month. Both cheeses were eventually tested on a large group of consumers through a survey in a popular supermarket chain. Both cheeses were rated highly by potential consumers, who were disappointed to hear they could not purchase our products. The survey revealed that 86% of consumers were prepared to buy both cheeses at a price of $21/kg (±1.02) for the semi mature and $32/kg (±0.8) for the spreadable cheese, confirming the existence of domestic markets and a consumers willingness to pay high prices for sheep milk products.

Another product developed within our project was sheep milk ice-cream in collaboration with our industry partners, the Peters & Brownes Group, who are major exporters of high quality ice-cream to Japan. We investigated the effect of fat concentration on the quality of sheep milk ice-cream. Batches of sheep milk ice-cream containing different concentrations of fat were produced and tested by an expert panel at the R&D Laboratory of the Peters & Brownes Group. The batches were scored poorly by the panel regardless of the fat content. By contrast, they were considered generally good by Animal Science staff. Since members of both organisations may have been biased against or in favour of the sheep milk ice-cream, this conflicting result will be further investigated in subsequent research and development.

Producers had also reported problems in processing sheep milk harvested in early lactation. We investigated the presence of colostrum immunoglobulins that are essential for the welfare of the lambs, but that could be the cause of the reported processing problems. To test this hypothesis sheep were separated from their lambs and milked immediately after lambing and samples of milk were collected daily and analysed for the presence of colostrum immunoglobulins by Capillary Electrophoresis. We found that colostrum immunoglobulins persisted in the milk of some ewes for up to nine days after separation from the lambs. Sheep dairy producers that milk the sheep immediately after they have given birth should therefore discard the milk for at least one week.

There was also the possibility that processing problems in early lactation could be due to the presence of an unbalanced ratio of fatty acids in the milk fat as in early lactation the sheep could mobilise body reserves to synthetise the milk fat. In this case the milk fat would contain more unsaturated long chain fatty acids as this is the form in which the mammary gland cells transform the fatty acids that come from body fat tissue. Short/medium chain fatty acids increased from 33 to 40% with the progression of lactation, supporting the hypothesis.

3) The lack of traditional markets for young milk-fed lambs.

The problem of weaning lambs when their mothers are milked in a dairy situation is extremely serious for the industry. Artificial feeding is expensive, but if lambs are weaned by their mothers, they drink so much milk that the whole operation becomes unprofitable. So far, the solution adopted by many farmers has been to kill the lambs at birth. However, this is an undesirable outcome for animal welfare reasons and because many producers dislike this practice (T. Dennis, Pers. comm.).
We investigated methods of weaning the lambs and markets for milk-fed lambs to make them a second source of profit for the enterprise.

Our studies confirmed that the artificial feeding of lambs is too expensive to be contemplated by a sheep milking enterprise. It was only through the generous intervention of our industry partners, the YHH Holdings, that we managed to feed artificially our first group of lambs at a cost of $60 per head. Subsequently we tested the share milking method, which has been reported to be economically viable to rear lambs while milking sheep (Knight et al, 1993). We tested a method in which the ewes were left with their lambs for one to two weeks. Then they were milked regularly twice a day, but they were allowed to nurse their lambs during the day. Our studies showed that share milking not only allows the production of both milk and lambs, but also it results in greater production of milk and longer lactations than those observed in sheep that were separated from their lambs at four weeks of age. We have also developed a very efficient system to separate the lambs from the ewes, by using a selective drafting gate that allows only lambs to move through.

Ms Fiona Shallcross investigated the meat production potential for milk-fed lambs for her honours project. She compared the carcase composition of lambs that were nursed by their mothers with that of lambs whose mothers were shared milked until slaughter (at 15 kg body weight). This work showed that although share milked lambs had slower growth rates than their counterparts, their carcasses did not differ in composition. Both groups of lambs were extremely lean, which could be used by the industry to promote milk-fed lamb as a healthy product.

One of the requirements of our agreement with the RIRDC was that we conducted an economic evaluation of sheep milking as part of our project. Since funds were not allocated in the budget to conduct this study, we involved a fourth year student, Mr Stuart Witham, who wrote his dissertation on the economical evaluation of sheep milking. Subsequently, we employed Mr Greg Hales, from the Agricultural Economics Group in our Faculty to further develop this work and produce a document that could be used by farmers to evaluate sheep milking as an alternative enterprise. This effort resulted in the development of the "Sheep dairying gross margin calculator", a user friendly spread sheet that allows producers to calculate gross margins for a sheep milking enterprise. The user manual for the calculator is located in the back of the report as well as the disk to run the program.

Our project also addressed some management issues that were not initially contained in our project description, but that became important through the course of our research. These were the problem of worm control in a dairy situation and the production of dairy products from frozen milk.

The problem of controlling worms in a dairy situation arose because it was a standard policy at The University of Western Australia to treat all sheep with Captec Extender 100 to control worms. This is a capsule that contains a slow release drench that protects sheep for up to 100 days. As it was not known if this drench could be translocated into the milk, we organised a collaborative experiment with Jim Reynoldson, Associate Professor in Veterinary Pharmacology and at the School of Veterinary Studies at Murdoch University. Our research showed that Captec Extender 100 is safe to use on dairy sheep as the dose released daily by the capsule is so low that levels in the milk do not reach the safety levels recommended by the EEC. Therefore, producers will able to use Captec Extender 100 safely on their dairy sheep.

The other issue that we studied was the production of dairy products from frozen milk. This study was undertaken firstly because milk production from sheep tends to be seasonal and there are inevitably periods in which there is not enough milk to supply the demand; therefore the possibility of freezing the milk needed to be evaluated. Secondly, we had a footrot outbreak that obliged us to freeze the milk produced as all our time was dedicated to the treatment of the animals so we had a quantity of frozen milk. The results of our study demonstrated that sheep milk can be frozen and processed later without any negative repercussions on the quality of the dairy products.
1 Introduction

Australia has a large ethnic population of European origin and imports some $8 million worth of sheep milk products every year (Dawe and Langford, 1987). About 8,000 tons per year of sheep milk products could find a market in Australia and to match this demand 250,000 ewes would have to be milked in 100-150 dairies (Dawe, 1990). Sheep dairying is not completely new for Australia: between 1963 and 1975 two sheep dairies operated in Victoria and in 1972 Peter Tavella started a sheep dairy and a cheese factory at Leeton, New South Wales (Dawe and Langford, 1987). In the same area, also S.T. Dawe and C.M. Langford were researching on sheep dairying at the Leeton Research Station of the Department of Agriculture. The lack of interest and the wrong economic environment caused, according to Dawe (1990), the unsuccessful outcome of the Tavella enterprise. In 1985 an export market for 4-6 week old lambs was established with Italy, and this revived the sheep dairy industry (Dawe, 1990). However, due to organisational problems the suckling lamb market failed (S.T. Dawe, Pers. comm.).

The Australian sheep milking industry is still relatively small, but it is rapidly growing. In 1987 there were only five sheep dairies operating in Australia. This number has now risen to 20 dairies mainly concentrated in Victoria. At the moment, returns from sheep milk are about $1.20-1.50/litre, or $100-150 per ewe per year, which is high if compared with the traditional production of wool and prime lambs. However, there are high costs associated with the purchase of the milking machinery, with the milking operations and with the rearing of the lambs, which make the milking of sheep barely profitable.

If the need for diversification was felt by farmers in the 60s and 70s, this should even be more so now that the animal industries, and particularly the wool industry, are providing low returns. The need for diversification in agriculture is reflected in a recent RIRDC publication, The New Rural Industries (1998) in which arrays of alternative animals are considered as possible sources of income.

Sheep milking has a distinctive advantage over other new animal industries: sheep farmers would not need to change much of the infrastructure because they would be still farming the same animals, and little new expertise would also be required.

Sheep milk has high farm gate returns of 1.20-1.50/litre and there are local and export markets for sheep milk products. The recent GATT agreement should stop the EEC from protecting their sheep milk products, so that Australia will have a chance to compete on the international market (Bencini and Dawe, 1998).

Despite this, the sheep milking industry is still in its infancy and many sheep dairies have appeared and disappeared over time. At The University of Western Australia, we identified three main reasons for this:

Firstly, Australia does not have specialised breeds of dairy sheep. The pioneering sheep dairy farmers of the 60s, 70s and 80s were milking local breeds of sheep that produce less than 100 litres of milk per lactation and this level of production is not profitable (Bencini and Dawe, 1998). Farmers may have been mislead, in part, by results produced at Leeton Research Station were some sheep produced 150 litres per lactation (Dawe, 1990). Many farmers converted to sheep milking based on yields of one litre per head per day, which are in fact rarely achieved when starting a sheep dairy with unselected sheep. With time and heavy culling, the yield of the local breeds can be lifted to one litre per day and above. These are for instance the yields recorded on local cross bred sheep at Cloverdene sheep dairy. Cloverdene has been selecting for milk production since 1992, when they started their operation. How much of this gain is due to genetic improvement and how much to environmental factors is not known.

Because milk production is only expressed by ewes, genetic improvement for milk production can only be achieved through a progeny testing scheme similar to those used in dairy cattle and overseas dairy sheep. Although this idea has been contemplated by ‘Lambplan’ (R. Banks,
Pers. comm.), the sheep milking industry at present does not have the resources to undertake such a programme.

A solution to the problem of low productivity of the local breeds could be the importation of specialised dairy breeds of sheep from overseas. Recently two breeds of sheep that have the highest production of milk in the world, the Awassi and the East Friesian (Epstein, 1985; Anifantakis, 1986) have been imported into Australia. These two breeds have the potential to increase yields and make sheep milking economically viable. However, in both cases, only small numbers of animals were actually imported, and their dairy potential under Australian conditions had not been measured before. As these new breeds are expensive, farmers are likely to milk the crosses of these breeds with local sheep. Our project aimed at evaluating the dairy potential of the Awassi sheep and its crosses with local breeds to establish which cross had the best potential for dairy production.

Our next project will evaluate the dairy potential of the East Friesian sheep and its crosses under Australian conditions.

The second problem faced by the Australian sheep milk industry is the fact that because sheep milking is not a tradition in our country, we do not have typical Australian sheep milk products. The majority of manufacturers entering the industry were aware of the importation of sheep milk products from overseas for the local ethnic communities. Therefore, their first attempts concentrated on imitating imported overseas cheeses such as the famous Pecorino and Fetta. However, these cheeses are protected by tariffs and DOC trademarks, or suffer from serious competition from cheap cow's milk imitations. Moreover, some of these cheeses (e.g. the Pecorino) require long maturation times involving high storage costs and risk of spoilage during storage.

These cheeses also have very strong flavours and they are imported and consumed within the local ethnic communities who are used to their strong taste. Australian consumers, by contrast, like milder products (e.g. Colby instead of matured Cheddar; Burton, 1990).

In overseas countries where milking sheep is an ancient tradition, most of the sheep milk produced is transformed into cheese and some into yoghurt (Bencini and Pulina, 1997). It is probably for this reason that initially only cheese and yoghurt were produced by manufacturers entering the industry. However, modern consumers are also attracted by novelty products, fresh products, and healthy and low fat products.

We believe that a viable sheep milking industry could only be established by developing typical Australian sheep milk products. These will eventually not only replace some of the importations, but also will be exported similarly to Australian wines. Our project aimed at developing new sheep milk dairy products including specialty cheeses, yoghurt and ice-cream that would be acceptable to Australian consumers and to investigate potential markets for these products.

The third problem faced by the sheep milking industry is that of the disposal of lambs. If lambs are left with their mothers the amount of milk they drink even with early weaning is such that the whole operation becomes unprofitable. Many farmers have concluded that it is better to kill the male lambs at birth and keep the females for replacement, either artificially feeding them or by allowing their mothers to wean them. This solution has animal welfare implication and is disliked by many farmers (T. Dennis, Pers. comm.). Moreover, sheep milking is relatively new with consumers that are curious and occasionally reluctant to accept even the idea of milking a sheep. It is possible that consumers could be turned off by the idea that new born lambs are killed to produce the milk. Some farmers attempted feeding the lambs artificially, similarly to what is done in the dairy cattle industry. However, artificial feeding is extremely expensive and labour intensive. Lambs tend to get sick and die, which increases dramatically the cost of the operation.

Overseas countries that have a tradition for milking sheep also have markets for young milk-fed lambs. For example in Italy, male milk-fed lambs are slaughtered at 4 weeks of age and 6-8 kg body weight. It is very common to see a whole lamb carcase sold in butcher shops fetching
prices of $25-35/kg. The females to be used for replacement are kept with their mothers for longer, but the sale of young male lambs allows the shepherds to start milking the flock relatively early in lactation. In Australia the traditional lamb consumed is the prime lamb (once called fat lamb), that often has been weaned by its mother and has eaten grass. By the time a prime lamb is ready for market often its mother has stopped lactating and would be of no use for milking.

Therefore, there is an urgent need to investigate economically viable methods to wean the lambs and markets for milk-fed lambs.
2 Objectives

The main objective of this project was to assist the establishment of a viable sheep milking industry in Australia by:

- Evaluating the dairy potential of the Awassi sheep and its crosses for local breeds
- Developing specialty dairy products made from sheep milk
- Investigating sustainable techniques to rear lambs
- Investigating local and export markets for sheep dairy products and milk-fed lambs through market oriented research
- Conducting an economical evaluation of sheep milking.
3 Methodology

3.1 Location and animals

Most of the experimental work for this project was conducted at The University of Western Australia, Nedlands. The animals were housed in the animal house and adjacent paddocks, while laboratory work was conducted in the Dairy Products Laboratory in Animal Science. The development of sheep milk ice-cream was conducted at the Balcatta R&D Laboratory of the Peters & Brownes Group, and the analysis of milk samples for calibration of the Milko Scan at the North Perth Laboratory of the Peters & Brownes Group.

Australian Merino Society (AMS) Merinos were sourced from Allandale, the research farm of The University of Western Australia and were used as controls in all of our comparative experiments as they are the most common breed of sheep in Australia.

The remainder of the experimental animals were supplied by our industry partners, YHH Holdings and were Awassi x Merino 1/2, 3/4, 7/8 and 15/16 cross ewes. These sheep came mainly from Toodyay (Glendearg Farm) and Bolgart (Avonlea Farm), with fewer animals coming from Moora and Lancelin.

The Awassi fat tail sheep has been milked for thousands of years in the Middle East and has recently been improved for milk production, with reported productions of 1000 litres of milk per lactation (Epstein, 1982). The Awassi sheep were imported into Australia as frozen embryos in 1986 and came from a flock that had been highly selected for milk production in Israel and subsequently imported to Cyprus (Lightfoot, 1987).

3.2 Management of the animals

Housing and nutrition –

During the experimental periods, animals were kept in communal paddocks where they grazed irrigated pasture composed predominantly of Kikuyu grass and subterranean clover and had meadow hay available ad libitum. They received 500g of lupins/head (392 g/kgDM protein, 21 MJ/kgDM energy) daily and at each milking, they were given approximately 500g of a mixture of 70% oaten chaff, 20% lupins, 10% oats and 0.5% hi-cal and salt. When experiments were completed and/or the lactation was concluded the sheep were returned to their respective properties of origin.

Lambs that were born to the experimental ewes were housed indoors when separated from their mothers. For some experiments they were fed artificially with milk replacements and also offered a mixture of 60% oaten chaff, 30% lucerne hay and 10% cracked lupins (creep feed). This was also offered when they were to be weaned on solid food and when they were separated from their mothers if the ewes were share milked.

Milking –

A 16 bay milking parlour was built at the workshop of The University of Western Australia. This consisted of a platform with head bails to restrain the sheep, a trough to feed the animals during milking and access and exit ramps. When possible the sheep were fed on the platform a few weeks before lambing, so that they learnt that by walking onto the platform they received food. The sheep were milked twice a day with an Alfa Laval milking machine that had a pulsation rate of 120/min and vacuum pressure of 40 kPa. At the end of each milking the teats were disinfected with an iodine based commercial preparation (Rendene Teat Dip, ICI, Australia).
3.3 Measurements of production and composition of milk

Milk production was measured with Tru Test milk meters (Tru Test Distributors, Auckland, New Zealand). These testers have a valve that diverts a proportion of the milk produced (in our case 22 g/kg produced) into a plastic jar. The jar is then weighed and the weight is multiplied by a constant to allow calculation of the daily milk output. In some cases, quarter bottles were used to collect and weight the milk. Quarter bottles are normally used in the dairy cattle industry to separate the milk of cows suffering from mastitis. They consist of a vessel that is connected by flexible rubber hoses to the main milk and vacuum lines so that the milk is diverted into the quarter bottle.

Samples of milk were collected from the Tru Test jars or the quarter bottles, stored at 1-4°C and analysed with a Milko Scan 133 (Foss Electric, Denmark) calibrated for sheep milk. This is a single-beam infra-red instrument, which measures the infra red absorption at wavelengths characteristic of the components to be analysed. When testing for fat concentration with the A filter it measures the absorption at 5.73 µ by the carbonyl group of the ester linkage. If the B filter is used it measures the absorption at 3.5µ by the -CH2 groups. For protein testing it measures the absorption at 6.46 µ by the amine II groups of the peptide bond and for lactose testing the absorption at 9.6 µ by the hydroxyl group. Total solids are automatically calculated by the instrument by adding protein, fat, lactose and a mineral bias of 0.07%.

3.4 Product development

The development of sheep milk dairy products was conducted in a Dairy Products Laboratory specifically equipped for this purpose. The following equipment was used for this project:

- **Cheese vat** - a stainless steel jacketed cheese vat of 30L capacity was built at the workshop at The University of Western Australia. The vat has a variable speed paddle to mix the milk and temperature adjustment to maintain the milk at the desired temperature.

- **Incubator** - an thermostated incubator of approximately 80L capacity is used to incubate dairy products such as yoghurt, cheese, etc

- **Disc Bowl Centrifuge** - An Armfield disc bowl centrifuge was purchased for the project to allow separation of milk fat. This is used to standardise the fat content of cheese milk and to produce batches of skim milk and cream for ice-cream development.

- **Batch pasteuriser** - a laboratory batch pasteuriser of 30L capacity was built at the workshop at The University of Western Australia. This is used to pasteurise the milk prior to processing at a temperature of 72°C for 20 seconds.

- **Milko Scan 133** - described above, used for analysis of milk composition before the milk is transformed into dairy products.

Other equipment used for the project included pH meter, balances, refrigerator (4°C) and freezer (-20°C).

For each experimental batch of dairy products the following measurements were recorded:

- Composition of the milk (protein, fat, lactose, total solids)
- Initial pH of the milk
- Amount of milk processed
• Processing procedures (e.g. amount of rennet added, type of starter culture used, time in cheese vat, etc)

• Yield of dairy products from each litre of milk

• Composition of dairy products derived from the milk (protein, fat, moisture, ash)

Protein was determined with a Leeko Nitrogen Analyser. Fat was determined by hexane: propanol (3:2) extraction. Water and ash were determined by freeze drying and furnace incineration at 550°C respectively.

The experimental batches were tested initially on small assessment panels and subsequently on large groups of consumers to establish their commercial potential.

3.5 Lambs studies

Weaning methods studied within this project were artificial weaning, natural weaning and share milking.

With artificial weaning, the lambs were separated from their dams soon after birth, housed indoors and fed milk replacements from a Lambar built at the workshop at The University of Western Australia. With natural weaning, the ewes nursed their own lambs until weaning or slaughter age. Share milking involved separating the lambs before the afternoon milking and housing them indoors until the next morning when they were allowed to rejoin their mothers.

We also studied the feeding pattern and milk intake of lambs that were shared milked to compare them with those of lambs that were left with their mother until slaughter age. This was done by direct observation and counting of feeding episodes over a 24 hour period. The milk intake was measured by a weigh - suckle - weigh technique in which a selected number of lambs were allowed to nurse from their mothers at intervals similar to those observed in the previous exercise. The lambs were weighed on a precision balance immediately before and after each feeding episode and the amount of milk consumed was recorded.

3.6 Statistical analyses

All results are presented as means ± standard errors, unless otherwise indicated.

The statistical analysis of the milk production and composition was done by Least squares analysis of variance and effects were assumed to be significant when the level of probability was 5% or less.

Student's t test comparisons were used when only two treatments were involved and differences were considered significant when the level of probability was 5% or less.

Regression analysis was used to establish relationships between milk composition and yields of dairy products.
4 Experimental

Our experimental work addressed the three main problems faced by the sheep milking industry. We conducted a series of experiments to evaluate the dairy potential of the Awassi sheep and its crosses with local breeds, to develop new dairy products suitable for Australian consumers and sustainable methods to rear the lambs born to experimental ewes.

4.1.1 Production and composition of milk from Awassi x Merino and Merino ewes under two different weaning methods

In most dairies in Australia and New Zealand, the ewes are milked immediately after lambing. By contrast, in the Mediterranean countries sheep are allowed to feed their lambs for 30 to 45 days before the lambs are slaughtered and milking starts. Dawe (1990) reported that sheep that nurse their lambs produce less milk than those whose lambs are separated at birth. However, Dawe (1990) conducted his studies on local breeds and his finding may not be applicable to the Awassi sheep.

In Australia, there is a limited market for milk-fed lambs, and returns from sheep milk are high, so lambs are not reared by the ewes. This method of weaning, however, may cause problems for the processing of the milk as at the beginning of lactation the ewes produce colostrum, which has been reported to affect the processing performance of the milk (Oosthuizen, 1962). Cheese makers at Jumbuck dairy in Western Australia had difficulties in processing early lactation milk even after discarding the first four days of production.

Also for the first 4-5 weeks of lactation ewes mobilise body reserves to synthesise milk fat which involves converting stearic acid into oleic acid by a mammary tissue desaturase (Pulina, 1990). The presence of unsaturated fatty acids in the milk could generate processing problems which, indeed, have been reported by cheese makers at Jumbuck Dairy in Western Australia and Tavella in New South Wales. On the other hand, milk containing unsaturated fatty acids could be preferred by health conscious people, implying the possibility of establishing a new market.

The yield and quality of the cheese depend on the composition of the milk (Ustunol and Brown, 1988). Seasonal patterns in the composition and processing properties have been reported for cows (O’Keeffe et al., 1981) and sheep milk (Askar et al., 1984), and it is likely that such patterns are present in sheep milked in Australia. In Australia sheep are milked all year round, using different flocks that lamb at different times, but composition patterns have not been previously reported.

Since the Awassi sheep is a specialised dairy breed, the processing performance of its milk may differ from that of local breeds. The Awassi or its crosses with local breeds are the most likely genotype that will be milked by sheep dairy farmers in the future (Bencini et al., 1992). This experiment was undertaken to determine the production, composition and seasonal variation of the milk from the Awassi sheep and its crosses with the Merino.

We tested the hypotheses that

1. Awassi x Merino ewes would produce more milk than Merino ewes when milked in a dairy situation (twice a day with a milking machine).

2. If sheep were separated from their lambs at birth, they would have higher lactation yields, but colostrum would remain in the milk for some days and affect the processing performance of the milk.

3. In early lactation sheep mobilise body fat to produce milk fat resulting in the presence of unsaturated C-18 fatty acids in the milk.
There is a seasonal variation in the composition, and therefore processing performance, of milk from Awassi x Merino and Merino sheep.

4.1.2 - Materials and methods

A flock of 45 Awassi x Merino (AxM) and 22 Merino (M) ewes were screened for udder development about two weeks before lambing and transferred to the animal house at The University of Western Australia. The ewes lambed over a period of eight weeks and they were split into two groups. Ewes in group 1 (n=28) were separated from their lambs within two days of lambing while ewes in group 2 (n=39) were allowed to nurse their lambs for the first four weeks after giving birth.

The ewes were milked twice a day and production of milk was measured at weekly intervals with Tru Test milk testers. The ewes were removed from the dairy and their lactation was considered finished when their milk yields fell below 200 g/day.

Samples of milk were collected and analysed for protein, fat, lactose, total solids (TS) and solids non fat (SNF) with a Milko Scan (Foss Electric, Denmark). Samples of the milk were frozen at -20°C for subsequent determination of unsaturated C-18 fatty acids in the milk. The samples were defatted and the fatty acids were analysed using a method described by Sukhija and Palmquist (1988).

During the first ten days of lactation milk samples were collected daily from the ewes that were milked immediately after lambing to determine the presence of colostrum immunoglobulins in the milk. The samples were analysed for protein, fat and lactose with a Milko Scan 133 to determine the gross concentration of protein in the milk. The milk samples were defatted by centrifuging at 3000 g for 5 minutes, dissolved in 0.1M Phosphate and 6M Urea buffer, placed in capillary electrophoresis tubes and run on a Biofocus capillary electrophoresis apparatus for 120 minutes. A Biofocus Integrator Programme was used to estimate the relative areas of the peaks corresponding to the various protein fractions.

4.1.3- Results

Awassi x Merino ewes produced more milk the Merinos (Figure 1), regardless of the weaning method (p=0.0016). The yield of milk for the whole lactation was only 15.9±3.64 kg for the Merinos that nursed their own lambs. Of this milk, only 9.6±2.39 kg were harvested, as the rest was consumed by the lambs during the nursing period. The Merino ewes that were milked from the first week of lactation produced 19.4±3.21 kg of milk. Of this milk 15.4 ±3.09 kg were harvested as the lambs consumed little milk in the period between birth and separation from the mothers.

Awassi x Merino ewes produced about three times as much milk as the Merinos (p=0.0016). If they nursed their lambs they produced 44.6±8.13 kg of milk of which 32.5±5.95 kg were harvested, and if separated from their lambs at birth they produced 62.2±6.92 kg, of which 53.8±5.93 kg were harvested.

Awassi x Merino ewes also had longer lactations than the Merinos (p<0.001): 16.6±1.07 weeks when they nursed their lambs and 14.2±1.32 weeks when they were immediately separated from the lambs. The lactation of the Merino ewes that nursed their own lambs was only 8.4± 0.95 weeks, while for those who were separated at birth it was 8.8±1.04.

Ewes that nursed their lambs produced less milk than those that were separated at birth (p<0.092). However, they also had slightly longer lactations (p=0.012), so that overall allowing ewes to nurse their lambs resulted in a loss of milk of 28.3 kg/head, equivalent to about $30.

The composition of the milk showed a large week to week variation as well as a seasonal pattern (Figure 2). The concentrations of fat and protein tended to be high towards the end of the lactation and the concentration of lactose followed closely the lactation yield.
There were no significant differences between the two genotypes in fat, lactose, solids-non-fat and total solids. By contrast, protein concentration was higher in the Merino sheep than in the Awassi x Merino ewes (p=0.002).

Figure 1. Lactation curves of Awassi x Merino (n=45) and Merino (n=22) ewes milked immediately after lambing (AxM, n=22; M, n=6) or after four weeks of nursing their own lambs (AxM, n=23; M, n=16).

Colostrum immunoglobulin (IGG) on average disappeared from the milk within five days from lambing (Fig 3a), but there was large variation between animals. In some ewes IGG was still high even after five days (Fig 3b). Significantly, most sheep dairies discard the milk at the beginning of lactation only for three days, similarly to practices adopted with dairy cows.
**Figure 2.** Composition of the milk from Awassi x Merino (n=40) and Merino (n=12) ewes milked immediately after giving birth (AxM, n= 22; M, n=6) or after four weeks of nursing their own lambs (AxM, n= 18; M, n=6).

The capillary electrophoresis work yielded another result: different numbers of peaks were observed in the caseins regions of different sheep (Figure 4) that could be due to the presence of different genetic variants of the caseins.
Figure 3. Colostrum Immunoglobulins in the milk of sheep. a) average IGG ± standard errors. b) IGG in sheep 479, showing that IGG was still high 5 days after the beginning of milking.

Figure 4. The electrophoretic patterns of two dairy sheep showing three and five peaks in the casein region.
The proportion of short/medium fatty acids (<C14) changed from 32.8±4.69% in early lactation to 39.9±8.07% in late lactation. Consequently, the ratio of short/medium to long fatty acids increased from 0.53±0.11 to 0.82±0.20. The difference between early and late lactation failed to reach significance (p=0.14).

4.1.4 - Discussion

Our results support the hypothesis that Awassi x Merino ewes would produce more milk than Merino ewes. Some of the Awassi x Merino ewes produced consistently above 1kg of milk/day and their lactation was exceptionally long, as much as 22 weeks. Their lactation could have been even longer as when we ended the milking some ewes were still producing above 200g of milk per day. Whilst only 2% of the ewes produced more than 150kg of milk in a lactation, 9% produced above 100kg and 11% produced above 90kg. This suggests that if selected for dairy production the Awassi has the potential to produce dairy yields far in excess of currently milked local breeds. Another striking characteristic of the Awassi x Merino ewes was their good temperament and behaviour on the dairy parlour. Although this cannot be measured objectively, the milkers clearly preferred to milk the Awassi x Merino ewes.

Despite their superior performance when compared with the Merinos, milk production from Awassi x Merino ewes was surprisingly low when compared with literature reports claiming that the Awassi can produce as much as 1,000L of milk per lactation (Epstein 1985). Although we milked their crosses with the Merino, we did not expect to obtain only an average of 62 kg of milk in a lactation. There can be several reasons for this unexpected result. Firstly, literature reports may be exaggerated. The Awassi sheep that were reported to produce 1,000L in a lactation by Epstein (1985) had also been imported to Cyprus where they produced only 150 kg under commercial conditions (Mavrogenis and Louca, 1980). Probably Epstein (1985) reported record yields and not average productions. Secondly, our ewes could not be selected for udder development. Knight and Bencini (1993) have shown that milk production is correlated with udder development two weeks before lambing, but because our ewes were not synchronised we were unable to select them for udder development without confounding it with time from lambing. Thirdly, the ewes milked in this experiment were maiden ewes that are known to produce less milk than mature ewes (Boyazoglu, 1963; Ozcan and Kaimaz, 1969) and do not have a peak of lactation (Holmes and Wilson, 1984). Our ewes did not have a peak of lactation (Figure 1), confirming these literature reports. Another possible explanation for the low yields observed may inadequate nutrition during pregnancy. Nutrition during pregnancy has paramount importance in affecting future milk yields (Bencini and Pulina, 1997) and late pregnancy supplementation can increase milk yields considerably (Bencini and Purvis, 1990). Upon arrival at The University of Western Australia the plane of nutrition was increased and the ewes gained an average of 4 kg in the first two months of lactation, suggesting that an improved nutrition during mid to late pregnancy may have increased milk yields.

Another reason for the low yields observed may be that some of the ewes had high worm burdens, which may have affected their milk production. Subsequently they were given the drench Cydectin, but this involved discarding the milk for four weeks after the treatment. This problem highlighted the importance of establishing suitable drenches for dairy ewes.

There was no difference in milk composition between the two genotypes, except for protein concentration that was higher in the Merino sheep. This was probably due to the low production of milk of the Merinos which has been associated with higher concentrations of milk components (Flamant and Morand-Fehr 1982). Since the Awassi x Merino ewes produced three times more milk than the Merinos this difference in composition is more than compensated by the higher milk production from the Awassi x Merino sheep.

The weekly measurements of milk composition confirmed that milk composition varies with time, with fat and protein increasing towards the end of the lactation and lactose following a
reverse trend. These results are similar to those reported by Pulina (1990) and Pulina et al (1992) for Sarda ewes, by Fadel et al (1989) for Awassi ewes and by Bencini and Purvis (1990) and Bencini et al (1992) for Merino and Awassi x Merino ewes.

The hypothesis that the proportion of short/medium fatty acids would change from early to late lactation was not supported as the difference failed to reach significance. This could be due to technical problems as some of the samples were lost and it is possible that if we had more samples the difference would have been significant. However, it is possible that even if not significant statistically, such difference may be the cause of the processing problems observed in early lactation.

The presence of colostrum immunoglobulin in the milk in early lactation could be the cause of the processing problems reported by processors. Therefore, it appears that lambs should be left with their mothers for a longer period to ensure colostrum has completely disappeared from the milk before the milk is used for processing. If sheep are milked immediately after giving birth the colostrum should be discarded for at least six or seven days to avoid processing problems. It is possible that a lack of production of endogenous oxytocin may prevent the ewes from having a normal milk let down. Further work needs to be done in this area to ascertain if colostrum IGG would still persist in the milk if the ewes were administered exogenous oxytocin.

The existence of different peaks in the casein region of our dairy sheep suggests the presence of genetic variants of the caseins. This has been demonstrated both in cows (Feagan et al, 1972) and sheep (Lyster, 1972). For dairy cows the presence of certain genetic variants of the casein affects the composition of the milk (Aleandri et al, 1990). Italian researchers have identified individual cows carrying particular genetic variants of the κ-Casein which make the milk unsuitable for the production of Parmesan cheese due to poor coagulation (Morini et al, 1975, 1979; Mariani et al, 1976, 1979; Losi et al, 1979, 1982; Losi and Mariani, 1984).

In European dairy sheep, genetic polymorphism of the casein has been reported by Lyster (1972), Arave et al (1973), Russo et al (1981), Chiofalo et al (1982) and Manfredini et al (1987). The αs1 casein variant provokes a reduction in casein content and a worsening of milk clotting properties (Piredda et al, 1993). Thomas et al (1989) reported the existence of genetic variants of the casein in Australian sheep, but it is still not clear whether these genetic variants have an effect on clotting properties and cheese outcome. The fact that different genetic variants of the casein are likely to be present in our dairy sheep requires further investigation to determine what variants are present and what effect they have on the processing properties of the milk.

4.2.1 - Comparative dairy production and composition of the milk from Awassi x Merino ewes under two different weaning methods

In Israel the Awassi sheep is often milked with a share milking method in which the ewes are allowed to nurse their lambs during certain periods of the day, as well as being milked regularly twice a day in a milking parlour (Epstein, 1985). Knight et al (1993) showed that this method could be adopted in New Zealand with Dorset ewes without compromising total lactation yield and/or the growth of the lambs.

The adoption of such a system in Australia would allow farmers to avoid costly artificial weaning of lambs, as well as obtain sheep milk for processing.

Because the suckling stimulus is believed to stimulate milk production (Alexander and Davies, 1959; Labussière, 1988) and the removal of milk is crucial for maintaining lactation (Wilde and Peaker, 1990) it is possible that sheep under a share milking regime will produce more milk than sheep that are milked twice a day, but do not nurse their lambs.
In this experiment we used a flock of Awassi x Merino ewes to test the suitability of share milking as a management strategy to produce both milk and lambs.

With this experiment we tested the hypothesis that Awassi x Merino ewes would produce more milk if allowed to nurse their lambs during the day as well as being milked twice a day in a dairy situation, compared to sheep that were only milked twice a day.

### 4.2.2 - Materials and methods

A flock of 45 Awassi x Merino (AxM) ewes were screened for udder development approximately two weeks before lambing and transferred to the animal house at The University of Western Australia. The ewes lambed over a period of nine days and they were allowed to nurse their lambs for the first two weeks after lambing. Then they were split into two groups. Ewes in group 1 (n=22) were left with their lambs for a further five or six weeks, until the lambs reached a weight of at least 12 kg and they were separated from their lambs and milked twice a day. Ewes in group 2 (n=23) were allowed to nurse their lambs during the day, but not at night, and were milked twice a day.

Production of milk was measured weekly and samples of milk were collected and analysed for protein, fat, lactose, total solids (TS) and solids non fat (SNF). When milk yields fell below 400 g/day lactation was considered concluded and the ewes were removed from the dairy.

### 4.2.3 - Results

The total lactation yield of the share milked ewes was more than double that of the control animals (25±5.1kg vs 12±3.2kg; p=0.04). The length of the lactation was also greater for the share milked ewes (7.5±0.73 vs 4.1±0.59 weeks; p=0.0008).

The weekly variation in the composition of the milk is represented in Figure 5. It was observed that the share milked ewes produced a milk that was low in fat, resulting in a low fat content in the bulk milk at the beginning of the lactation.

### 4.2.4 - Discussion

The results strongly supported our hypothesis that share milked ewes produce more milk than ewes separated from their lambs. This is also supported by the discovery by Wilde and Peaker (1990) of a local inhibitor of milk secretion contained in milk. The logical consequence of this finding is that the more milk is removed from the mammary glands, the more milk is produced. In our share milking regime the ewes were not only milked twice daily, but further milk was withdrawn during the day by the lambs and this extra milk removal may explain the greater amount of milk produced by the shared milked ewes.

Although we did not hypothesise that the share milked ewes would have longer lactations, this could have been expected as milk removal in early lactation promotes mammary gland development and results in longer lactations (Henderson et al, 1985).

Both groups of ewes produced very little milk. This may be explained by the fact that the ewes were undernourished during pregnancy as they were raised on a property characterised by a shortage of feed in Autumn. As stated previously, nutrition during pregnancy affects milk yields (Bencini and Pulina, 1997; Bencini and Purvis, 1990).
It is also possible that first cross Awassi x Merino ewes do not inherit the full dairy potential from their father and that further back-crossing to the purebred Awassi may be needed to obtain higher yields of milk.

During the weekly measurements of milk production and milk composition we observed that the share milked sheep produced milk of low fat content, resulting in a low concentration of fat in the milk when we had only share milked ewes in the flock, from weeks three to five. In commercial situations different groups of sheep lamb at different times, so the practice of share milking should not generate processing problems. Nevertheless, an experiment was conducted to further investigate this finding.
Figure 5. Variation in milk composition throughout lactation for Awassi x Merino crossbred ewes that were milked from week five or were share milked from the third week of lactation. The share milked ewes produced low fat milk at the beginning of the share milking regime.
4.3.1 - Share milking affects the milk ejection pattern of dairy ewes

The Awassi x Merino crosses in the share milking treatment of the previous experiment appeared to have extremely low fat percentages in their milk. For instance at the first measurement of milk production the fat content in the milk was only 1.79±0.14 %, (normally sheep milk has 6-7 % fat).

There was anecdotal evidence (S.T. Dawe, Pers. comm.) that when sheep are share milked they "retain the milk fat" and produce a low fat milk. Physiologically, sheep cannot deliberately retain the milk fat (Labussière, 1988), but they could produce a milk low in fat if they did not have a normal milk ejection pattern. In other words, if the sheep did not produce endogenous oxytocin that promoted milk ejection the only fraction of the milk that could be collected would be the cisternal milk, which is lower in fat than the alveolar milk (Labussière, 1988).

Therefore we selected a sub-sample of our share milked and control ewes to test the hypothesis that if sheep are share milked they would not have a normal milk ejection and only the low fat cisternal milk would be collected.

4.3.2 - Materials and methods

A sub-sample of 15 ewes from the share milked and control groups described in the previous chapter were selected for this experiment. We deliberately selected a small number of animals because we intended to milk them with quarter bottles, which is both slow and labour intensive. Seven of the ewes were share milked and the other eight were control sheep that had been separated from their lambs five or six weeks after lambing. At the morning milking, the ewes were milked with quarter bottles to weigh the amount of milk produced by each individual ewe, and milk samples were collected. The ewes were then given an intramuscular injection of 1 IU oxytocin (Bencini, 1995) and milked again. The amount of milk produced after the injection of exogenous oxytocin was measured and a second sample of milk was collected. This procedure was conducted during the morning milking and repeated for the same sheep during the afternoon milking.

The samples of milk were analysed for fat, protein, lactose, total solids (TS) and solids non fat (SNF).

4.3.3 - Results

The total amount of milk produced during the whole day was higher for the control ewes (742±37.0g) than for the share milked ewes (573±10.0g; p= 0.0024).

In the morning the amount of milk produced at the first milking by the share milked and control ewes did not differ significantly. However, the fat content of the milk of the share milked ewes was 3.34±0.30%, significantly lower than that of the control ewes which was 6.08±0.20% (p=0.0001). The lactose concentration also differed significantly and it was 5.22±0.09% in the share milked ewes and 4.39±0.30% in the control ewes (p= 0.037).

The amount of milk collected after the injection of exogenous oxytocin also differed significantly (p=0.004) as the share milked ewes produced 228±54.9g, while the control ewes produced only 97±22.6g. The difference in fat concentration at this second milking failed to reach significance (p=0.11), while lactose concentration was significantly different between share milked (4.90±0.04%) and control ewes (4.40±0.10%; p=0.0027).

In the afternoon the amount of milk produced by the share milked ewes was significantly lower (15±3.0g) than that of the control ewes (158±36.0g; p= 0.0052). This is not surprising as the share
milked ewes during the day nursed their lambs and a low milk production in the afternoon was expected. In contrast to the morning milk, the milk collected after the first milking in the afternoon did not differ significantly in its composition. However, the amount of milk produced after the oxytocin injection was significantly lower for the share milked ewes (22±9.4g) than for the controls (48±8.2g). Also this second milk did not differ in composition.

4.3.4 - Discussion

Our results strongly support the hypothesis that share milking affects the milk ejection pattern of sheep. This is shown by the fact that treatment and control ewes produced different amounts of milk when milked after an injection of exogenous oxytocin. It is possible that animals that are accustomed to release their milk for their lambs fail to do the same for the milkers, who can collect only the cisternal milk. The unusually low fat content of the milk produced by the share milked ewes supports this hypothesis.

The fact that share milked ewes produced less milk than the controls is not surprising, as they were nursing their lambs. If the low fat content in the milk does not represent a problem, share milking could be a convenient way of rearing lambs as well as obtaining milk.

A direct consequence of the share milking method could be that the milk could be suitable for the production of low fat milk and yoghurt, but its fat content may need to be adjusted if cheese was to be produced.

It is unlikely that the low fat milk produced by the share milking method will ever be a problem for the sheep milking industry. Normally different groups of sheep would lambs at different times and the milking flock would therefore contain both share milked and non share milked ewes. This was indeed the case in our experiment after the first three weeks of lactation, when both share milked and control ewes were milked and the composition of the bulk milk returned to normal values.

The fat concentration of sheep milk is normally very high (Anifantakis, 1986) leading to an unfavourable ratio of protein to fat (Chapman, 1981; Banks et al, 1981). Therefore, the presence of share milked ewes in the milking flock may result in bulk milk of better processing performance.

4.4.1 - Dairy potential and seasonal variation in milk composition of higher Awassi crosses

Our results have shown that first cross Awassi sheep do not produce as much milk as could be expected from literature reports (Epstein, 1985). High worm burdens and poor nutrition during pregnancy could partially explain these results. However, it is possible that first cross ewes do not inherit the full dairy potential from their fathers and that further backcrossing to the Awassi is necessary to achieve commercially viable productions. To test this hypothesis we milked a flock of higher Awassi crosses and compared them with first cross Awassi x Merino ewes to establish their comparative dairy potential and seasonal variation of milk composition.

4.4.2 - Materials and methods

A flock of 47 sheep composed of first, second, third and fourth crosses was supplied by the YHH Holdings (Table 1). The ewes lambed during the month of July and were allowed to nurse their lambs until the lambs reached a weight of 12 kg, about 10 weeks after birth. Then the lambs were separated from their mothers and weaned on a solid diet.
Milk production and milk composition from the ewes were measured at weekly intervals. Samples of milk were analysed for protein, fat, lactose, total solids (TS) and solids non fat (SNF). When milk yields fell below 350 g/day lactation was considered concluded and the ewes were removed from the dairy.

Due to the small number of ewes per treatment for some of the comparisons the data relative to the 7/8 and 15/16 ewes were combined into one treatment to compare them with the other crosses.

4.4.3 - Results

The average daily production from the higher cross ewes was significantly higher than that of the first cross ewes (p=0.0011), but the difference in total lactation yield between the crosses failed to reach significance, probably due to the high coefficients of variation.

Table 1. Daily milk production (g/day), total lactation yield (kg) and total lactation length (weeks) of Awassi crossbred ewes.

<table>
<thead>
<tr>
<th>Cross type (n)</th>
<th>Daily production</th>
<th>Lactation yield</th>
<th>Lactation length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 (16)</td>
<td>383±26.0</td>
<td>33.4±7.83</td>
<td>21±2.1</td>
</tr>
<tr>
<td>3/4 (13)</td>
<td>515±42.9</td>
<td>45.0±12.87</td>
<td>21±2.6</td>
</tr>
<tr>
<td>7/8 (11)</td>
<td>557±38.7</td>
<td>50.3±16.06</td>
<td>22±3.4</td>
</tr>
<tr>
<td>15/16 (7)</td>
<td>606±56.5</td>
<td>65.3±16.17</td>
<td>25±3.5</td>
</tr>
</tbody>
</table>

The higher crosses also produced milk which had a significantly higher concentration of fat than that of the lower crosses (p = 0.0062; Table 2). This meant that the total production of fat of the 15/16 crosses over the lactation was higher than that of the other crosses (p=0.052; Table 2). By contrast, the concentrations of protein and lactose in the milk did not differ between crosses (Table 2).

Table 2. Milk composition (%) and fat yield (kg) for the whole lactation of Awassi crossbred ewes.

<table>
<thead>
<tr>
<th>Cross type (n)</th>
<th>Fat</th>
<th>Protein</th>
<th>Lactose</th>
<th>Fat yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 (16)</td>
<td>5.6±0.12</td>
<td>5.4±0.11</td>
<td>4.1±0.11</td>
<td>1.8±0.44</td>
</tr>
<tr>
<td>3/4 (13)</td>
<td>5.9±0.16</td>
<td>5.5±0.11</td>
<td>4.2±0.13</td>
<td>2.7±0.77</td>
</tr>
<tr>
<td>7/8 (11)</td>
<td>6.1±0.24</td>
<td>5.6±0.11</td>
<td>4.4±0.06</td>
<td>3.1±1.01</td>
</tr>
<tr>
<td>15/16 (7)</td>
<td>6.6±0.15</td>
<td>5.6±0.10</td>
<td>4.4±0.06</td>
<td>4.2±1.01</td>
</tr>
</tbody>
</table>
The composition of the milk varied throughout lactation as shown in Figure 6. The concentrations of fat and protein were high at the end of the lactation and low at peak lactation, while the concentration of lactose followed closely the lactation yield.
Table 1 shows average daily productions, total lactation yields and lactation length for the various crosses. Clearly dairy potential tends to increase with backcrossing to the Awassi.
4.4.4 - Discussion

There is an evident trend towards increased dairy potential with backcrossing to the Awassi. This should be confirmed by conducting another experiment with a larger number of sheep. To detect a 20% difference between treatments at least 20 animals per treatment are required (Bencini, 1993). However, insufficient higher crosses were available for this experiment to satisfy this requirement.

The higher crosses not only produced more milk, but also their milk was higher in fat than lower crosses. It is possible that this difference is due to selective breeding for dairying. However, this is in contrast with reports of a negative correlation between milk quantity and quality (Flamant and Morand-Fehr, 1982; Barillet et al, 1986; Bencini and Pulina, 1997).

Previous work conducted in Australia (Bencini and Purvis, 1990; Bencini et al, 1992) and New Zealand (Geenty, 1979), indicated that local breeds of sheep do not differ in the composition of their milk. Evidently, the genetic make-up of the Awassi is completely different from that of Australian breeds, as we observed higher fat concentration in its higher crosses.

As the ewes were milked from the 10th week of lactation to avoid affecting the growth of their valuable lambs, it was not possible with this experimental design to evaluate milk composition at the beginning of lactation. However, it is likely to be similar to trends reported by other workers (Pulina, 1990; Pulina et al, 1992; Fadel et al, 1989; Bencini and Purvis, 1990; Bencini et al, 1992).

4.5.1 - Captec Extender 100 is safe for use in sheep dairies

When the experiments described in this report began, it was a standard policy at The University of Western Australia to treat all new sheep with Captec Extender 100, a slow release drench, to control internal parasites. This drench has no withholding period for meat animals, however it was not known whether it translocated into the milk and to what extent. If the active principle (albendazole) or its metabolites (albendazole sulphoxide and albendazole sulphone), were translocated into the milk, they could have an effects on its processing performance.

Philbey (1992) reported that sheep dairy producers should not use any drenches on milking ewes. Therefore it was essential to establish a safe method to combat internal parasites occurring in dairy ewes. The European Community regulations impose a maximum residue limit for albendazole and its metabolites of 100 ppb (Heeschen and Harding, 1995). Assuming no cumulative effects of the slow release drench, a simple calculation would suggest that using Captec Extender 100 this limit should not be exceeded as each Captec Extender 100 capsule only releases 3.2 mg/day, of which only a fraction is likely to end up in the milk.

Albendazole is used to treat hydatid disease in humans at a dose of 600mg twice daily (J Reynolds, Pers. comm.), so it is unlikely that this drench would have any ill effect on human health.

Experimental work was undertaken to establish if Captec Extender 100 was safe to use in a dairy situation. The research was conducted in co-operation with Associate Professor Jim Reynolds, from the department of Veterinary Pharmacology and Chemotherapy at the School of Veterinary studies of Murdoch University.

The experiment tested the general hypothesis that the drench albendazole in the form known as Captec Extender 100 if translocated to the milk does not reach levels above those imposed by the EEC and therefore it can be safely used in sheep dairies. The experiment was conducted in...
three stages: the first aimed at determining the effect of a single dose of albendazole, the second to determine the effect of using Captec Extender 100 and the third, to test the effect of the metabolite of albendazole on the processing properties of milk.

4.5.2 - Materials and methods

**Single oral dose of albendazole of 3.8 mg/kg**

Ten sheep were weighed and given a single oral dose of 3.8 mg/kg of albendazole. Samples of milk and blood were taken before the administration of the drench and subsequently at 12 hourly intervals for 96 hours.

The milk of the drenched sheep was kept separate from the milk of the other sheep by using quarter bottles that divert the milk away from the line and into a separate container.

The blood and milk samples were analysed for the presence of albendazole and its metabolites, albendazole sulphoxide and albendazole sulphone by HPLC (High Pressure Liquid Chromatography) according to a method described by Fletouris et al (1996).

**Captec Extender 100**

The ten sheep described above were given a week recovery period to eliminate residues of the single dose of albendazole. After this period samples of milk and blood samples were taken from the sheep, and they were administered a Captec Extender 100 capsule. Milk and blood samples were subsequently collected at 12 hourly intervals until 96 hours, and then again at 30, 60 and 90 days following drenching.

The blood and milk samples were analysed for albendazole, albendazole sulphoxide and albendazole sulphone with the method described above (Fletouris et al, 1996).

**Effect of the metabolite of albendazole on the processing properties of milk**

2 L of bulk sheep milk were pasteurised and added to a standard yogurt culture (YC 180) containing *Lactobacillus bulgaricus*, *L. acidophilus* and *Streptococcus thermophilus*. To 10 mL sub-samples of the milk were added 0 (control) 1, 3 and 10 µg/ml of albendazole sulphoxide, the principal metabolite of albendazole. These concentrations were chosen because 3 µg/ml was the maximum concentration observed in the plasma of sheep that were given a single bolus of 3.8 mg/kg of Albendazole. In the form Captec extender 100 the daily dose of albendazole released by the Captec capsules is 3.2 mg/day, equivalent to 0.064 mg/kg for a 50 kg sheep. Presumably the amount translocated into the milk will be less than the concentration observed in plasma, but since at the time of the experiment we had no data on concentrations achieved in milk we adopted the dose observed in sheep plasma.

The milk samples were incubated at 40°C for 10 hours. The pH of the samples was monitored at hourly intervals, following our standard yogurt making procedure. When pH reached 4.4 the samples were removed from the incubator and transferred into a refrigerator at 4°C. The activity of the starter cultures was observed directly using a transmission microscope.

4.5.3 - Results

The concentrations of albendazole and its metabolites in the plasma and the milk of the treated sheep are shown in Figures 7 and 8.
When a single dose of albendazole was administered to the sheep the concentrations of albendazole metabolites in plasma were consistently above those of milk, however even in the plasma, they did not reach the limits prescribed by the EEC (Figure 7).

The Captec Extender 100 bullet resulted in low doses in the plasma of the sheep, and extremely low doses were translocated into the milk (Figure 8).

In our yoghurt experiment, all of the milk samples reached the pH of 4.4 and coagulated at the same time, regardless of the concentration of albendazole sulphoxide present. In all of the samples, lactic bacteria from the starter culture were observed to be alive and active.

4.5.4 - Discussion

Our results strongly support the hypothesis that Captec Extender 100 is safe to use in sheep dairies. Firstly, it is translocated into the milk in extremely low doses and secondly even the highest dose of albendazole sulphoxide did not affect the activity of the starter cultures in the milk.
Figure 7. Concentration of albendazole, albendazole sulphoxide and albendazole sulphone (ng/L) in the plasma and in the milk of sheep treated with a single dose of 3.8 mg/kg of albendazole. Bars represent the standards errors.
It was concluded that Captec Extender 100 can be used both within our project and in commercial dairies as the milk contains amounts of albendazole and its metabolites well below the limits prescribed by the EEC. Moreover, the processing performance of the milk is not affected by the use of this drench.

4.6 - Product development

To address the second problem faced by the sheep milking industry we used the milk produced by the experimental ewes to develop specialty sheep dairy products. This research effort resulted in the development of two new cheeses.
4.6.1 - Development of a spreadable fresh sheep milk cheese

According to sheep dairy manufacturers (M. Temby, Pers. comm.; T. Dennis, Pers. comm.), fresh products such as sheep milk yoghurt, milk and cream provide the 'cash flow' for the enterprise. Long maturation cheeses such as those imported for the local ethnic communities have high storage costs and risk of spoilage during maturation.

Pasteurised milk products are fresh and satisfy this requirement, but generally their shelf life is short. UHT and sterilised milk may have large markets in the Middle East, but the sheep milking industry does not have the production to supply the large amounts required for the processing of such products.

The need to target the local market with a fresh cheese of relatively short maturation and long shelf life prompted this developmental work.

The major factor affecting the yield of cheese is the amount of water removed from the milk after clotting, called syneresis. The syneresis can be affected by the cheese maker and to a large extent, it will determine the type of cheese produced. So if the curd is only slightly pressed and is cut within a day and preserved in brine the Fetta, a high yielding cheese, is produced. Instead, if the cheese maker adopts methods of removing water from the curd a hard grating cheese like the Parmesan or the Pecorino can be obtained.

Of the various methods adopted to remove water from the curd, acidification, obtained by adding a starter culture and allowing it to ferment the milk or the curd until the desired pH is reached promotes the least syneresis. Therefore, cheeses produced with such methods are high yielding as they contain large quantities of water. Such cheeses also have a low pH (often less than 4.5), which improves their keeping properties (Resmini, 1978).

Few cheeses are produced exclusively from acid coagulation of milk. In the Middle East a cheese called Labneh produced with this method is very popular (Tamime et al., 1991), and in Italy a similar cheese produced with goat milk and called Caprino is also famous (Resmini, 1978).

Developmental work was initiated to produce a fresh, short maturation product similar to the Labneh and the Caprino.

4.6.2 - Materials and methods

To make this cheese the milk is initially pasteurised at 72°C for 20 seconds. The milk is then transferred into tubs and incubated with a yogurt culture (YC 180 or YC 380) until it reaches the isoelectric pH of casein (4.6). This causes the acid precipitation of the casein and consequent ‘curdling’ of the milk. This results in an acid curd that is then strained in cheesecloth for 24 hours. Salt is added to the resulting paste, which is ready for immediate consumption. We tested the addition of different amounts of salt (1%, 2% or 3%) and the consensus is that 1% salt is preferred. The resulting cheese is creamy in consistency and it has the potential to be sold after mixing it with herbs, or, similarly to the Italian Caprino, it can be sold as such and served with olive oil and pepper.

Since the cheese is in the form of a spread, we tested different packaging methods. A very convenient one consists in extruding the paste in rolls that are approximately 2.5 cm in diameter and 12 cm long. The rolls are wrapped in food grade paper and packaged in fast food trays, similarly to the way Caprino is packaged in Italy.

For each experimental batch, samples of the cheeses were analysed for fat, protein and moisture content and the yield of cheese from each litre of milk was calculated.

Samples of the cheese were used in a consumer survey designed to test its acceptability to Australian consumers and its marketing potential.
4.6.3 - Results

The composition of the spreadable cheese is shown in Table 3. A consumer survey as well as personal observations revealed that this cheese is very popular and has the potential to be sold for $30-32/kg. The average yield of cheese from the milk is between 35 and 40%, so returns from this cheese would be in the order of $12-14 per litre of milk processed.

Table 3. Average composition (%) of the spreadable cheeses developed within the project. Values in brackets represent the standard error of the mean.

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Dry matter (DM)</th>
<th>Fat</th>
<th>Fat on DM</th>
<th>Protein</th>
<th>Protein on DM</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.2</td>
<td>38.8</td>
<td>18.3</td>
<td>46.9</td>
<td>13.2</td>
<td>33.9</td>
<td>4.8</td>
</tr>
<tr>
<td>(0.88)</td>
<td>(0.88)</td>
<td>(0.67)</td>
<td>(1.01)</td>
<td>(0.30)</td>
<td>(0.56)</td>
<td>(0.09)</td>
</tr>
</tbody>
</table>

4.6.4 - Discussion

The method of preparation of this product is very simple and any manufacturer already making yoghurt could easily produce this cheese.

The above results indicate that this cheese has a high yield from each litre of milk, has no maturation time, and therefore low risk of spoilage during maturation and low storage costs.

The consumer survey revealed that this cheese could also fetch high prices on the market, providing cash flow possibly competing with dips and spreads. Potential returns from each litre of milk processed also appear to be very high.

The cheese has two distinctive advantages over other commercial dips, namely, that having active lactic cultures in it can be promoted as a health product, and that it has a low pH which considerably extends its shelf life.

4.7.1 - Development of semi mature cheese

The attempts by the sheep milking industry to replace importations of Pecorino from Italy have been frustrated by the fact that the EEC heavily subsidised this product: exporters of Pecorino were awarded a subsidy of $4 for each kg of Pecorino exported out of Italy. This meant Pecorino could be purchased in Australia for less than $15/kg. As a consequence, large amounts of Pecorino were regularly imported not only in Australia, but anywhere where large Italian communities are present. For instance the USA import some 15,000 tons of Pecorino per year (Dawe, 1990). Hopefully this will change with the recently introduced GATT agreement, and Australia may one day compete for this market.

However, Pecorino is a DOC product, so in theory it should be illegal to use this name for cheeses made outside of its area of origin. Moreover, the authentic Pecorino is made with raw milk, a practice
that is not permitted in Australia, and has a long maturation time, involving both storage costs and the risk of spoilage. The traditional Pecorino has also a piquant taste due to the use of lambs rennet in its processing. Lambs rennet contains a large number of bacteria as well as lipolytic enzymes (Dellaglio et al., 1981; Resmini, 1978). The use of lambs rennet is not practiced in Australia, where consumers prefer milder tasting cheeses than the traditional Pecorino (Burton, 1990).

Therefore, there was a need to develop a cheese with a medium maturation time and to test its acceptability to Australian consumers.

4.7.2 - Materials and methods

Initially 20 batches of semi mature cheese were made to test two different cheese making procedures. With both procedures the milk was filtered and pasteurised at 72°C for 20 seconds. The milk was then transferred into the cheese vat and cooled to the desired coagulation temperature. In both cases calf rennet (0.22 mL/L) was used to coagulate the milk and the curd was cut with curd knives into 2-3 cm cubes and transferred into round hoops of 150 mm diameter. The rounds were incubated at 27-28°C to encourage the development of acidity brought about by the starter culture. Maturation took 20 to 30 days. The major differences between the two procedures were the starter cultures used (Lactobacillus bulgaricus and Streptococcus thermophilus in one case and Flora danica in the other), the temperature of coagulation (35°C and 43°C respectively), and the duration of the salting process (3 hours and 6 hours respectively).

Since there was consensus that both cheeses were excellent we adopted the second cheese making method as it was slightly faster as it did not require the cooling down of the milk to 35°C. The higher temperature of coagulation is also more favourable for the action of rennet. This is because the optimum temperature for rennet action is 40-44°C, or about the body temperature of the calf. With clotting temperatures higher than 33°C the enzyme approaches its optimum temperature and curds achieve a higher consistency and have a better syneresis (Resmini, 1978).

Another 20 batches of cheese were produced until a product of consistent flavour and taste was achieved. Due to the recurring presence of moulds on the surface of the cheese requiring regular washing with brine and scrubbing of the rounds we adopted the practice of painting the rounds with cheese paint (Home Cheese Making Supplies) containing a mould inhibitor.

For each batch of cheese the milk was analysed for fat, protein, lactose and total solids content and the yield of cheese from each litre of milk was calculated. Samples from each experimental batch were collected, and analysed for protein, fat, moisture and ash. The cheese was also tested on a large sample of consumers during our consumer survey.

4.7.3 - Results

The composition of the cheese is shown in Table 4. This cheese has a lower moisture and higher fat content than the previously described spreadable cheese.

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Dry matter (DM)</th>
<th>Fat</th>
<th>Fat on DM</th>
<th>Protein</th>
<th>Protein on DM</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.6</td>
<td>64.4</td>
<td>27.3</td>
<td>42.5</td>
<td>26.2</td>
<td>40.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>
The yield of cheese from milk was approximately 13%. Our consumer survey revealed that 86% of consumers would be prepared to buy this cheese, but they would not pay more than $17-21/kg for it.

4.7.4 - Discussion

Although this cheese has good organoleptic qualities and is liked by consumers, it has some disadvantages compared to the spreadable cheese described previously.

It has a lower moisture content and therefore a lower yield and a longer maturation time which involves storage costs and the above mentioned risk of spoilage during maturation. Indeed several batches of the cheese had to be cleaned at regular intervals to remove moulds developing on their surface. The practice of painting the rounds with cheese paint addressed this problem, but cheese paint is expensive and the painting of the rounds is tedious and time consuming. Our survey showed that consumers would be prepared to buy this cheese, but at a price lower than that of the spreadable cheese described above. Despite this, the cheese should compete favourably with cheeses like the Pecorino, which has a maturation time of up to six months and cannot be made according to its traditional recipe.

People in the industry that have tried this cheese found it exceptionally good and one manufacturer has requested permission to reproduce this product.

Within a sheep milk manufacturing plant there would be a need for a variety of different products to satisfy the different consumers requirements and this cheese could easily be part of this range of products.

4.8.1 - Correlation between milk composition and cheese outcome

Literature reports suggest that the fat and protein concentrations of milk are major factors affecting the yield of cheese (Van Den Berg, 1993).

Bencini and Johnston (1996) showed that the composition of milk affects its clotting properties as milk that is high in protein and low in fat produces harder curds than milk that is high in fat and low in protein. The clotting properties of milk affect cheese outcome (Ustunol and Brown, 1985; Buttazzoni and Aleandri, 1990; Cavani et al, 1991). Chapman (1981) and Banks et al (1981) reported that in cow's milk the casein to fat ratio can change considerably with changes in milk composition. Therefore, provided other cheese making conditions do not vary, the yield of cheese varies according to the casein to fat ratio in the milk because different amounts of fat and casein are lost in the whey. Therefore the composition of the milk is likely to affect the outcome of the cheese, and variations in milk composition such as those observed in the milk of our dairy sheep, may affect the transformation of milk into dairy products. Regression analysis was conducted for experimental batches of Fetta and the semi mature cheese described above in order to establish if there were correlations between the composition of the milk and the outcome of the cheese.

4.8.2 - Materials and methods

To determine the correlation between milk composition and cheese outcome, 18 batches of Fetta were made with milk of known composition. The casein/fat ratio was calculated by assuming that
Casein represents approximately 80% of milk protein (Resmini, 1978) and correlated to the yield of cheese. Due to technical problems, the casein/fat ratio could be calculated only for 9 batches.

Subsamples of each batch of cheese were frozen and analysed for fat, moisture and protein content. The same procedure was repeated with 20 experimental batches of the semi mature sheep milk cheese developed within the project. For technical reasons, the relationship between composition and yield could be calculated on 12 batches only.

4.8.3 - Results

The composition of the experimental batches of Fetta cheese is reported in Table 5. There were no significant correlations between milk composition and the fat, protein or water content of the cheese.

Table 5. Gross composition of the experimental batches of Fetta cheese (figures in brackets represent the standard errors).

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Dry matter (DM)</th>
<th>Fat</th>
<th>Fat on DM</th>
<th>Protein</th>
<th>Protein on DM</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.35</td>
<td>42.65</td>
<td>55.46</td>
<td>23.65</td>
<td>34.85</td>
<td>14.86</td>
<td>12.57</td>
</tr>
<tr>
<td>(0.56)</td>
<td>(1.16)</td>
<td>(1.09)</td>
<td>(1.53)</td>
<td>(0.67)</td>
<td>(1.10)</td>
<td>(0.56)</td>
</tr>
</tbody>
</table>

The relationship between the casein/fat ratio and the yield of Fetta cheese is represented in Figure 9. There was a significant (p=0.03), but weak ($r^2=0.5$) correlation between milk composition and yield of cheese.

Figure 9. There was a linear relationship between milk composition and cheese yield ($y = 34.4 + 300.4x; r^2=0.5$).

For the semi mature cheese, the yield of cheese was correlated to the protein concentration in the milk, but the relationship failed to reach significance (p=0.08, Figure 10). There was no relationship between the casein to fat ratio and the yield of cheese.
4.8.4 - Discussion

Our results support the hypothesis of a relationship between milk composition and cheese outcome. However, the correlation for the Fetta cheese was weak, probably due to the small number of batches that were used to draw the correlation. Clearly, there is a trend of increasing yield when the casein/fat ratio approaches 1. This is supported by previous reports for cow's milk (Chapman, 1981; Banks et al 1981), and it suggests that sheep milk has an unfavourable casein/fat ratio. This finding supports the adoption of a share milking method as with this method the milk has a lower fat concentration.

Surprisingly, there was no correlation between the casein/fat ratio and the yield of semi mature cheese, which was instead correlated (but not significantly) with the protein concentration of the milk. While this could be due, again, to the small number of samples analysed, previous literature reports support the finding of contrasting results when comparing yields among different batches of cheese and ascribed these discrepancies to the concentration of ionic calcium in the milk (Banks et al, 1981). Calcium concentration affects the clotting properties of sheep milk (Bencini and Johnston, 1996) and it is possible that a significant correlation between casein/fat ratio and cheese yield could be found if a correction factor for calcium concentration could be introduced in the equation. Unfortunately, in our laboratory we cannot measure the concentration of calcium in milk.

4.9.1 - A study on the suitability of frozen milk to produce yoghurt out of season

Both in Australia and overseas (Bencini and Pulina, 1997) the sheep milking industry faces the problem of seasonality of production. Researchers overseas are working on breeding sheep out of season to allow for year round production. This problem is less felt in Australia where the local breeds are less seasonal than overseas breeds and advanced reproductive technology allows the breeding out of season of dairy sheep. However, even when sheep can be reproduced out of season lower quantities of milk are produced in summer. Therefore, sheep dairy manufacturers experience shortages of milk in the middle of summer, when the demand for fresh sheep milk yoghurt is at peak (Bencini and Dawe, 1998).

Italian literature (Ledda et al, 1992) suggests that frozen milk is suitable to produce dairy products provided it is of high microbiological quality, and British literature (Mills, 1989) suggests that frozen milk will keep for up to 6 months provided thawing occurs slowly.
We organised an experiment to test the hypothesis that Frozen milk is as good a substrate for yoghurt starter cultures as fresh milk so there would be no difference in the growth of yoghurt cultures and in the quality of the yoghurt produced between fresh and frozen milk.

Sheep milk yoghurt is particularly popular because of its high viscosity, which is perceived as thickness and creaminess by consumers (Voutsinas et al., 1996), so if the hypothesis was supported there would be no difference in the viscosity of the yoghurt and consumers would not find the yoghurt made with frozen milk different from that made with fresh milk.

Involved in this study were also two high school students, Alison Barker and from La Salle College and Leah Jennings from Wanneroo Senior High School, who had been granted awards under the CSIRO Student Research Scheme. This scheme allocated highly successful high school students to conduct small projects within existing research projects with the aim of encouraging young people to enter a career in science and related areas. Alison and Leah helped with the experiment and Alison was elected to present the results at the closing ceremony of the scheme, at Perth Scitech. This generated considerable interest for our project.

### 4.9.2 - Materials and methods

To test the above hypotheses five batches of yoghurt were produced from fresh milk and five were produced from frozen milk. The milk (both fresh and frozen) was pasteurised at 70°C for 20 seconds and analysed for fat, protein, lactose and total solids. A yoghurt starter culture (YC 180, 0.1g/L) was added to the milk and the milk was transferred to yoghurt pots that were incubated at 43°C. pH was checked every hour to follow bacterial development and the pots were removed from the incubator and placed in a refrigerator when pH reached 4.5.

The outcome of the yoghurt was determined objectively by measuring its viscosity with a Mettler RM 180 Rheomat. Subjective assessment of the experimental batches was obtained by panel testing of the batches. Panel members rated the batches on a scale of 1 to 5 for flavour, perceived acidity and perceived consistency. An analysis of variance of the time taken to reach pH 4.5, of the score awarded by panel members and of the composition and viscosity of the final product was used to compare batches made with fresh and frozen yoghurt.

### 4.9.3 - Results

There was no difference in the time taken to reach the desired pH, a sign that the starter culture was not affected by the use of frozen milk. There was no difference in panel assessment of the yoghurts, and panel members were unable to distinguish yoghurt made with fresh or frozen milk.
Figure 11. The viscosity over time did not differ for yoghurt batches made with fresh and frozen milk.

There was also no difference in the viscosity of the final product (Figure 11), showing that the inability of panel members to distinguish between batches corresponded to an objective similarity in consistency.

4.9.4 - Discussion

Our results clearly indicate that frozen milk can be successfully used by sheep dairy manufacturers to produce yoghurt out of season, as consumers find the product acceptable, and indeed they cannot distinguish it from that made with fresh milk.

Reports by Voutsinas et al (1996) that yoghurt produced from frozen sheep milk was of lower quality than yoghurt made with fresh milk were not supported by our results. However, Voutsinas et al (1996) used milk which had been concentrated by reverse osmosis and stored frozen while in our experiment we used whole sheep milk that had not undergone any treatments except for the freezing.

After this experiment was conducted Trevor Dennis at Cloverdene Dairy started freezing the excess milk produced during the winter months to process later, during the summer period. This allows him and his family to stop milking in summer and take a break.

Apart from the obvious need of taking holidays, if all sheep can be dried up on a dairy farm, even for a short period, this would allow a period of rest for the milking paddocks (for instance allowing to reduce worm burdens) as well as time to carry out maintenance work at the dairy.

The possibility of processing frozen milk could also save considerable sums of money currently spent to breed sheep out of season.

4.10.1 - Development of sheep milk ice-cream

Sheep milk ice-cream has the potential to be sold within Australia and to be exported to Japan. The Peters & Brownes Group already exports ice-cream to Japan, and Japanese consumers are very keen on Australian ice-creams and on novel high quality products. A major factor affecting the flavour and taste of ice-cream is the concentration of fat in the starting cream (Guinard et al, 1997). The minimum legal requirement in Western Australia for a product to be labeled as ice-cream is 10% fat. However, gourmet style ice-creams such as the Connoisseur contain up to 15% fat (S. Johnson Pers. Comm).

Sheep milk has a higher fat content that cow's milk (6-7% vs 3.5-4%), but the fat in sheep milk has a greater amount of short and medium chain fatty acids which are responsible for the particular flavour and aroma of sheep milk dairy product (Anifantakis, 1986). It was therefore necessary to establish the concentration of fat required in the cream used for sheep milk ice-cream production to obtain an acceptable ice-cream. We conducted an experiment in collaboration with the Peters & Brownes Group to determine:

a) the suitability of sheep milk to produce ice-cream
b) the effect of fat content on the quality of the ice-cream.

4.10.2 - Materials and methods

30 litres of sheep milk were pasteurized in our milk products laboratory. Then an Elecrem Armfield centrifuge was used to separate the milk fat from the skim milk. The skim milk and the
milk fat were mixed in various proportions to produce four different batches of cream containing 6, 10, 15 and 20% fat. The batches of cream were then processed into vanilla flavoured ice-creams at the Balcatta R&D Laboratory of the Peters & Brownes Group.

The exact procedure for making these ice-creams cannot be reported as it is confidential. Essentially, the sheep milk cream was added flavours and stabilisers and whipped at very low temperatures until it was frozen.

A panel of four experts from the Peters & Brownes Group tasted and assessed the ice-creams ranking them on a scale of 1 to 10 for aroma, colour, flavour, texture and also provided a mark indicating the comprehensive evaluation of the ice-creams. The ice-creams were then returned to The University of Western Australia and stored in the freezer, where we conducted a small non-expert panel assessment within the Animal Science Group.

4.10.3 - Results

All the batches of cream proved suitable for the production of ice-cream and no technical or manufacturing problems were observed.

Assessment of the ice-cream by the Peters & Brownes Group expert panel is shown in Table 6. There was no significant difference between ice-cream batches, even though the ice-cream made with 6% cream rated very poorly in the comprehensive evaluation.

Overall none of the ice-cream batches rated very well, and the aroma was disliked by most assessors. By contrast, a small group of people within our group tasted the ice-creams and concluded that they were very palatable.

Table 6. Average marks awarded to batches of sheep milk ice-cream by an expert panel. Values in brackets represent the standard errors.

<table>
<thead>
<tr>
<th>Fat % in cream</th>
<th>Aroma</th>
<th>Colour</th>
<th>Flavour</th>
<th>Texture</th>
<th>Comprehensive evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4.13</td>
<td>6.25</td>
<td>4.50</td>
<td>4.00</td>
<td>3.75</td>
</tr>
<tr>
<td>10</td>
<td>4.63</td>
<td>6.38</td>
<td>6.38</td>
<td>6.00</td>
<td>5.63</td>
</tr>
<tr>
<td>15</td>
<td>4.38</td>
<td>7.50</td>
<td>6.00</td>
<td>6.25</td>
<td>5.50</td>
</tr>
<tr>
<td>20</td>
<td>5.00</td>
<td>7.25</td>
<td>6.00</td>
<td>5.67</td>
<td>4.88</td>
</tr>
<tr>
<td>All batches</td>
<td>4.53</td>
<td>6.84</td>
<td>5.72</td>
<td>5.43</td>
<td>4.94</td>
</tr>
</tbody>
</table>

37
4.10.4 - Discussion

All batches of cream appeared to be suitable for the production of sheep milk ice-cream, and it is not possible to decide from these results what is the optimum fat concentration in cream to obtain good sheep-milk ice-cream.

The results of the panel assessment were disappointing and in contradiction with the assessment conducted within the Animal Science Group. This was probably to be expected from personnel who have always been working with cow's milk and may be biased against sheep milk. However, people in Animal Science may be biased in favour of sheep milk ice-cream. For this reason, another panel assessment should be conducted, this time with a random sample of people, if possible comparing sheep and cow's milk ice-cream in a blind test.

4.11.1 - Consumer acceptance of sheep milk dairy products

There is anecdotal evidence of the existence of local markets for sheep dairy products and that a share of these markets may be in the health food products. There is also a perception (M. Temby, Pers. comm.) that sheep milk products are preferred by the ethnic communities, in particular the Italian and Greek communities.

As with all new industries, the existence of markets for the products that are being developed is paramount for the success of the industry (Hyde, 1998).

We conducted a consumer survey in collaboration with Ms Sue Watts, from the Psychology Department, The University of Western Australia, to determine consumer's acceptance and possible retail prices for sheep milk cheeses in general and for the two cheeses developed within our project in particular. The aim of the survey was to establish:

1) If there are local markets for sheep milk cheeses
2) Who are the potential consumers
3) What are the prices they would be prepared to pay for sheep milk cheeses and in which quantity would they buy them
4) What other sheep milk dairy products are they likely to buy
5) What is their conception of sheep dairy products (health, gourmet or ethnic products) and therefore where would they expect to buy them (supermarket, delicatessen, health food shop).

4.11.2 - Materials and methods

Over 200 consumers were interviewed at Woolworths Supermarkets at six different locations (Ballajura, Cottesloe, Spearwood, Midland, Kingsway-Landsdale and Mount Hawthorn).

Participants were shown pictures of the two cheeses developed within our project and asked to rate them on a scale of 1 to 7. Then participants were asked to taste samples of the cheeses and rate them again. They were also asked if they had heard about sheep milk dairy products before, if they had tried them and if they were prepared to buy them and at what price and in what quantity. This was designed as a bidding process with prices starting from either end of a possible scale, and questionnaires were randomised in order not to bias the participants.

Participants were then asked how likely they would be to buy other dairy products (fresh milk, yoghurt and ice-cream) made with sheep milk and if they considered sheep milk products to be a
health food, a gourmet food or an ethnic food, and therefore would they expect to buy them in a supermarket, a delicatessen, a grower's market or a health food shop.

The participants were asked also demographic questions relating to age, education, occupation, household structure, income bracket and country of origin.

A sample of the questionnaire is attached (Appendix 1).

We would like to acknowledge the help and collaboration from the Woolworths supermarket chain. Their staff have been terrific in facilitating the conduct of the survey.

### 4.11.3 - Results

In total 142 females and 67 men were interviewed. This reflects the fact that often women do the shopping in Australian households. Of the respondents, 94 (44%) had heard of sheep milk cheeses before and only 24 (11%) had previously tried them.

When asked to predict how much they would like the cheeses developed within our project by examining a photograph of the cheeses, both cheeses achieved the same mark. The average mark (out of 7) was 4.1±0.32 for the semi mature cheese and 4.1±0.35 for the soft spreadable cheese.

When invited to taste the cheeses, only 15 people (7%) refused to try the hard cheese and 24 (11.5%) refused to try the soft cheese. Of these, 7 and 9 respectively would have tried the cheeses if they were made with cow's milk.

After tasting the cheeses, the average score rose to 4.7±0.37 for the hard cheese and to 5.5±0.29 for the soft cheese, an increase of 8.6 and 20% respectively.

A majority of consumers stated that they would be prepared to buy the cheeses: 87 (42%) would not buy a whole round of the hard cheese, but the remaining 58% would be prepared to pay an average of $17/kg for a whole round (±1.3). Only 29 (13%) stated that they would not be prepared to buy a slice of the cheese and the remaining 86% would be prepared to buy it for $21/kg (±1.02).

For the soft cheese, 54 (26%) would not buy a whole tray of cheese, but the rest (74%) would buy it for $30/kg (±0.91). 29 consumers (14%) would not buy even a small tub of the spreadable cheeses but the remaining 86% would be prepared to buy it for $32/kg (±0.8).

When asked how likely they were to purchase other sheep milk products 51% stated that they would buy fresh sheep milk, 61% stated that they would buy sheep milk yoghurt and 57% that they would buy sheep milk ice-cream.

When asked what they considered sheep dairy produce to be 130 (62%) responded that they considered it a health food, 133 (64%) considered it a gourmet food and 100 (47%) considered it an ethnic food. Most respondents expected to buy sheep dairy products in supermarkets (73%), delicatessen (78%) or health food shops (74%), while only 57% expected to find them in grower's markets.

### 4.11.4 - Discussion

The above data clearly indicates that there is a local market for sheep milk cheeses and that people are prepared to pay high prices for them. This confirms previous personal experience with Jumbuck Dairy, that the main problem was to process enough milk to satisfy the demand for sheep milk products. The soft spreadable cheese could be a particularly interesting option for sheep milk manufacturers as it has virtually no maturation time, which makes it similar to yoghurt and milk in terms of providing excellent returns from each litre of milk and cash flow for the enterprise.
The low rate of refusal to taste the cheeses supports the concept that consumers are not prejudiced against sheep milk and in fact are happy to try them if given a chance. It is also clear that after trying them, they liked both cheeses more than what they thought they would, and they liked particularly the soft spreadable cheese.

Our results also indicate that at least 50% of consumers or more are likely to purchase sheep dairy products, confirming that there are local markets for such products. The fact that most consumers expected to find these products in Supermarkets suggests that producers should process large amounts of milk to achieve the economies of scale to supply a supermarket chain. Although the survey was labour intensive and required a great organisational effort, its results are of paramount importance for the sheep milking industry. We can eventually say confidently that there are local markets for sheep dairy products and that consumers will pay high prices for these quality products.

4.12 - Milk-fed lambs

As outlined before, there is a limited market for milk-fed lambs in Australia. However, the establishment of such a market is essential if farmers want to milk sheep. Killing the lambs at birth is not an acceptable option, not only for the consumers, but also by some members of the industry.

Our project aimed at developing a viable method to wean the lambs and also tested the hypothesis that milk-fed lambs produce leaner carcasses than traditional prime lambs. If this hypothesis was supported, farmers would be able approach the National Heart Foundation to obtain their 'tick of approval', which should induce consumers to pay higher prices for milk-fed lamb.

4.12.1 - A cost analysis of artificial weaning

Artificial weaning of lambs involves the early separation of lambs from their mothers and the use of artificial feeders (e.g. Lambar) to wean the lambs. This process may continue until weaning or until slaughter age if lambs are to be sold as milk-fed lambs. In our first experiment half of the ewes were allowed to wean their lambs at 4 weeks of age and the other half were separated from their lambs two days after birth. We undertook an economic evaluation of these weaning methods to establish if artificial feeding has a role to play in the sheep milking industry.

4.12.2 - Materials and methods

The lambs born from the ewes used in our first experiment were the subjects of this study. 45 lambs were nursed by their mothers and 34 were artificially fed with a Lambar using the milk replacement Veanavite until slaughter age or weaning. The lambs were housed indoors when separated from their mothers and were offered a mixture of 60% oaten chaff, 30% lucerne hay and 10% cracked lupins as creep feed.

The Awassi lambs were returned to our industry partners, while the Merino lambs were slaughtered and sold as milk-fed lambs to an Italian butcher. Due to a serious human error at the abattoirs it was not possible to identify the carcasses to conduct an analysis of carcase composition of the two groups of lambs.

A comparative cost analysis of the two weaning methods was conducted.

4.12.3 - Results

Lambs that were fed artificially consumed an average of 12kg of Veanavite per head, for a total cost of $38 and the labour involved in the artificial weaning method costed about $25 per lamb (Table 7).
A high mortality of approximately 31% was observed in these lambs, but could not be ascribed to a particular pathology. A post mortem examination of one of these lambs was conducted by veterinarians at Murdoch University and it revealed that the lamb had died of starvation, having failed to obtain milk from the Lambar.

An analysis of costs and returns of our preliminary trial with the Italian butcher (Table 7) indicated that returns from milk-fed lambs do not compensate for the costs of the artificial weaning.

Table 7. Comparison of costs and returns of two lamb rearing techniques (on a dollar per lamb basis). The cost of artificial feeding is prohibitive, but the loss of milk incurred if lambs are nursed by their mothers is also considerable. (Table compiled with the co-operation of Ms V. Stewart, Department of Agricultural and Resource Economics, Faculty of Agriculture, The University of Western Australia).

<table>
<thead>
<tr>
<th>Item</th>
<th>Weaning method</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fed by ewe</td>
<td>Artificially fed</td>
</tr>
<tr>
<td>Milk replacer (Veanavite, 12kg/lamb @ $3.15/kg)</td>
<td>-</td>
<td>-37.8</td>
</tr>
<tr>
<td>Dry food (chicken pellets and chaff)</td>
<td>-7.5</td>
<td>-</td>
</tr>
<tr>
<td>Lost milk (28kg/lamb @ $1.10)</td>
<td>-30.8</td>
<td>-</td>
</tr>
<tr>
<td>Labour for artificial feeding (1.8hrs/lamb @ $13.80)</td>
<td>-</td>
<td>-24.84</td>
</tr>
<tr>
<td>Labour for feeding solid food (0.3hrs/lamb @ $13.80)</td>
<td>-4.14</td>
<td></td>
</tr>
<tr>
<td>Slaughter costs ($/lamb)</td>
<td>-11.8</td>
<td>-11.8</td>
</tr>
<tr>
<td>Price sold ($/kg carcase)</td>
<td>+15</td>
<td>+15</td>
</tr>
<tr>
<td>Net loss or income</td>
<td>-39.24</td>
<td>-59.44</td>
</tr>
</tbody>
</table>

4.12.4 - Discussion

It is evident from our cost analysis that the artificial feeding of lambs is prohibitive and that slaughter costs are not compensated by the returns from the sale of milk-fed lambs. This is probably due to the fact that the Merino lambs yielded very long and lean carcases and the butcher refused to pay us the price agreed initially. Discussion with the butcher convinced us that better results would have been achieved with crossbred lambs.

The above results also explain the decision made by many farmers to kill the lambs at birth: even when the lambs are fed by their mothers the loss in milk is such that lambs represent a net cost to the enterprise.

The fact that some lambs systematically failed to drink from the Lambar is also a problem. Some of these lambs were force fed with a bottle, but they succumbed during week-ends or busy periods when the labourers had less time to look after them.

The following studies aimed at addressing the above problems.
4.13.1 - Carcase composition of milk-fed lambs

Ms Fiona Shallcross, a fourth year student, attempted to address the problem of lambs in a dairy situation. She compared two different weaning methods and determined the carcase composition of milk-fed crossbreed lambs. Her study tested the hypothesis that milk-fed lambs have lean carcasses and compare favourably with traditional prime lambs.

4.13.2 - Materials and methods

30 Merino ewes were synchronised and mated to Dorset rams. 15 of the ewes were share milked, while the other 15 were allowed to nurse their lambs until slaughter age. Ms Shallcross compared the composition of the carcasses from lambs whose mothers were share milked versus lambs that were kept with their mothers until slaughter age.

During the study, Ms Shallcross measured the feeding pattern and milk consumption of the two groups of lambs. Feeding behaviour was studied by direct observation and counting of feeding episodes over a 24 hour period. The milk intake was measured by a weigh - suckle - weigh technique in which a selected number of lambs were allowed to nurse from their mothers at intervals similar to those observed in the previous exercise. The lambs were weighed on a precision balance immediately before and after each feeding episode and the amount of milk consumed was recorded.

After slaughter subcutaneous fat was measured with calipers and each carcase was frozen and divided in half. Each lamb half carcase was ground for the determination of carcase composition. The fat was extracted with a hexane: propanol (3:2) solution and measured by weighing the dry residue after the extraction. Protein was determined with a Leeko Nitrogen Analyser. Water and ash were determined by freeze drying and furnace incineration respectively.

4.13.3 - Results

There was no difference in the composition of the carcase from the two groups of lambs and both milking regimes resulted in the production of very lean carcasses (Table 8).

Growth rates attained by the lambs whose mothers were share milked were lower than those of lambs that remained with their mother all the time (p<0.005).

Table 8. Carcase composition (%) of lambs fed by their mother to slaughter weight (15kg) and lambs whose mothers were shared milked.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fat</th>
<th>Protein</th>
<th>Ash</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fed by ewes</td>
<td>15.0 ± 0.93</td>
<td>16.9 ± 0.42</td>
<td>4.3 ± 0.18</td>
<td>65.0 ± 0.74</td>
</tr>
<tr>
<td>Shared milked</td>
<td>13.5 ± 1.13</td>
<td>16.5 ± 0.52</td>
<td>4.6 ± 0.22</td>
<td>64.8 ± 0.89</td>
</tr>
</tbody>
</table>

The lambs whose mothers were share milked drank less frequently (every 84±5.1 minutes) and consumed less milk (609±57.4 g/day) than those that were together with their mothers all the time which drank every 62±5.4 minutes and consumed 891±100.7 g/day.
Mortality in both groups of lambs was very low and we only lost two lambs from the control group due to predation by foxes.

4.13.3 - Discussion

The result of this study supported the hypothesis that milk-fed lambs have lean carcasses and that lambs can be produced in a share milking regime in which their mothers are milked in a dairy situation. Although the growth rate of the lambs whose dams were share milked were lower than those of lambs who had continuous access to their mothers, their growth rates were comparable to those attained by lambs grown on a low plane of nutrition (Butler-Hogg, 1986). These results agree with those of Knight et al (1993) who found that share milking could be conducted without severely affecting the growth rate of the lambs.

The share milking method also resulted in low mortality of the lambs and longer lactations and greater lactation yields in the milking ewes. All of these results strongly support the adoption of share milking methods in Australian sheep dairies.

4.14.1 - Economic evaluation

As outlined in the introduction, we had involved a fourth year student, Mr Stuart Witham, to conduct an economic evaluation of sheep milking as an alternative to lamb and wool production. Mr Witham developed a model to evaluate gross margins of a sheep milking enterprise. This model was further developed by Mr Greg Hales from the Agricultural Economics Group (Faculty of Agriculture) who also produced a spreadsheet suitable for use by producers.

4.14.2 - Materials and methods

The methodology for this work was based on the use of gross margins to evaluate the profitability of a sheep milking enterprise. Gross margins are defined as the gross income from an enterprise over a 12 month period less the variable costs incurred. Variable costs are those costs directly attributable to an enterprise and vary in proportion to its size. Examples of these variable costs include drenches, vaccines, shearing costs, feed, etc.

The gross margin is not the gross profit as it does not include fixed or overhead costs such as interest payments, depreciation, rates and permanent labour that have to be met regardless of enterprise size.

A user friendly spreadsheet named "Sheep dairying gross margin calculator" was produced together with a user's manual.

These tools will allow current and potential sheep dairy farmers to investigate the impact of management decisions and market conditions on the gross margins generated by sheep dairying.

The gross margins calculated by our spreadsheet are based on a 'steady-state' situation, and do not include the capital costs involved in building a dairy and/or a sheep milk processing plant. Such costs can vary enormously and could not be built into our spreadsheet.

4.14.2 - Results

The "Sheep dairying gross margin calculator" and the user's manual are attached.

The spreadsheet revealed that the major cost of a sheep milking enterprise is represented by labour and that with current productions large numbers of sheep have to be milked as below a
certain number of sheep the enterprise will lose money. However, if breeds that are more productive can be milked sheep milking can be profitable.

The major source of profit comes from the sale of the milk and if higher prices for the milk can be obtained (for instance by vertical integration and on farm production of dairy products) the gross margin would increase.

4.14.4 - Discussion

The "Sheep dairying gross margin calculator" (see back of this report, disk is also enclosed) represents a major step forward for the industry when compared to published work that was impossible to apply to individual situations. For instance the Economics of sheep dairying chapter (Crean, 1992) of "Sheep dairying. The manual" reported a standard gross margin budget and allowed one column for farmers to calculate their own budgets. With our "Sheep dairying gross margin calculator" farmers will be able to change figures in the whole spreadsheet and to adapt the figures to their own situation. Since individual situations are likely to change not only between different producers, but also for each producer, with time, the "Sheep dairying gross margin calculator" will also allow producers to follow their ventures over time and to make corrections and adjustments to their budgets.

As mentioned above, our spreadsheet is based on a 'steady-state' situation, which does not include capital investment and relative interest. These should be taken into account if a producer is contemplating investing in a new dairy and /or a cheese factory.
5 General Discussion

The above results clearly indicate that our project has delivered a number of findings that will assist the establishment of a sheep milking industry in Australia.

The problem of the lack of a productive breed of dairy sheep was addressed by evaluating the dairy potential of the Awassi sheep. Unfortunately the outbreak of virulent footrot and the presence of high worm burdens prevented the animals in our care from expressing their full dairy potential and resulted in yields that would be commercially non-viable. However, Awassi cross sheep milked within our project consistently produced up to three times more milk than our control Merino ewes. If environmental constraints such as the footrot and the worms were not present and the Awassi crosses continued to produce three times more milk than the local breeds its production would be commercially viable.

Significantly, our project addressed the problem of the worms burden by demonstrating that Captec Extender 100 can be used safely on dairy sheep, a finding which should be of great benefit to the industry.

The problem of the lack of typical Australian sheep milk products was addressed by developing two new cheeses that were subsequently tested on a large sample of consumers demonstrating that there are strong local markets for specialty sheep milk products. Consumers are prepared to buy sheep milk products at high prices, which definitely should encourage dairy manufacturers to venture into sheep milk processing. Of the two new cheeses, the soft spreadable is particularly interesting due to its short maturation time, high yield and high returns.

Our results indicate that milk can be thawed and processed after freezing, a finding which should allow producers to address the problem of seasonality of production as well as saving labour costs.

The problem of the lambs has been addressed not only by establishing that milk-fed lambs are a lean meat that could get the tick of approval from the Heart Foundation, but also by developing a sustainable method to obtain both milk and lambs, the share milking method.

This method also causes the sheep to produce more milk over longer lactations, as well as to wean their own lambs at a fraction of the cost of artificial feeding, a fact that was not considered in previous studies (e.g. Dawe, 1990). The main criticism to this method may be that separating the lambs from the ewes is difficult and labour intensive. However, we have developed a self drafting gate that selectively allows the drafting of lambs with minimal fuss. We have also observed that lambs learn the drafting routine within a week and become very co-operative if fed creep feed when separated from their mothers.

Our research has shown that milk-fed lambs do not return high prices, but this could be because we could not reach an agreement with a local butcher. To support this, a local farmer has managed to establish a trade of milk-fed lambs with Perth restaurants and is making considerable profits.

Our project has also delivered a user friendly spread sheet that easily allows farmers to calculate the economics of a sheep milking enterprise. This represents a major break through compared with previously available literature.
6 Implications

Our project has major implications for the Australian sheep milking industry.

Our holistic approach has demonstrated to be successful by addressing together the many problems faced by the sheep milking industry. For instance our experiments on the share milking method addressed the management of a sheep dairy and the problem of how to wean the lambs at the same time. The result that share milking not only is a viable method to rear lambs but also results in higher yields of milk from the sheep could have not been achieved without our holistic approach.

The industry now has a viable method to rear lambs, two new breeds of dairy sheep, the Awassi and the East Friesian, two new cheeses that can fetch high prices on the local market, as well as the knowledge that local markets for sheep milk products exist, at least in Western Australia.

The results of our "Sheep dairying gross margin calculator" also provide a strong indication that sheep milking can be profitable.

7 Recommendations

Our results clearly indicate that producers milking sheep should discard the milk for at least a week to eliminate colostrum immunoglobulins, if they intend to milk sheep immediately after they lamb. Better still, they should adopt the share milking method which allows the production of both milk and lambs and also results in higher total lactation yields. Further research should investigate efficient methods of eliminating colostrum immunoglobulins from the milk.

This project showed that the Awassi sheep has greater milk productions and longer lactations than Merino sheep, but selection for dairy production should be an essential component of any sheep dairy enterprise. There is also a need to investigate the dairy potential of the newly imported East Friesian sheep.

Our consumers survey indicated the presence of local markets and the willingness of consumers to pay high prices for sheep milk products. However, promoting these products would be essential to make consumers aware of their existence. Only 11% of Western Australian consumers had tried sheep milk products before and only 44% had heard about them before despite media coverage of the industry. Clearly, consumers will not buy sheep milk products unless they are aware of their presence on the market. Personal experience with Jumbuck Dairy suggests that the best way to achieve this is promoting the products with tasting stalls in shopping malls, delicatessens and supermarkets. Such exercises are cost effective and once consumers learn about the products, they continue purchasing them.

Producers should plan carefully to achieve large volumes of production and economies of scale in order to supply the big supermarket chains where consumers are likely to purchase sheep milk products. A co-operative approach such as that adopted in New Zealand (Christiansen, 1980) should be considered seriously by potential producers.

The fact that sheep milk ice-cream was generally disliked by experts at the Peters & Brownes Group but liked by people in the Animal Science group should be further investigated to establish if a local market for such product could be established.

It is also recommended that further research be undertaken in the product development area, particularly to simplify the production and shorten the maturation time of semi mature cheese.

The "Sheep dairying gross margin calculator" is a powerful instrument that should be used by producers to predict the outcomes of management decisions and changing markets on the profitability of their enterprises. One obvious recommendation stemming from an examination "Sheep dairying gross margin calculator" is that profits from milk are of paramount importance and vertical integration could be used to increase returns from the milk. The soft cheese developed
within our project should provide excellent profits to a vertically integrated enterprise as well as to manufacturers of sheep milk products.

8 References


9 Appendix

Form used in a survey undertaken to establish consumers acceptance of sheep milk products (in general) and of two sheep milk cheeses developed within this project. The survey was designed by S. Watt, Department of Psychology, The University of Western Australia.

Each tasting stall is to be set up identically, and testing is to be conducted simultaneously at all locations.

Hello, I'm conducting a marketing survey of a new cheese product for The University of Western Australia. It takes just a couple of minutes to complete, and your answers will remain anonymous. Would you be so kind as to participate? (only interview participants aged over 17. If in doubt, ask their age).

☐ Yes ☐ No

☐ Male ☐ Female

1. **Have you ever heard of cheese made from sheep's milk?**

☐ Yes ☐ No

2. **Have you ever tasted sheep's milk cheese?**

☐ Yes ☐ No

We have two products, a hard sheep's milk cheese and a soft sheep's milk cheese.

*Show the participant a picture of the hard cheese and the soft cheese. The picture will indicate a small sample and a large sample of each (e.g., a complete round with a wedge cut from it, and a container of soft cheese, with some on a biscuit).*

*This is the first page of the booklet to be used in the survey. Each page of the booklet is A5 in size, and printed in landscape orientation, with ring binding on the long end. When opened the photo will be on the upper page, with a seven-point scale printed on the lower page. The scale has the anchors 1=not at all and 7=very much.*

*Show the participant the seven-point scale where 1=not at all and 7=very much.*

3. **On a scale of one to seven, how much do you expect you would like the hard sheep's milk cheese?**

☐

4. **On a scale of one to seven, how much do you expect you would like the soft sheep's milk cheese?**

☐

5. **Here's a sample of the hard sheep's milk cheese for you to taste.**
If refuses, ask:

6. Would you taste it if it were made from cow's milk?

☐ Yes  ☐ No

For those who taste the cheese, ask:

7. On a scale of one to seven, how much do you like the hard sheep's milk cheese?

Show the participant the seven-point scale, where 1=not at all and 7=very much.

☐

8. Here's a sample of the soft sheep's milk cheese for you to taste.

☐ Tastes  ☐ Refuses.

If refuses, ask:

9. Would you taste it if it were made from cow's milk?

☐ Yes  ☐ No

For those who taste the cheese, ask:

10. On a scale of one to seven, how much do you like the soft sheep's milk cheese?

Show the participant the seven-point scale, where 1=not at all and 7=very much.

☐

Show the participant the picture of the cheeses (used for question 3).

Point to the large portion of the hard sheep's milk cheese (an entire round) in the photo.

11. Would you buy the hard sheep's milk cheese in this quantity for:

$10?  ☐ Yes  ☐ No

$7?  ☐ Yes  ☐ No

$5?  ☐ Yes  ☐ No
Point to the small portion of the hard sheep’s milk cheese in the photo.

12. Would you buy the hard sheep’s milk cheese in this quantity for:

$10?  Yes ☐  No ☐

$7?  Yes ☐  No ☐

$5?  Yes ☐  No ☐

$3?  Yes ☐  No ☐

$1?  Yes ☐  No ☐

if it were free Yes ☐  No ☐

Point to the large portion of the soft sheep’s milk cheese in the photo.

13. Would you buy the soft sheep’s milk cheese in this quantity for:

$10?  Yes ☐  No ☐

$7?  Yes ☐  No ☐

$5?  Yes ☐  No ☐

$3?  Yes ☐  No ☐

$1?  Yes ☐  No ☐

if it were free Yes ☐  No ☐
14. **Would you buy the soft sheep's milk cheese in this quantity for:**

   $10?  & Yes & No  

   $7?   & Yes & No  

   $5?   & Yes & No  

   $3?   & Yes & No  

   $1?   & Yes & No  

   if it were free & Yes & No

*Turn to the next page of the booklet. Show the participant the seven-point scale, where 1=not at all likely and 7=definitely.*

On a scale of one to seven, how likely would you be to buy:

15. sheep's milk?  &  

16. sheep's milk yoghurt?  &  

17. sheep's milk ice-cream?  &  

18. **Would you consider sheep's milk cheese to be:**

   a health food?  & Yes & No  

   a gourmet food?  & Yes & No  

   an ethnic food?  & Yes & No  

19. **Would you expect to buy it in:**
a supermarket? [ ] Yes [ ] No

a delicatessen? [ ] Yes [ ] No

a grower’s market? [ ] Yes [ ] No

a health food shop? [ ] Yes [ ] No

Turn to the next page of the booklet. Show the participant the seven-point scale on its own, where 1=completely different and 7=the same.

21. On a scale of one to seven, how similar do you think sheep’s milk cheese is to goat’s cheese?

[ ]

Hand the participant the booklet for demographic details

The following questions will allow us to work out which groups of people are most likely to be interested in buying sheep’s milk products.

22. Which age group do you fall into (a through g)? [ ]

23. Which educational group do you fall into (a through g)? [ ]

24. Do you have a job? [ ] Yes [ ] No

If “Yes”, go to question 26. Make sure they skip one page on the booklet, and turn to the occupational groups page.

Otherwise, make sure they are looking at the activities card in the booklet, and ask:

25. Which of these categories best describes you (a through d)? [ ]

26. Which occupational group do you fall into (a through h)? [ ]

27. What is the structure of your household (a through i)? [ ]
28. Which bracket would the combined income of your household fall into (a through g)?

29. Which country were you born in?

That completes the survey.

SHEEP DAIRYING
GROSS MARGIN CALCULATOR

User's Manual

By
Greg Hales
Agricultural and Resource Economics
and
Roberta Bencini

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Introduction

This chapter provides a brief introduction to Sheep Dairying and an overview of the Sheep Dairying Gross Margin Calculator.

Producers experiencing decreases in profitability due to increased costs and greater competition for markets may seek to diversify their enterprises. Traditional agricultural products are very volatile in price, due to the large fluctuations in demand and supply. Sheep dairying has the potential to allow producers to diversify to minimise these risks.

The methodology of the present analysis was based upon the use of gross margins. These gross margins can be used to compare the ‘profitability’ of a sheep milk enterprise to that of other agricultural enterprises, or to compare different management scenarios within an enterprise. Gross margins are the gross income from an enterprise over a 12 month period less the variable costs incurred. Variable costs are those costs directly attributable to an enterprise and which vary in proportion to the size of an enterprise. Examples of these variable costs include drenches, vaccines, shearing costs, feed, etc.

The gross margin is not the gross profit as it does not include fixed or overhead costs such as interest payments, depreciation, rates and permanent labour which have to be met regardless of enterprise size.

The gross margins presented are based on 'steady-state' situations, and exclude the substantial capital costs involved in building a sheep dairy and/or a sheep milk manufacturing facility. This must be considered when comparing these gross margins to the returns from other sheep enterprises.
What is the Sheep Dairying Gross Margin Calculator?

The Sheep Dairying Gross Margin Calculator is a static bioeconomic model. It allows users to simulate their individual farm conditions to gain information on the gross margin they could expect from a sheep dairying enterprise. The flexibility of the Sheep Dairying Gross Margin Calculator permits current and potential sheep dairy producers to investigate many scenarios of adoption for sheep milking. This makes it suitable for new entrants to the industry, established farmers who wish to diversify, and even established sheep dairy operators who wish to expand or predict the effect of management decisions and market conditions on their gross margins.

The Sheep Dairying Gross Margin Calculator uses arithmetic to estimate a gross margin for each user-defined scenario. This calculated gross margin can then be compared to other enterprises. Additionally, two spreadsheets for the determination of capital return from their initial investments, and for the determination of the minimum amount of pasture needed for the sheep dairying enterprise are included.

The Sheep Dairying Gross Margin Calculator uses a system which includes costs and income related to milk, wool and meat. All calculations are completed within this system, however the user may not require all of these options.
Model Overview and Basic Assumptions

The methodology behind this model is based on the use of gross margins. The gross margin is not the gross profit as it does not include fixed or overhead costs such as interest payments, depreciation, rates and permanent labour which have to be met regardless of enterprise size.

• The gross margins presented are based on 'steady-state' situations, and exclude the substantial capital costs involved in building a dairy and/or a sheep milk manufacturing plant.

• The flexibility of the model allows users to apply it to their own individual situations. Therefore the model is not limited to a particular region or market situation. Default values are given based on current information. These may be updated accordingly.

• The main output is the estimated gross margin from a sheep dairy enterprise. These results are given on the basis of Gross Margins (GM) per hectare (GM/ha), per ewe (GM/ewe) and per Dry Sheep Equivalent (GM/DSE).

• The model is deterministic and it does not represent variations in costs and revenues. Users are encouraged to alter parameters to get a feel for these variations.

• Users are advised to be careful when modelling their individual scenarios to prevent double counting. For example, the costs of additional labour units may not be needed for the whole year (for instance if casual labourers are employed only during peak periods). Additionally, some husbandry costs may not be required every year.

Fixed costs are not included
Model Basics

*Using the Sheep Dairying Gross Margin Calculator.*

First, users should open the file on their computer. To do this they will need to have Microsoft Excel 5 or a later version such as Office 98 installed on the computer. Then simply open the file supplied on the floppy disk.

Sheep Dairying Gross Margin Calculator will open onto the 'Title' sheet. The sheets that follow are broadly split into two groups: input sheets and output sheets. Data is entered into the input sheets and the results are given in the output sheets.

- The **Results Sheet** provides a quick and easy method to alter key values of the enterprise under investigation and provides the estimated Gross Margins.

- The **Data Values Sheet** allows the user to define biological and economic data values. The current version of the spreadsheet already contains default values.

- The revenues calculated from the input sheets are presented in the **Revenues Sheet** for each of the 3 main products (milk, wool and sheep) providing revenue for the enterprise.

- In the **Costs Sheet**, calculation of the total variable costs are conducted by partitioning these costs into costs related to the dairy, to the sale of products and to the husbandry. User defined inputs can also be entered in this sheet.

- In the **Land Sheet**, the minimum amount of pasture land which will be required to operate the dairy is calculated based on the DSE of the farm.

- The **Return sheet** calculates the capital return on the establishment costs for the dairy. The flexibility of this spreadsheet allows users to simulate different scenarios.
Running the Sheep Dairying Gross Margin Calculator

- Firstly, change any of the default values that need to be altered to suit the individual situation. Values may need to be changed on both the Data value and Costs Sheets.

- Next return to the Results Sheet and start analysing different scenarios by changing the major variables on this sheet.

- The Results Sheet displays the estimated Gross Margin on hectare, ewe and DSE units. To find a more detailed result review the other output sheets.

- Note that Labour costs account for a large percentage of the costs for the dairy and as such conservative estimates of flock size should be used. Labour costs are entered on the Data Value Sheet and should be altered accordingly to reflect the type of dairy and management practices to be investigated.
Explanation of Sheets

A sheet by sheet review of the Sheep Dairying Gross Margin Calculator.

All spreadsheets are formatted similarly. Only the boxes shaded in yellow may be changed by the users. All the Blue cells are protected from change as they contain formulas for the calculations.

Results Sheet

This sheet gives the gross margin returns on a per hectare, ewe and DSE basis. Changing input boxes on this sheet allows the user to examine the effect of the change on the Gross Margin of the enterprise.

The first box allows the user to simulate the volatility of the market price for milk. Reasonable returns may be between $1 to $1.30 per litre.

The next box allows the user to alter the average production on a ewe per lactation basis. This figure will depend on the breed of sheep milked, but may be increased through flock selection and breeding.

The last box allows the user to alter the size of the milking flock. This will be linked to the design of the dairy parlour and to the availability of labour. Note that labour requirements are changed on the Data Values Sheet. The returns on the capital investment in the establishment costs are determined on the Return sheet.

The Data Values Sheet allows to input the major costs and revenues to the enterprise. This sheet is partitioned into the Biological and Economic components.
**Biological**

Biological information is entered by the user. These inputs relate to the user’s particular situation, mainly to the genetics of the sheep and local husbandry practices.

**General**

Input the lambing rate, number of wool clips per year and the number of rams to include in the enterprise.

**Wool produced**

Input the wool produced by the flock.

**Flock control**

Flock control inputs should be set to a closed flock to allow for the steady-state condition of the enterprise. Lambs and Cull For Age (CFA) rams (10%) are calculated automatically by the spreadsheet. The number of replacement lambs is set at one third of the flock plus 5% per annum. Default values are given for CFA (13%) and cull (14%) ewes.

It may be necessary to cull heavily for milk production over the first number of years. By varying these inputs, users can observe how this will affect their enterprise.

**DSE Ratings**

Input the DSE rating of the flock here. These are used to calculate the gross margins on the results sheet.

**Feed supplements**

Supplement feeding will depend on individual farm practices and location. However, feeding in the parlour is commonly used to calm the milking ewes.

The default values of feeding 0.3 kg/head/day for 200 days is the average over the year and includes supplementary feeding to the pregnant ewe.

**Economic**

Economic Information is entered here by the user. These inputs will depend on the individual situation.
General
These costs account for a major proportion of the enterprise. The costs of pasture
maintenance and labour are large and will require tight management. Input the values for
these costs and the number of full-time additional labour units required. If using casual
labour for only part of the year, modify the figure accordingly. Price of ram replacements
will depend on the breed.

Wool produced
Input the wool prices received from the farm in $/kg greasy for each component of the flock.

Flock control
Flock price inputs will depend on market rates and location. Ewe and ram prices can be
estimated by recent prices.
Selling of the milk-fed lambs will be user specific and may require marketing as no
established markets exist.

DSE Ratings
Input the DSE rating of the farm here. This is used to calculate the financial returns and
amount of required land for the enterprise.

Feed supplements
The cost of supplement feeding is entered here. The default value is 0.3 kg head$^{-1}$ day$^{-1}$ of
lupins for 200 days at $170$ ton$^{-1}$. This is the current price of lupins, which are commonly
used in Western Australia.

Costs Sheet

The Costs Sheet allows the input of other costs relevant to the enterprise. This sheet is
partitioned into dairy, selling and husbandry costs.

Dairy costs
Information provided on the Results and Costs Sheets are automatically entered into this
section. The user should input here the hygiene and dairy operating costs. While some dairy
costs are already included in the spreadsheet, it is possible for users to include other costs as
they require.
Selling costs
Selling costs relate to the three main products of the enterprise and include the storage, transportation and fees for each. Some of the levies and charges will remain the same for each farm location (i.e. insurance, commissions, etc.), while costs relating to storage and cartage will be site specific.

Animal Husbandry costs
All husbandry costs are included here. The spreadsheet allows users to input their costs for the care and health of the sheep. These include shearing, crutching, drenching, marking, mulesing, pregnancy testing and vaccines. If a particular practice is not conducted on the farm, a value of zero should be set.

Ram replacements
The costs for ram replacements is transferred from the Data Sheet.

Land Sheet

The Land Sheet calculates the amount of pasture land that will be required by the flock size under consideration and the DSE of the farm. The total area (hectares) that is calculated by this spreadsheet will enable users to decide the functionality of the size of the enterprise under consideration. Users should be aware that this calculated number does not include the land required for buildings, sheep runs or holding yards.

Establishment Costs Sheet

The Establishment Costs Sheet allows users to calculate the financial return on the capital invested into the enterprise. The spreadsheet calculates the return on capital investment by dividing the Gross Margin of the enterprise, by the capital investment. This is only an indication of the return on investment as the Gross Margin does not include fixed costs.

Users should input their establishment costs in the relevant section. These include the land and ewes required and the costs associated with the dairy itself. Only purchase prices need to be included in the spreadsheet.