Marketable products from sheep milk

A report for the Rural Industries Research and Development Corporation

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Sheep milking in Australia started in the 1960s by some farmers seeking to diversify from the traditional productions of wool and prime lambs. Since then, many enterprises have initiated sheep milking ventures with mixed fortunes. The Australian sheep milking industry is still not established despite potential markets and high farm gate prices for the milk.

Through consultation with industry and years of research in this area, at The University of Western Australia, we identified prior to this project the major reasons for this. We believe that these were:

1) The lack of specialised breeds of dairy sheep
The recently imported Awassi and East Friesian sheep are reported to be the highest milk producers in the world (Epstein, 1985; Anifantakis, 1986a) and have the potential to change this situation dramatically.

2) The lack of typically Australian dairy products made with sheep milk
There are local markets for sheep dairy products (Bencini, 1999), but both products and markets need to be developed, possibly in collaboration with industry.

3) The lack of outlets for the lambs
This problem was addressed in a previous report (RIRDC Publication 99/069) which highlighted the need to develop markets for milk fed lambs and the adoption of share milking methods (Bencini, 1999).

The present report focuses on the first two problems and reports on results obtained investigating them.

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

This report, a new addition to RIRDC’s diverse range of over 800 research publications, forms part of our New Animal Products R&D program, which aims to facilitate 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
- purchases at www.rirdc.gov.au/eshop

Simon Hearn
Managing Director
Rural Industries Research and Development Corporation
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This project has been extremely hard work. I have to thank all the people that gave their time, often overworked and underpaid, to help get the sheep milking industry off the ground:

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Peter Cowl, Shenton Park Field Station Animal Facilities Manager
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Cliff Tarry, Managing Director, Casa Dairy Products
Jane and Bruce Wilde, Jarrah-Lee Springs East Friesian Sheep Stud, Nannup (WA)
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>iii</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>iv</td>
</tr>
<tr>
<td>Executive Summary</td>
<td>vi</td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Objectives</td>
<td>2</td>
</tr>
<tr>
<td>3. Methodology</td>
<td>3</td>
</tr>
<tr>
<td>3.1 - Location and animals</td>
<td>3</td>
</tr>
<tr>
<td>3.2 - Management of the animals</td>
<td>3</td>
</tr>
<tr>
<td>3.3 - Measurements of production and composition of milk</td>
<td>4</td>
</tr>
<tr>
<td>3.4 - Product development</td>
<td>4</td>
</tr>
<tr>
<td>3.5 - Statistical analyses</td>
<td>5</td>
</tr>
<tr>
<td>4. Experimental</td>
<td>6</td>
</tr>
<tr>
<td>4.1 Dairy potential of imported breeds</td>
<td>6</td>
</tr>
<tr>
<td>4.2 Dairy Sheep Management</td>
<td>9</td>
</tr>
<tr>
<td>4.3 Product development</td>
<td>11</td>
</tr>
<tr>
<td>4.4 Processing performances of sheep milk</td>
<td>15</td>
</tr>
<tr>
<td>4.5 Cheese maturation studies</td>
<td>20</td>
</tr>
<tr>
<td>4.6 Sheep milk ice cream</td>
<td>24</td>
</tr>
<tr>
<td>4.7 Use of cardoon rennet</td>
<td>26</td>
</tr>
<tr>
<td>5. General Discussion and implications</td>
<td>33</td>
</tr>
<tr>
<td>6. Recommendations</td>
<td>34</td>
</tr>
<tr>
<td>8. References</td>
<td>35</td>
</tr>
<tr>
<td>9. Appendix</td>
<td>37</td>
</tr>
</tbody>
</table>
Executive Summary

This project addressed two of the three main problems faced by the emerging sheep milking industry in Australia. These were identified as (Bencini, 1999):

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

2) A lack 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 to a collaboration between The University of Western Australia and Charles Sturt University, we conducted research on the two 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, 1986a), 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 East Friesian sheep and its crosses with the Awassi and the Merino sheep to establish the genotype that had the best potential for dairy production.

Throughout the course of two lactations, we measured the production and composition of milk from East Friesian x Awassi, East Friesian x Merino, Awassi, Awassi x Merino and Merino ewes. Our results indicated that the East Friesian x Awassi is very suitable to produce milk as it produced more than all the other genotypes, at least in their second lactation. We have also found significant differences in the composition of the milk from these different crosses, and this may have important processing implication as most of the sheep milk produced in Australia is transformed into cheese.

We also investigated the role of the let-down hormone, oxytocin and the presence of lambs (share milking) on milk production and milk composition. Results confirmed previous findings (Bencini, 1999) that sheep that are allowed to nurse their lambs while they are milked do not produce less milk than sheep that are separated from their lambs at birth. The share milking method therefore has the advantage that ewes feed their own lambs, and the enterprise does not have to face the prohibitive costs to feed the lambs artificially.

2) A lack typical Australian sheep milk products.

It has been established that it is not economically viable to attempt to imitate famous imported cheeses such as the Roquefort, Fetta and Pecorino (Bencini, 1999).

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 typical Australian sheep dairy products.

Our project addressed the need to develop new dairy products made with sheep milk by developing a mould-ripened Camembert style cheese (at The University of Western Australia), and a Pecorino style cheese made with cardoon rennet (at Charles Sturt University). Both cheeses were well received by semi-trained panels and consumer panels. The mould-ripened cheese has a short maturation time and this is a desirable characteristic for sheep milk manufacturers.

We also tested methods to accelerate or modify cheese maturation methods by adding lipase, adjunct cultures and vacuum packaging. The cheeses produced with these different methods were assessed by a semi-trained panel, and all of them resulted to be less acceptable than control cheese made without lipase, adjunct cultures or vacuum packaging. These results suggest that in the development of novelty sheep milk cheeses, producers should consider the use of traditional maturation methods, as the resulting cheeses seem more acceptable to consumers.
We also investigated consumer acceptance of sheep milk ice creams developed in collaboration with the Peters & Brownes Group. A small sample of volunteers was interviewed and compared low fat and full cream sheep and cows’ milk ice creams in a blind test. Results showed that the consumers could detect the low fat ice creams and gave them a lower score. Disappointingly, consumers were not prepared to pay higher prices for sheep milk ice creams compared to cows’ milk ice creams. This suggests that, although the local market may be receptive to sheep milk ice-cream, the prices that consumers may be prepared to pay for it do not warrant its production. However, only a small sample of consumers could be interviewed, and it is possible that markets for sheep milk ice cream could be developed overseas.
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 sheep dairies (Dawe, 1990). Compared to cow's milk, sheep milk produces cheeses of higher yield, whiter colour, richer taste and better nutritional quality (Kalantzopoulos, 1999). Therefore, the development of sheep milk cheeses suitable for Australian consumers would increase the variety and quality of cheeses consumed in the diverse Australian market.

The existence of potential local market for sheep milk products has been confirmed by research funded by the RIRDC (Bencini, 1999), but despite this the Australian sheep milking industry is still small. This may be due in part to the fact that returns from the sale of lambs have recently soared due to the animal industries crisis experienced in the rest of the world.

At The University of Western Australia, we have been researching the three main problems faced by the fledgling sheep milking industry, as outlined below.

Firstly, until recently Australia did not have specialised breeds of dairy sheep. Local breeds of sheep produce less than 100 litres of milk per lactation, a level of production that is not profitable (Bencini and Dawe, 1998). Milk production is a trait only expressed by ewes, and genetic improvement for milk production can only be achieved through progeny testing schemes similar to those used in dairy cattle and overseas dairy sheep. This idea has now been pursued by the RIRDC, with a tender awarded to Emeritus Professor DR Lindsay to investigate the feasibility of such schemes for the Australian sheep and goat milking industries.

The low productivity of the local breeds could be addressed immediately by importing specialised dairy breeds of sheep from overseas. This was the aim of the recent importation Awassi and East Friesian sheep, two breeds that have the highest production of milk in the world (Epstein, 1985; Anifantakis, 1986a). These two breeds have the potential to increase yields and make sheep milking economically viable. 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 also expensive, farmers are likely to milk the crosses of these breeds with local sheep. We undertook an evaluation of the Awassi sheep and it crosses with local breeds in our previous project (Bencini, 1999). This project aimed at evaluating the dairy potential of the East Friesian sheep and its crosses under Australian conditions. We also aimed at evaluating the cross between the East Friesian and the Awassi, as this was the basis for the establishment of the famous breed Assaf, currently milked in Israel. This was also a unique opportunity as we are the only research organization in Australia to have access to both Awassi and East Friesian genetics.

Problems in processing performance of the milk in early lactation have been reported by sheep milk producers and manufacturers. These could be due to the presence of colostrum immunoglobulin that we have found can persist for up to nine days in the milk of sheep that were separated at birth from their lambs (Bencini, 1999). Therefore we investigated different weaning and mother/lams separation techniques and tested their effect on the composition of the milk.

The second problem faced by the Australian sheep milking industry is represented by the need to develop new typical Australian sheep milk products. Attempts at imitating imported overseas cheeses such as the famous Pecorino and Fetta may fail because these cheeses are protected by tariffs and DOC trademarks, or suffer from serious competition from cheap cow's milk imitations. A viable sheep milking industry could be established only by developing typical Australian sheep milk products. Our project aimed at developing new sheep milk specialty cheeses that would be acceptable to Australian consumers. At UWA we concentrated on the development of mould ripened cheese (Camembert style), while at CSU we worked on the use of vegetable rennet from cardoon plants (Cynara cardunculus) to produce specialty cheeses.
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
  - East Friesian x Awassi sheep
  - East Friesian x Merino sheep

- Researching on management techniques for milking ewes and their effect on milk composition

- Developing specialty cheeses made from sheep milk based on
  - mould ripening processes (Camembert style)
  - use of vegetable rennet to clot the milk.

- Assessing the consumer acceptance of sheep milk ice creams developed in collaboration with the Peters & Brownes Group.
3. Methodology

3.1 - Location and animals

Most of the experimental work for this project was conducted at The University of Western Australia’s Shenton Park Research Station, Floreat, where the animals were kept in paddocks. Laboratory work was conducted in the Dairy Products Laboratory in the School of Animal Biology at The University of Western Australia.

Australian Merino Society (AMS) Merinos were sourced from Allandale (Wundowie, WA), 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 East Friesian x Awassi cross ewes and Awassi x Merino 7/8 and 15/16 cross ewes. These sheep came from Avonlea Farm, (Bolgart, WA).

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, 1985). 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).

The East Friesian crosses were produced within the project from semen donated by the industry partners Silverstream (Dunedin, NZ) and Jarrah Lea Springs (Nannup, WA).

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 and subterranean clover and had meadow hay available ad libitum. They received up to 1 kg of lupins/head (392 g/kgDM protein, 21 MJ/kgDM energy) daily and at each milking, they were given approximately 300g of a mixture of 70% oaten chaff, 30% lupins, 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 in an outdoor pen when separated from their mothers and were offered a mixture of 60% oaten chaff, 30% lucerne hay and 10% cracked lupins (creep feed).

Milking - A 12 bay rapid exit milking parlour was purchased from Prattley (Temuka, NZ) with funds provided partly by the RIRDC and partly by The University of Western Australia (Figure 3.2.1). Entry and exit ramps for the platform were built at the workshop of the faculty of Agriculture at The University of Western Australia. 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 (Alfadyne Teat Sanitiser, 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 58 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.

Samples of milk were collected from the Tru Test jars, stored at 1-4°C and analysed with a Milko Scan 133 (Foss Electric, Denmark) calibrated for sheep milk. This is a single-beam infrared 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 constant mineral bias of 0.79%.

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 - a thermostated incubator of approximately 80L capacity was used to incubate dairy products such as yogurt, cheese, etc
- Disc Bowl Centrifuge - An Armfield disc bowl centrifuge was purchased for the project to allow separation of milk fat. This was used 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 was used to pasteurise the milk prior to processing at a temperature of 72°C for 20 seconds.

• Milko Scan 133 – described above, was used for analysis of milk composition before the milk was transformed into dairy products.

• Lattodinamografo or lactodynamograph (Foss Electric, Italy) - This instrument was used to measure the clotting properties of the milk. These were the renneting time, r, or time it took for the milk to clot, the rate of curd formation, k20, which is the time it took for the clotting milk to reach a standard consistency of 20mm and the consistency of the curd, A30, which is the distance between the two arms of the lactodynamograph output (Bencini, 2002).

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)
• Clotting properties of the milk (renneting time, r, minutes; rate of curd formation, k20, minutes and curd consistency, A30, mm).
• 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 assessed by panel tasting by semi-trained panels.

3.5 - 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 (SuperANOVA, Abacus Concepts, 1991) and effects were assumed to be significant when the level of probability was 5% or less. Analysis of covariance was conducted on lactation data to take into account the effect of stage of lactation.

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

4.1 Dairy potential of imported breeds

Our experimental work addressed the lack of a productive breed of dairy sheep as well as the development of new sheep milk dairy products. We conducted a series of experiments to evaluate the dairy potential of the East Friesian crosses with the Awassi and the Merino breeds and to develop specialty cheeses suitable for Australian consumers.

4.1.1 - Dairy Production of East Friesian x Merino and East Friesian x Awassi ewes

The lack of productive breeds of dairy sheep has been a hindrance to the establishment of a sheep milking industry in Australia (Bencini and Dawe, 1998). The recent importation of Awassi and East Friesian sheep may change this situation. So far we have assessed the dairy potential of the Awassi sheep and we have shown that Awassi sheep produce more milk and have longer lactations than local sheep (Bencini, 1999). However, even milking Awassi sheep may not be the ultimate solution to the problem, and improving the genetic basis of the sheep milking flock was identified as a key strategy at a recent sheep milk workshop organised by the RIRDC (P. McInnes, Pers. Comm). Therefore testing new genotypes of sheep such as the East Friesian is of paramount importance for the industry. At The University of Western Australia, we are in the unique position of having access to the genetic material of both East Friesian and Awassi ewes. We have crossed the East Friesian with the Awassi (a cross that formed the basis for the famous Assaf sheep currently milked in Israel) and with the Merino (a cross that would be readily available to farmers willing to milk sheep). In 2000, we started milking these crosses to test the hypothesis that the East Friesian crosses would produce more milk than Merino sheep. Two subsequent lactations were monitored in 2000 and 2001.

4.1.2 - Materials and methods

2000 lactation

In 2000, we milked a flock of 28 Awassi, 8 East Friesian x Awassi, 6 East Friesian x Merino and 9 Merino ewes. Low numbers for some of the genotypes were due to poor conception rates. The ewes lambed in June-July 2000 and were milked twice a day in our milking parlour. Milk production and composition were assessed at weekly intervals, except towards the end of the lactation when we adopted testing at two weekly intervals. Production and composition data were analysed by one way ANCOVA (SuperANOVA, Abacus Concepts, 1991), where the main effect was the genotype and the covariate was the week of lactation. Fisher’s protected LSD tests were adopted to compare the differences in milk production and composition between genotypes.

2001 lactation

In 2001, we milked a flock of 19 Awassi, 9 East Friesian x Awassi, 7 Awassi x Merino, 16 East Friesian x Merino and 24 Merino ewes. Low numbers for some of the genotypes were, again, due to poor conception rates. The ewes lambed between June and September 2001 and were milked twice a day in our milking parlour. Milk production and composition were assessed at weekly intervals until the peak of lactation was reached. After the peak, we adopted testing at two weekly intervals. Production and composition data were analysed by one way ANCOVA (SuperANOVA, Abacus Concepts, 1991), again using the genotype as the main effect and the week of lactation as the covariate. Fisher’s protected LSD tests were adopted to compare the differences in milk production and composition between genotypes.
4.1.3- Results

2000 lactation

The Awassi and the East Friesian x Awassi ewes had longer lactations than the East Friesian x Merino and Merino ewes (Figure 4.1).

The Awassi ewes produced twice as much milk than the Merino ewes (Table 4.1). There was no difference in production between the East Friesian x Awassi and East Friesian x Merino ewes, but both produced significantly more milk than the Merino ewes.

The concentration of protein did not differ between genotypes, but that of fat was significantly greater in the East Friesian x Awassi and Awassi genotypes. By contrast, there was no difference in the fat concentration in the milk of East Friesian x Merino and Merino ewes (Table 4.1.1).

![Figure 4.1.1. Milk productions (g/day) of Awassi, East Friesian x Awassi (EF x A), East Friesian x Merino (EF x M) and Merino ewes](image)

Table 4.1.1. Production of milk (g/day) and concentrations of protein and fat (%) from Awassi, East Friesian x Awassi, East Friesian x Merino and Merino sheep over the course of the lactation. Data are Means ± SE. Different letters indicate a significant difference (p<0.05) between means.

<table>
<thead>
<tr>
<th>Genotype (number of sheep)</th>
<th>Milk yield (g/day)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awassi (28)</td>
<td>672 ± 18.9 (a)</td>
<td>5.2 ± 0.24</td>
<td>6.7 ± 0.09 (a)</td>
</tr>
<tr>
<td>East Friesian x Merino (6)</td>
<td>514 ± 36.1 (b)</td>
<td>4.8± 0.08</td>
<td>5.2 ± 0.17 (b)</td>
</tr>
<tr>
<td>East Friesian x Awassi (8)</td>
<td>397 ± 30.9 (c)</td>
<td>4.9 ± 0.15</td>
<td>6.5 ± 0.27 (a)</td>
</tr>
<tr>
<td>Merino (9)</td>
<td>291 ± 25.1 (d)</td>
<td>4.9 ± 0.13</td>
<td>5.1 ± 0.26 (b)</td>
</tr>
</tbody>
</table>
2001 lactation

The 2001 lactation proceeded until the end of January 2002. Some East Friesian x Awassi ewes were still producing over a litre of milk/day and had to be dried up by drastically reducing the milking frequency. The East Friesian x Awassi ewes produced almost twice as much milk as the Awassi ewes and three times as much milk as the merino ewes (Figure 4.2.1).

![Figure 4.1.2.](image)

Figure 4.1.2. Milk productions (g/day) of Awassi, Awassi x merino (A x M), East Friesian x Awassi (EF x A), East Friesian x Merino (EF x M) and Merino ewes. The curve is quite truncated for the East Friesian x Merino ewes because a few of them were still producing over a litre of milk/day and had to be dried off rapidly by reducing the frequency of milking.

The Awassi, Awassi x Merino and Merino genotypes had significantly greater concentrations of protein in their milk (p<0.05; Table 4.1.2). The concentration of fat was significantly lower in the milk from the Merino and East Friesian x Merino sheep that in the milk from East Friesian x Awassi and Awassi x Merino ewes. Pure Awassi ewes had the greatest concentration of fat in their milk (p<0.05; Table 4.1.2).

Table 4.1.2. Production of milk (g/day) and concentrations of protein and fat (%) from Awassi, East Friesian x Awassi, East Friesian x Merino and Merino sheep over the course of the lactation. Data are Means (± SE). Different letters indicate a significant difference (p<0.05) between means.

<table>
<thead>
<tr>
<th>Genotype (number of sheep)</th>
<th>Milk yield (g/day)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Friesian x Awassi (9)</td>
<td>979 ± 38.7 (b)</td>
<td>4.8 ± 0.04 (a)</td>
<td>6.0 ± 0.13 (a)</td>
</tr>
<tr>
<td>Awassi (19)</td>
<td>589 ± 25.7 (a)</td>
<td>5.1 ± 0.05 (b)</td>
<td>6.3 ± 0.12 (b)</td>
</tr>
<tr>
<td>East Friesian x Merino (16)</td>
<td>445 ± 21.8 (c)</td>
<td>4.8 ± 0.05 (a)</td>
<td>5.3 ± 0.11 (c)</td>
</tr>
<tr>
<td>Awassi x Merino (7)</td>
<td>383 ± 21.0 (c)</td>
<td>5.3 ± 0.07 (b)</td>
<td>5.9 ± 0.023 (a)</td>
</tr>
<tr>
<td>Merino (24)</td>
<td>267 ± 11.0 (d)</td>
<td>5.0 ± 0.05 (d)</td>
<td>5.2 ± 0.14 (c)</td>
</tr>
</tbody>
</table>
4.1.4 - Discussion

2000 lactation

The hypothesis that crosses of the East Friesian with either the Awassi or the Merino breeds would produce more milk than the Merino ewes was strongly supported by our results. Surprisingly, their milk production was lower than that of the Awassi sheep. This could be to the small number of animals in each genotype or to the fact that, except for two of the East Friesian x Merino ewes, they were in their first lactation, and primiparous ewes are known to produce less milk (Boyazoglu, 1963; Ozcan and Kaimaz, 1969). The East Friesian x Merino ewes also produced more milk that the East Friesian x Awassi ewes. Again, this difference could be due to the small numbers involved or to the fact that two out of the six East Friesian x Merino ewes were in their second lactation.

The differences in fat concentration between the different genotypes are surprising. So far we have never observed a difference in composition due to genotype and the literature suggests that nutrition has a greater effect than genotype in affecting milk composition (Bencini and Pulina, 1997).

Previous studies have shown that the presence of lambs can affect the concentration of fat in the milk (Bencini, 1999). However, the presence of lambs was time related, as lambs were kept with their mothers only for a few weeks after birth, and this effect should have been accounted for by the covariance analysis. The Awassi and East Friesian x Awassi ewes were kept on the Industry Partners’ property throughout their pregnancy while the East Friesian x merino and merino ewes were kept at Allandale Farm. Differential nutrition during pregnancy may account for the difference, but no literature reports exist on the effect of nutrition during pregnancy and the composition of the milk, because previous studies concentrated on the effect of nutrition of milk quantity rather than milk quality (Bencini and Pulina, 1997). However, since milk fat is partially synthesised from body reserves, it makes sense that nutrition during pregnancy may affect fat synthesis during lactation if it leads to differences in the body reserves of the animals. It is beyond the scope of this project to investigate this matter, but we will endeavour from now on to keep all animals under the same conditions during pregnancy.

2001 lactation

The results of this lactation again supported the hypothesis that East Friesian crosses would produce more milk than the Merino ewes. What we did not expect was that the East Friesian x Awassi ewes would produce more milk than the Awassi ewes. East Friesian x Awassi ewes outperformed not only the East Friesian x Merino ewes, but also the Awassi ewes, and clearly showed that they are a superior genotype in the 2001 lactation. This could be because some of them were in their second lactation. However, the outstanding producers in this group were in fact a small number of primiparous ewes born from the cross between Rambo, the ram lent to us by Jane and Bruce Wilde (Jarrah-Lee Springs East Friesian Sheep Stud). Therefore, it appears that we may be observing at a sire effect more than a breed effect. Nevertheless, the identification of superior rams has been recognised as a priority by the RIRDC, and this is still a very important observation.

The weekly measurements of milk composition confirmed that there was a significant difference in composition between genotypes, this time involving also the protein concentration. Again, this could be due to a genotype effect or to the effect of differential nutrition during pregnancy.

Regardless of the cause, the significant difference in protein concentration between genotypes may have important production implications as the yield of cheese depends on the clotting of the protein faction in the milk.

4.2 Dairy Sheep Management

4.2.1 – The Management of Dairy Sheep and its relationship to milk processing

Colostrum IGG persisted for up to nine days in the milk of sheep that were separated from their lambs soon after birth and it was suggested that this could be the cause of processing problems in early lactation reported by sheep milk processors (Bencini, 1999). By contrast, colostrum IGG disappears in the milk of dairy cows within two to three days (Holmes and Wilson, 1984). In sheep, a lack of production of endogenous oxytocin may prevent the ewes from having a normal milk ejection and cause the persistency of some colostrum components in the milk. To support this hypothesis, one of
our experiments showed that ewes that were allowed to nurse their lambs during the day (share milking) had impaired milk let down (Bencini, 1999).

This experiment aimed to further investigate the role of the let-down hormone (oxytocin) on the persistency of colostrum and milk composition of sheep separated from their lambs at birth and of sheep that were allowed to nurse their lambs during the day. The hypothesis tested was that colostrum immunoglobulins would persist in the milk of sheep whose lambs were weaned early and in those that did not receive oxytocin.

4.2.2 - Materials and methods

For this experiment, we used a nested experimental design involving two weaning methods, early weaning or share milking, as well as the administration of exogenous oxytocin versus a control saline solution, as shown in Table 4.2.1.

Table 4.2.1. Allocation of sheep to treatments according to a nested experimental design.

<table>
<thead>
<tr>
<th></th>
<th>Oxytocin</th>
<th>Saline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early weaning</td>
<td>5 sheep</td>
<td>6 sheep</td>
</tr>
<tr>
<td>Share milking</td>
<td>8 sheep</td>
<td>5 sheep</td>
</tr>
</tbody>
</table>

Samples of milk were collected daily from the sheep for the first 10-15 days and were analysed for fat, protein, lactose and total solids with a Milko Scan.

For colostrum 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 colostrum IGG. Unfortunately, some of the samples were lost during storage and as a consequence some treatments were underrepresented.

Routine measurements of milk production and composition were continued once weekly to determine the total lactation yield and the length of the lactation.

Results were analysed by least square means ANOVA (SuperANOVA, Abacus Concepts, 1991) by comparing the different treatments within each of the weeks of lactation.

4.2.3 - Results

There were no significant differences in the total lactation yield and duration of the lactation between treatments (Table 4.2.2). In other words, ewes that nursed their own lambs did not produce less milk than those that were separated from their lambs.

Table 4.2.2. Total lactation yield (kg) and lactation length (weeks) of sheep that were separated from their lambs at birth (early weaning) of allowed to nurse their lambs (share milking) and were given an injection of 1 IU of oxytocin at milking or a saline injection (control). Data are Means (± SE).

<table>
<thead>
<tr>
<th>Treatment (number of sheep)</th>
<th>Total lactation yield (kg)</th>
<th>Lactation length (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline + early weaning (6)</td>
<td>27 ± 10.7</td>
<td>10 ± 0.5</td>
</tr>
<tr>
<td>Saline + share milking (5)</td>
<td>24 ± 9.8</td>
<td>10 ± 0.3</td>
</tr>
<tr>
<td>Oxytocin + early weaning (5)</td>
<td>27 ± 11.6</td>
<td>9 ± 1.5</td>
</tr>
<tr>
<td>Oxytocin + share milking (8)</td>
<td>23 ± 3.3</td>
<td>11 ± 0.3</td>
</tr>
</tbody>
</table>

There were no significant differences in colostrum IGG between treatments for the first four days of lactation (Table 4.2.3).
Table 4.2.2. Colostrum IGG (mg/mL) in the milk of sheep that were separated from their lambs at birth (early weaning) of allowed to nurse their lambs (share milking) and were given an injection of 1 IU of oxytocin at milking or a saline injection (control). Data are Means (± SE).

<table>
<thead>
<tr>
<th>Treatment (number of samples)</th>
<th>Colostrum IGG (mg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>Saline + early weaning (2)</td>
<td>0.22 ± 0.100</td>
</tr>
<tr>
<td>Saline + share milking (3)</td>
<td>0.51 ± 0.410</td>
</tr>
<tr>
<td>Oxytocin + early weaning (1)</td>
<td>0.50</td>
</tr>
<tr>
<td>Oxytocin + share milking (4)</td>
<td>0.79 ± 0.401</td>
</tr>
</tbody>
</table>

4.2.4 - Discussion

Due to the loss of samples during storage, it is not possible to conclude much from the results of this experiment. Our previous findings (Bencini, 1999) suggested that colostrum IGG may persist for up to nine days in the milk of sheep that were separated from their lambs at birth.

Ewes that were allowed to nurse their lambs did not produce less milk than those separated from their lambs at birth. This is also supported by our previous findings (Bencini, 1999) and confirms that ewes that are allowed to nurse their lambs perform as well as those that do not. Therefore, the practice of share milking has the advantage that since the ewes feed their lambs, the lambs can be sold or, if females, used as replacement ewes, removing the need for expensive artificial feeding.

Surprisingly, the ewes that were allowed to nurse their lambs did not have longer lactations than those that were separated early from their lambs. Our previous results (Bencini 1999) showed that share milked ewes have longer lactations. This was attributed to the more frequent removal of local control factors that regulate milk secretion (Wilde and Peaker, 1990). In the present experiment, we only had very small number of ewes in each treatment, and this could have masked the effect of the share milking treatment.

4.3 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. We assessed the consumer acceptance for sheep milk ice cream and studied the relationship between the clotting properties of the milk and cheese yield. We also investigated methods to accelerate or simplify ripening of the cheese developed within our previous project (UWA 23 A).

4.3.1 - Development of a Camembert style (mould-ripened) sheep milk cheese

We developed a new Camembert style mould-ripened sheep cheese. Camembert is one of the most famous French cheeses and is ripened by a luxurious growth of white mould on its surface.

According to sheep dairy manufacturers (M. Temby, Pers. comm.; T. Dennis, Pers. comm.), fresh products such as sheep milk yogurt, 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.
4.3.2 - Materials and methods
To make this cheese the milk was initially pasteurised at 72°C for 20 seconds. The milk was then cooled up to 40-42°C, filtered and transferred to the cheese vat at a temperature of 33-34°C. Mesophilic lactic starter cultures (CHR Hansen) were added (0.1g/l of milk) together with 0.1g of white mould spore powder (*Penicillium* sp). Both cultures were mixed thoroughly and left for 45 minutes. Calf rennet (CHR Hansen) at the concentration of 0.8ml/l of milk was used to coagulate the milk. After 35 minutes the curd was cut with curd knives into 2-3 cm cubes and left for another 35 minutes in order to expel part of the whey. Then the curd was turned over gently every ten minutes (three times) and one third of whey was drained off and replaced with warm (35°C) boiled water. The curd was turned over gently once and half of the whey was drained off. The remaining curd was transferred into hoops and left overnight at room temperature (20°C). The following morning the cheeses were removed from the hoops and placed into a cold 20% brine solution, with a speck of mould powder added, for 30 minutes. The cheeses were removed from the brine and placed on a plastic rack to dry for 24 hours at room temperature (20°C). They were then put in plastic containers to maintain a humid environment at 11-15°C and stored for ten days. By the end of this time the cheeses were fully covered with mould and were wrapped in foil and stored for another four weeks at 11-15°C temperature.

In total 13 batches of cheese were made. For each batch of cheese the milk was analysed for fat, protein, lactose, total solids concentrations, clotting properties and the yield of cheese from each litre of milk was calculated. Samples from each experimental batch were collected, and analysed for protein, fat and moisture. Regression analysis was applied to detect the existence of correlations between the composition of the milk, its clotting properties and the yield of cheese.

Sensory evaluation of each batch of cheese was conducted on each batch of cheese at two weekly intervals by a semi-trained panel.

Panel members were asked to taste the cheeses and evaluate the cheeses for aroma, colour, flavour and texture on a scale from 1 to 7 where 1 meant very bad and 7 meant excellent. They were also asked to evaluate if the cheese was ready to eat and to make any additional comments.

4.3.3 - Results

The experimental batches of Camembert style cheese had 48.5% dry matter and 28.7 % fat on DM (Table 4.3.1). There was weak correlation between the protein content and cheese yield ($r=0.50$).

**Table 4.3.1.** Average composition (%) of the Camembert style cheeses developed within the project. Values in brackets represent the standard error of the mean.

<table>
<thead>
<tr>
<th>Dry matter(DM)</th>
<th>Moisture</th>
<th>Fat on DM</th>
<th>Protein on DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.5</td>
<td>51.5</td>
<td>28.7</td>
<td>6.21</td>
</tr>
<tr>
<td>(12.12)</td>
<td>(12.87)</td>
<td>(7.18)</td>
<td>(1.55)</td>
</tr>
</tbody>
</table>

Most of the milk used to make the experimental batches of cheese clotted within 7 minutes from the addition of rennet and the rate of curd formation was very rapid (1.18±0.41 minutes; Table 4.3.2).

**Table 4.3.2.** Clotting properties (renneting time, $r$, minutes; curd consistency, A30, mm; rate of curd formation, K20, minutes) ± SE of the milk used for the production of Camembert style cheese.

<table>
<thead>
<tr>
<th>Clotting properties</th>
<th>$r$ (minutes)</th>
<th>A30 (mm)</th>
<th>K20 (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.8</td>
<td>31.8</td>
<td>1.2</td>
</tr>
<tr>
<td>SE</td>
<td>2.60</td>
<td>10.60</td>
<td>0.42</td>
</tr>
</tbody>
</table>
There was a significant correlation between the yield of cheese and the clotting time $r$ (Figure 4.3.1). The equation describing this linear relationship was:

\[
\text{Yield} \, (\%) = 17.8 + 0.58r \quad R^2 = 0.476 \quad (p<0.05)
\]

**Figure 4.3.1.** Correlation between the renneting time ($r$, minutes) and the yield of Camembert style cheese ($\%$).

There was a trend between the yield of cheese and the clotting time $r$ (Figure 4.3.2), but it failed to reach significance. The equation describing this linear relationship was:

\[
\text{Yield} \, (\%) = 17.8 + 0.58 \text{ protein} \quad R^2 = 0.476 \quad (p=0.06)
\]
Figure 4.3.2. The correlation between the protein concentration (%) and the yield of Camembert style cheese (%) failed to reach significance (p<0.06).

The semi-trained panel scored the cheeses were quite highly after two weeks of maturation, but scores fell by a considerable amount after four and six weeks of maturation (Table 4.3.3). The majority of the panel (92% of surveys) believed that the cheeses were ready to eat after two weeks.

Table 4.3.2. Panel assessment of the experimental batches of Camembert style cheese. The panel member were asked to score cheeses on a scale of 1 to 7 where 1 meant very bad and 7 meant excellent.

<table>
<thead>
<tr>
<th>Cheese characteristic</th>
<th>Maturation time (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Aroma</td>
<td>6.4 ± 0.40</td>
</tr>
<tr>
<td>Colour</td>
<td>6.2 ± 0.20</td>
</tr>
<tr>
<td>Flavour</td>
<td>6.2 ± 0.37</td>
</tr>
<tr>
<td>Texture</td>
<td>6.2 ± 0.20</td>
</tr>
<tr>
<td>Comprehensive evaluation</td>
<td>6.0 ± 0.32</td>
</tr>
</tbody>
</table>

4.3.4 - Discussion

The method of preparation of this cheese is simple. The above results indicate that this cheese has a high yield from each litre of milk. The poor correlations between clotting properties and cheese yield may be attributed to the small number of batches involved. Further work may allow us to establish predictive equations for the yield of cheese once the composition of the milk or its clotting properties are known (Mijatovic, 2001).

The semi trained panel survey revealed that this cheese can be sold within two weeks from production. Such a short maturation time involves low risk of spoilage during maturation and low storage costs. A
comparison with similar cheese made with cows’ milk suggests that potential returns from each litre of milk processed may be very high.

4.4 Processing performances of sheep milk

4.4.1 – Relationship between composition of milk, clotting properties and cheese yield

The yield and quality of cheese depend on the clotting properties of the milk. To obtain a high yield of cheese the clotting of milk must occur rapidly and the consistency of the curd must be high (Bencini and Johnston, 1996).

The clotting properties of milk are related to cheese yield and cheese composition, which are very important in cheese quality. Therefore, the factors that can affect the clotting properties of milk and can have an effect on the yield and quality of cheese. Some of these factors are the conditions under which clotting occurs such as pH, temperature of coagulation, addition of calcium and concentration of rennet. Cheese makers have control over these factors, but they do not have control over the composition of the milk.

A major factor that affects the yield of cheese is the composition of the milk, particularly its content in protein and fat. For instance, a 0.1% increase in the protein content of milk can increase Cheddar cheese yield by 0.14 kg per 100 kg of milk (Covington, 1993). 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 cheese in order to establish if there were relationships between the composition of the milk and the outcome of the cheese.

4.4.2 - Materials and methods

To determine the correlation between milk composition and cheese outcome, 20 batches of Fetta were made with milk of known composition that had been previously frozen for short periods (1-2 month). 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. The pH of the milk was also measured with a portable pH meter PHM 201 (Radiometer- Copenhagen). The clotting properties of the sheep milk were determined with a Lattodinamografo (Foss Electric, Italy).

To make Fetta cheese, sheep milk was pasteurized at 72°C for 20 seconds. The milk was then filtered and transferred into a cheese vat and cooled to the desired coagulation temperature. The method for processing of Fetta was an adaptation of that reported by Anifantakis (1986b). The coagulation temperature in the vat was 32°-33°C. Mesophilic lactic starter cultures (F-DVD, Hansen) were added (0.1g/L) to the milk and it was then left at 32°-33°C for five minutes. Calf rennet (Hansen), at the concentration of 0.8ml/l of milk, was used to coagulate the milk and the curd was ready for cutting after approximately 50 minutes.

The curd was cut with curd knives into 2-3cm cubes, and left for another 50 minutes in order to expel part of its whey. The whey was separated, and the curd was weighed and transferred into a stainless steel mould with small round holes (0.2cm diameter) on its surface and bottom. Then a lid was placed on the cheese that was then left in an incubator at 37°C for 24 hours. Then the cheese was removed from the mould and cut into slices, weighed and transferred into plastic buckets with a 10% NaCl brine into a refrigerator at 4°C to complete the maturation (seven days). After reaching the time of maturation, each experimental batch was weighed and the yield was calculated. Samples of the cheeses were analyzed for moisture, fat, protein and ash content.

The concentration of fat, protein, lactose and total solids in the whey was also determined with Milko Scan 133 (Foss Electric, Denmark) and the casein content of the milk was estimated by difference (Van den Berg, 1993).

The moisture of the experimental batches of Fetta was determined by freeze-drying. The fat content was determined by hexane: propanol (3:2) extraction. Protein content of Fetta was determined with a Leeko Nitrogen Analyser. Ash content of the experimental batches of Fetta was determined by furnace incineration at 500°C (AOAC, 1980).
Regression analysis was used to determine the correlation between milk composition (protein, casein, fat, total solids), clotting properties (r, k20, A30), and cheese yield. In some instances, data points were removed before performing the analysis if they were outliers.

4.4.3 - Results

Composition of cheese

The experimental batches of Fetta cheese had a moisture content of 48.9% and a fat concentration of 40% on DM (Table 4.4.1). There were no significant correlations between milk composition and the fat, protein or water content of the cheese.

Table 4.4.1. Composition (%) of the experimental batches of Fetta (numbers in brackets represent the standard error).

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Fat on DM</th>
<th>Protein on DM</th>
<th>Ash on DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.9</td>
<td>40.0</td>
<td>5.7</td>
<td>6.90</td>
</tr>
<tr>
<td>(10.90)</td>
<td>(0.09)</td>
<td>(1.3)</td>
<td>(1.6)</td>
</tr>
</tbody>
</table>

For most of the cheese batches the milk clotted within 25 minutes from the addition of rennet and the rate of curd formation was very rapid (1.78 ± 0.41 minutes). The average consistency of the curd was 39.70 ± 9.35 millimeters (Table 4.4.2).

Table 4.4.2. Renneting time (r), rate of curd formation (k20), and consistency of the curd after 30 minutes (A30), after 45 minutes (A45) and after 60 minutes (A60) of the sheep milk processed in the experiment (numbers in brackets are standard errors).

<table>
<thead>
<tr>
<th>r</th>
<th>k20</th>
<th>A30</th>
<th>A45</th>
<th>A60</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0</td>
<td>1.8</td>
<td>39.7</td>
<td>45.3</td>
<td>42.6</td>
</tr>
<tr>
<td>(5.74)</td>
<td>(0.41)</td>
<td>(9.35)</td>
<td>(10.69)</td>
<td>(10.63)</td>
</tr>
</tbody>
</table>

There was a significant correlation ($r^2=0.4$; $p<0.05$) between the protein content of milk and the consistency of the curd (Figure 4.4.1). The equation describing this relationship was:

\[
\text{Curd consistency (mm)} = -22.88 + 13.53 \text{protein} \% \quad (r^2=0.4; \ p<0.05)
\]
There was also a significant correlation \( r^2=0.4; \ p<0.05 \) between the casein content and curd consistency (A30) of milk (Figure 4.4.2). The equation describing the relationship was:

\[
\text{Curd consistency (mm)} = 14.72 + 16.30 \ \text{casein} (\%) \quad (r^2=0.4; \ p<0.05)
\]

There was trend for curd consistency (A30) to be a greater when fat/casein ratio approached 1. However, the correlation failed to reach significance \( p=0.09; \) Figure 4.4.3.

\textbf{Figure 4.4.1.} Linear relationship between protein content (%) and curd consistency (A30, mm) of the milk \( (r^2=0.4; \ p<0.05). \)
Figure 4.4.2. Linear relationship between casein (%) and curd consistency (A30, mm) of milk ($r^2=0.4$; $p<0.05$).

Figure 4.4.3. The negative correlation between fat/casein ratio and curd consistency (A30, mm) of milk failed to reach significance ($p=0.09$).
There was no significant relationship between clotting properties (r, A30 and k20) of the milk and the yield of cheese.

There was a significant correlation (r=0.54; p<0.01) between the concentration of fat in the milk and the yield of cheese (Figure 4.4.5). This was described by the equation:

\[ \text{Cheese yield(\%)} = -2.79 + 0.44\text{fat(\%)} \quad (r^2=0.54; \ p<0.01) \]

\[ \text{Fat content(\%)} = 5.0 \quad 5.5 \quad 6.0 \quad 6.5 \quad 7.0 \quad 7.5 \quad 8.0 \quad 8.5 \quad 9.0 \]
\[ \text{Cheese yield(\%)} = 19 \quad 20 \quad 21 \quad 22 \quad 23 \quad 24 \quad 25 \]

\[ \text{Figure 4.4.5. Linear relationship between the concentration of fat(\%) in the milk and the yield of cheese(\%)} \]

There was weak (r=0.35) and non-significant (p=0.24) correlation between the protein content and cheese yield.

4.4.4 - Discussion

The linear relationship between the concentration of protein in the milk and the consistency of the curd (A30) was significant, supporting the hypothesis that milk composition would affect the clotting properties of the milk. However, this was only partially supported as the relationships between milk composition and renneting time (r) and rate of curd formation (k20) were not significant.

The results of this experiment showed that milk composition has an influence on the outcome of Fetta cheese. The casein fractions of milk are of especial commercial importance since casein is captured in cheese making. There was a trend of increasing yield of cheese when the content of fat and protein were high. Since fat is entrapped in casein, the fat to casein ratio in the original milk is also important in the cheese making process, as if fat content is too high fat is lost in the whey (Chapman, 1981). Processors normally standardize the milk to a constant fat to casein ratio (approximately 0.7:1 in Cheddar cheese) to achieve an optimal fat recovery and the desired moisture level in the cheese (Harding, 1995). In this experiment, the fat to casein ratio the milk was not standardized and its mean was 1.95, which was very high. The negative correlation between fat/casein ratio and curd consistency (A30) demonstrated that curd consistency tended to be greater when the fat/casein ratio was approaching 1.
In this experiment, surprisingly, there was no correlation between the clotting properties of the milk and the yield of Fetta cheese. This could be due to the small number of batches analysed and to unusually low readings for some of the samples during the measurement of clotting properties with the Lattodinamografo.

The clotting time (r) of sheep milk was slower than reported in the literature (Bencini and Johnston, 1995, Bencini 2002). The reason for these slow renneting times could be due to the use of frozen milk as cooling of milk before renneting results in a prolonged rennet coagulation time (Van Hooydonk, 1987). This has been attributed to the dissociation of casein, to the solubilisation of micellar calcium phosphate at low temperature and to an irreversible increase of the pH after cooling. According to Balcones et al (1996), the clotting properties of milk are influenced by the concentration of calcium and by pH. Since the acidification of milk increases Ca\(^{2+}\), the clotting properties of sheep milk are probably influenced largely by Ca\(^{2+}\) concentration.

The pH of the milk in this experiment was in range 6.37-6.78 and it was not correlated with the clotting properties of the milk. According to Marshall et al (1982), the maximum curd-firming rate of the milk is achieved at around pH 5.8 and it is possible that the existing small range of pH did not allow the detection of a correlation.

The rate of firming was very rapid and it was achieved within times reported in the literature (Bencini and Johnston, 1995; Bencini, 2002). Since cheese outcome depends on the rapidity of the clotting process, these results show that sheep milk is very suitable to produce high quality cheeses.

The curd consistency (A30) resulted in lower readings than those reported in the literature (Bencini and Johnston, 1995; Bencini, 2002). White and Davies (1958) and Green and Manning (1982) reported that when clotting is achieved rapidly, harder curds are produced. As the renneting time in this experiment was slower than literature reports, it was not surprising that curd consistency was also lower.

The results of this experiment support the existence of a relationship between milk composition and cheese yield. The fat concentration of milk was highly correlated with cheese yield. Surprisingly, the relationship between protein content of milk and yield failed to reach significance (p=0.24). This could be due the low proportion of caseins to total proteins (72%), while Kalanzopoulos (1999) reported values of 82-83% for sheep milk.

There was no correlation between fat/casein ratio and the yield of cheese, which was instead correlated, but not significantly, with the protein content of milk. This could be due to the small number of samples analysed. The literature reports support the finding of contrasting results when comparing yields of different batches of cheese and ascribed these discrepancies to the concentration of ionic calcium in the milk (Banks et al., 1981). According to Bencini and Johnston (1996), it is possible that a significant correlation between fat/casein ratio and cheese yield could be found if a correction factor for calcium concentration could be introduced in the regression equation.

### 4.5 Cheese maturation studies

#### 4.5.1 – Acceleration of cheese maturation 1 - Use of lipase

One of the products developed as part of our previous UWA 23A project is a semi-matured cheese, with a maturation time of approximately two months. This compares well with the six months required to mature a Pecorino, but for the manufacturing industry it is highly desirable to accelerate the maturation to reduce storage costs and increase cash flow. The maturation of cheese can be accelerated with enzymes such as lipase and proteases (Wilkinson, 1993). Lipase is particularly important for the maturation of sheep cheeses as these are often made with raw milk and clotted with lambs rennet, which contain lipases that impart a piquant flavour to the cheese (Resmini, 1978).

#### 4.5.2 - Materials and methods

To study the effect of adding lipases on the maturation time of cheese experimental batches of cheese were made using varying amounts of lipase, as shown in Table 4.5.1. The cheese making process was standardised so that every batch of cheese was made with milk of similar composition.
Table 4.5.1. Number of experimental batches of cheese made with different amounts of lipase.

<table>
<thead>
<tr>
<th>Amount of lipase</th>
<th>Number of batches</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 grams (control)</td>
<td>8</td>
</tr>
<tr>
<td>1 gram</td>
<td>8</td>
</tr>
<tr>
<td>2 grams</td>
<td>6</td>
</tr>
<tr>
<td>4 grams</td>
<td>8</td>
</tr>
</tbody>
</table>

Every week starting from week four after the batches were made, samples were collected from each batch and frozen for analysis. Chemical analyses of the frozen cheese samples for fat, moisture, free fatty acids and ash were performed. A semi-trained panel tasted the cheeses weekly to assess if they were ready to eat (giving a subjective evaluation of maturation) and ranked the batches of cheese for aroma, texture, flavour, colour and taste. They also gave them a score for maturity and comprehensive evaluation.

4.5.3 - Results

There were significant differences in the content of fat and ash of the cheeses, with fat content decreasing as the amount of lipase used increased (Table 4.5.2). There were also significant differences between treatments in terms of the panel assessment for aroma, flavour, texture and comprehensive evaluation between treatments (Table 4.5.3).

Table 4.5.2. Chemical composition (% ±SE) of cheeses produced with increasing amounts of lipase.

<table>
<thead>
<tr>
<th>Amount of lipase</th>
<th>Fat</th>
<th>Protein</th>
<th>Moisture</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 grams (control)</td>
<td>49.0 ± 1.55</td>
<td>36.9 ± 1.35</td>
<td>44.5 ± 1.88</td>
<td>6.9 ± 0.99a</td>
</tr>
<tr>
<td>1 gram</td>
<td>47.9 ± 0.77</td>
<td>38.0 ± 0.39</td>
<td>48.6 ± 1.67</td>
<td>6.8 ± 0.12a</td>
</tr>
<tr>
<td>2 grams</td>
<td>44.6 ± 1.06</td>
<td>39.5 ± 0.76</td>
<td>44.2 ± 2.42</td>
<td>5.8 ± 0.08 b</td>
</tr>
<tr>
<td>4 grams</td>
<td>43.6 ± 1.14</td>
<td>37.4 ± 0.66</td>
<td>46.0 ± 1.11</td>
<td>5.6 ± 0.15 b</td>
</tr>
</tbody>
</table>

Although there was also a significant difference due to maturation time, there was no clear pattern for the scores given to the cheeses for aroma, flavour and texture. The weeks of maturation had a significant effect on the scores given for readiness to eat, with readiness to eat perceived to be maximum after 9 weeks of maturation.

Table 4.5.3. Average panel assessment scores for aroma, flavour, texture and comprehensive evaluation (out of 7 ±SE) of cheeses produced with increasing amounts of lipase.

<table>
<thead>
<tr>
<th>Amount of lipase</th>
<th>Aroma</th>
<th>Flavour</th>
<th>Texture</th>
<th>Comprehensive evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 grams (control)</td>
<td>4.3 ± 0.15</td>
<td>4.8 ± 0.14</td>
<td>5.06 ± 0.13</td>
<td>4.9 ± 0.13 a</td>
</tr>
<tr>
<td>1 gram</td>
<td>4.3 ± 0.09</td>
<td>4.5 ± 0.09</td>
<td>4.5 ± 0.09</td>
<td>4.5 ± 0.09 b</td>
</tr>
<tr>
<td>2 grams</td>
<td>4.0 ± 0.01</td>
<td>4.4 ± 0.10</td>
<td>4.2 ± 0.10</td>
<td>4.2 ± 0.11 c</td>
</tr>
<tr>
<td>4 grams</td>
<td>3.9 ± 0.10</td>
<td>4.1 ± 0.11</td>
<td>4.0 ± 0.11</td>
<td>4.1 ± 0.13 c</td>
</tr>
</tbody>
</table>
4.5.4 - Discussion

Clearly the panel disliked something about the cheese made with lipase, as scores worsened as the amount of lipase added increased. It is possible that the lipase increased the amount of bitter compounds in the cheeses (Fernandez-Garcia et al., 1988) and that these were perceived and disliked by the panel. This is supported by the lower fat content of cheeses made with 2 and 4 g of lipase, suggesting that lipolysis was effectively occurring in the cheeses.

Surprisingly, there was no clear pattern of scores over time. Since the purpose of adding lipase was to accelerate cheese maturation, we would have hoped that higher scores would be reached sooner by cheeses made with lipase compared to the control. It is possible that this kind of panel assessment data cannot be easily analysed with common statistical packages and that more sophisticated analyses should have been undertaken.

4.5.5 - Acceleration of cheese maturation 2 - Use of adjunct cultures

This was not one of the milestones of our project. It stemmed from the necessity to address a mould contamination problem occurring in our laboratory and from attending the 25th International Dairy Congress in Denmark in 1998. Occasionally, the semi mature cheese developed within our previous project has developed moulds on the cheese surface. These have been controlled by painting the cheeses with cheese paint containing a mould inhibitor. However, the paint is expensive and the painting process is tedious and time consuming.

Vacuum packaging and maturing the cheese in plastic has the potential to eliminate mould development as moulds are aerobic organisms and it could be expected that the vacuum packaging would inhibit their growth (Khamrui and Goyal, 1999). It has, however been observed that sheep milk cheese matured under vacuum packages matures more slowly and does not develop a full flavour (Nuñez et al, 1986).

At the 25th International Dairy Congress, Høier (1998) presented results of a cheese maturation trial conducted on cow’s milk using a new adjunct culture containing *Brevibacterium* strains and *Lactobacillus helveticus* that significantly accelerated cheese maturation.

Since one of the aims of our project was to develop methodologies to accelerate cheese maturation, we conducted an experiment to test if vacuum packaging eliminated mould development and to test the efficacy of adjunct cultures in accelerating the maturation of our semi-mature cheese.

It would be expected that control cheeses made with the traditional method would take approximately two months to mature while the cheese made with the adjunct culture should be ready to eat sooner. However, because adjunct cultures may hydrolyse the protein in the cheese the cheeses may acquire a bitter taste. This should be detected by the panel and may correspond to high levels of proteolysis. By contrast, vacuum packaging without adjunct culture should result in slower maturation.

4.5.6 - Materials and methods

We studied the effect of vacuum packaging and adding adjunct cultures containing *Brevibacterium* strains and *Lactobacillus helveticus* (F-DVS CR-130, CHR Hansen, Denmark) on cheese maturation times. The resulting cheeses were assessed by chemical analysis (fat, protein, moisture and ash) and by semi-trained panel assessment. The experimental cheeses were compared with control cheese made with our usual method, by painting each round with cheese paint.

The cheese making process was standardised so that each batch of cheese was made with milk of similar composition.

Five batches of cheese per treatment were made (Table 4.6.1) with either adjunct culture and vacuum packing, adjunct culture and cheese paint, no adjunct culture and vacuum packing and no adjunct culture and cheese paint.
Table 4.6.1. Number of experimental batches of cheese made with or without the addition of adjunct cultures and with or without vacuum packaging.

<table>
<thead>
<tr>
<th></th>
<th>Adjunct culture</th>
<th>No adjunct culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal method</td>
<td>5 batches</td>
<td>5 batches</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum packed</td>
<td>5 batches</td>
<td>5 batches</td>
</tr>
</tbody>
</table>

Every two weeks starting from the second week after the cheeses were made a semi-trained panel tasted the cheeses and evaluated their maturation and other characteristics (flavour, colour, aroma, and consistency). Assessment scores were on scale from 1 to 7, where 1 meant very bad and 7 meant excellent.

4.5.7– Results

The experimental cheeses made with adjunct culture were unpalatable. The cheeses were dry, crumbly and unacceptable in terms of texture and taste. Control cheeses received significantly higher scores for aroma, flavour and texture. This resulted in a very low score for the comprehensive evaluation. Vacuum packed cheeses did not score much better than those made with adjunct culture (Table 4.6.2).

Table 4.6.2. Average panel assessment scores for aroma, flavour, texture and comprehensive evaluation (out of 7 ±SE) of cheeses produced with or without adjunct culture and vacuum packaging.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Aroma (±SE)</th>
<th>Flavour (±SE)</th>
<th>Texture (±SE)</th>
<th>Comprehensive evaluation (±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.5 ± 0.12 a</td>
<td>5.2 ± 0.15 a</td>
<td>5.2 ± 16 a</td>
<td>5.1 ± 0.14 a</td>
</tr>
<tr>
<td>Adjunct culture</td>
<td>3.5 ± 0.19 b</td>
<td>4.0 ± 0.19 b</td>
<td>4.3 ± 1.9 b</td>
<td>3.9 ± 1.78 b</td>
</tr>
<tr>
<td>Vacuum packed</td>
<td>3.6 ± 0.28 b</td>
<td>3.8 ± 0.26 b</td>
<td>4.1 ± 0.24 b</td>
<td>3.8 ± 0.26 b</td>
</tr>
<tr>
<td>Vacuum packed + Adjunct culture</td>
<td>3.4 ± 0.23 b</td>
<td>3.3 ± 0.27 c</td>
<td>3.5 ± 0.22 c</td>
<td>3.2 ± 0.23 c</td>
</tr>
</tbody>
</table>

4.5.8 - Discussion

The results of this experiment clearly showed that the panel disliked cheeses made with adjunct culture. Vacuum packed cheeses did not score much better than those made with adjunct culture, suggesting that our semi-trained panel preferred cheeses made with the traditional method, using no adjunct culture and cheese paint instead of vacuum packaging.

This is in sharp contrast with the results reported by Høier (1998), who found that the adjunct culture decreased significantly the maturation times of cow’s milk cheeses. Evidently, differences between sheep and cow’s milk make the adjunct culture unsuitable for sheep milk processing. This is a disappointing result, but it is an important finding for the sheep milking industry, as it suggests that sheep milk cheeses are preferred when made with traditional methods. Our results are in agreement with Nuñez et al (1986), who reported that sheep milk cheese under vacuum packages matured more slowly and did not develop its full flavour.

It is possible that the adjunct culture liberated some bitter compounds (Fernandez-Garcia et al., 1988) that were perceived and disliked by the panel, but this would not explain the preference for control cheeses over the vacuum packaged cheeses.
Similarly to the results of the previous experiment, it is possible that a more sophisticated statistical analysis may have been more appropriate for the panel assessment results.

4.6 Sheep milk ice cream

4.6.1 – Consumers’ acceptance of sheep milk ice cream

Sheep milk ice cream has the potential to be sold within Australia and to be exported to Japan. Our industry partner, the Peters & Brownes Group already exports ice cream to Japan and in 1998 developed vanilla flavoured ice creams made with the milk of sheep milked within our project.

A panel of four experts from the Peters & Brownes Group assessed the experimental ice creams ranking them on a scale of 1 to 10 for aroma, colour, flavour, texture and provided comprehensive evaluation of the ice creams. The results of the panel assessment were disappointing as 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 the Animal Science Group stated that the ice creams were very palatable.

For this reason it was suggested that another panel assessment should be conducted, this time with a random sample of people, if possible comparing sheep and cow’s milk ice creams in a blind test (Bencini, 1999). Since often sheep milk is considered to be a health product, we also included ice creams made with two different fat contents (low fat and normal fat) from sheep and cow’s milk, to examine the attitude of consumers towards low fat products.

4.6.2 - Materials and methods

Thirty litres of sheep milk were pasteurized in our dairy products laboratory. An Elecrem Armfield centrifuge was used to separate the milk fat from the skim milk. These were then mixed to produce batches of cream containing 6 and 10% fat. The batches of cream were then processed into vanilla flavoured ice creams at the Balcatta R&D Laboratory of the Peters & Brownes Group. A similar procedure was followed at the Peters & Brownes Group to produce cow’s milk ice creams containing 6 and 10% fat respectively.

The ice creams were then returned to the Animal Science Group, where a panel of consumers selected among the staff of The University of Western Australia tasted and assessed them in a blind test, ranking them on a scale from 1 to 7 where 1 meant very bad and 7 meant excellent. Only after completing the tasting, participants were revealed the identity of the ice creams. Participants were also asked if they had heard of low fat ice cream and the reasons why they would prefer it to normal ice cream. They were then asked if they would buy the ice creams and, to assess the price they would be prepared to pay, a bidding system was used. A set of questions to assess the demography of participants were also included in the questionnaire. A sample of the questionnaire is in Appendix 1.

4.6.3 - Results

Thirty-one people participated in the test. 29 (93.5%) of respondents normally ate ice cream and 18 (58%) had tried low fat ice creams before. Their score for the low fat ice cream that they had previously tried was 3.6 ± 0.41 (out of 7). All respondents but one (96.7%) accepted to try the ice creams (Table 4.7.1).

Table 4.7.1. Assessment scores (out of 7) ± SE and price that participants would be prepared to pay ($/L ± SE) for sheep and cows’ milk ice creams.

<table>
<thead>
<tr>
<th></th>
<th>Full cream sheep milk</th>
<th>Full cream cows milk</th>
<th>Low fat sheep milk</th>
<th>Low fat cows’ milk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Score (out of 7)</strong></td>
<td>5.0 ± 0.25</td>
<td>5.1 ± 0.15</td>
<td>4.1 ± 0.26</td>
<td>5.1 ± 0.25</td>
</tr>
<tr>
<td><strong>Price ($)</strong></td>
<td>5.9 ± 0.47</td>
<td>4.9 ± 0.53</td>
<td>6.5 ± 0.35</td>
<td>6.0 ± 0.44</td>
</tr>
</tbody>
</table>
Most participants did not find the sheep milk ice creams offensive, but some were able to differentiate between low fat and normal fat and gave a significantly lower mark to the low fat ice creams. They were also prepared to pay slightly more (50 cents to 1 $) more for sheep milk ice cream, but the differences were not significant.

When asked if they would buy other sheep milk products they were quite prepared to buy sheep milk cheese and yogurt, but were not likely to buy fresh sheep milk (Table 4.7.2).

Table 4.7.2. Likelihood that participants would buy other sheep milk products (fresh milk, yogurt or cheese). Scores (± SE) are out of 7; 1 = not at all likely and 7 = definitely.

<table>
<thead>
<tr>
<th></th>
<th>Fresh milk</th>
<th>sheep yogurt</th>
<th>Sheep milk cheese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>2.5</td>
<td>4.2</td>
<td>5.1</td>
</tr>
<tr>
<td>SE</td>
<td>0.32</td>
<td>0.30</td>
<td>0.36</td>
</tr>
</tbody>
</table>

The demographics of the participants showed that participants were not a random sample. All of them were employed and had at least a degree if not a PhD.

4.6.4 – Discussion

The results of this survey indicate that participants did not find the sheep milk ice creams offensive. This is in contrast with the expert panel evaluation that was produced by the Peters & Brownes Group (Bencini, 1999). It is possible that the experts at the Peters & Brownes Group were biased against sheep milk ice creams because they were aware of their nature. Here, in a blind test, participants showed no particular dislike for sheep milk ice cream.

Not surprisingly, panel members were capable of detecting the different characteristics of low fat ice creams and appeared to dislike them. This is also supported by findings by Guinard et al (1997) that levels of sugar and fat affect the sensory properties of ice cream.

The prices that participants would be prepared to pay for either low fat or full cream sheep milk ice cream are not much higher than the price they would be prepared to pay for cow’s milk ice cream. This finding suggests that producing sheep milk ice cream for the local market is not economically viable, and producers should concentrate on developing and producing specialty sheep milk cheeses, as participants would be readily prepared to buy them. However, the results of this survey should be treated with caution as we only interviewed 31 participants. Our original goal had been to interview at least 100 consumers. This was not achieved because the Peters & Brownes Group would not allow us to test experimental products on consumers. As a consequence, we had to conduct the survey on a small number of volunteers within The University of Western Australia. This problem is probably linked to the demographics of the participants, which showed that participants were not a random sample. This was to be expected since we did the survey within the University and mainly staff from the Faculties of Agriculture and Science willingly participated. Unfortunately, the policy of the Peters & Brownes Group of not testing experimental products on consumers meant that we had no choice on this matter.

It is possible that sheep milk ice cream may find a niche market overseas and processors interested in sheep milk ice cream should possibly investigate overseas markets before dismissing sheep milk ice cream as an option.
4.7 Use of cardoon rennet

4.7.1 – Development of cheese made with cardoon and commercial rennets

This work was undertaken at Charles Sturt University to examine the application of cardoon (*Cynara cardunculus* L) rennet for cheese making from sheep milk to develop a marketable product from sheep milk, focussing mainly on hard cheeses. Initial studies consisted of the following:

- Isolation and characterisation of rennet-like proteases from wild artichoke (*Cynara cardunculus* L);
- Determination activity and substrate specificity of extracts from wild artichoke (cardoon rennet) and
- Determination milk clotting properties of cardoon rennet using milk from bovine and ovine sources.

These initial studies were used as a basis for optimising the conditions for the application of cardoon rennet to cheese making from sheep milk.

The usefulness of cheese chemical and biochemical indices is determined by how well they correlate with the results of human sensory evaluation. Assessment by human panels is also necessary for determining the sensory qualities and acceptability of a cheese and is therefore the ultimate test for the success or failure of a rennet substitute. On the other hand, compared to instrumental analysis, sensory evaluation is usually more time-consuming and expensive to run and the results can be highly variable. For these reasons, it is desirable for sensory evaluation to be replaced or complemented by instrumental analysis. However, a good correlation between the results of the two types of analysis must be established for this to be possible.

We compared the properties of cheeses made with cardoon rennet to those of cheeses made with commercially available rennets, such as those obtained from animal (calf) and microbial sources.

The effects of two different types of starter culture on these properties were also investigated and compared. Sensory qualities of the experimental cheeses aged for various times were assessed by both a trained panel and a consumer panel. Textural attributes of the cheeses were also analysed instrumentally using the TA-TX2 Universal Texture Analyser.

4.7.2 - Materials and methods

Production and sampling of ovine milk cheeses

A small quantity (about 36 kg) of Pecorino style of cheese was made using both commercial (Naturen™ calf rennet and Microlant™ microbial rennet) and cardoon rennet (partially purified water extract from fresh cardoon flowers). The cheese making procedure is outlined in Figure 1.

![Flow chart of the procedure for the manufacture of Pecorino style cheese.](image)

**Figure 4.8.1.** Flow chart of the procedure for the manufacture of Pecorino style cheese.
Sensory evaluation of cheese

Sensory evaluation of the experimental cheeses was conducted by both a trained panel and an untrained consumer panel.

Sensory evaluation by a trained panel

A panel of 12 people was selected from the staff of Charles Sturt University. Most (11) of the panelists were chosen from the School of Wine and Food Sciences and one from the Charles Sturt University Winery, for their familiarity and experience with sensory analysis of wine and cheese. These panelists were trained according to the methods described by Barcenas et al (1998, 1999).

Cheeses aged for 30, 60 and 90 days were subjected to sensory evaluation by the trained panel, which was carried out at the Charles Sturt University sensory evaluation laboratory. Samples of the cheeses were cut into standard bite-size pieces, which measured about 1.25 x 1.1 x 1.1 cm. The cut samples were placed in plates and kept at a constant temperature of 20 °C before serving.

Sensory analysis of cheeses was conducted following published sensory techniques (Meilgaard et al, 1991) as guidelines. The panel was asked to evaluate seven sensory characteristics namely, overall liking, hardness, bitterness, sourness, saltiness, creaminess and chewiness.

Consumer sensory evaluation

Cheeses aged for 90 days were subjected to sensory evaluation by untrained consumer panelists. Consumer sensory evaluation sought to compare potential consumers' attitudes and perceptions to cheeses made with cardoon, calf and microbial rennet and with the Flora Danica and TCC-20 starter cultures. Consumer sensory evaluation was conducted at the cellar door of Charles Sturt University (CSU) for two weeks, CSU canteen for two days and Sturt Shopping Mall of Wagga Wagga, NSW, for one day respectively. The aim was to survey a wide range of potential cheese-buying consumers and record their attitudes towards the different types of cheeses.

Cheese samples were also cut into standard bite-size pieces with each piece measured about 1.25 x 1.1 x 1.1 cm. The cut samples were served in plates together with a consumer sensory evaluation questionnaire on a blind-labelled basis.

Texture Profile Analysis (TPA) by TA-TX2 Universal Texture Analyser

Seven textural (TPA) characteristics namely, hardness, cohesiveness, adhesiveness, springiness, fracturability, gumminess and chewiness were measured by using the TA-TX2 Universal Texture Analyser connected to a PC installed with the Texture Expert for Windows software.

Samples of experimental cheeses, stored in plastic bags to minimize losses of moisture and warmed to 18 (C prior to the testing, were cut into 5 x 3 x 3 cm cubes. These were placed onto the sample platform of the texture analyser. A plunger with a diameter of 0.3cm was attached to the moving crosshead. The speed of the crosshead was set at 2mm s-1 for pre-test, 5 mm s-1 for test and 1 mm s-1 for post-test. The depth of the plunger into the sample was set at 30 mm. One bite was taken as one cycle of a downward and upward motion of the plunger, which penetrated into and immediately retrieved from the cheese sample and two consecutive bites comprised one measurement. Five measurements were performed on each sample. The seven textural measurements were automatically recorded by the controlling PC. Of these, hardness, adhesiveness and fracturability were based on force-displacement measurements with the plunger attachment, while springiness, gumminess and chewiness were calculated from the data of the measurements using the formulas programmed in the software.

4.7.3 - Results

Overall liking of cheeses evaluated by consumer panelists

Two hundred and eighty seven survey forms were returned. Respondent consumers varied from eating cheese daily to those who rarely eat cheese.
Table 4.8.1 presents the breakdown of the respondents by the frequency of their cheese consumption. Most respondents (45%) eat cheese on a weekly basis, with those who consume cheeses fortnightly (25%) and daily (17%) forming the next two biggest groups. These three groups represented 87% of the total respondents.

**Table 4.8.1.** Breakdown of respondents by their frequency of cheese consumption.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>16.70%</td>
</tr>
<tr>
<td>Weekly</td>
<td>46.20%</td>
</tr>
<tr>
<td>Fortnightly</td>
<td>25.10%</td>
</tr>
<tr>
<td>Monthly</td>
<td>6.90%</td>
</tr>
<tr>
<td>Rarely</td>
<td>1.10%</td>
</tr>
<tr>
<td>No response</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Figure 4.8.2** shows the scores of overall liking of the different cheeses given by the respondents. For the 17% consumers who eat cheese daily, cheese made with cardoon rennet and the Flora Danica starter culture (CF) was rated the highest (69) which was significantly higher than the other three cheeses (p<0.05).

**Figure 4.8.3.** Average liking scores of cheeses made with different rennet and starter cultures assessed by consumer panelists who consume cheese (a) daily, (b) weekly, (c) fortnightly, and (d) monthly. Scores were calculated from a line scale with 0 = dislike extremely and 100 = like extremely. The cheeses were made with: CF = cardoon rennet and Flora Danica starter culture; CT = cardoon rennet and TCC-20 starter culture; MF = microbial rennet and Flora Danica starter culture; AF = animal rennet and Flora-Danica starter culture.

The second most liked cheese was that made with animal rennet and Flora Danica starter culture (AF). This was followed by the cheese made with microbial rennet and Flora Danica, while cheese made with cardoon rennet and TCC-20 starter culture (CT) was the least liked (51). A similar trend was found in the responses from the other three groups who consume cheeses weekly, fortnightly and monthly. Among these groups, cardoon cheese with the Flora Danica starter culture always received the highest scores. The cheese made with animal rennet and Flora Danica starter culture consistently scored the second highest. Cheeses made with microbial rennet and TCC-20 starter culture and those made with cardoon rennet and TCC-20 starter culture scored either lowest or second lowest.
The ratings of cheeses by the 5% consumers who did not indicate their frequency of cheese consumption and the 1% consumers who rarely eat cheese also recorded similar results to those from the other consumer groups (data not shown).

When the responses of all the respondents were considered together, the highest average overall liking (quality) score was received by cardoon rennet cheese with the Flora Danica starter culture (67). This was followed by the animal rennet Flora Danica (60) and Microbial rennet Flora Danica (51) cheeses, and cheese made with cardoon rennet and TCC-20 received the lowest score (49).

**Sensory evaluation by trained panel**

Table 4.8.2 shows the average scores for seven sensory attributes of the cheeses made with different rennet and starter cultures, given by the trained panel of 12 panelists.

The hardness of all cheeses decreased during the 90-days ripening period. In the later stages (60 to 90 days), the hardness decreased significantly. An exception was the cheese made with calf rennet and the Flora Danica starter culture. For this cheese, the hardness remained statistically unchanged during the 90 days ripening period. The use of cardoon rennet and Flora Danica starter culture resulted in significantly softer cheeses in comparison to cheeses made with calf and microbial rennet, especially for the cheeses made with the Flora Danica starter culture. The effect of starter culture on the hardness scores was considerable, and the cheeses made with the TCC-20 starter culture showed much higher hardness scores than the cheeses made with the Flora Danica starter culture.

**Table 4.8.2.** Mean scores of sensory attributes as evaluated by a trained panel. Values in the same sensory attribute without a common superscript were significantly different: (P < 0.05).

<table>
<thead>
<tr>
<th>Sensory attribute</th>
<th>Starter culture</th>
<th>Cheeses aged for</th>
<th>30 days</th>
<th>60 days</th>
<th>90 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C*</td>
<td>A</td>
<td>M</td>
<td>C</td>
</tr>
<tr>
<td>Hardness</td>
<td>Flora Danica</td>
<td>2.9 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.2 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.8 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>4.5 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.6 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.6 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.5 &lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bitterness</td>
<td>Flora Danica</td>
<td>2.8 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.2 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.5 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.9 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>2.8 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.1 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.9 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Creaminess</td>
<td>Flora Danica</td>
<td>5.1 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.7 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.4 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.7 &lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>4.6 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.9 &lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.6 &lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.2 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chewiness</td>
<td>Flora Danica</td>
<td>12 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>12 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>13 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>13 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>11 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>12 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>12 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>13 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Saltiness</td>
<td>Flora Danica</td>
<td>4.5 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.5 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.3 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.5 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>4.5 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.6 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.6 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Soursness</td>
<td>Flora Danica</td>
<td>4.2 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.1 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.2 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.2 &lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>4.2 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.1 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.3 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3 &lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall liking</td>
<td>Flora Danica</td>
<td>4.8 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.4 &lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.8 &lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>TCC-20</td>
<td>3.9 &lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.5 &lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.7 &lt;sup&gt;f&lt;/sup&gt;</td>
<td>4.9 &lt;sup&gt;a&lt;/sup&gt;</td>
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C = cheese made with cardoon rennet; A = cheese made with animal rennet, M = cheese made with microbial rennet. Cheeses were packed with plastic bags during maturation.

By contrast, the effect of starter culture on the perceived bitterness was not significant. Bitterness scores of all the cheeses made with the Flora Danica starter culture did not differ significantly (P>0.05) from their TCC-20 counterparts. An exception to this was the cheese made with microbial rennet, which had a significantly higher bitterness score than its TCC-20 counterpart at day 30.
The creaminess of the cheeses was markedly affected by the rennet used. The creaminess of cardoon rennet cheeses was much greater than both the calf and the microbial rennet cheeses, and the microbial rennet cheeses gave the lowest scores in creaminess. Creaminess of cardoon rennet cheeses increased steadily throughout the ripening period, reaching the highest score at day 90. The creaminess of calf rennet cheeses attained the highest score at day 60 then decreased thereafter, while the creaminess of microbial rennet cheeses was virtually unchanged throughout the 90 day ripening period. The effect of starter culture on the creaminess scores of the cheeses was also significant. Cardoon cheeses made with the TCC-20 starter culture recorded lower scores than their Flora Danica counterparts. By contrast, microbial rennet cheeses made with TCC-20 received higher creaminess scores than their Flora Danica counterparts, while no significant difference (P>0.05) was observed for the calf rennet cheeses made with the two starter cultures.

The chewiness scores of cheeses made with cardoon rennet were practically unchanged during the 90 days ripening period. The chewiness scores of both calf and microbial rennet cheeses increased substantially between day 30 and day 60 then remained largely unchanged during the rest 30 days of ripening. Cardoon rennet cheeses had significantly (P<0.05) lower chewiness scores than calf and microbial rennet cheeses and the chewiness scores of the latter two cheeses were similar. The effect of starter culture on chewiness scores was not significant.

The saltiness scores of all the cheeses were similar to one another at about 4.5, and they remained statistically unchanged throughout the 90 days ripening period.

The sourness scores of all cheeses were highest (about 4.2) after ripening for 30 days and then declined to about 3.4 at day 60. For the cheeses made with the Flora Danica starter culture, the sourness scores remained statistically unchanged over the next 30 days, while for the TCC-20 cheeses, the sourness scores increased to about 4.0 over the same period. No significant difference in the sourness scores was observed among cheeses made with cardoon, calf and microbial rennet.

Finally, the use of cardoon rennet resulted in cheeses with significantly higher (p< 0.05) scores of overall liking than the other two cheeses. The effect of starter culture on the overall liking score of cheeses was also significant (P<0.05) and higher scores were received by the Flora Danica cheeses than the TCC-20 cheeses.

Changes in rheological properties of ovine milk cheeses during ripening

Figure 4.8.4 shows the changes in hardness and chewiness of the cheeses over the 90 days period of ripening. At the early stages of ripening (30 days), packed and unpacked cheeses were similar in hardness, which was slightly less than 900g for calf and microbial rennet cheeses, and about 700g for cardoon rennet cheese. The hardness of packed cheese decreased throughout the ripening period, while the unpacked cheeses developed a slightly firmer body (harder in texture). At the end of the 90 day period, the hardness of unpacked cheeses was markedly greater than that of the packed cheeses. The hardness of cheeses was also affected by the rennet used. For packed cheeses, the use of microbial rennet resulted in the cheeses with greater hardness followed by calf rennet cheese, while cardoon rennet was the softest. For unpacked cheeses, cardoon rennet cheese was again the softest while calf and microbial rennet cheeses were similar in hardness.

For cheeses made with the same rennet, packed and unpacked cheeses were similar in chewiness at early stages of ripening (30 days). During subsequent ripening, the chewiness of all the cheeses increased, but the increases were much greater for unpacked cheeses than for their packed counterparts. At the end of the 90 day period, chewiness of unpacked cheeses were markedly greater than packed cheeses. Chewiness was also affected by the rennet used to make the cheese. For packed cheeses, the calf rennet cheese had the greatest chewiness. Cardoon and microbial rennet cheeses were similar in chewiness for up to 30 days of ripening, but microbial cheeses became slightly chewier than cardoon cheeses at later stages (60-90 days) of ripening. For unpacked cheeses, calf rennet was greatest in chewiness in the early stages of ripening (7-30 days), followed by cardoon and microbial rennet cheeses. During subsequent ripening, however, this order was gradually reversed with microbial rennet cheeses becoming the greatest in chewiness, followed by calf and cardoon rennet cheeses (Fig. 4.8.4 c, d).
Figure 4.8.4. Changes in the hardness and chewiness of ovine cheeses made with cardoon (ąd), calf (á) and microbial (ë) rennets and the Flora Danica starter culture measured by TA-TX2 Universal Texture Analyser. (a) and (c) were packed while (b) and (d) were unpacked cheeses.

4.7.4 - Discussion

Our results indicated that cheese made with cardoon rennet received the highest overall liking scores from both the trained panel and consumers while Flora Danica starter culture cheeses received higher overall liking scores than their TCC-20 counterparts. These results suggest that cardoon rennet could be used to make highly appreciated sheep milk cheese.

Most consumers surveyed in this study consume cheese (of various types) regularly (87%) and if frequent cheese eaters can be arbitrarily defined as those who consume cheese at least once a week, their percentage of the surveyed consumers was 62%. As these are likely to be the potential buyers of new cheeses, their attitude and perception to the cheeses are most important. Regardless of how often they eat cheese, all of the surveyed consumers displayed the same preference for cardoon rennet cheese made with the Flora Danica starter culture.

Izzo et al. (2000) reported that sweetness, hardness, bitterness, creaminess, salty taste, and characteristic aroma were the most important attributes affecting the overall rating of cheese. In the present study, the consumer panel was asked to indicate their overall liking of the different types of cheeses only, while the trained panel was asked to evaluate several sensory attributes including hardness, bitterness, sourness, saltiness, chewiness, creaminess, as well as overall liking of the cheeses. Attributes such as sourness and bitterness were clearly correlated negatively with the overall acceptability of the cheeses. However, other attributes, including hardness, saltiness, chewiness and creaminess could have either a positive or a negative coefficient value on overall liking. Bitter taste is one of the most common defects in cheeses made from milk or curd to which proteolytic enzymes have been added (Fernandez-Garcia et al., 1988). The higher scores of bitterness of the cheese made with microbial rennet has no doubt contributed to its low overall liking scores awarded by both the consumer and the trained panels. As there were no differences among the sourness and saltiness scores of the various cheeses (consistent with the similar levels of salt and pH), their contribution to the differences in the overall liking scores of the cheeses would be minimal. As to the other sensory attributes, the highest overall liking scores received by the cardoon rennet cheese made with the Flora
Danica starter culture were accompanied by higher scores in creaminess but low scores in hardness. The microbial rennet cheese, with its lowest overall liking scores, had the hardest texture and lowest creaminess scores, while the calf rennet cheese was intermediate in these sensory attributes as well as overall liking ratings. Thus, it appears that, besides a low intensity of bitterness taste, Pecorino style sheep milk cheeses preferred by the panel were those that had a soft texture, but relatively high degree of creaminess.

Chewiness scores, which were perhaps less well defined in comparison to the other sensory attributes, were similar among the different types of cheeses, but increased during ripening and may have contributed to the higher overall liking scores of all the cheeses aged for longer times.

For all the cheeses made with different types of rennet, the use of TCC-20 as a starter culture resulted in cheeses with significantly lower overall liking scores than its Flora Danica counterparts. TCC-20 cheeses were generally harder in texture, slightly less creamy in some cases (but more creamy in other cases) but otherwise comparable to their Flora Danica counterparts. This highlights the importance of texture for the overall liking of this style of cheese.

Apart from the above discussed sensory attributes, overall liking was surely also influenced by the appearance and overall flavour of cheeses. The comments made by both the trained panelists and the consumers indicated that the characteristic flavour and aroma of cheeses was one of the most important attributes that had influenced their decision on the overall liking scores. Although the exact reasons for the higher overall liking scores received by cardoon rennet cheeses than calf and microbial rennet cheeses were not clear, it was almost certain that the flavour of the cheeses played an essential role. Nuñez et al., (1991) showed that La Serena cheese made with cardoon rennet had a more pleasant and pronounced flavour. Similar findings were reported by Fernandez del Pozo et al. (1988). Similarly, the much higher overall liking scores received by Flora Danica cheeses was most likely due to the flavour produced by the Flora Danica starter culture. According to the information supplied by the manufacturer, the Flora Danica starter culture produces aroma compounds, but the TCC-20 starter culture does not. Present results suggest that Flora Danica starter culture was a better starter culture than TCC-20 for making Pecorino style sheep milk cheese.

The softer texture of the cardoon rennet cheese was most likely caused by the greater degree of proteolysis. A strong relationship was found to exist between the degree of proteolytic breakdown, particularly of Alpha s1-casein, and the consistency of cheese texture when calf rennet is used (Noomen, 1977; Noomen, 1978a, 1978b). Fernandez del Pozo et al. (1988) and Nuñez et al. (1991) suggested that the broader specificity of cardoon rennet resulted in higher levels of soluble nitrogen that were responsible for the softer texture of cardoon rennet cheeses.

The use of cardoon extract together with the Flora Danica starter culture produced a cheese that had the characteristics of a soft texture, low bitterness and moderate creaminess and chewiness. It was preferred to calf and microbial rennet cheeses by both the consumer and trained sensory evaluation panels. This suggests that cardoon rennet could be used to make highly appreciable ovine milk Pecorino cheese.
5. General Discussion and implications

The results presented in this report have major implications for the Australian sheep milking industry.

The problem of the lack of a productive breed of dairy sheep was addressed by evaluating the dairy potential of the crosses between the East Friesian and the Awassi and the Merino sheep. The East Friesian x Awassi sheep appear to be a very promising genotype as they produced almost three times as much milk as the highly specialised Awassi sheep, a sign that hybrid vigor might be at play in this cross.

The possibility that we may be observing a sire effect should be considered, as the number of animals tested for each genotype was small, and most of the East Friesian x Awassi ewes were the daughters on only one sire. However, for the sheep milking industry it is also important to identify superior rams capable of improving the dairy productions of their daughters.

The results of our experiment on the management of dairy sheep demonstrated that the share milking method does not result in lower productions of milk. Share milking also has the advantage that the ewes feed their own lambs, therefore avoiding the artificial feeding of lambs.

The need to develop typically Australian sheep milk products was addressed by developing a mould ripened Camembert style cheese and a hard cheese produced with cardoon rennet. Both cheeses are very promising in terms of their consumer acceptance, and the mould-ripened cheese has the advantage of a short maturation time, a characteristic highly sought by dairy products manufacturers. The cardoon rennet cheese has the potential to be marketed as a specialty dairy product.

The fact that consumers were also prepared to consume sheep milk ice creams is promising, but it was disappointing to discover that consumers were not prepared to pay a higher price for sheep milk ice cream. This suggests that processors should focus on making high quality cheeses rather than ice cream, or that overseas markets could be investigated for sheep milk ice cream.
6. Recommendations

Our results clearly indicate that the East Friesian x Awassi sheep have exceptionally good productions of milk. These were not only greater than those of local sheep, but they were also greater than those of the specialised Awassi sheep. This could be the effect of the genetic improvement brought about by a superior ram, and selection for dairy production should still be an essential component of any sheep dairy enterprise. The choice of superior sires capable of improving the milk production of their daughters should be a major goal for any sheep milking enterprise.

Our results indicated that share milking does not result in reduced productions of milk, and has the advantage that the ewes feed their own lambs, so the cost of artificially feeding the lambs can be avoided by adopting this practice.

The two cheese developed within the project were well received by consumers. The mould-ripened cheese has a short maturation time, which is a desirable characteristic, and the cardoon rennet cheese may appeal to vegetarians and consumers of specialty dairy products.

Our cheese maturation experiments suggested that consumers prefer traditionally made cheeses, not vacuum packaged and without the addition of enzymes and adjunct cultures. Therefore, perhaps producers should aim at producing small amounts of specialty cheeses that will fetch high prices. The fact that consumers did not dislike sheep milk ice cream was encouraging, but the fact that consumers would not be prepared to pay higher prices for it suggests that it may not be worth producing for the local market where it would have to compete with cows’ milk ice cream. However, possible overseas markets may still be worth investigating.
8. References


Mijatovic, S. (2001). The yield of sheep milk cheese can be predicted if the composition of milk is known. MSc Prelim. Thesis, The University of Western Australia.


9. Appendix

Form used in a survey undertaken to establish consumers acceptance of sheep milk ice cream developed within this project.

Ice creams will be labelled A, B, C, D and you must not tell participants if they are made with cow’s or sheep milk and if they are normal or low fat until they have tried them and evaluated them.

Hello, I’m conducting a survey of a new ice cream for The University of Western Australia. It takes about 5 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

• Do you normally eat ice cream?

☐ Yes ☐ No

• Have you ever tried low-fat ice cream?

☐ Yes ☐ No

3. If yes. On a scale of 1 to 7, where 1 = not at all, and 7 = very much, how much did you like it? Show participants the seven-point scale, where 1 = not at all and 7 = very much.

☐

• Do you believe that low fat ice cream is preferable because:

• It is more healthy ☐ Yes ☐ No

• It has low cholesterol ☐ Yes ☐ No

• I am/was on a diet ☐ Yes ☐ No
Have you ever heard of dairy products made with sheep milk?

☐ Yes   ☐ No

At The University of Western Australia we have developed ice cream made with sheep milk, both normal and low fat.
The normal contains 10% fat like other commercial ice creams.
The low fat contains 6% fat.
5. We have samples of the ice creams for you to taste. We also have cow’s milk ice cream made exactly with the same method and same fat content. We would like you to try the ice creams in a blind test (that is, you will not know which ice cream is made with cow’s milk and sheep milk and how much fat there is) and tell us what you think. Would you like to participate?

☐ Tastes  ☐ Refuses.

*If refuses, ask:*

- Would you taste them if they were made from cow's milk?

☐ Yes   ☐ No

*For those who taste the ice creams, ask:*

On a scale of one to seven, where 1 = not at all, and 7 = very much, how much do you like ice creams?

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

*Get participants to try the ice creams at random, that is do not always follow the order A, B, C, D.*

A  ☐

B  ☐

C  ☐

D  ☐

You can now disclose to participants the identity of the ice creams:

A = sheep milk, normal
B = cow's milk, normal.
C= sheep milk, low fat  
D= Cow’s milk, low fat.  

Then ask:

8. Would you buy a half litre tub of the normal sheep milk ice cream?
   - if it were free  
     - Yes  
     - No  
   - $3?  
     - Yes  
     - No  
     ($6 per Litre)  
   - $5?  
     - Yes  
     - No  
     ($10 per Litre)  
   - $10?  
     - Yes  
     - No  
     ($20 per Litre)  

9. Would you buy a half litre tub of the low-fat sheep milk ice cream?
   - if it were free  
     - Yes  
     - No  
   - $3?  
     - Yes  
     - No  
     ($6 per Litre)  
   - $5?  
     - Yes  
     - No  
     ($10 per Litre)  
   - $10?  
     - Yes  
     - No  
     ($20 per Litre)  

10. Would you buy a half litre tub of the normal cow’s milk ice cream?
    - if it were free  
      - Yes  
      - No  
    - $3?  
      - Yes  
      - No  
      ($6 per Litre)  
    - $5?  
      - Yes  
      - No  
      ($10 per Litre)  
    - $10?  
      - Yes  
      - No  
      ($20 per Litre)  

11. Would you buy a half litre tub of the low-fat cow’s milk ice cream?

- if it were free
  - Yes
  - No

- $3?
  - Yes
  - No
  ($6 per Litre)

- $5?
  - Yes
  - No
  ($10 per Litre)

- $10?
  - Yes
  - No
  ($20 per Litre)

Thinking about other sheep's milk products, on a scale of one to seven, where 1 = not at all likely and 7 = definitely, how likely would you be to buy:

12. fresh sheep milk?

13. sheep milk yoghurt?

14. sheep milk 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.

15. Which age group do you fall into (a through g)

16. Which educational group do you fall into (a through g)?

17. Do you have a job?

  - Yes
  - No

*If "Yes", go to question 22. Skip one page on the booklet, and turn to the occupational groups page.
Otherwise, show the activities card in the booklet, and ask:*

18. Which of these categories best describes you (a through d)?
19. Which occupational group do you fall into (a through h)?

20. What is the structure of your household (a through i)?

21. Which income bracket does your household fall into (a through g)?

22. Which country were you born in?  -------------------------------

That completes the survey.

Many thanks for your participation!