

it to be easily read from a distance of 2 metres. Despite the Strong's utilising these tags for their own purposes, it is interesting to note that the use of tags such as these also remains a requirement of the NLIS regulations until the 1st of January 2006, regardless of whether NLIS-compliant RFID tags are also attached (New South Wales Department of Primary Industries – Agriculture 2004).

4.1.5. The Dairy

The dairy was rebuilt approximately 4 years ago, on the site of a previous dairy that had undergone multiple restorations since originally being developed in the late 1800's (The Strong's have retained the original house building from this time, simply for historical interest). The current dairy contains a 14-a side Herringbone milking parlour (therefore providing a simultaneous milking capacity of 28 cows), and is situated centrally on the farm. The dairy features a high degree of automation, however these processes are triggered by operator actions rather than RFID technology.

The dairy contains the following features:

- Automated entry gate opening and closing
- Automated exit gate opening and closing
- Feed bins above bails
- Feed troughs for each milking bail
- Drop-down bail entry blockers
- Set of milking cups for each milking bail
- Milking controller units for each set of milking cups
- Multiple high pressure hoses throughout

4.1.6. Milking Times & Operators

The Strong's have quite a unique milking arrangement, in that they milk their cows three times a day - as opposed to the more common arrangement of milking cows twice a day. To facilitate this, milking takes place at 4am, 12pm (midday), and 8pm daily. Such an arrangement is not possible for many dairy herds, however the Strong's believe that they are able to achieve this additional milking session due to the high quality breeding of their cows.

Having this additional milking session has provided the Strong's with numerous benefits. Most notably, this additional session has enabled the Strong's to significantly enhance their milk output per cow - currently estimated to be providing an additional 1,500 litres of additional milk per cow every year (Semex 2005, p. 8). Subsequently, this increased production provides increased revenue for the farm.

However, there have also been other noteworthy benefits gained through this additional milking cycle. Interestingly, since adopting the additional milking session in April 2005, the Strong's have noticed a significant improvement in the health of their cattle, as well as the quality of milk being produced. On average, the somatic cell count of their cows has decreased by half (indicating a much lower risk of their cows gaining any infections or diseases such as mastitis), and many cows that were previously considered to be underperforming in terms of milk production have increased their output to meet or exceed expectations.

Each milking session is run by one operator. This person is responsible for the entire milking process – from dairy preparation, bringing the cows to the dairy, milking them, moving them back to the desired paddock, and taking any other actions that may be required for specific cattle. The operators rotate milking sessions regularly, however each operator will only take 1 or 2 milking sessions per day, thus enabling them enough time to undertake other duties or activities and to rest.

4.1.7. Strong Dairy Layout

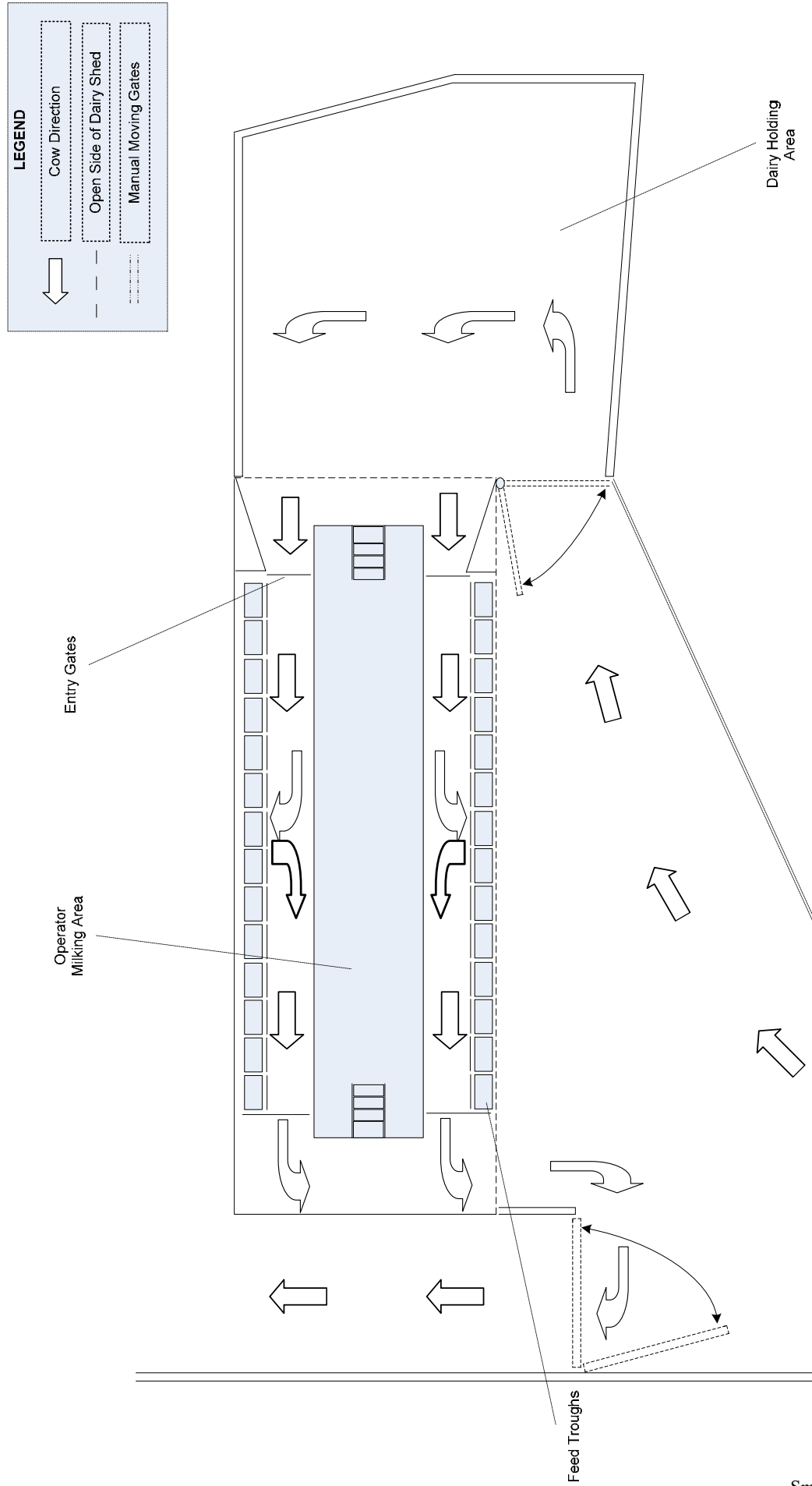


Diagram 4.1 Strong dairy layout

4.2. Milking Procedure

The milking procedure is a fundamental activity that is performed on all dairy farms. Subsequently, it is believed that this procedure will inevitably gain strong benefits through the development of RFID in dairy farm management. Furthermore, it is a procedure that can be directly affected by other farm management activities where RFID may be utilised in the future (such as recording cow injections, calving etc.). As such, a thorough understanding of how this process is currently being conducted is essential to understanding the operations of a dairy farm, and also to provide a solid basis for future development of RFID in the dairy industry.

4.2.1. Workflow Diagram of the Strong Milking Procedure

The following workflow diagram summarises the milking procedure undertaken on the Strong dairy. Detailed information regarding each of these steps is provided in the following section (section 4.2.2).

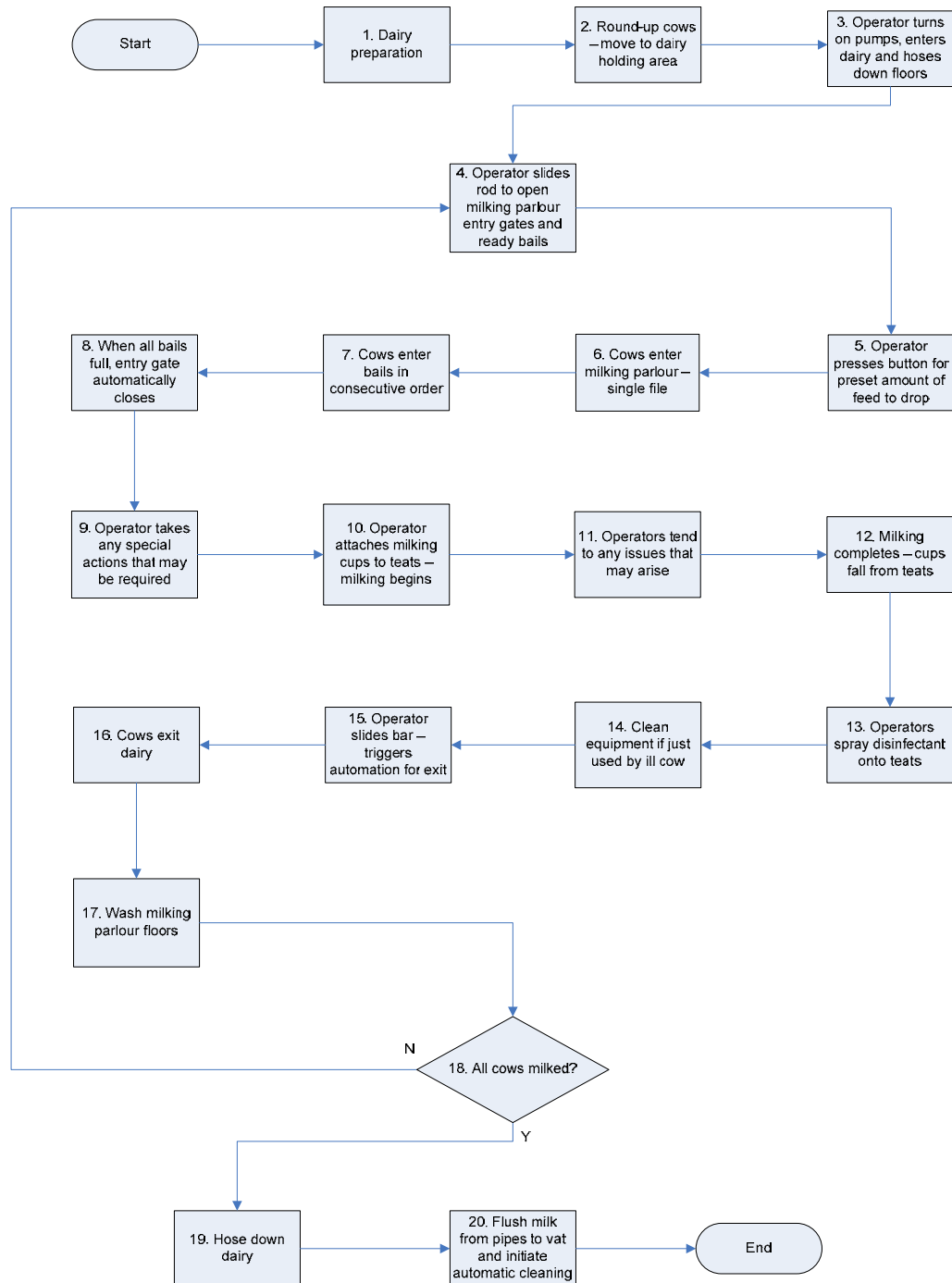


Diagram 4.2 Strong dairy milking procedure

4.2.2. Details of the Strong milking procedure

For each milking session on the Strong farm, the following steps are taken:

4.2.2.1. Dairy preparation

This involves the operator ensuring that the dairy is ready for milking. The operator will then open the gates to the dairy holding paddock, and place guide ropes across all other open thoroughfares, so as to provide the cows with a direct path to the dairy holding area.

4.2.2.2. Round-up cows – move to dairy holding area.

Utilising a quad-bike, the cows are rounded up from their current paddock and moved to the dairy holding area. This may take some time, as the cows may have to be walk from a paddock hundreds of metres away. They are allowed to walk to the dairy at their own pace, and the operator on the bike simply follows them from the rear.

As they arrive at the dairy, most cows enter the dairy holding area of their own accord. Some of the herd may initially remain just outside the holding area, exploring, or taking advantage of a water trough situated just prior to entry to the holding area. Once all cows have arrived near the dairy, the operator will move them all into the holding area, and close the gate. This will ensure that all cows due to be milked are located in the one location, and cannot leave without being milked.

During the process of moving cows to the dairy holding area, the operator will keep a watch for any cows that have been identified as being on heat. To identify cows on heat, the Strongs utilise a device known as a Karmar. This device is attached to the loin (backside) of cows that they believe will be on heat in the near future. Subsequently, when a cow with a Karmar is mounted (as will occur to a cow on heat), this Karmar changes colour from green to red. As such, the operator will identify any cow with red Karmars, and note their identification numbers. If the selected cow is past their first 60 days in their current lactation cycle, the cow will be extracted from the herd at the completion of the milking session for artificial insemination. The Strongs wait until the cow is past their first 60 days of

lactation as inseminating cows after this time provides the cow with two months in which they do not provide milk after their current lactation cycle completes, before giving birth again and returning to milking.



Exhibit 4.1 Cows waiting in dairy holding area

4.2.2.3. Operator turns on pumps, enters dairy and hoses down.

The operator then finalises preparations for milking. This involves activating the computerised milking system (this allows the milking cups to be utilised for milking, controls the flow of milk to the vat etc.). The operator then places an apron on and enters the dairy. One of the high-pressure hoses located in the dairy is then used to hose down the floor of the milking parlour. Taking this action at the start enables the easier removal of cow faeces that will inevitably be dropped during milking.

4.2.2.4. Operator slides rod to open milking parlour entry gates and ready bails

When the operator is ready for a batch of cows to enter the milking parlour, they pull a rod that spans the length of the milking parlour to the right. Movement of this rod to the right will trigger a number of simultaneous automated actions - the entry gate to the milking parlour will open, the exit gates will close, and the bail entry barriers for each bail will reset to their 'closed' position (this position is discussed further in section 4.2.2.7).

4.2.2.5. Operator presses button for preset amount of feed to drop.

The operator then presses a button to begin the release of a pre-defined standard amount of mixed feed into the feed trough of each bail. This feed is dropped from feed holders that are placed directly above each bail, and serve as intermediate storage locations for feed (between the main feed silos and each feed trough). The standard amount and composition (mixture) of this feed is set by the operator before milking (and is rarely changed).

The feed holders do not drop the total amount of feed into the feed troughs immediately, but rather the release of this feed is broken down into timed intervals. This interval can be selected by the operator to be every 5, 10 or 45 seconds, at which time a small amount of feed will be delivered to the trough until the allocated amount of feed has been provided. Dropping the feed in this manner ensures that the cows receive a regular, fresh supply of feed into their troughs during milking.

Initially, all cows will receive the same standard amount of feed. This feed is a mixture of 70% grain and 30%, and the standard amount provided is a total of 10 kilograms per cow per day. However, the operator is provided with a button for each cow bail that will allocate an additional amount of feed to that bail for each press of the button (approximately an additional 0.7kg of feed per press). This button is utilised to provide high producing cows with the additional feed that their bodies require in order to continue to produce a higher than average volume of milk. Elite production cows (those producing over 60 litres per day) will receive up to 4 kilograms of additional feed per day.

Cows that have been identified as high milk producers are distinguishable by a green tag having been placed onto their tail. Thus, when an operator sees this coloured tail tag on a cow, they know to press the button for additional feed to be dropped specifically to her feeding trough. In addition to this form of identification, the operators also utilise their own tacit knowledge of the herd to recognise these high producing cows, and to decide upon how much extra feed each of these cows should receive.

Cows in their first day of lactation on the Strong dairy are able to receive the full standard amount of feed due to a transition program that cows undertake in the three weeks leading up to their giving birth (calving). This program provides cows with a feed mixture that prepares the rumen (the first of a cows four stomachs) for full grain feeding from the first day of their lactation, while also aiding to prevent metabolic diseases. Preparing this stomach in this way is important, as if a cow is provided a large amount of grain without their stomach having built up the required bacteria to handle it, a cow can die of grain poisoning. Utilising this pre-calving program prevents such an event from occurring, while also enabling a cow to take in the full standard amount of grain on their first milking session - thus optimising the cows milk production potential from the first day.

4.2.2.6. Cows enter milking parlour – single file

The milking operator will then encourage the cows to enter the milking parlour, moving single file from the dairy holding area and into the milking parlour.

4.2.2.7. When all bails full, entry gate automatically closes

The cows will enter their bails in consecutive order, from the first bail in the row to the last bail (the first bail being the bail furthest from the entrance gate to the milking parlour). This consecutive bail entry order is enforced by utilising bail entry blockers that are setup so as to provide access to only one bail at a time. These entry blockers are composed of a large metal sheet that is placed horizontally in the bail, extending to both cover the bails feed trough and prevent entry to the bail.

Initially, the only bail that does not have one of these blockers in place is the bail furthest from the milking parlour entry gate (bail number 1). Thus, the first cow to enter the milking parlour only has the option to enter this open bail. As the cow enters the bail, she nudges a light bar that bridges the entrance to the bail. The movement of this bar releases a catch on the next bail (bail number 2), causing it to gently lower down, thus providing the next cow in line with access to this bail. Again, as the next cow enters this newly presented bail, they nudge the light bar bridging the entrance to this bail, thus causing the third milking bail to open. This

relay procedure is repeated for all bails until the row is full. Enforcing this entrance procedure is important to ensure easy access to bails for the cows, and to ensure that all bails are occupied during each batch of cows milked.



Exhibit 4.2 Milking parlour entry (featuring bail entry blockers)

4.2.2.8. Entry gate automatically closes

When a cow enters the last bail in the row, the entry gate to the milking parlour automatically closes, thus preventing other cows from attempting to enter the dairy during milking.

4.2.2.9. Operator takes any special actions that may be required

As the cows enter the bails, the operator is able to take any additional actions that may be required for specific cows. For example, if a cow has had a penicillin injection and it is still within the milk withholding period for her treatment, action must be taken to separate her milk from the rest of the herd, thus allowing it to be disposed of and not contaminate the rest of the herds milk. To achieve this, the hose connecting the milking cups to the main milk flow pipe is detached from the milk flow pipes, and attached to a designated barrel instead. This allows the cow to be milked through the usual actions (from the cows perspective, it is milking as usual) however their milk will be separated from the quality milk, and later disposed of.

There are three main methods employed by the Strongs to identify cows requiring any special actions to be performed. Firstly, all cows requiring particular attention will have a green leg band on one of their legs. This will signify to the operator that there is a problem with this cow. The operator then uses their own tacit knowledge of the herd to recall what the problem is, and take the required action. Alternatively, the operator may refer to the second identification method utilised by the Strongs – a whiteboard at the end of the milking parlour displaying the identification numbers of cows that are on a treatment regime or require any other particular attention (each cows identification number is printed on the green tags placed in each cows ear, as noted in section 4.1.4). This board also provides relevant data on the subsequent actions required for each of the cows listed. Thus, the operator can refer to this board prior to, and during the milking process to identify cows requiring particular attention and also to establish what action is required. Thirdly, cows that have received a penicillin injection (or other treatment that requires their milk to be withheld) are identified by a green leg band combined with a coloured dye mark on the back of the cow's udder. This dye is placed onto the udder at the time of injection, and serves as a further visual notice to the milking operator to dispose of this cow's milk.



Exhibit 4.3 Bail Components

4.2.2.10. Operator attaches milking cups to teats – milking begins

Each bail has a set of milking cups associated with it, and a milking controller unit that controls the operation of these milking cups. The operator presses a button on the milking controller to begin the suckling motion and suction in the milking cups. This suckling motion provides the required action to extract the milk from the cow, while the suction moves the milk through the pipes to the main vat, while also ensuring that the milking cups remain attached to the cows teats. The operator then attaches the four milking cups to the teats of the cow, thus beginning the milk extraction process. The extracted milk from the cow will be pumped through to the main storage vat throughout this process. For slow milking cows, the operator will begin the milking process by hand so as to get the milk flowing. Slow milking cows are identified by the operators own tacit knowledge of the herd and each cows characteristics.

The milking controller unit provides three modes for milking. The first of these is the standard automatic milking. Under this mode, the cow is milked by the machine until it detects that she has stopped providing milk (the flow of milk is gauged by an automatic detection unit placed in the milking lines). At this point, the cups cease suckling and suction, subsequently falling from the cows udder. The frequency of the suckling motions also varies under this mode. When the cups are first attached, the suckling begins at a relatively slow pace (approximately 30

pumps per minute), thus allowing the cow to adjust to the milking and release her milk. The pace of the suckling then increases to the standard rate for the majority of the milking (approximately 50 pumps per minute). As the flow of milk is detected to decline again, the pace of milking will return to the reduced speed (30) until the milk has reached a flow rate considered to indicate the end of the milk flow from the cow. This ensures an easy and comfortable finish to the milking for the cow.

The milking controller unit also provides a function for manual release of the cups. Under this mode, the milking will continue until the operator presses the button to cease milking, thus ensuring the cups stay on the cows teats until the operator elects to remove them.

The final available function is for full-paced milking for the whole time that the cups are attached (approximately 50 pumps per minute). This may be utilised for cows that have an udder formation that result in the milking cups having difficulty staying attached. As such, this faster paced milking is associated with greater suction, which aids to ensure the milking cups to do not fall from the cows teats unnecessarily. This array of milking functions is quite useful, and the operator uses his own tacit knowledge of the cows to determine which function to use for each cow.

4.2.2.11. Operators tend to any issues that may arise (e.g. Milking cups coming off, cups not retracting correctly).

There are occasionally unpredictable events that will require the operator's attention. An example of this may include instances where cows manage to shake or kick the milking cups off before they have finished milking. Another example is provided when a cow may elect not release her milk. In such a situation, the milking cups will rightfully not detect any milk flow, and thus will fall from the cows teats in belief that the cow has finished giving milk. Cows may elect to withhold their milk for a range of reasons, including being fearful of the environment, if it is their first time being milked etc. In this situation, the operator utilises an injection of a stimulant (synthetic oxytocin) to entice the cow to release her milk. This works quite rapidly and she will then release her milk.

4.2.2.12. Milking completes – cups fall from teats

As mentioned previously, depending on the function selected on the milking controller unit, the cups will either fall from the teats automatically, or will be removed manually by the operator when the cow has finished providing milk.

4.2.2.13. Operators spray disinfectant onto teats

When the cows are finished milking, the operator will spray an iodine-based disinfectant onto each of the cows teats. This will protect the teats for about twenty minutes after milking while the teats re-seal. This is an important step to help prevent foreign bodies from entering the teats, and subsequently aiding to reduce the possibility of infection or disease in the teats (e.g. mastitis).



Exhibit 4.4 Milking parlour in action - cows on left side continuing to be milked, cows on right side completed milking; Operator spraying disinfectant onto teats

4.2.2.14. Clean equipment if just used by ill cow

If a cow with an illness has just been milked, the operator cleans the inside of the milking cups that were used on that cow. This is achieved by rinsing the cups

thoroughly with one of the high pressure hoses located in the dairy, before dipping them into an iodine-based disinfectant solution to complete the clean. Conducting this cleaning process after an ill cow has been milked is an important step in aiding to prevent transfer of disease between cows.

The Strong's keep both their ill cows, freshly calved cows and show cows in a separate paddock beside the dairy. This aids them to identify cows that will require special treatment, as they only allow these cows into the milking parlour after the regular herd have completed milking.

4.2.2.15. Operator slides bar – triggers automation for exit

When all cows in a row have been milked and any additional actions that may be required are taken, the operator will trigger the dairy to be arranged for the cows to exit. This is achieved by simply sliding the control rod to the right, resulting in two automation actions being triggered. The first of these is to open the exit gate to the dairy. This gate will lift up and outwards, thus providing an exit for the cows. Secondly, the sheets of metal that act as bail blockers upon entry are then raised slightly, thus providing a gentle nudge to the cows to indicate that it is time to leave the bail. The operator verbally provides instructions and encouragement to the cows to exit the dairy throughout this step.

4.2.2.16. Cows exit dairy

The cows then exit the dairy, moving outside to a large holding area where they are free to move about, and have access to a water trough.

4.2.2.17. Wash milking parlour floors

As each row of cows are released, the operator uses one of the high pressure hoses to hose down the floor where the cows were standing. This keeps the floor clean and ensures cow faeces are quickly removed.

4.2.2.18. Repeat process until all cows milked.

The above milking process is repeated until all cows have been milked. This includes milking the cows from the nearby paddock containing those that require particular attention (sick cows, freshly calved cows etc.).

4.2.2.19. Clean Dairy

After the milking process has been completed for all cows, the cleaning process must then take place. Firstly, this involves a final wash down of the dairy floors and equipment with the high pressure hose.

The automated cleaning process is then initialised. To begin this phase, the milking cups must be placed back into their holding/cleaning position (four prongs at each bail). During the next step the operator will select automated cleaning from the dairies computer controller unit to complete this cleaning process.

4.2.2.20. Flush milk from pipes to vat and initiate automated cleaning

The operator then exits the milking parlour and enters a separate room in which the vat and computerised milking equipment is housed. Here, the operator makes a selection on the automated cleaning system control unit (entitled Hygenius 2000 – which controls the flow of liquids through the milking pipes) to flush water through the pipes to push the milk currently left in the pipes through to the vat (can be a large quantity due to the distance between vat and milking parlour). A clear section of pipe several metres from the vat allows the operator to view the movement of milk through these pipes. When they see water begin to come through the pipes, the pipe leading to the vat is disconnected, ensuring water does not enter the vat, and the pump is turned off. The main filter leading to the vat is then cleaned.

To facilitate the automated cleaning process, the pipe that previously led to the vat is then plugged into the cleaning system connection, thus creating a complete loop within the pipes and milking equipment in the dairy. The operator then selects ‘cleaning’ mode on the cleaning system control unit, which will subsequently begin the automated cleaning process. This process involves circulating a variety of water and chemicals through the pipes, at varying temperatures and pressure rates, thus providing a complete clean of all the pipes and equipment that milk flows through. Once this cleaning process has been initiated, the operator is then free to exit the dairy, and begin moving the herd to their next grazing paddock.

The automatic cleaner will manage itself and turn off when the cleaning cycle has completed.



Exhibit 4.5 Automated cleaning system controller unit

4.3. Calf Feeding

Managing the amount of milk and feed provided to calves is another important management aspect of a dairy farm. This process is integral to the development and health of a calf, and as such must be handled appropriately. The Strongs undertake this task by grouping their calves into similar age groups, and manually providing each group with a specific amount of milk via buckets at designated feeding times. The calves are also always provided with a solid feed mixture, fresh running water and hay in their pens, allowing them to eat or chew on this feed as they desire. The calves are provided this treatment for the first twelve weeks of their lives, during which time they are also provided shelter.

This manual approach to calf feeding enables the farmers to provide the required amount and type of milk to encourage and maintain solid calf development and growth. For the first week of a calf's life, they are fed with milk from freshly calved cows. This milk contains the required amount of colostrum and nutrients to aid in the calf's early development. This milk is not necessarily provided from the calf's direct

mother, but from whichever of the freshly calved cows is producing the best quality milk for this purpose. This cow usually continues to provide the milk for the calves for the first few days, as changing the source of the milk will certainly change the composition of the milk, which can subsequently make the calves sick.

After this first week, the calves no longer require this solid amount of colostrum, and subsequently they are then fed with milk that is being produced from cows with high somatic cell counts. This milk is considered to be of lower quality than the rest of the herds milk, however is still certainly safe for consumption. Utilising this lower quality milk in this fashion ensures that the farm is optimising their use of the milk produced by their herd - only providing high quality milk to the manufacturer, while still utilising the lesser quality milk for the valuable purpose of calf feeding.

The age group of the calves will define the amount of milk that they are provided. Initially, each calf is provided with 4 litres of milk, before this amount is gradually increased as they get older to a maximum of up to 8 or 9 litres, depending on the amount of milk the dairy has available at the time. The amount of milk available to the calves is then gradually decreased as they approach time to exit the calving environment. At this time, they are provided with pellets and given access to pasture for grazing until the time comes for them to join the rest of the herd in the grazing paddocks (approximately 12 weeks).

4.4. Herd Information Storage and Retrieval

4.4.1. Herd Management Software

To aid in supporting their herd management activities, the Strong's utilise a software application entitled Dairy Store, produced by Dairy Express. This application is specifically tailored to suite the data storage and herd management needs of the dairy industry. Information such as date of artificial insemination, treatments and a wide variety of other information and individual characteristics pertaining to each of the Strong's cows can all be stored by the application. This data can be accessed and updated based upon the cow's identification number as assigned by the Strong's at the time of birth. As there are currently no automated procedures for writing daily

information to this database, it is up to the Strongs to enter daily information into the database themselves.

4.4.1.1. Manual Recording Processes

In order to record information relating to individual cows on a daily basis, the Strongs currently utilise a manual working diary to record any action taken on cows, or other information pertaining to the cows that they feel should be recorded. This may include information such as the date of artificial insemination for a cow, date calved, date received a form of veterinary treatment etc. This data is then manually entered into the herd management software, thus providing the information both in hardcopy and on the computer.

This approach subsequently requires duplication of information recording, however having this data stored on the computer enables the information to be easily stored, viewed and manipulated (for reports etc.), thus justifying the duplication of effort. Having the data stored in these two locations also provides a valuable form of back for this information.

4.4.1.2. Dairy Express Herd Recording

A great deal of data pertaining to each cow is also input into the herd management software via electronic data files that are produced as a result of the Dairy Express herd recording services. The Strongs utilise this herd recording service to gain information pertaining to each of their cows individual milk quality and production. This service involves a company representative visiting their farm once a month, and taking a sample of each of their cows milk for analysis.

To gain this sample, the representative sets up quite a large amount of additional equipment at each bail in the dairy. This equipment will catch a designated amount of the milk produced by each cow in a small container (for example, 2.5% of the total amount of milk they produce). As each cow finishes milking, the farm identification number of each cow is written onto the container, and it is retained by the Dairy Express representative. This sampling is performed for all cows, and over two of the standard milking sessions.

These samples are then taken back to the Dairy Express laboratory for analysis. This analysis can provide the following information pertaining to each individual cow sampled:

- Somatic cell count (important for detecting the likelihood of mastitis)
- Litres produced per day
- Fat components in milk
- Protein components in milk
- Other optional information – including pregnancy testing

The results of the two samples taken on the day are averaged to provide the final results. This information can be accessed via the Internet within 48 hours of completed sampling. Results can also be printed and sent to the consumers within a brief period. These printed result sheets also provide historical information related to each cow, such as the information from the last test day, when a cow went dry, their age, calving date etc.

When these results become available online, the Strong's are able to download them to their home computer. They then import this data directly into their herd management software, thus providing regular monthly updates to the information pertaining to each cow. This information can provide a valuable insight into the health, milk quality and production of each cow in the herd. These results can also be compared against national, state and regional results, providing the ability to benchmark themselves against the industry.

4.4.2. Daily Collected Milk Sampling

Information similar to that provided by Dairy Express is also provided by the Strong's milk manufacturer 'Dairy Farmers' on a daily basis. This information however, is provided in regards to the milk production of the herd as a whole, rather than on an individual basis (as Dairy Express provide). This information is gained by taking a sample of the milk from the vat daily, when the Dairy Farmers tanker arrives to collect the milk from the farm. The tanker driver takes a milk sample from the vat, and returns this to the laboratory at the processing plant. This sample can then be analysed as representative of the whole milk batch collected. The results of this

sample analysis are then provided over the Internet to the farmer within 12 hours, providing them with feedback regarding the total amount of litres collected, fat and protein percentage and other figures. This sample also serves as a basis for Dairy Farmers to track the source of any impurities if they are found in the milk contained in the tanker (such as traces of penicillin).

Chapter 5 – Advanced Case Study: The Cochrane Dairy

5.1. The Cochrane Dairy

5.1.1. *The Advanced Case Study*

This case study was undertaken on the Cochrane dairy farm, located in Pyree (minutes from Nowra) on the NSW South Coast. This farm has been selected as the advanced case study, as it has a strong use of RFID technology, and is well known in the region as one of the most advanced RFID setups. As the farm also utilises RFID tags that are compliant with Australia's NLIS (National Livestock Identification System) system, the farm provides a currently applicable example of how participants in this system can derive additional benefits through the use of RFID on their dairy farms.

5.1.2. *Meet The Cochrane's*

The Cochrane dairy is a family-run business, operated by partners Geoff and Cathy Cochrane, and two of their sons Tim and Tom. They are also currently training Jason, a young apprentice to assist in the milking and work on the farm.

The farm's core business function is dairy, however they have recently diversified, and begun experimenting with rearing steers until they are 2 or 3 years old. However, dairy certainly remains their core business function, and is likely to remain so in the future. The Pyree farm is one of several properties in the region owned by the Cochranes, however this is where the dairy is located, and thus serves as the location for this case study.

5.1.3. *The Cows & RFID Tags*

Established on approximately 360 acres, the Pyree farm supports around 350 head of lactating Illawarra cattle (their full herd size is approximately 420 including the dry cows they have on their other properties). All cows in the herd have an NLIS-compliant RFID tag attached to their right ear. This tag is applied to calves immediately (0-4 days) after birth, and plays an integral role in the total farm management operations of this farm.

This RFID tag is utilised to aid in farm management operations from early in a cows life. For a new born calf these tags are first utilised merely weeks after birth, as they

provide the identification mechanism to enable automated calf feeding. Later in the cows life (when they enter lactation), the RFID tags are also utilised in the dairy to identify each cow as she walks into the milking parlour. This identification subsequently facilitates a number of functions within the dairy. As each cow exits the dairy, these tags are also utilised to facilitate the use of automatic drafting gates. Further information regarding these practices is provided throughout section 5.2.

A separate plastic identification tag is also placed in the cow's right ear (traditional tag), which displays the cows on farm identification number (as opposed to the RFID tag number). This number is allocated by the Cochrane's at the time of a cow's birth, and used to identify the cow in relation to their own herd. These tags provide farmers with an important immediate visual identification mechanism for each cow, as they are currently not utilising portable RFID readers, and is traditionally one of the most common forms of identifying cows on farms that are not utilising RFID. Additionally, the Cochrane's are maintaining the use of these tags in order to comply with NLIS regulations, which state that farmers must maintain the use of either a tail or ear tag as a secondary identification mechanism until the 1st of January 2006 (New South Wales Department of Primary Industries – Agriculture 2004).



Exhibit 5.1 Cow identification tags

5.1.4. Herd Management Software

Similar to the Strongs (case study A), the Cochranes utilise a software package to aid in their herd management. The Cochrane's however, extend the use of this application to also provide the basis for their RFID operations. The software application utilised by the Cochrane's is entitled Dairy 2000, and is produced by Victorian company OnFarm Electronics. As with the Strong's software, Dairy 2000 has been specifically tailored to suite the data storage and herd management needs of the dairy industry, and provides the ability to store information pertaining to each individual cow in the Cochrane herd. Further details of this software application are provided in section 5.4.1.

5.1.5. The Dairy

The current dairy was built approximately two years ago, and features a twenty-five a side Herringbone milking parlour (25 bails on each side, therefore catering for up to 50 cows at once). The dairy features a high degree of automation, some of which is combined with RFID technology, while others are triggered by manual actions.

The dairy contains the following features:

- RFID reader upon entry to the milking parlour
- Automated entry gate opening and closing
- Feed bins above bails
- Feed troughs for each milking bail
- Rotating bail entry blockers
- Two LCD computer screens (displaying cow information)
- Audio speaker (to provide audio notification of particular cow attributes)
- Set of milking cups for each milking bail
- Milking controller units for each set of milking cups
- Automated raising of the feed trough to allow cows to exit milking parlour
- RFID reader upon exit to the dairy
- Drafting gates associated with RFID reader upon exit to dairy
- Multiple high pressure hoses throughout

5.1.6. Milking Times & Operators

Milking takes place twice daily on this farm – firstly, at 5am, and secondly at 3pm. Each milking session takes approximately two hours, and is conducted by two operators.

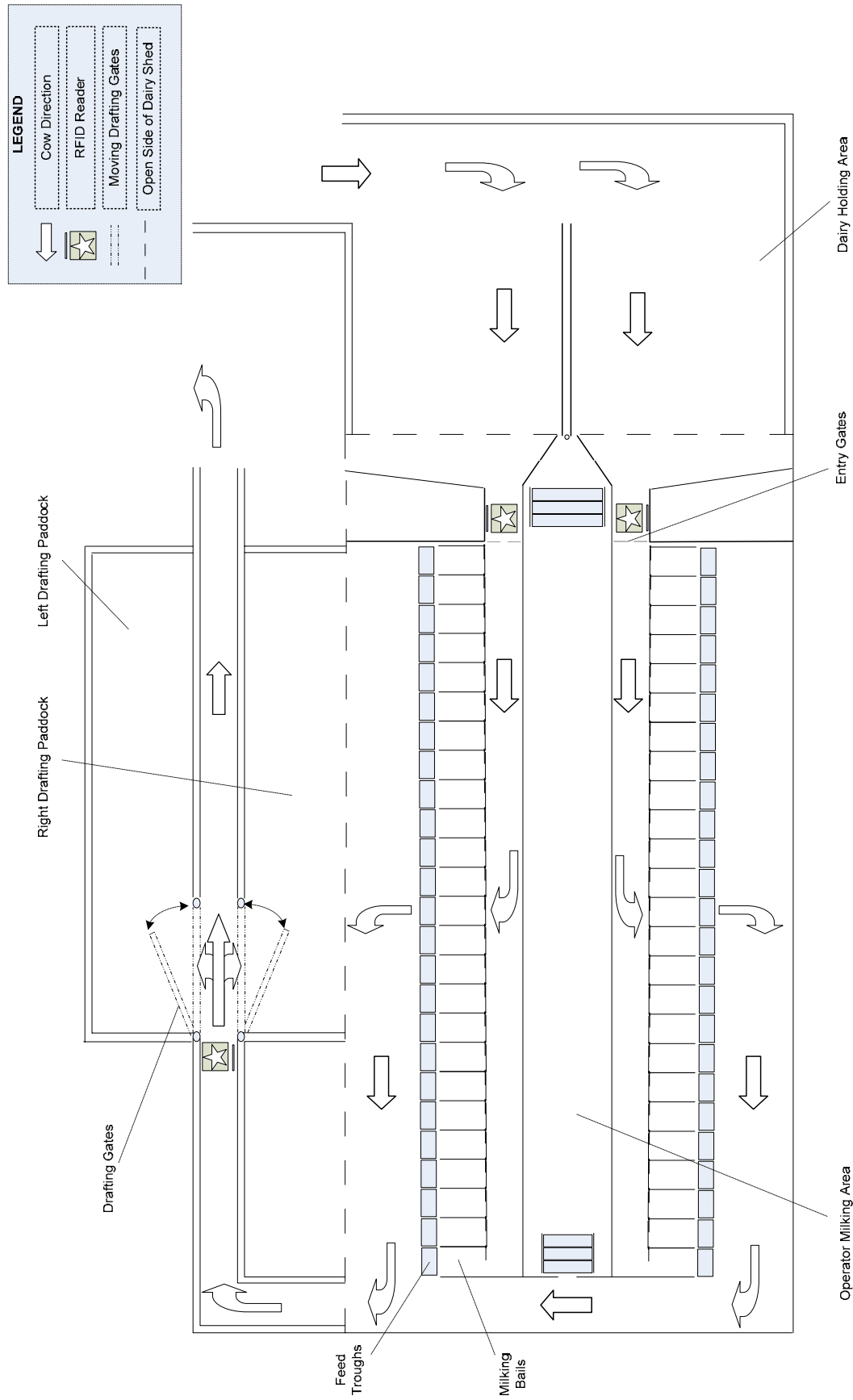


Diagram 5.1 Cochrane dairy layout

5.2. Milking Procedure

The milking procedure of the Cochrane dairy is one major area gaining benefits from the use of RFID. As previously noted in section 4.2 (case study A), it is also an integral component of dairy farm management in general, and thus provides an important area in which further benefits may be derived from RFID in the future. As such, a thorough understanding of this procedure is an essential element to understand both how RFID is currently being utilised, and as well as to provide a basis for future development of RFID on dairy farms.

5.2.1. Workflow Diagram of the Cochrane Milking Procedure

The following workflow diagram summarises the milking procedure undertaken on the Cochrane dairy. Detailed information regarding each of these steps is provided in the following section (section 5.2.2).

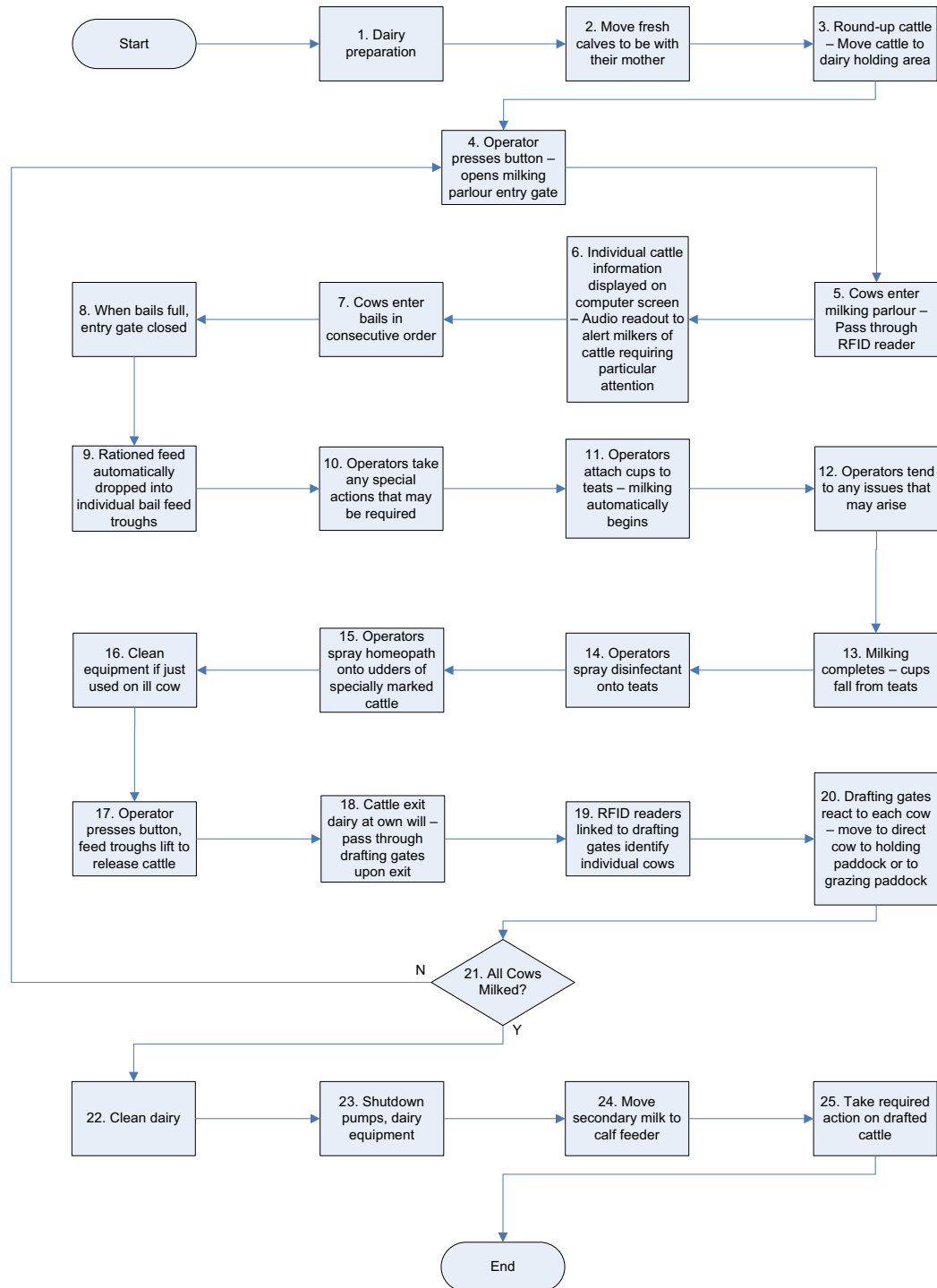


Diagram 5.2 Cochrane dairy milking procedure

5.2.2. Details of the Cochrane milking procedure

At the Cochrane dairy, the following steps are taken for each milking session:

5.2.2.1. Dairy Preparation

Prior to milking, one operator prepares the dairy for milking. This involves ensuring the equipment is clean and ready, and that the computer system is ready for operation. This may also involve entering data about cows into the computer system, or perhaps entering information pertaining to what cows are to be drafted for this milking session.

5.2.2.2. Move fresh calves to be with their mother.

Fresh calves (new born calves) require their mother's milk for the first few days of their lives. The Cochrane's facilitate this by moving the fresh cows into a pen with their natural mother. The calves can then suckle their mother for milk while the milking in the dairy is conducted (after milking the remainder of the herd, the mother cows are moved to the dairy and milked to extract the remaining milk).

5.2.2.3. Round-up cattle – Move cattle to dairy holding area.

Utilising a motorbike, one operator rides out to the paddock, groups the cattle and escorts them to the dairy holding area. While the cows are approaching the dairy, both operators spend time observing the herd for any signs of cows that may be on heat. This is primarily signified by other cows mounting the cow on heat from behind, and may also be indicated by the cows taking a special interest in the bull in a nearby paddock. If the operators determine a cow to be on heat, they will record her identification number (from the visual identification tag placed in her ear beside the RFID tag). If this cow is determined to be beyond their first 60 days of lactation, the operators will then record this cow number into the nearby computer and select it to be drafted when it exits the dairy (where the cow will then be artificially inseminated). As with the Strongs (as described in section 4.2.2.2), the Cochrane's wait until a cow is beyond 60 days of her lactation cycle before attempting to impregnate her. This allows for the cow to have two months away from milking ('dry') before calving again and entering a new lactation period.

After the cows reach the holding area, and the operators have recorded any cow identified as being on heat for drafting, both operators finalise the preparations for milking. The gate to the holding area is then closed by an operator (ensuring the cows to be milked are retained in the holding area), before re-entering the dairy, ready for milking to begin.



Exhibit 5.2 Cows in dairy holding area

5.2.2.4. Operator presses button – opens milking parlour entry gate

Operator presses button to open the milking parlour entry gate - gates open automatically.

5.2.2.5. Cows enter milking parlour – pass through RFID reader

Cows enter the milking parlour in single file, passing through a permanent RFID reader installed on the entry gates. This reader retrieves the identification number from the RFID tags attached to the ear of each cow. This unique identification number is then used to gather data pertaining to each cow from the central database.



Exhibit 5.3 Entry to milking parlour

5.2.2.6. Individual cattle information displayed on computer screen – audio readout to alert milkers of cattle requiring particular attention

As each cow passes through the RFID reader, their individual information is displayed on the two computer screens located in the dairy. These screens provide a selection of information pertaining to each cow. This information is drawn from the central herd management database, and the user is able to specify the specific fields of information to be displayed on the screen. The cows are listed in rows, with their characteristics displayed in the corresponding columns. Importantly, this display also provides the bail number that each cow will enter (the program is able to recognise which bail the cow will be entering, as cows must enter the bails in sequential order, as described in the next section - 5.2.2.7).

Cows with attributes requiring particular attention from the operators are highlighted with various colours on the computer screen. For example, slow milking cows are highlighted in red on the computer screen, cows that have freshly calved are highlighted in yellow etc. For these cows, an audio readout is also generated from the computer system, providing a verbal signal to aid in identifying cows requiring particular attention. This allows the operators to better plan their milking approach for a batch of cows, and aids to ensure they take the required actions. For example, the operators will begin to milk the slow milking cows before the others, thus aiding in efficiency for each batch of cows. For

freshly calved cows, and cows who have had a penicillin injection (and thus their milk must be withheld) the operator will also attach the milking cups to a separate holding drum. This effectively separates specific cow's milk from the main milk, allowing it to be thrown away after milking has completed.



Exhibit 5.4 LCD screen – displaying individual cow data

5.2.2.7. Cows enter bails in consecutive order

Cows enter their bails in sequential order (from one to twenty-five). The order in which they enter bails is enforced by having each bail blocked when the cows first enter. The only bail available for entry is the end bail (number 1). When a cow enters this bail, it will push forward a rotating bar. This will subsequently rotate and open the next bail (bail number 2).). Enforcing this sequencing process allows the computer to establish which bail number each cow will enter as they are read. This is also important to ensure that all bails are occupied, and provide easy entry to the bail for each cow.

5.2.2.8. When bails full, entry gate closed

By reading each cow's RFID tag as she enters the dairy, the computer system is able to determine when twenty-five cows have moved into the dairy. Thus, when a

side is full, the entry gate automatically closes. This prevents other cows from entering the milking parlour during milking.

5.2.2.9. Rationed feed automatically dropped into individual bail troughs

Approximately 40 seconds after the cows have passed through the reader (enough time for them to reach their bail), feed is automatically dispensed from feed holders above the bails. This feed is a mixture of approximately 80% wheat, and 20% pellets. These feed ingredients are stored in large silos beside the dairy, and are mixed into a designated ratio before being pumped through to the feed holders in the dairy. The amount of feed given to each cow varies according to her production and lactation cycle.

Roughly, a cow producing 50 litres or more per milking session (extremely high) will receive 12 kilograms of feed. Those producing approximately 30 litres will receive 8 kilograms, 20 litres will receive 6 kilograms, and finally, those producing 12 litres or less per milking will be provided 2 kilograms of feed during the milking session. Production amounts in between these boundaries will receive an amount of feed rationed to their exact production (e.g. a cow producing 15 litres will receive a calculated ration between 2 and 6 kilograms).

Once a cow has passed their 150th day of their 300 day lactation cycle, they are considered to have past their peak production abilities. As such, the feed provided is then gradually decreased to only 75% of the figures provided above. As a cow passes the 250th day of lactation, they are considered to be well past their peak production capacity, and the feed is again gradually decreased to 50% of the above provided figures, so as to gradually wean the cow off this food supply. This 50% of the original stated amount is then maintained until the cow is dry and thus does not return to the dairy.

The data regarding how much milk each cow is producing is extracted from the central herd management database (this data is recorded by Dairy Express herd recording services) according to the cow's unique RFID identification number. This rationing of feed ensures that cows are provided the nutrients they require to

continue their milk production, while not overfeeding those cows who do not need it.

When a cow enters the dairy for the first milking of her new lactation cycle, the automatic feeder also starts this cow at a low amount of feed (approximately 1 kilogram). The amount of feed is then gradually increased over a 20 day period, up to a standard 8 kilograms of feed. This feed is then maintained until the cows production capacity is measured (through the use of Dairy Express herd recording), and her amount of feed is then determined by this figure. This gradual incrementing of feed is required so as to allow time for the cow to develop the required bacteria in their stomachs to handle the wheat and grain in the feed. If they are not gradually introduced to the feed in this way, a cow may be susceptible to fatal wheat or grain poisoning.

5.2.2.10. Operators take any special actions that may be required

As the cows enter their bails, operators are able to take any required action on cows. For example, if a cow has had a penicillin injection in the last few days, their milk must be disposed of, as it is not suitable for consumption by any animal. To achieve this, the hose connecting the milking cups to the main milk flow pipes are detached from the main milk pipes, and instead attached to a barrel. When milking is complete, the milk in this barrel is disposed of.

Other actions that may be required include attaching the milk pipes for specific cows to a secondary milk vat. This vat is used to store milk that the Cochrane's consider second grade milk, and is later used to feed the calves via the automatic calf milking machine (details of this automatic calf feeding machine are provided later in section 5.3). This second grade milk is still quality milk, and suitable for consumption, however it is considered of lower quality than that being produced by the rest of the herd. Therefore, to maximise the quality of the milk provided to the manufacturer (in this case Dairy Farmers), the Cochrane's separate the lower quality milk. Thus, this separation and use of secondary milk maximises the use of produced milk and provides enhanced benefits for the farmer.

5.2.2.11. Operators attach cups to teats – milking automatically begins

Operator presses lever to begin milking pulsation and suction within milking cups before attaching these cups to the teats of a cow. The milking cups provide pulsations that mimic a calf suckling, and thus extract milk from the cow through these gentle nature-inspired pulsations. For slow milking cows, the operator will often begin the milking process by hand, so as to get the milk flowing.



Exhibit 5.5 Milking cups attached and suckling milk from teats

How the operators attach the cups may vary depending on the current udder condition of the cow. For the majority of cows, the cups are simply attached to all four teats on the cow without any further action being required. However, some cows may have problems with a specific teat on their udder, may have had one teat dried off for a particular reason, or are currently being treated for a disease in a teat. To cater for such individual attributes, operators are required to take different actions to the standard milking procedure (such as not attaching a cup to a dried teat).

Cows requiring these varied actions are identified by coloured leg bands that are attached to the legs of cows using Velcro straps. The colour and placement of the leg band signifies the position of the problem teat on this cow, and how the milking operator should conduct milking for her. A green leg band on the cow indicates that there is a problem with the front teats, and the leg band is placed on

the left or right leg to signify which of the front teats have the problem (thus indicating left or right front teat). A red leg band is also used, which indicates that there is a problem with the rear teats, and the leg band is again placed on the left or right to signify which of the rear teats have the problem (thus indicating left or right rear teat). Having two leg bands of the same colour on the one leg of a cow indicates that one of her teats is bad, or has been dried off for a particular reason. It is up to the operators to recognise these leg bands and combinations, and to not apply milking cups to the teat identified as having the problem.

Cows that have had a penicillin injection are identified with a single leg band (utilising the colour and placement code previously described to identify the problem teat), as well as having blue spray paint on their back of their udder. Thus, the milk from this cow is to be separated from the main milk and disposed of (as described in section 5.2.2.10).

5.2.2.12. Operators tend to any issues that may arise

Occasionally unpredictable events will occur that will require the operator's attention. These events include cows kicking the milking cups off before they have finished milking, cups not retracting correctly when milking completed, slow milkers may require a check to ensure they have provided all of their milk (requiring a manual feel of the milk left in the teat).

Operators may also be monitoring certain cows that they believe may be coming down with an illness, or are recovering from an illness (such as mastitis). Thus, the operators may take extra steps to monitor the progress of this cow, such as ensuring this cow has given all of her milk, or check that cows milk line filter for signs of clogging.

This milk line filter is placed in the milk line between the milking cups and the main milk flow line that leads to the milk storage vat. As milking is being conducted, milk flows through this filter before it enters the main milk flow line, thus aiding to remove any impurities in the milk. Additionally, as this filter is associated with each individual milking bail, this filter is a good indicator of the milk quality being provided by the cow in that milking bail. If the milk is of poor

quality (a good sign of a cow being ill), the filter will catch quite a lot of impurities, thus appearing somewhat clogged. Keeping a watch of these filters (as they are surrounded by clear surface) aids operators to detect any illnesses in cows and also poor quality milk.

5.2.2.13. Milking completes – cups fall from teat

The milking cups automatically detect when the cow has finished giving milk. At this point, the cups will cease their suckling and suction, and subsequently fall from the cow's teats. As they fall from the teat a piece of cord linking the milking cups to the base of the milking controller unit will retract, thus raising the cups to a stationary position – keeping them off the floor and at a position ready for attachment on the next cow. This signals to the operators that the milking has completed for the cow that these were attached to.

As previously noted, operators may wish to ensure that slow milking cows have been fully milked. This involves manually feeling the udder to identify if any milk may be left. If there is, then the operator may manually pull the teats to extract remaining milk, or reattach the milking cups for a brief period.

5.2.2.14. Operators spray disinfectant onto teats.

As cows finish milking, operators spray an iodine-based disinfectant onto cow teats. This solution aids to kill bacteria present on the teat, and protect the teat against foreign bodies for a brief period while the teat returns to being fully closed after milking.

5.2.2.15. Operators spray homeopathy onto udders of specially marked cattle

While the process of spraying disinfectant onto teats is being conducted, homeopathy is also applied to the udders of those cows identified as requiring the treatment. This homeopathy treatment is a naturally developed solution that is utilised on cattle that the Cochrane's feel may be developing an illness (such as mastitis). The solution is applied to the udder of cows via a spray bottle that the operators carry on their belts. This treatment is first tried when the operators believe a cow may be falling ill, and the cow is monitored for any progress. If the homeopathy does not resolve the issue, drugs such as penicillin will then be

utilised. Cattle requiring this treatment are identified by a yellow tag attached to their tail.



Exhibit 5.6 Yellow tail tag to identify cow requiring homeopathy

5.2.2.16. Clean equipment if ill cow just used

If a cow with an illness has just been milked (cows with illnesses are identified by their leg straps, as noted in section 5.2.2.11), the operators clean the inside of the milking cups that were used on that cow. This is undertaken to prevent the possibility of spreading disease between cows via the milking cups. This cleaning is performed for all cows that have been treated with penicillin (or another drug), homeopathy, or who the operators feel may developing an illness. The milk line filters are also checked and cleaned after such cows, thus clearing any impurities that may have been caught here.

5.2.2.17. Operator presses button, feed troughs lift to release cattle

When all cows in the row have completed milking, all additional actions taken (such as spraying homeopathy), and disinfectant has been sprayed onto all cows teats, the operator is free to release the row of cows. This is achieved by pressing the designated release button.

Pressing this button triggers the feeding bails that are currently placed in front of the cows to automatically be brought backward and raised into the air. This enables the cows to move out of their bails in a forward direction, underneath the feed bails. Once they have moved far enough out of their bails (approximately a metre clear of the bails), the operator presses the lower button to bring the feeding bails back to the feeding position and ready to hold the next group of cows.



Exhibit 5.7 Bails raised, cows exiting milking parlour

5.2.2.18. Cattle exit dairy at own will – pass through drafting gates upon exit
Once they have moved beyond the bails, cows may exit the dairy at their own will. As the cows are not occupying the bails, the operators can immediately bring in the next group of cows for milking into that row, thus aiding to save time and effort for the operators.

As the cows exit the dairy, they again move single-file through a drafting gate. These gates are located outside of the physical dairy building, and thus cows have plenty of room to freely move and arrange themselves before moving back to single file to move through the drafting gates.

5.2.2.19. RFID readers linked to drafting gates identify individual cows
An RFID reader is placed slightly in front these drafting gates so as to determine the identity of each cow before they enter the gates. This reader attains the unique

identification number from each cow's RFID tag, and utilises this number to query the database and derive information relating to the direction in which the current cow should be directed.

5.2.2.20. Drafting gates react to individual cows – move to direct cow to holding paddock or back to grazing paddock

From the information gathered on each cow, the drafting gates will move to direct the cow to the desired area. By default, these gates point straight ahead, thus providing a thoroughfare for cows to continue to walk towards the grazing paddock. However, if a cow has been selected to be drafted out of the main group, then the drafting gates will move to direct a cow either to small holding paddocks on the left or right of the main thoroughfare.

When a cow that has been selected for drafting is recognised by the RFID reader, two flipper gates will rotate to block entry to the drafting gate for this cow. This gate prevents the selected cow from entering the drafting gate section until it has completely changed direction, and is ready to lead the selected cow directly to their designated paddock. Visual detection devices are utilised on the entry to the drafting gates to ensure that the cow that was read previous to the currently selected cow is clear of these gates before they close. The same devices are also utilised on the exit to the drafting gate to detect when the previous cow has completely left the drafting gate section. Once the previous cow has completely moved free of the drafting gates, flipper gates on the exit to the drafting gate will then also close, thus preventing other cows from returning. The drafting gates will then move either to the left or right (as specified in the information collected from the herd management software), directing the next cow to their designated paddock.

Once the drafting gates are in position, the entry flipper gates will retract, and allow the selected cow to proceed to their designated paddock. As she enters the drafting gate, and is detected to have moved past the entry flipper gates, the entry gates will then close again to prevent other cows from following her path. Again, when the drafting gate devices detect that the selected cow has moved completely free of the drafting gates, the gates will move back to their default position of

straight ahead. The flipper gates on both the entry and exit to the drafting gates will then open again, allowing cows to move through the drafting gate.

Cows may be selected for drafting for a variety of reasons. In general, any cows requiring additional treatment, such as veterinary treatment, artificial insemination etc., are drafted to the holding paddock to the right of the drafting gates (and main thoroughfare). High producing cows, or cows that the Cochrane's have selected to be show cows, are directed to a holding paddock to the left of the drafting gates, where they will have access to additional feed in the form of hay and silage.

5.2.2.21. Repeat process until all cows milked.

This completes the milking process for a batch of cows (one row of 25 cows). This process is then repeated for the remainder of the herd (approximately 300 cows), and is conducted on both sides of the milking parlour (enabling the dairy to cater for 50 cows at once). Each row of the dairy can be at a different stage of this process, thus aiding to maximise efficiency in milking – i.e. on one side of the dairy the operators may begin attaching milking cups to the cows, while the cows on the other side are moving in or out of their bails (where human intervention is not required).

5.2.2.22. Clean dairy

Once all cows in the herd have been milked and moved out of the dairy, the cleaning process then begins. This involves thoroughly washing out the dairy floor and milking area, flushing out the faeces catcher, and hosing down any other areas that may have been dirtied, including the outside of the milking cups.

Automatic cleaning of the milking equipment is then undertaken. To facilitate this, the milking operators place each set of milking cups onto their holding rack (four fixed prongs). A milking operator can then exit the milking parlour, and select on the central milking controlling computer to begin the cleaning cycle for the dairy equipment. This cleaning process involves pumping a range of chemicals (including alkaline and acid) throughout all pipes and milking equipment through which milk flows. This includes all milk lines and milking cups. When selecting to start this cleaning cycle, the milking operator can enter a range of parameters

for the cycle, including what chemicals to use, how long each chemical should be used, what temperature to run each chemical at etc., thus providing the ability to customise this cleaning process. The milking operators can then exit the dairy, and leave the cleaning process to manage itself (including completion, pumping all water and chemicals out of the milk lines and turning itself off).

5.2.2.23. Move secondary milk to calf feeder.

The milk that was pumped to the secondary vat (milk taken from cows considered to be giving secondary quality milk) is then transported from the dairy to the calf feeding area. This is easily transported to the calving area due to the vat being relatively small and mobile, as it is placed on wheels. This milk is then poured into the refrigerated vat that is linked to the calf feeding machine.

5.2.2.24. Take required action on drafted cattle

Once the dairy has been cleaned, the required action is then taken on the drafted cattle before releasing them to return to the grazing paddock with the rest of the herd. This may include artificial insemination, veterinary treatments etc.

5.3. Automatic Calf Feeder

The other key area in which RFID is utilised on the Cochrane farm is for the important process of calf feeding. To undertake this task, the Cochrane's have implemented an automatic calf feeder. This feeder utilises a calves RFID tag to gain their unique RFID identification number and regulate the amount of milk being provided to each calf on a daily basis.

5.3.1. Operation

The automatic calf feeder dispenses milk through an artificial teat, which the calves suckle to gain the milk. Calves access this teat by walking into an entry gate (barrier) that ensures only one calf has access to the teat at any one time. As they approach the teat through this walkway, an RFID reader built in to the walkway gains the identification number of the calf from the RFID tag in its right ear. This number is then used to retrieve data regarding the amount of milk this calf is allowed to drink over a 24-hour period, and how much of this they have consumed already. If they

have already drunk their full quota of milk over the past 24 hours, no milk will be supplied to the fake teat. This ensures that calves do not drink excessive amounts of milk. However, if they have not drunk their full quota, they will be provided with more milk until they reach this full quota. The calves can stop drinking at any time, and the computer will record data pertaining to the amount of milk taken during that session. Utilising this approach ensures that calves are provided with the required amount of milk to support their current age and growth.

5.3.2. Feeder Setup

The calf feeder at the Cochrane dairy provides two separate milking points for feeding, thus enabling two calves to be fed at once. These are placed at opposing sides of the feeder, ensuring there is plenty of space at both entry gates. The automatic feeder draws its milk from a refrigerated milk vat placed a few metres from the feeder. This vat is topped up with the secondary milk retained from every milking session, and serves as the primary source of milk for the calves. The automatic calf feeder also has the ability to deliver milk to calves from a powdered mixture base. This manner of providing milk will be automatically reverted to if the main milk vat is detected to have run dry. In such a case, the machine will begin mixing water with the milk powder to create liquid milk and continue feeding the calves.



Exhibit 5.8 Calf Feeding Equipment – Top Left: Calf suckling milk from artificial teat; Top Right: Calf feeder unit; Bottom Centre: Refrigerated vat for holding milk to feed calves.

5.3.3. Milk Quotas

The preset limit for the amount of milk each calf is permitted to drink is dependent upon the age of the calf. When the calf is first introduced to the calf feeder (from around 4-7 days after birth – before which they feed from their mother), they are provided 4 litres a day. As they grow older, they are gradually allowed more, up to a maximum of 7 litres.

After approximately three months on the calf feeder, the calves will join the rest of the cows in the grazing paddocks, where they will not receive this supply of milk. This transition is aided by the calf feeder, by gradually weaning the calf from the provided milk before being released to the paddock. The amount of milk available to the calf is lowered from 7 litres to 6, then 5, 4 etc., all the way down to providing only 1 litre of milk per day. This weaning encourages the calves to eat more grass, and adapt to life without the automated feeding.

5.3.4. Viewing Consumption

The calf feeder allows the farmers to view the amount of milk that any specific calf is drinking through a simple screen attached to the machine. This feature is highly useful, and the operators frequently utilise this to check that calves are drinking most, if not all of their allocated amount of milk. This is especially useful when a calf is first introduced to the milking machine, as it provides the farmers with feedback to ensure that the new calf is adapting to this new feeding mechanism.

The milking machine also provides alerts to farmers if a calf has not taken any milk for an extended period, or if it is only consuming a small percentage of its total available amount. These characteristics could indicate a problem with a calf, such as illness, and thus requires investigation by the farmer. These alerts are posted to the display screen of the milking machine, which the farmers check at regular intervals.

5.3.5. Introducing a Calf to the Feeder

To introduce a new calf to the feeding machine, the operator simply sets the mode on the calf feeder to record new calf. They then swipe the RFID identification tag past the RFID reader in the feeder entry, and that calf is immediately registered. The calf can then begin suckling for milk, and the calf feeder will manage their allocated amount of milk over the next three months of the calf's life.

5.3.6. Other Feed Provided

Other feed provided to calves include a mixture of grain and pellets (the same mixture that is provided to cows in the dairy), and also hay (which calves sometimes just like to chew on). However, this feed is not dispensed or controlled by any device, but rather is simply placed around the calf paddock, allowing calves to eat this feed whenever they desire.

5.4. Herd Information Storage and Retrieval

5.4.1. Herd Management Software

As earlier noted in section 5.1.3, the Cochrane dairy utilises the Dairy 2000 software application to assist in their herd management operations. This software has been

designed to meet the requirements of the dairy industry, and provides the ability to store information pertaining to each individual cow in the Cochrane herd. This includes the ability to store data on a range of characteristics for each cow, such as the date of artificial insemination, date calved (date a cow gave birth to a calf), treatments (such a penicillin), milking rates etc., as well as a range of data that may assist in facilitating herd management. As such, this software is able to provide an entire history of any particular cow. This data can be easily accessed and updated based on a cow's unique RFID tag number, or also by the cow's unique farm number as assigned by the Cochrane farm.

This software application is the underlying component of all of the RFID operations of the dairy. The data contained in this program is accessed by the RFID readers and utilised to facilitate the relevant automation operations, such as deciding on the amount of feed to be provided to a cow, which direction a cow is to be drafted etc. It also provides the interface to display individual cow data to the milking operators in the dairy during the milking process. It is important to note however, that this software application is not being utilised to operate the automatic calf feeder, as this machine utilises its own self-contained software for data storage and operation.

5.4.2. Manual Recording Processes

Complementing this software package, the Cochrane's also utilise 2 manual entry books as a form of running diary for their herd management operations – one for the purposes of recording cow information, and the second for recording paddock information. They fill in the cow diary with information pertaining to any actions taken on cows for that day. For example, penicillin injections, artificial inseminations etc. They manually write down the cow number, action taken and any other relevant information in this book. The paddock work diary is used to store information pertaining to any work completed on any of the farms paddocks. This may include seeding a paddock, spraying chemicals etc. These diaries are retained as manual form of recording, enabling the computer system and written diaries to complement one another.

Retaining this form of manual record keeping subsequently requires the farmers to record cow data twice - once in the diaries, and again to transfer this information into

the herd management software. This approach is required however, so as to enable the farmers to record information while they are in the field conducting the actions. Despite this double recording of cow information, it is felt that the benefits provided by storing data in the herd management software certainly make this additional step worthwhile. Additionally, having this information provided in two forms and in two locations (the computer system located at the dairy and also the portable diary) provides valuable backup sources for this information.

5.4.3. Dairy Express Herd Recording

Like the Strong dairy (case study A), the Cochrane dairy also utilise the services of Dairy Express herd recording to test the milk produced by each of their cows. The Cochrane's also download the results of this analysis, and are able to import this information directly into their herd management software. This allows for the information relating to each cow to be updated on a frequent monthly basis, thus aiding to provide up to date information to be utilised in RFID operations, and providing a common ground for analysis and comparisons to be made.

5.5. RFID Benefits

The Cochrane's believe that they are certainly gaining a good return on their RFID investment, both financially and in general convenience. The following are some of the areas in which benefits being are provided by the use of RFID on this dairy farm.

5.5.1. Automatic Feeding

One of the benefits of the RFID setup is that it makes individual feeding far easier. Having the computer calculate and deliver the appropriate amount of feed for each cow (depending on their production as measured during the last herd recording), makes the feeding process far easier for the operators, as it relieves them from managing this aspect of the milking process.

Providing this automated feeding also guarantees that cows are provided the required amount of feed to sustain the amount of milk they are currently producing. Subsequently, this ensures that the cows are given the best chance at good health, while leaving no room for human error in providing the varied amounts. This

approach also saves the farm significant money, as they do not have to provide large amount of feed for low producing cows, nor do they suffer from wasted feed through spilling. With feed accounting for a large proportion of dairy farm costs, it is certainly beneficial to ensure that this feed is being utilised to gain the best possible return.

The ability to automatically detect recently calved cows (those new to the dairy for this lactation cycle), and to gradually introduce them to the feed is also a valuable asset. This ensures the cows do not fall victim to wheat or grain poisoning, as may happen if they immediately are provided with a large amount of feed. Thus, this provides another avenue to aid in the ensuring the health of cows, which subsequently aids to encourage high milk production and continued good health for the farms most important assets.

5.5.2. Automatic Drafting

Another large benefit is obviously the ability to automatically separate cows that require particular attention from the rest of the herd. This is achieved through the use of the RFID reader linked with the automatic drafting gates. By entering the numbers of the cattle to be drafted into the herd management software, these cows will be automatically separated from the rest of the herd at the designated milking session. This saves the farmers from having to attempt to identify individual cows outside of the milking session, and also saves them from having to exit the milking parlour and retrieve a cow as she exits the milking parlour if they wish to gain her at that time. As such, this automatic drafting can be seen to provide a reduction in hassle for the farmers, while increasing the efficiency of the milking process.

The Cochrane's also utilise this drafting ability to provide additional attention for their selected show cows. By drafting their show cows to a separate paddock after each milking session, the Cochrane's are able to easily provide these cows with additional feed of hay and silage, thus aiding to supplement their existing diets that they share with the rest of the herd. While these cows are in the separate paddock, the Cochrane's are also being able to monitor the condition of these cows, and take any further steps that may be required to keep them in the best possible health and show condition.

5.5.3. *Automatic Calf Feeder*

Automating the practice of calf feeding provides large benefits for the Cochrane's, primarily through the reduction of labour required to undertake this activity. Prior to the automated calf feeder, the Cochrane's undertook calf feeding in the same manner as many other dairy farms (including the Strong's) – by grouping calves into age groups, and manually providing milk to each group of calves via buckets at designated feeding times. While effective, this approach is quite time consuming for the farmers, and depending on the manner in which the calves are fed, it may be difficult to gauge exactly how much milk each calf is receiving.

Utilising the automatic calf feeder, this human labour requirement is reduced, as the calf feeder will automatically manage the task. This results in the only remaining labour required for calf feeding being a regular check of the machine to ensure it is working correctly, and for the farmers to view the amount of milk each calf is currently consuming (easily achieved via the associated information screen for the machine). Of course the calves will require human attention for a number of other activities, however this large labour requirement for feeding is now virtually eliminated. This provides additional valuable time to the farmers to undertake other activities on the farm. Alternatively, the Cochrane's have elected to increase the amount of calves being raised on the dairy, without having to increase the amount of labour provided.

The ability of the calf feeder to adjust the amount of milk being provided to each calf ensures that each calf receives the correct amount of milk required for their age on a daily basis. This aids to ensure that calves develop and grow healthily, while providing them with the ability to drink when they desire, rather than at a preset feeding time. As the calf feeder is capable of determining each calves age (and subsequently the amount of milk to provide) through their identification tag, the machine also removes the requirement to group calves into similar age groups. As such, this further removes the labour requirement and hassle for farmers. This also benefits the calves, as they are free to associate and learn from a larger and more diverse group of other calves.

5.5.4. Provision of information during the milking procedure

As noted in section 5.2.2.6, selected information relating to each individual cow, as well as the bail number that each cow is assigned to in each milking row is displayed on two screens located at either end of the milking parlour. The ability for the milking operators to be provided with this information as the cows enter the milking parlour is highly useful for the Cochranes. Primarily, this ability provides another mechanism for informing milking operators of any cows with particular characteristics that may subsequently require particular attention or additional steps to be taken during the milking process (e.g. disposing of milk from cows that have had a recent penicillin injection). The associated audio readout of this information, as well as the colour-coded highlighting of this cow on the computer screens also aids to ensure that these characteristics are recognised by the operators and appropriate action taken.

This relay of information also enables the operators to better plan their milking procedure for each row of cows that enter. This is possible as milking operators may begin preparations for milking of cows requiring particular attention as soon as they enter the milking parlour – as opposed to only recognising that a cow requires additional actions to be taken when the operator arrives at this cow to place the milking cups on her. Additionally, the operators can also begin milking the slow milking cows first. Taking these actions aids to increase the efficiency of milking for each row of cows, subsequently aiding to reduce the total time taken for milking the herd.

5.6. RFID Cost – Benefit

The cost, as well as the effort and labour required to implement the current RFID setup on the Cochrane dairy certainly required a large investment of both time and money. The combined cost of both the hardware and software for the upgrade to RFID was estimated to be \$60, 000. As to whether the Cochranes believe this large investment has been justified, Tom Cochrane (2005) states,

“the advantages have outweighed the cost of it, long term. Like, if you’re talking only over a year, there’s no way you can justify that cost, but if you justify it over 20 years, it’s paid for itself well and truly.”

Regarding the ongoing costs of RFID, the Cochrane's do not see these are being excessive either. The main ongoing cost for this implementation is for additional RFID tags. However, as these tags are now mandated by law in NSW (due to NSW NLIS regulations), the Cochrane's point out that there is now no option but to identify cows with RFID devices anyway. As such, this cost cannot be attributed solely to ongoing costs of this setup, but is a required cost by law. Rather, the application of these tags at the start of a cows life (rather than only as they exit the farm) and subsequent use of these tags to facilitate farm management operations is simply an optional way for the farm to gain benefits from this required cost.

5.7. Future RFID Implementations for this Farm

The Cochrane's have found great benefits from their use of RFID currently, and are interested in further advancing their RFID operations in the future. However, the only advancement that they are realistically considering is the implementation of milking meters for every milking bail. Implementing these milking meters will provide the ability to record the amount of milk each cow has provided at every milking session. This is in contrast to the current practice of only gaining these figures once a month through the use of the herd recording services of Dairy Express.

Attaining milk production figures for every cow from every milking session will provide vastly more information for the farmers to utilise in their farm management decisions. This ability may facilitate enhancements to a range of other activities also, such as enabling more up-to-date figures to be utilised for the calculation of feed requirements for each cow. Further, this frequent recording of information may also serve as a means to detect problems with cows. For example, a cow producing significantly less milk than her calculated average may be suffering from an illness, or other stress factor that is reducing her milk production abilities. Thus, the farmers can investigate this cow and resolve any issues, enabling the cow to return to health and her increased production capacity in much quicker time.

Chapter 6 – Towards Total Farm Management

6.1. The Current State

Chapters 5 and 6 have demonstrated the operation of a dairy farm without RFID, and also how RFID is currently being utilised at a relatively advanced level for farm management. From these case studies, it is possible to identify numerous common elements evident from both farms, and the assistance that RFID is currently providing to dairy farm management practices. This chapter will attempt to build upon the current RFID usage as identified in the case studies, proposing a framework for the use of RFID on dairy farms, while also proposing enhancements and ideas which could be considered as future additions to further add value to the utilisation of RFID in farm management.

6.2. Mandatory Components for RFID-Enabled Dairy Farms

The following section describes components that are believed to be mandatory for a dairy farm that wishes to utilise RFID to aid in farm management in any manner (whether advanced or basic). These components can be used on their own to provide a variety of advantages for the farmer, however also form the basis for the use of more advanced components, described later in section 6.3.

6.2.1. RFID Tags/Boluses

RFID tags, boluses or microchips form the basis of any dairy farm RFID system. The choice of what RFID device a farm utilises is specifically a matter of personal preference for the farm owners. Each of these devices provide the same functionality, reliability and accuracy, and are intended to last for the life of the cow. Further to this, each device has their own advantages and disadvantages (such as tags being cheaper, boluses being irretrievable until the time of slaughter etc.), leaving the eventual choice of device to the individual farmer to select the device type that best suits their requirements and farm. It is important to note that for the remaining sections of this chapter, the word ‘tag’ is utilised generically, however microchips and boluses can be used to perform the same functions.

6.2.1.1. NLIS-Compliant RFID Tags/Boluses

There are a number of tags, boluses and microchips available from various vendors, however there are currently only three tags, and one bolus that have been approved for use with Australia's NLIS (Meat and Livestock Australia n.d.b, p. 18). As such, Australian farms that are required to participate in the NLIS by state law, or who wish to participate voluntarily (which is permitted), should adopt one of these NLIS recommended devices. This will ensure that they both provide themselves with RFID capability, and also comply with the relevant NLIS specifications (as required by law in some states). Microchips cannot currently be utilised by those participants in the NLIS, as none have been approved to date.

6.2.1.2. Timing of Attaching RFID devices

The chosen RFID device should be attached to the cow immediately after birth (or several days thereafter). This will ensure that all cows on a farm are tagged, and allow the RFID tags to be utilised for farm management practices immediately from birth. Even if RFID devices are not utilised until later stages of a cows life, attaching these devices at birth ensures that the tagging has been conducted for all cows, and removes the need for any special RFID attaching sessions at later dates (thus causing an unnecessary change in routine and possible stress for a cow). Both the Cochrane and the Strong farms have been shown to utilise this approach to attaching RFID devices, despite the Strongs currently not utilising RFID devices in their farm management operations at all.

6.2.2. Herd Management Software

The ability to digitally store herd information is certainly a valuable tool for all farms, and a necessity for those desiring to utilise RFID to aid in farm management. Herd management software provides farmers with this ability, providing mechanisms for them to store individual cow data into a database. Data can be entered into this software application manually via an easy to use, standardised interface, or alternatively (and predominantly for the purposes of this framework), data can be automatically entered through the use of other digital devices (such as milk meters, cow weight scales – discussed later in this chapter) linked to this database. Automating data entry through the use of other digital devices enables data to be

stored reliably and accurately, while reducing the labour requirements of the farmers by saving them from entering the data themselves.

Many capabilities of herd management software are virtually impossible to achieve utilising traditional paper-based techniques. For example, utilising such an application allows a farmer to easily view, analyse, manipulate and sort data, all in a matter of keystrokes. Such an activity would be extremely time consuming at the least, if not completely impossible for farmers to complete via traditional, paper-based techniques. Subsequently, farmers are able to easily and immediately view information on individual cattle, view an entire cows history (calving date, artificial insemination dates, treatments etc.), produce reports on individual cows, selected cows or the herd as a whole etc. All this can be conducted without physically looking at hand-written or previously printed documents. Additionally, the data, and results from any analysis/reports can then be viewed via a digital display (such as computer screen) or in hard copy documents (via printouts). Such information storage and manipulation capabilities provide farmers with an extremely valuable resource to aid them in their farm management activities and decisions.

6.2.2.1. Reference Point for RFID devices

Such herd management software also provides RFID devices with the information required to make a decision or conduct an action. The Cochrane dairy case study provided a valuable demonstration of how herd management software is utilised in this fashion. For example, the information stored regarding each cows last recorded volume of milk production and their stage of lactation provides the basis for the automated decision of how much feed to be provided to each cow during the milking session. A complete herd management system provides such devices with this ability to access detailed individual cow information, thus making it a central element to any dairy wishing to implement RFID to aid in farm management.

6.2.2.2. Herd Management Software and the NLIS

Australian dairy farmers may also receive additional benefits by utilising herd management software that provides the capability to communicate automatically with the NLIS central database. Utilising this approach, in the event of a farmer recording the receipt of cattle from another farm, or the movement of cattle from one of their

farms to another, the software can then prepare and send the required information update files to the NLIS central database via the Internet. This process would otherwise have to be undertaken by the farmer as an additional step to recording cow movements if not automated in such a way. Thus, purchasing herd management software with this in-built capability further aids to reduce labour, while also saving farmers who may not be highly experienced with computers and technology from having to learn how to send these NLIS updates themselves. Cattle software vendors such as HerdLink Currently provide software with this capability (HerdLink 2004).

6.2.3. Fixed RFID Reader

In order to derive any use and subsequent benefit from the practice of identifying every cow with RFID tags, a farm requires an RFID reader device. Subsequently, at every position in which a farmer wishes to utilise a cows RFID number on a regular basis, a fixed RFID reader should be utilised. These provide a reliable and robust source of identification, while also providing a greater range for reading RFID devices than portable RFID readers.

6.2.3.1. Deriving Benefits from Fixed RFID Readers

These fixed readers can be used in conjunction with other devices to enable a subsequent action or series of actions to be performed, or decisions to be automatically made (based on set data parameters). For example, fixed readers may be utilised for the purposes of identifying a cow as she enters the milking parlour, and subsequently recording the time and date of this read to the central herd management database (indicating the milking time for this cow). Likewise, fixed RFID readers may be utilised to record a cows milk production (in association with milk meters), to identify cows required for drafting gate operations etc. To facilitate such actions, a communication (network) link is required to the herd management software (networking will be discussed in greater details in section 6.2.4).

6.2.3.2. Minimum Fixed RFID Implementation

At the simplest level of RFID implementation, a fixed RFID reader should be placed upon entry to the dairy, and have a network link to the herd management software. This is the most fundamental placement of a fixed RFID reader on dairy farms, as lactating cows must pass through this reader at least twice a day on their way to be

milked. At a minimum, placing the RFID reader in this position allows data to be automatically recorded regarding the time and date that each cow enters the milking parlour, and should at least be arranged so as to display cow information (displayed via relevant interface of the herd management software) on a computer screen at the end of the dairy. Placing the reader in this position also provides the possibility for the reader to serve as the basis for a wide range of optional operations to be conducted within the dairy that require individual identification of cows (e.g. automatic feeding etc.). Even if no further RFID linked components are currently utilised in the dairy, placing the reader in such a location provides the possibility for these additional components to be implemented in the future.

6.2.4. Digital Device Network – Wireless/Wired

A form of digital network is required so as to enable the communication of devices between one another, with RFID readers and the central herd management software. There are essentially three methods of establishing such a network – wired, wireless or a hybrid of the two. Each has their own advantages and disadvantages, and the eventual selection of the implementation type will depend upon the characteristics and preferences of individual dairy farms.

6.2.4.1. Completely Wired Network

A completely wired network involves connecting all devices with network cable, with no ability to cater for wireless connections or wireless devices. Utilising this network, all devices will have a direct connection to the herd management database, thus providing access to the latest information, and providing the capability to immediately write information to this database. Such a network is best suited for farms where all devices requiring network communication abilities are permanently fixed in a location (e.g. milking controller unit, fixed RFID reader on entry to dairy etc.).

A wired network arrangement is likely to be cheaper than establishing a wireless network on the farm in terms of up-front costs. However, ongoing costs for this network may be higher due to maintenance that is likely to be required for the cables used to operate the network. Additionally, these cables may suffer reliability problems due to unforeseen circumstances, such as rodents eating away at exposed cables in or near the dairy, general wear and tear on the cables etc. If communication through a

cable in this network type is affected, it could cause a malfunction, or halt the operation of a device (such as a milk meter, or feeding control units), or even force the entire network to become inoperable (for example if a basic ring topology is used). In general however, if precautions are taken to protect these cables and they are laid out in correct fashion, such networks usually provide strong reliability. Naturally, completely wired networks also pose limitations on the portability of devices, as they must be connected via cables for communication.

6.2.4.2. Wireless Network

Ideally, farmers will be utilising wireless networks in future arrangements. This will enable an array of devices, whether fixed or portable, to be linked directly to real-time data in the herd management database. Such devices include the mainstream computer network devices, such as PDAs (Personal Digital Assistants), laptops, desktop personal computers and printers, however will also provide the vital links to dairy farm devices, such as RFID readers, milking controller units, feed management units, drafting gates, and a vast array of other devices that could be configured to operate under computer control, or require access to herd information for operation.

Providing this direct link from these devices to the herd management database enables all devices to refer to the latest herd information for their operation. Likewise, a wireless network also provides these devices with the ability to record changes, updates or new information immediately to the herd management database (as with a completely wired network). Additionally, new devices are also quite easy to introduce to a wireless network, as no cable extensions are required to be linked to them. However, to facilitate a wireless network, all the devices selected to be utilised on this network must be capable of wireless network connections.

6.2.4.3. Hybrid Network

Alternatively to a completely wired or wireless network, a hybrid of the two can be formed. This involves some components of the network utilising direct wired connections to the herd management software and server application, while other devices are provided with portable abilities, however do not have a direct link to the herd management database or to any other device on the network at these times. This may be the preferred option where there are devices that are intended to be

permanently placed in a position, while other devices require portability, however do not need immediate read and write access to the herd management database. Such devices may include PDAs, laptops etc. Utilising the hybrid approach, these portable devices can be connected to the network and subsequently the central herd management database at regular intervals (e.g. daily), where they can download the latest information from the central herd management database. The farmer can then remove these devices from the network (a simple case of unplugging the network cable), and take this device with them out into the field, where they can use this device to view, record updates or modify existing data. However, any changes made will only be reflected in their local portable version of the database at the time of recording. The farmer must then return to base, and attach the device to the central network again to upload the data they recorded while in the field onto the wired central herd management database (synchronizing data between the two).

A hybrid network obviously provides the advantage of being able to utilise both portable and fixed devices. This provides farms with greater possibilities for use of devices and their information. In terms of disadvantages, a hybrid network will require the additional step of synchronising data between portable devices and the central database, thus meaning that the data that is accessed from this database via the wired network may not be current. This may occur as an update may not have been performed on the central database from the portable devices when the data for a particular cow is accessed from the central herd management database.

6.2.4.4. The Final Decision & Future Prediction

Essentially, the decision of wireless, wired or hybrid networks must be completed at each individual farm, based on the requirements and a cost-benefit analysis for each situation. It is believed that as wireless technologies advance in the future, providing greater capability and functionality while reducing costs, that wireless network arrangements will become the predominant network type. Either way however, providing a robust, quality network is a central component to enabling the use of RFID devices for farm management practices. The network established by the Cochrane's to link their RFID readers to their dairy software (and herd management software), feed dispensers and drafting gates provide a strong example of the use and value that such networks can provide. While this network is currently completely

wired, it could also be easily adaptable to support mobile devices (such as PDAs) in a hybrid arrangement, to enable an even greater range of abilities in the future.

6.3. Optional Components for RFID-Enabled Dairy Farms

Implementation of the mandatory components will provide farms with the equipment they require to conduct basic RFID operations. If desired, these components can be utilised as the foundation for a much larger RFID operation, designed to provide additional value for farm management practices. This can be achieved through the use of any, or all of the following optional components - the selection of which should be made so as to meet the requirements and aims of individual dairy farms.

6.3.1. Portable RFID Reader

Having an RFID reader that is portable provides farmers with the ability to read the RFID number of individual cattle, regardless of the cow's location on the farm. This may enable simple actions to be taken, such as identification of cows in the field, or possibly enable a range of actions to be taken, depending on the abilities of the portable RFID reader.

6.3.1.1. Basic Portable RFID Reader

At a basic level, portable readers are capable of reading the RFID tag of a cow, and displaying the cows RFID number on a small digital screen in-built into the portable reader, and possibly providing an audible reading of the identification number e.g. the Allflex Compact Reader (Allflex Australia, n.d.b). Such an ability will allow farmers to guarantee the identity of the cow they are dealing with, pick a cow out from a group without having to know the distinguishing visual features of the cow, be able to identify a cow if an alternative form of identification has fallen off the cow etc.

6.3.1.2. Advanced Portable RFID Reader

At a more advanced level, a portable RFID reader could be attached to a personal digital assistant (PDA – also known as hand-held computer, palmtop) device. Prior to use, the PDA can be loaded with herd management software, and the data stored on the farms central herd management software application can be copied to this PDA – effectively providing a mobile copy of the herd information. Utilising this

arrangement, the farmer can then scan a cow's RFID tag with the portable RFID scanner, and the identity and information pertaining to that cow can be provided on the screen of the PDA. The farmer can then use the PDA similar to how they would utilise their host desktop computer, being able to browse the cow's information, and should also be allowed to record and update cow information on-site. For example, a farmer could give a cow a penicillin injection – to record this, they simply scan the RFID tag of the treated cow, then use their PDA to record the details of that injection.

6.3.1.3. Updating Records in the Central Herd Management Database

Such data recording and updates may be immediately reflected in the central herd management software if the portable device has a direct network link to it (e.g. wireless network). Alternatively, if a direct link to the software is not possible, the updated information could be retained in the portable device, and uploaded to the herd management database at a later time when the device can gain a direct link to the network (i.e. transfer via network cable). Either way, the farmer will be receiving the benefits of being able to easily and rapidly retrieve and view data in the field, while also enabling simple, accurate and timely data recording. Such an arrangement would also remove the duplication of effort that is currently required on both the Strong and Cochrane farms for recording information to their herd management applications - as farmers would not be required to manually record this data in the field before entering it again into the herd management software at a later time. Considering the benefits and enhanced capabilities for farm management operations that such an advanced portable RFID reader would provide, the adoption of such a device is highly recommended.

6.3.2. Weight Scales on Entry to Dairy

The weight of cows is another significant factor that can be used to determine the overall health of a cow, detect any possible problems that may arise, and aid to identify if there are any nutritional changes that may be required to a cow's diet. Placing a weight scale on the entrance to the dairy will ensure that each cow is weighed at a regular interval, and would not require any changes to a cow's routine to gain this weight data. This weight scale can be associated with a permanent RFID reader, thus enabling each cow to be identified before standing on the scales, and their resulting weight to be recorded in the herd management database. This data can then

later be viewed and analysed by the farmer, or alternatively, an advanced arrangement could involve software that is able to recognise and alert farmers of anomalies or concerning variances in weights for each cow. For example, a cow may lose weight when she is not provided (or is not eating) enough food to satisfy her energy requirements to continue producing high quantities of milk (thus she utilises the fat reserves on her body to maintain this production rate). However, a loss of body weight may also occur if a cow falls sick, feed intake is restricted etc. (Ontario Ministry of Agriculture, Food and Rural Affairs 1996). Whatever the reason, it is important that farmers are informed of such changes, and thus allowed to investigate and take any required action.

6.3.2.1 Proposed Advanced Application

It is proposed that advanced software be developed to work in conjunction with these weight scales. Such advanced software could analyse the cows current stage of the lactation cycle, age and the amount of feed she is currently receiving and possibly provide a suggested reason for any concerning weight variances detected. For example, a cow may require more feed. These suggestions could then be provided to the farmer at the end of each milking session, allowing them to then inspect the cow and agree or disagree with the recommendation, depending on their own analysis of the cow and her situation.

6.3.2.2. Source of Feedback

Further, this weight gauging ability may also be used as a source of feedback for the farmer, to see how changes to a cows environmental factors impact their weight – subsequently aiding farmers to tailor their farm management practices to suit their own herd and farm characteristics (beyond the ‘standard’ approaches).

6.3.3. Automated Feed-Dropping Control Units (Feed Bins)

Feed bins that have the ability to automatically drop a designated amount of feed into the feed trough of each individual cow have been demonstrated to be highly effective in dairy farms. Both case studies have been shown to use this technology, and consider it an integral component of their herd management activities. However, the Cochrane dairy derive greater use from their feed bins, by actually combining the operation of their feed bins with the RFID tags of their cows and the herd

management software. This subsequently enables automated feed calculation and delivery in the dairy.

6.3.3.1. Review of benefits

Automated feed units provide a variety of benefits to farms, including reduced labour, cost savings, removal of possibility for human error, and of course the ability to automatically calculate and provide the required amount of feed for cows to sustain or increase their milk production (these benefits are provided in greater detail in section 5.5.1). Considering such strong benefits, it is believed that these automated feed bins, operating in conjunction with RFID tags and herd management software will certainly play an important role in RFID enabled dairy farms in the future.

6.3.3.2. Enhancing Capabilities

Beyond their current abilities, it is believed that future development of these automated feed bins could provide enhanced benefits for the farmers. Firstly, the use of milk meters to record the amount of milk produced by each cow at every milking session will also enable greater possibilities for extending the capabilities of feed bins. Utilising such an approach will enable feed amounts to be derived upon the most recent data of cow milk production, thus enabling feed amounts to adapt to meet the changing requirements of each cow.

Utilising milk meters will also allow an average milk production value to be derived and utilised in calculating the amount of feed to provide for each cow. This average may be taken from the production of the cow during their entire current lactation cycle, or perhaps derived from a selected amount of previous milking sessions (e.g. the average milk provided over the past 10 milking sessions). This ability to refer to an entire cows production history may also enable herd management software to recognise certain patterns in the production of each cow. Subsequently, feed may be adjusted to meet these patterns (e.g. every 10 days there is a rise in the production of a certain cow, thus provide it more feed than meets its average on this day).

Recognising patterns in milk production, and providing up-to-date production records to serve as the basis for feed amount calculation aids to ensure each cow is provided with the required amount of feed to sustain their current milk production, and also to

encourage this production rate to increase – a vital element to maximising milk production from a herd.

Additionally, it is proposed that not only will feed bins be utilised to vary the ingredients of this feed. These feed bins could mix additional additives to each individual cows basic feed to boost specific elements that the cow has been recorded as requiring. For example, increased fibre, protein etc. The requirements for what additives to be supplied for individual cows should be entered by the farmer (possibly based on veterinary results, milk analysis etc.), and the automatic feed bins can then execute this requirement, mixing in the required additive for a specified amount of milking sessions. This subsequently further aids farmers in managing their farm, providing them with assistance to ensure the development and good health of their cows, while aiding to ensure high milk production of a high quality and volume.

6.3.4. Feed Troughs with Measuring Capability

The ability to provide a specific amount of feed to each cow to meet their requirements (as noted in section 6.3.3) is certainly one of the most valuable abilities for a dairy farm. However, this ability can be undermined if there is no way of telling if a cow is actually eating all of their allocated feed. From the floor of the milking parlour in which the milking operators stand, it is difficult, if not impossible to view if there is any feed left in the feed bails when each batch of cows leaves. As such, a cow may not be eating all (if any) of their allocated feed, however the farmer and the herd management software will not be aware of this unless there is a form of checking done when every cow leaves their bails. Utilising weight scales to measure the amount of feed left in each feed trough provides this important feedback ability for the farmer and software to measure any feed left in the feed troughs.

6.3.4.1. Proposed Operation

This can be achieved by placing weight scales underneath the feed trough of each bail, and having feed troughs with bases that open (base flaps drop down), allowing any feed remaining in these troughs after each cow has left to be dropped below to the scales. This leftover feed can then be weighed, and the resulting weight recorded in the herd management software, thus providing information on the amount of feed

provided, amount leftover, and subsequently the gross amount of feed induced by each cow.

It is proposed that this measurement process be triggered by the milking operators taking the required action to signify the end of milking. This may be the press of a button (as at the Cochranes), pull of a rod (as at the Stronges) or other means. So as to save the milking operators from then having to clear the feed from the scales before the next batch of cows enter the milking parlour, it is proposed that containers be used on the top of the scales with the ability to store a large amount of feed. Thus, when the operator takes the required action to open the milking parlour for the next batch of cows (press of a button/pull of a rod etc.), the scales will then re-calibrate themselves to consider their current weight as the starting point ('zero') for the next calculation. Subsequently, when the next batch of cows complete milking, the feed can be dropped into the container atop of the scales again, and the scales perform the required calculation to provide a weight reading for the amount of feed left in each independent bail (current reading minus the reading taken at the end of previous milking session).

6.3.4.2. Additional Benefits

Utilising this approach will not only allow farmers to ensure that their cows are eating their required amount of feed, but will also aid to detect any cows that may be having a problem, such as illness. It is proposed that the software that stores this eating data be able to identify any cows with concerning feed intake rates, and subsequently alert farmers to this issue. For example, if a cow is eating less than 70% of their allotted feed, there may be a need for the farmer to examine this cow and investigate possible reasons why this may be happening. Such low eating could be an early warning sign of sickness, and thus this approach would allow the farmer to separate this cow from the herd and take any required action to bring her back to good health. Additionally, a reduced feed intake is also a characteristic of a cow on heat, and thus this may provide further information to support other signs of a cow being on heat (DeLaval 2005b).

6.3.5. Milk Meters

In a business where milk is the primary product, it is important to know how much milk each cow is producing, and likewise, to have a source of feedback to establish

what factors enable your cows to produce the maximum amount of milk. Milk meters provide this valuable ability, measuring the amount of milk each cow provides at every milking session.

6.3.5.1. Operation

Milk meters are placed in the milk flow line leading from each set of milking cups to the main milk flow line (leading to the vat). From here, the meter can gauge the amount of milk flowing through the pipes from each cow. To be useful, this information should be automatically recorded in the herd management database, and associated with the cow currently registered by the software as being present in that particular bail number. Other pieces of information, such as the time at which the reading took place, the cows bail number, and duration of milking can also be derived from milk meters, and should be stored in the database. These pieces of information serve as solid records of each cow's milking session, and may provide grounds to various analysis activities for the farmer.

6.3.5.2. Current Practices for Gauging Milk Production Volumes and Negative Aspects of This

Both the Strong and Cochrane dairies currently utilise the services of Dairy Express herd recording to provide information relating to the production volume of each individual cow. This service also provides information relating to the fat and protein components, somatic cell counts, and other information as requested. While this is all certainly valuable information, the infrequency at which this sampling occurs (monthly) reduces the scope of applications that this information can be used for. For example, this data does not provide a reliable basis on which to conduct day-to-day herd management operations. A great deal of cow characteristics can change over the course of a month, and utilising such distributed testing, farm operations will not be able to adapt to meet the changing characteristics and subsequent requirements of cows. Additionally, as this information is not collected regularly, it does not provide enough data to enable a direct analysis of how varying certain aspects of a cows environment may impact their milk production (whether positively or negatively).

Similarly, utilising data collected only on one day of the month could provide misleading results. For example, a cow may have an unusually bad milking day on the

day of herd recording - providing poor quality milk and a low volume of it. Subsequently, she will receive a bad report on her milk, and also have her feed adjusted to suit a low production cow for the rest of the month. However, she may normally be producing a much greater quantity of milk, and at higher quality than what was sampled on the day. Consequently, treating her as a low production cow would reduce her ability to maintain or increase her true milk output, and could result in decreased health.

Despite these negative aspects for the use of this information in farm management operations, the results of Dairy Express analysis remain a valuable asset for dairy farms. The information provided by these analyses other than production volume (fat content, protein etc.) provide valuable feedback on the quality of herd milk for the farmer, and are also information products that individual farms are unlikely to be able to practically gain through their own on farm testing facilities. Additionally, Dairy Express provides the ability for the individual results to be accumulated for the various categories of this analysis (thus providing total herd information), and compared to other dairies in the farms particular region, state or indeed the whole of Australia. This provides a great ability to benchmark the performance of your herd in multiple aspects, something that would be much more difficult by any other means. As such, it is not proposed that the implementation of milk meters replace the use of herd recording services, but rather they should be used to supplement this process - providing information relating to milk production volumes that can be more effectively utilised for farm management activities, and unveil a wider range of possible applications for such data.

6.3.5.3. Desire for Milk Meter Utilisation

Both the Cochrane and the Strong dairies stated their desire to implement milk meters in the future, indicating the presence of a firm desire within the dairy industry to adopt these devices. It is believed that the implementation of these devices could become an integral component of dairy farming in the future, and certainly plays an important role in this proposed framework.

6.3.5.4. Cycle of Information

As previously alluded to, a great benefit that milk meters provide is the ability for farmers to achieve a complete cycle of information. Currently, farmers are able to control and measure many aspects of a cows environment and lifestyle. For example, they are able to control the amount of feed provided to each cow, the ingredients and ratio of mixture for feed in the dairy (e.g. grain and wheat mixture), what paddock the cows are placed into (subsequently the type of grass present, fertilizer or other products used in maintaining this paddock etc.), when cows are milked, when they are fed and a variety of other factors. However, without milk meters, farmers are unable to accurately gauge how varying certain elements in a cows environment may affect their milk production.

Armed with the information collection ability provided by milk meters, farmers are able to experiment with varying elements of certain cows environments in an attempt to identify the ideal conditions for achieving maximum production with their particular herd. Every farm property is different, and every herd of cows may be considered different. Thus, while many dairy management practices are common between farms, it is important for farmers to fine tune their herd and farm management practices to suit their specific herd and farm, so as to attempt to gain the greatest possible milk production and quality from their cows.

Such experimentation can be achieved by taking a selection of cows, and modifying any of a wide array of elements that make up their environment. These elements should be varied only one at a time (so as to be able to identify what the characteristic is that caused any changes that may be realised), and the milk production of the selected group monitored for any growth or decline. Examples of varying elements may include varying the milking times for the selected group, the quality of feed provided, the amount of feed provided, paddocks placed in (and the grass/characteristics of their paddock compared to others), whether they are given hay or not, additional feeding sessions etc. The results of varying these factors should be analysed, and any positive aspects implemented with the remainder of the herd. To date, it is believed that such testing and data analysis is an aspect of farm management that has largely been under utilised.

6.3.5.5. Illness Detection

Utilising milk meters will also aid to identify any problems that may arise in the herd (such as illness). For example, if a cow provides a significantly lower amount of milk than their usual output, the system will be able to identify this disparity and alert the operators to check this cow when milking has completed. In this way, any illnesses or problems occurring with cows can be identified quickly and easily, subsequently enabling rapid treatment. The quicker that such issues are identified and treated, the sooner the cow can return to her normal milking and health, and thus minimise the loss of production for the dairy on the whole.

6.3.5.6. Audit Potential

A further benefit of such a device is the ability to provide audit functionality for the amount of milk produced. Currently, the only record of the amount of milk provided to the manufacturer is via a report provided by the manufacturer after they have collected a vat of milk from the dairy farm. Utilising milk meters, the farm is able to verify that the amount of milk stated by the manufacturer as having been received is in alignment with the total amount recorded by the milk meters. This will of course aid to ensure that farmers are being paid for the correct volume of milk, while also acting as a mechanism to identify if there may be a leak in the milk transportation pipes in the dairy. As milk is the primary product produced by dairies, this audit capability is an important aspect to ensuring farms are receiving the right income, and also minimising possible shrinkage (through leaking pipes etc.).

6.3.6. Milking Controller Unit

Milking controller units are essential pieces of equipment for all modern dairy operations. This is the device that controls the suction and suckling motion of the milking cups attached to the teats of each cow. This unit can function effectively without the use of RFID technology (as demonstrated in the Strong dairy case study), however it is recommended that RFID technology, combined with herd management software be incorporated in all future implementations of milking controller units. Combining these technologies will provide a range of enhanced options and capabilities for the operation of the milking controller unit.

6.3.6.1. Automatic Selection of Milking Style

Utilising this combination of components, it is proposed that future implementations may be able to gain and interpret a cows complete milking history. Subsequently, the units will then be able to establish for themselves the required manner for milking the cow that has been assigned to their bail. Some of the possible milking styles were outlined in the Strong dairy case study (case study A), including rapid milking, normal escalation milking etc. - however the abilities of each milking controller unit vary between products and vendors. As such, the software would need to have the ability to work with a range of milking controller units, or may be provided by a vendor to work in conjunction with their milking controller units. This ability to automatically select the milking style would remove the need for the operator to do this, thus reducing the demands on operators, while also reducing the possibility for human error in selecting milking styles. In order for the operator to know what milking style has been selected by the device, a form of visual feedback should be provided to the operator (such as various light sequences on the milking controller unit etc.).

6.3.6.2. Display Devices at Point of Milking

At a more advanced level, it is proposed that display devices be incorporated into the milking controller units, providing a mechanism to display a range of information to the dairy operator relating to the cow currently located in the milking bail. This could include any information stored in the herd management database, however it is felt that the essential information would include whether penicillin has been injected, if milk is required to be withheld for any reason, if a cow has a bad teat (thus this teat is not to be milked), if the cow is a slow milker, if the milk should be used for second grade milk (if farm utilises such a category of milk) and if the cow has freshly calved. This specific information is critical in determining if and how a cow should be milked differently.

The Cochrane dairy demonstrated that such information can be made available on screens at either end of the dairy, and audible readouts also provided for such information to provide a further alert to operators of a cow requiring additional attention during the milking process. While this setup is quite useful, the information

regarding each cow is still not directly available to be viewed at each individual milking station, as would ideally occur.

Rather, both the Cochrane and Strong dairies utilise other visual identification mechanisms to recognise particular attributes of individual cows at the point of milking (and also to simply identify cows with particular attributes for general herd management). These identification mechanisms include coloured tail tags, coloured ankle tags, paint on cow udders etc. The meaning, and number of these identification markings however, differ between the case studies. It is further believed that this sort of variance in identification devices will exist between all dairy farms. Whilst quite effective, these mechanisms are not foolproof. The requirement for milking operators to notice these identifiers, and subsequently take appropriate action (such as disposing of milk unsuitable for production) leaves room for human error in milking. Additionally, these identifiers may inadvertently fall from the cow while in the paddock, be covered by mud during milking sessions or suffer fading (thus being less eye-catching) etc., subsequently making it difficult or impossible for operators to recognise these markings.

If these identifiers are not recognised during milking, the farmer may face quite serious consequences. For example, such occurrences could lead to a cow being milked in an incorrect fashion, such as attempting to milk a teat that has been dried off. Even greater consequences will be realised if milk that should be disposed of (such as that extracted from a cow who has had a recent penicillin injection), accidentally flows through to the main milk vat. This will result in the bad milk contaminating an entire vat of milk. This will subsequently cost the farmer the intended revenue for the entire vat of milk, as it must then all be disposed of. Furthermore, if the farmer does not realise that contaminated milk has entered their vat and allow the dairy manufacturer to collect the milk (placing it into their large collection tanker with milk from other farms), the dairy manufacturer will end up detecting this contamination when testing the collection tanker of milk at their own depot. Subsequently, the farmer responsible will then be identified by the manufacturer via testing of individual farm samples taken at the time of pickup. The farmer may then face a fine, or be forced to reimburse the manufacturer for the value of the entire collection tanker of milk that must now be disposed of. As such, it is

evident that failure to notice visual identification markers on cows, for whatever reason, can be costly for a dairy, both financially and in terms of their reputation.

6.3.6.3. Proposed Enhancement – Data Interpretation Display, Interaction and Feedback

For this reason, it is proposed that the milking controller unit, combined with display devices (a form of computer screen) at each milking bail be utilised to aid the milking operator in identifying important requirements for each cows milking. This can be achieved by utilising RFID readers on the entry to the dairy, combined with bail blockers (or other mechanism that ensures cows enter the milking bails in consecutive order), and the ability for the herd management software to assign a cow (and its related data) to a milking bail as they pass through the RFID reader. The milking controller unit can then be linked with the herd management database, thus providing it with the ability to receive and interpret individual cow data for the milk assigned to it's corresponding bail number. This received data can then be displayed to the milking operator via the related bail information display device. It is important to note that such a system should be used to complement the existing visual identification methods on each cow, rather than replace them – thus providing dual identification capabilities for important cow characteristics.

At the most advanced (and expensive) level, this display device would be a small (and very well shielded) computer screen, displaying each cow's information in an easy to view interface. Information that may affect the milking procedure would be highlighted, and if the information is critical to milking (such as if the milk is to be withheld), the milking controller unit will not allow milking to proceed until it receives a signal to continue from the milking operator. This would act as a check that the milking operator is aware of any special actions that may be required for particular cows, has taken the required action (such as plugging the milk flow lines into a barrel for disposal), and is now ready to begin milking this cow. This 'continue' signal could be achieved by placing a small keypad beside each screen (even a single button to provide recognition of information), however, ideally an entire keyboard could be provided at each milking bail (with a bendable plastic mould covering the keys). Having a keyboard would enable a range of feedback to be provided by the milking operator, and also allow for data to be entered into the database regarding each cow.

This may include information such as whether any drugs were administered during milking (such as synthetic oxytocin), any problems that arose during milking, additional comments etc.

Additionally, a 'watch' button could also be provided as an input device. This button would be pressed by an operator if they notice something about a cow during milking that they would like to investigate after milking. The software will then remind farmers to investigate this cow at the end of milking, and if drafting gates are being utilised at the dairy, then pressing this button will immediately select this cow for drafting as it exits the dairy – thus providing easy access to this cow after milking.

Using this approach will provide a reliable means for transferring milking information to the operators, and aid to ensure that required actions are always taken – thus reducing the risk of discomfort for cows, and financial implications for the farmer of incorrect milking. This also enables rapid and immediate data entry into the herd management database, thus saving the farmer from having to enter this data at a later time.

6.3.6.4. Lower Priced Alternative

Utilising computer screens at every milking bail for conveying information to milking operators would be quite costly in large dairies, thus, a similar, but less expensive approach may be adopted. A less expensive version of the above information intensive milking controller system can be established utilising a panel of lights to transmit information from each milking controller unit. Each light on the panel could be labelled, and illuminated to display any pertinent information for the milking of the cow. For example, four lights could be placed so as to represent the four teats on a cows udder, and each light would subsequently illuminate to represent a teat that is not to be milked (thus complementing the use of ankle tags as is the practice on the Cochrane farm). Other lights may be set to represent certain information by default, or customised to represent any information that the farmer desires.

Despite not having a computer screen, this system could still provide the automated data interpretation features of the advanced milk controller unit. As previously noted, this will allow the unit to act as a final information check point, ensuring that milking

cannot begin for cows requiring particular treatment until the milking operator provides a recognition signal to the system. Again, a button could be used to gain this feedback from the operator. The main drawback of this lower cost arrangement is that it is unlikely to allow direct entry of information to the herd management database.

6.3.6.5. Personnel Benefits

An additional benefit of either of the bail information display device arrangements is that such a system may provide greater flexibility for farmers in employing milking operators. Utilising either of the previously described systems, milking operators do not need to be extensively trained in what visual identifiers to look for at each farm, as each cows information is clearly provided to them at each bail via a chosen display device. Further, the system can aid to ensure operators have recognised any particular characteristics that would require a varied milking procedure, as it will prevent the milking cups from working until the operator provides the required signal to continue (e.g. pressing 'continue' button) at the specific bail. These abilities therefore reduce the risk of contamination for the farms milk and aid to ensure cows do not suffer any undue stress during the milking process if a new milking operator is being utilised at the dairy. This may provide farmers with the ability to hire outsiders or contracted milking operators to fill in for regular milking operators in unforeseen circumstances, or to allow the regular farmers to take a holiday.

6.3.6.6. Existing Technology

Milking control unit vendors such as DeLaval currently provide milking controller units with similar capabilities to this. The DeLaval 'MPC' provides information to the milking operator through a series of labelled lights and a small display screen with scrolling text. A keypad is also provided to enable information to be directly updated and entered into the herd management database (DeLaval provide a herd management system entitled 'ALPRO'), and a variety of information can be viewed on the screen of the unit (DeLaval 2005a). As such, it is believed that at least part of the proposed milking controller unit arrangement is achievable currently, and the technology involved in these units is likely to further advance in the future.

6.3.7. Automatic Drafting Gates

The use of drafting gates has been demonstrated at the Cochrane dairy, and has been shown to provide large savings of both time and labour for the farmers in extracting individual cows from the main herd. These cows may be extracted for a wide variety of reasons, including the need for veterinary treatment, artificial insemination etc. Additionally, this automatic drafting ability enables farmers to provide additional attention to selected cows on a regular basis (such as by drafting show cows into a paddock with additional feed). The most useful location for these drafting gates is believed to be on the exit to the dairy, as this is where all lactating cows must pass at least twice a day. Operating in conjunction with herd management software, these gates would be a valuable asset to almost any dairy farm.

6.3.8. Temperature monitoring within RFID

It is evident from the articles of Higgins (2003) and Hostetter (2003) (articles described in section 2.7), that it is possible to incorporate temperature sensing abilities into RFID microchips currently – the application of which may soon be extended to the livestock industry. Such a device will provide the temperature of the cow along with the cows unique identification number every time the tag is read by an RFID reader.

6.3.8.1. The Value of Temperature Monitoring

The temperature of a cow is certainly a valuable attribute for a farmer to utilise in managing their herd. Importantly, fluctuations in the body temperature of a cow can indicate that the cow may be falling ill. Thus, reading this temperature will allow a more rapid response to aid in detection and subsequent treatment of any illnesses that a cow may have attracted. It will also enable the farmer to take action to minimise the spread of the illness by being able to rapidly isolate the cow for observation and treatment. Of course, the quicker an illness can be detected and treated, the less time a cow will spend affected by this illness and hence minimise probable reduction in milk production. As such, rapid treatment of cow illness is in the best interests of a farm financially, as well as to aid to keep the cows in good health.

A rise in temperature may also indicate that a certain cow is entering heat. It is important to know when this occurs, as this presents the farmer with a window of

opportunity to artificially inseminate the cow (if they are intending to impregnate the cow). This temperature sensing ability may aid to supplement the current visual manual mechanisms of detecting heat utilised on farms such as the Cochrane's, and also supplement or replace the use of Karmars, as utilised on the Strong farm (the use of Karmars is described in section 4.2.2.2).

There may also be other reasons for temperature fluctuations among cows, however whatever the reason, it is important that anomalies in temperatures be identified and investigated as soon as possible. As such, when temperature fluctuations are recognised by the system, functionality could be incorporated to allow the system to alert the farmer of such fluctuations via means such as a beeper device that the farmer may carry, sending a text message to their mobile phone, or by similar rapid alert device.

6.3.8.2. Using the temperature sensing device

At a basic level, a temperature sensing RFID device could be read by fixed RFID readers at the entry to the dairy. Such an arrangement would ensure that each cow has their temperature read at a regular interval at least twice a day, thus providing valuable information to the farmer. At a more advanced level, it is proposed that RFID readers also be placed at other high congregation areas throughout the farm. For example, placing a high powered RFID reader near a water trough in a paddock, hay feeders or similar areas that are frequented by cows. Under this approach, more temperature readings can be gained between milkings, thus providing an enhanced ability to detect temperature variations, and also to view patterns of temperature change among the cows (e.g. middle of the day they may be warmer than at sunrise). The obvious flaw in this system however, is that the temperature readings are not gained at the same time for the herd (thus making them somewhat incomparable), and it cannot be guaranteed that each cow will be read at any more frequent intervals than at the entrance to the dairy.

6.3.8.3. Ideal Use

Ultimately, if readers could be utilised to read a multitude of low-powered RFID devices over a large distance, then such readers could be placed in each paddock to interrogate the entire herd's RFID devices at pre-determined intervals. This would

provide a far greater picture of temperature fluctuations and patterns among individual cows in the herd.

6.3.8.4. Other Biological Sensing RFID Potential Combinations

As noted by Higgins (2003) and Hostetter (2003), there could be other applications with RFID and the monitoring of cow biological signs, however it is believed that these may be quite some time away, and their exact uses are not known as yet. As such, details of such devices have not been included in this framework. On the other hand, RFID temperature sensing is a currently available technology, and its use in the livestock industry is currently being investigated.

6.3.9. GPS Tracking

The precise details of GPS (Global Positioning System) operation are outside the scope of this research, however it is believed that a device may be developed in future that provides a combination of GPS and RFID technology, subsequently providing enhanced farm management capabilities. Thus, the application of GPS within this context will be discussed.

In brief, GPS is a technology that is used to track objects via satellites. There are a range of software and hardware products that can be used to facilitate GPS tracking, and depending on the quality of the GPS products used, these systems are believed to be able to track the movement of objects to within several metres. Even greater accuracy may be achieved through the use of Differential GPS – an implementation method requiring both a local fixed GPS receiver, acting as a relay for other mobile GPS devices (Federal Aviation Administration n.d.; Corvallis Microtechnology 2000; WiseGeek 2005). It is proposed that GPS technology be included in RFID tags in the future, thus providing the ability to track cattle movements, and locate individual cows with a single program. This will provide a range of abilities and benefits for farmers.

6.3.9.1. Utilisation for Location Identification & Tracking

One of the primary benefits of utilising GPS with RFID tags is the ability to gain the exact location of where a cow is currently located on the farm. This saves the farmer from having to lookup records of where the cow is currently located, or having to visit

the paddocks and try to visually identify the cow they are looking for. Obviously, with a small herd size, this is not a particularly prominent issue (as farmers will be able to know cow locations from their own knowledge of the herd and cow movements), however as herd size increases, GPS location ability becomes increasingly valuable. This ability is further enhanced as the farmer may be able to use a PDA or other mobile device to display a map of their farm and pinpoint the cows location within this farm layout. Utilising this approach, farmers can be guided to the exact location of any cow they desire.

6.3.9.2. Utilisation for Boundary Crossing Detection

Further to the primary use of tracking of cattle, a more advanced GPS-RFID setup could provide software that enables farm boundaries to be plotted and associated with the GPS devices. Using this arrangement, the software could detect if a cow (or cows) move beyond these plotted boundaries (i.e. escaping from a paddock). When such an occurrence is detected, the software can inform the farmers of this by displaying an alert message to all available display devices (computer monitors, PDAs etc.), and send a further message to designated people via mobile phone text messages, paging devices etc., so as to attempt to raise immediate notification. This will aid to ensure that if cows do escape their paddocks, that rapid action can be taken to precisely locate them, and bring them back to their paddock - thus hopefully reducing the chances of an injury being sustained by the cows while outside their paddocks (such as being hit by a car, eating poison baits, encountering other predatory animals or humans etc.), or the dairy simply losing their cows.

Once the cow has been retrieved and returned to their paddock, farmers can then also use their GPS software to trace back the path the cow took to escape from their paddock, and subsequently take any action they feel may be necessary to prevent the incident from occurring again (e.g. patching a fence, implementing electric fences). Any loss of lactating cows will have an immediate impact upon the milk production of the herd, and thus has direct financial implications for dairy farmers. Similarly, if any injuries are sustained to a cow this may impact their milk production also (permanently or temporarily). As such, it is in farmer's best interests to minimise the risk of such incidents, which a GPS system utilising plotted boundaries can facilitate.

Similarly, the combination of GPS with RFID will aid to prevent and detect any theft of cows. While this is not a particularly serious problem in Australia, it remains a volatile possibility. If a farm is utilising GPS-RFID devices to tracking their cows, in combination with software that recognises farm boundaries, it will be quite apparent to a farmer if their stock is being stolen, as there will be a large and rapid exodus of cows from their property boundaries. Not only will GPS capability aid to detect such an act, but it can then be used to trace the cows if the thieves manage to successfully remove them from a property. Additionally, proof of identification and ownership of each cow can be provided via the RFID capability of such devices.

6.3.9.3. Further Abilities Enabled

Furthermore, software could be designed to detect individual cow movement that may be considered out of the ordinary. This may include if a cow does not move as much as it is expected (based upon the previous history of the cow), or likewise, if it is moving significantly more than expected or usual. If a cow is moving significantly less than usual, this could be a strong sign of illness, and certainly something worthy of a farmer's investigation. Additionally, this tracking may also be used as a mechanism for detecting when cows are in heat. When a cow is in heat, it is stated that their activity (movement) will increase by up to eight times the normal rate (DeLaval 2005b). Thus, if a cows movement is detected to be abnormally high, this may be a strong sign that she is in heat, and thus notification of this should be provided to the farmer. Further, this can be used as another form of feedback for the farmer, if they wish to test how certain environmental changes impact the cows – they may feel healthier and happier, and subsequently move more, or they may move less, thus indicating a negative impact. Having software enabled with such detection abilities will enable improved farm management capabilities for farmers.

6.3.10. Automatic Calf Feeding Machine

Through the demonstration of the use of an automatic calf feeder on the Cochrane dairy farm, it is evident that strong benefits can be gained from the use of this device. Primarily, this includes a dramatic reduction of labour, ensuring that calves are fed the most appropriate amount of milk for their age to encourage and support their growth, and to provide management information for the farmers. These benefits can save farmers both time and money, while also acting as an investment in their cows

futures. As such, it is believed that while this is not a necessary requirement for operating an RFID-enabled dairy farm, the benefits of utilising this device make it highly recommended, especially for large herds, or simply farms with many calves.

6.3.10.1. Potential Developments

While significant benefits are being realised currently, it is believed that additional benefits may be possible through further development of this device. A possible enhancement to the current implementation of this device on the Cochrane dairy is to enable this device to communicate with and store data in the central herd management software. Currently, this device uses its own in-built software to manage its own operation, and while effective, it would be more useful if this data could also interact with the herd management software.

Such an arrangement would make accessing data simpler for farmers, as they would be provided with a single point of reference for all cow information. This would further aid farmers who may not be proficient with technology and computers, as they would only need to learn to use the one software package to conduct their farm management operations and view individual cow/calf data. Additionally, storing calf feeding information in the central herd management database would allow feeding information to be recorded almost immediately from birth. This new category of information provides greater possibilities for data analysis, aiding to provide farmers with another aspect of feedback for their various strategies. This may also provide farmers with a greater understanding of their herd, and aid them to identify particular characteristics that impact/benefit their cows throughout their life. For example, this may provide farmers with an ability to relate how the feeding rates of calves impacts upon their eventual development and milk production – thus enabling farmers to fine tune calf feeding practices to suit the characteristics of their particular herd.

Chapter 7 – Conclusion

7.1. Principle Conclusions

There are a number of conclusions that can be drawn from this research. The first is that RFID is currently being utilised and development of RFID hardware and software is continuing. Secondly, size does matter, both regarding herd size and the corresponding benefits of using RFID and in terms of economies of scale for the technology. Thirdly, RFID expands management capability through the information and automation capabilities, and finally it is concluded that legal requirements around the world have become a driving force behind the adoption of RFID on dairy farms.

7.1.1. Currently Used and Continuing Development

It has been seen that RFID is being utilised currently on dairy farms, both in Australia and around the world. While there is currently a large disparity in the scale of use from farm to farm, the level of interest in this technology and its applications is providing a solid base for future development of this technology within the dairy industry. Both hardware and software continues to be designed and enhanced to specifically cater for the needs of the dairy industry and its adoption of RFID technology.

7.1.2. Size Matters

The size of a farm's herd will be a large factor in determining the value of the benefits realised through utilising RFID. On farms with relatively small herds, farmers are likely to have intimate knowledge of the herd through their own interactions with the animals, and additionally, farm labour is unlikely to be in constant demand. Thus, the abilities of RFID to provide information storage, manipulation and easy retrieval, or dairy automation possibilities are unlikely to add significant value, and thus may be perceived as an unnecessary cost. On the other hand, with large herds, whereby farm labour is virtually on constant demand, and an intimate knowledge of each cow in the herd is difficult or impossible to achieve, RFID technology provides the ability for dramatic benefits to be realised. Thus, it is concluded that generally, the benefits provided by RFID are directly proportional to the size of the herd.

Similarly, the rate of RFID uptake will be a determining factor in the cost of the technology in the future, as it is believed that economies of scale will be realised for this technology. i.e. The greater the market and purchases of RFID devices, the lower the cost will be in the future. Additionally, it is expected that the market for RFID devices for dairy farms will expand, subsequently increasing competition between vendors, which will further drive prices down for this technology.

7.1.3. Expanding Management Capability

The use of RFID certainly provides the ability to enhance farm management practices. This technology provides the farmer with the ability to gain a far greater depth and accuracy of information on their individual cows and overall herd, thus enabling them to make more informed decisions. Furthermore, this wealth of information can be stored, manipulated, and viewed with unprecedented speed, accuracy and ease, undoubtedly providing the potential for massive benefits in the manner in which farm management is conducted.

Furthermore, RFID technology provides the capability to automate certain farm management practices. This includes the likes of automatic feed dispensing units, automatic calf feeding, automatic drafting etc. – all of which can dramatically save labour requirements, provide more reliable and accurate operations, and enables farmers to spend more time managing the vast array of other activities involved in operating a dairy farm. Additionally, these automation practices may aid the development, health and overall milk production of cows, thus providing further benefits for the farmer.

7.1.4. Legal Requirements a Driving Force of RFID Within Dairy

Despite being a quite mature technology, until recently RFID has had only limited application within the dairy industry. However, external forces, such as worldwide regulations attempting to provide whole of life traceability for livestock have been a catalyst for a dramatic growth in the interest, abilities and use of RFID technology within the dairy industry. It is only a matter of time before RFID becomes mandatory nationwide within the dairy industry in Australia (and likely many other countries) – subsequently, this is encouraging even those farmers who may be more

technologically conservative to investigate and embrace the opportunities presented by this technology.

7.2. Major Implications

7.2.1. Maximising Productivity

The use of RFID will assist farmers to maximise their productivity – an important aim in the modern competitive dairy industry. It is expected that the new farm management practices enabled by RFID will allow farmers to increase the volume and possibly the quality of milk output from their herd. This may be achieved through improved practices to monitor the health of their herd – thus minimising illness and subsequent low production of cows, speeding up the milking process – thus enabling the cows to return to the paddocks quicker, optimising feed to suit each cow production and stage of lactation cycle etc. The use of RFID for automation will also aid to minimise labour inputs, thus allowing each farmer to cater for more cows, or enabling farmers to have more time to spend on other activities – either way, maximising results from their input.

7.2.2. RFID Adoption to Continue

Considering the potential benefits offered by the implementation of RFID on dairy farms, combined with the global push for RFID to be utilised for livestock tracking, it is believed that the development and adoption of RFID technology on dairy farms will continue for quite some time. This adoption rate may even grow as the benefits of such implementation become more widely recognised, and correspondingly the costs of the technology lower with expected economies of scale. This adoption may continue to the point where the use of RFID becomes a mandatory aspect to survive in the future dairy market.

7.2.3. Increase in Farmer IT Literacy

As a consequence of the RFID adoption within the dairy industry, it is likely that farmers will become more involved with IT (Information Technology) generally. Traditionally, farmers have had little use for computers, however with the introduction of the NLIS, the potential benefits of NLIS etc., it is likely that

computers will become a central part of farm management. Subsequently, this is expected to raise the level of IT literacy amongst the industry.

7.2.4. Third Party Opportunities

The current and predicted continued uptake of RFID technology on dairy farms provides a large opportunity for the involvement of third parties. This may include existing vendors diversifying into this industry, or new enterprises opening and developing products to specifically suit the industry, consultants opening up to provide advice on dairy layouts, how and what devices to implement, third-party distributors and intermediaries etc. Considering that many traditional farmers may not have a great deal of technological experience or are comfortable with radical changes, such third party involvement may be considered more of a requirement than an opportunity. In Australia's case, the state or national government may wish to commit more resources to provide support and information on the technology and its possible uses for the dairy industry, especially considering the mandatory regulation of NLIS current in some states, and soon to spread nationwide.

Additionally, it may be possible for labour agencies to provide temporary milking operators for a brief or extended term to aid in operating a dairy farm. On farms with advanced RFID automation systems in the future, there may be little need for operators to have extensive knowledge of a farm or herd to conduct milking, as the machines will prevent them milking cow incorrectly, provide them with each cows information etc. Being able to hire such personnel could provide a temporary employee in the case of unexpected absence of a milking operator, or may enable the usual operators to take time away from the farm (holidays, family occasions etc.).

7.3. Research Scope

7.3.1. To Whom Do These Findings Apply?

The findings of this study primarily apply to dairy farmers, however other groups such as government agencies, dairy corporations, consultants, hardware and software vendors, anyone interested in the applications of RFID and the development of the dairy industry may find relevance in the findings of this study.

7.4. Recommendations

7.4.1. Further Research

A vast array of research could be undertaken to extend this work. At the time of completion there has been little academic research conducted on this particular topic, and as such, it is believed that there are a myriad of possible avenues for further research. This may include detailed research into a particular technology that has been described, technical research into what may be required to implement a suggested device, cost-benefit studies of implementing specific technologies, case studies on how utilising a particular technology has impacted the milk production volume of a farms cows, labour saving estimates for the automation of certain components etc.

This research has attempted to bring together a vast array of devices from two fields of study that have traditionally been widely separated (dairy farming and information technology), so as to provide a solid overview of the operations of a dairy farm and how RFID may be utilised to aid in total farm management within this industry. Specialist studies from either of these parties would aid to further develop the findings of this research.

7.4.2. Adoption & Implementation of the Findings

After completing this research, it is believed that RFID technology provides dairy farmers with a vast array of possible enhancements for existing farm management practices, as well as opportunities for adopting entirely new ones. Subsequently, it is recommended that farmers implement this technology, so as not simply to comply with legislative requirements, but with the aim to derive significant benefits for themselves and continue to enhance their total farm management capabilities.

A cautionary note to this research is that farmers should not simply change their current farm management practices on the basis that RFID appears the new popular technology. Rather, it is important they weigh up the requirements and aims for their farm alongside the costs and benefits of their own possible RFID implementation. The framework proposed in chapter 6 provides flexibility for farmers to select the components and benefits to meet their own individual aims and requirements - not all of the additional components described in chapter 6 may be desirable for some dairy

farms, while others may wish to implement all of them. Careful consideration should be provided to such a decision before committing to a large investment of RFID operations.

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Appendix A – Transcript of Interview with Lynne Strong

Interviewer - Adam Trevarthen

Participant - Lynne Strong

Interviewer: What industries does your farm serve? For example, dairy only, dairy and meat etc.

Participant: Dairy

Interviewer: Could you please provide a brief outline of the work processes involved in the milking operations of this dairy farm. For example, how/when you round up the cattle, what do they do when they reach the milking sheds etc.

Participant: The bulk of the milking herd is “Strip grazed” in the paddock on the farm containing the most suitable stage of pasture for milk production

The cows are rounded up three times daily by quad bike and travel back to the 14 aside double up herringbone dairy which is centrally located on the farm

The fresh cows (cows who have calved in the last 7 days) and cows with any health problems are located in a paddock adjacent to the dairy and are milked last

Interviewer: What information do you record during this process, and how do you collect it currently?

Participant: Once a month we herd record individual cows

The resultant prints provide information on Somatic cell count

Litres/cow/day

Fat & protein components /cow/day

As well as a number of other pieces of data e.g. pregnancy testing facilities are available

Appendix

On a daily basis this information is provided for the herd as a whole by the processor from a bulk vat sample taken daily by the tanker driver. The tanker driver then delivers this to the laboratory at the processing plant

This data can be accessed within 24 hours over the internet

Interviewer: Could you please provide a brief outline of the everyday farm operations undertaken. For example, maintaining vaccine records, feeding livestock etc).

Participant: Accurate data is kept for all farm operations as per detailed by the HCAAP and NSW Food Authority (I have a booklet for you which outlines this thoroughly)

Interviewer: What information do you record during these processes, and how do you collect it currently?

Participant: As above / computer records and manual record

Interviewer: How would you consider your knowledge of IT - (Poor, below average, Average, above average, excellent)?

Participant: 2 out of three full time staff have above average to excellent IT knowledge (software specific) The third staff member has poor knowledge of IT

Interviewer: Do you know much about the technology of Radio Frequency Identification (RFID)?

Participant: Yes

At this point, the following description of RFID is provided:

What is RFID?

RFID is defined as "... a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves" (RFID Journal 2005a).

Appendix

This technology is commonly implemented using a system of reusable and programmable RFID tags (also known as transponders) and readers (also known as interrogators). These tags can be attached/built-in to virtually any good/object and provide a storage capacity of up to 2 kilobytes of data (RFID Journal 2005a). This allows more than just a unique identifier to be stored on the tag, but may also allow additional information pertinent to the object to be stored (such as expiration date, manufacture date, owner information etc.). The receiver can be a mounted or hand-held computer-controlled device, and when a tag is brought within the reading range of a receiver, the receiver captures the data stored on the tag and forwards this to the host computer (Ames 1990, p. 1:5; RFID Journal 2005a; Williams 2004).

The following example system is then provided:

Systems have been developed to automatically feed cattle, depending upon their lactation cycle, automatically weigh them as they enter the dairy, separate the cattle into different yards, and many more.

Interviewer: Are you aware of such applications (as described above)?

Participant: Yes

Interviewer: Could you describe the ways in which you currently utilise RFID (both for milking, and farm management).

Participant: Not at all

Interviewer: (If not specified above) – Do you utilise an RFID reader at all, and for what purpose? The NSW regulations state that readers are not mandatory.

Participant: No

Appendix

Interviewer: Do you utilise a software application to work with your RFID, or for any other purposes on your farm? If so, how does these applications function (if not specified earlier in Q1 or Q3).

Participant: No

Interviewer: What benefits do you believe your use of RFID provides to you?

Participant: RFID offers us the opportunity to combine all our software packages and manual farm managements systems into a single system

Interviewer: Do you believe there are any disadvantages that have arisen due to your use of RFID?

Participant: Yes their will be some challenges we will have to surmount

Interviewer: Do you feel you are gaining a good enough return on your RFID investment?

Participant: We will ensure we do

Interviewer: Are you considering extending the use of RFID for farm management operations on your farm in the future (such as feed enhancement, gate control etc)?

Participant: Yes

Interviewer: Do you find the cost of RFID to be excessive?

Participant: Compared to how the white collar sector would have addressed this challenge/opportunity Yes

Appendix

Interviewer: Do you have any concerns regarding the use of RFID in general?

Participant: Accuracy of data collection. Software packages Red tape in early stages – to much focus on regulation rather than outcomes

Interviewer: Is there an application where you feel RFID would be useful on your farm, or for dairy farms in general, that you haven't as yet heard of?

Participant: Not at this stage – too early to say will need to have a greater understanding and more time spent with system (“clinical experience”) at the present its all theoretical

Interviewer: Have you considered the use of RFID for monitoring the temperature of animals? Would you adopt such an invention?

Participant: It could do a hell of a lot more than just measure temperature – my god when was temperature the be all and end all of health monitoring

Appendix B – Transcript of Interview with Tom Cochrane

Interviewer - Adam Trevarthen

Participant - Tom Cochrane

Interviewer: What industries does your farm serve? For example, dairy only, dairy and meat etc.

Participant: Main industry is dairy. Obviously do sell beef from cull cows out of the dairy. Also dropping a bit into rearing steers until they're 2 or 3 years old, also excess bull calves.

Interviewer: Could you please provide a brief outline of the work processes involved in the milking operations of this dairy farm. For example, how/when you round up the cattle, what do they do when they reach the milking sheds etc.

Participant: Standard day includes waking up at 5, 2 people heading to the dairy, 1 person going to get the cows on the motorbike, the other one setting up the dairy. Once the cows are back at the dairy, about half-past 5 and they start milking, and finish around about 7 or quarter-past. After that, someone goes and puts the cows in the paddock, the other person cleans up a bit. The other person comes back and cleans up and feeds calves, and does odd jobs around. After that we go and have breakfast, and after breakfast if we haven't got enough grass we'll go and feed the cows with a supplement like corn silage or grass silage, just depending on what we've got available, or hay. Apart from that, we're just doing odd jobs around the farm - fencing, water pipes, fixing anything you can find, machinery, anything. Or working machinery, slashing, making hay, or doing anything like that. Back at 3 o'clock two people go into the dairy and do the same thing milking, finishing about 5. Walking away from the dairy about half past after you've finish all of the small little tasks.

Appendix

Interviewer: What information do you record during this process, and how do you collect it currently?

Participant: On a standard milking there's not a lot recorded apart from if any cows are on heat, we need to record that, and artificially inseminate them. And the other things is just a visual check if any cows have got mastitis, using the mastitis detectors, and if we find a new case we'll have to either treat it, or just currently watch it and see how bad she gets or see if she gets better. There's also homeopathy sprayed on for cows with mastitis

Interviewer: For the mastitis checking, is that checking the filters?

Participant: yeah, checking those little filters mainly, another thing is just visually checking the cattle, and if one part of the udder looks very inflamed, like very large and hard, it's a very good indication that you're going to have a problem that afternoon or the next milking, so just a visual check.

Interviewer: Could you please provide a brief outline of the everyday farm operations undertaken. For example, maintaining vaccine records, feeding livestock etc).

Participant: From when the calf is about, from day one, you're just looking at the calf, seeing if it's ok, as in health wise. Giving it antibiotics if it's sick. At about 2 months of age, a calf gets it's first 5-in-1 vaccine, and it gets it's booster shot about a month later, on a rough basis. Once a year, every cow in the herd gets a 7-in-1 vaccine.

Interviewer: and they're vaccinations for certain diseases are they?

Participant: Yeah, like black leg and others.

Feeding livestock, well the dairy cows it's pretty constant sorta thing, as long as you've got enough feed for them, but the dry stock, on this farm they just follow up the milking

Appendix

stock to eat out what they haven't eaten. On other farms we just move them round on a bi-weekly basis – so twice a week.

Interviewer: With things like vaccine records, do you record them in any way currently?

Participant: When we're vaccinating calves, at their 2 months of age, we have a system where an ear mark is taken out of their on their first one, and on the second one, a bigger mark is taken out of their ear. So we know if an individual calf has been vaccinated and it's booster shot. So, for instance there's a couple cows in our herd that were never given that second vaccination when they were young, because we've noticed that they've only got the first ear mark out of their ear. And we see that a little bit, it just means we're not on top of things enough, too many other things to do. But when it comes to annual vaccination within the herd, it's get in and do every cow, we don't sorta write anything down as such, we just get in and do everything. They're also recorded in the diary when we've actually completed it.

Interviewer: Do you keep much records about anything on the farm, or just records about specific cattle?

Participant: There's records on AI'ing, that is our main records. Penicillin given to any cow has got to be written down for HASAP accreditation. If you give a cow any antibiotics it's got to be written down in a certain form, you write it down and then you write down when she can be currently sold or milked again.

Interviewer: That's sorta like what was recorded on the computer system the other day?

Participant: Yeah, the computer's making that a lot easier, you can just type it in once, you don't have to do it again, and it can remind you for the next however many days not to sell her, or not to drink her milk.

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Interviewer: What information do you record during these processes, and how do you collect it currently?

Participant: Yeah, every dairy has a manual diary they write in, or if they don't have one, they should – is just a daily, day book. Which is, anything that gets done on that day, you just write it down, in regards to penicillin or... yeah mainly penicillin. We've just got a normal school diary that we write all our AI's and all our penicillin in that little book, any cows that calved.

We've got 2 diaries, one for cows, and one for paddock work. Any work that gets done on a paddock – if we seed a paddock it gets written in this book, or spraying, anything like that.

Interviewer: How would you consider your knowledge of IT - (Poor, below average, Average, above average, excellent)?

Participant: Average.

Interviewer: Do you know much about the technology of Radio Frequency Identification (RFID)?

Participant: Myself being an electrician, I know a little bit about it, we briefly went into it. I can't speak for my brother's or my father. I suppose I'm a little bit ahead of them, but not much. At a general statement, I'd imagine it's the same sorta thing as what they use in shopping centres, when you steal a piece of clothing with a tag on it. I imagine it's very similar to that.

At this point, the following description of RFID is provided:

What is RFID?

RFID is defined as "... a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves" (RFID Journal 2005a).

This technology is commonly implemented using a system of reusable and programmable

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RFID tags (also known as transponders) and readers (also known as interrogators). These tags can be attached/built-in to virtually any good/object and provide a storage capacity of up to 2 kilobytes of data (RFID Journal 2005a). This allows more than just a unique identifier to be stored on the tag, but may also allow additional information pertinent to the object to be stored (such as expiration date, manufacture date, owner information etc.). The receiver can be a mounted or hand-held computer-controlled device, and when a tag is brought within the reading range of a receiver, the receiver captures the data stored on the tag and forwards this to the host computer (Ames 1990, p. 1:5; RFID Journal 2005a; Williams 2004).

The following example system is then provided:

Systems have been developed to automatically feed cattle, depending upon their lactation cycle, automatically weigh them as they enter the dairy, separate the cattle into different yards, and many more.

Interviewer: Are you aware of such applications (as described above)?

Participant: Yes.

Interviewer: Could you describe the ways in which you currently utilise RFID (both for milking, and farm management).

Participant: We've got a tag in every animal on the farm, including calves. From or day four of a calves life it gets a tag. It's fed from then on for three months of its life on an automatic calf feeder, so when a calf comes in, it's allowed a certain amount of milk. And if, say 4 hours later it comes in, it will give it a bit more, and so forth during the day until it's allowed so much for that one day. As it gets older it gets more milk, until it gets weaned at about three months.

Later on in life, when the cows hit milking stage at 2, 2 and a half years of age, they run through the dairy with automatic feeding, starting them at low feed, and building them up

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to a higher amount of feed, about 8 kilos of grain a day, depending on how much milk they produce, they go higher or lower to that for the next 300 days of their lactation.

Interviewer: So when they go in there they start off pretty low with their feeding?

Participant: Yeah about one kilo. Or about 2 kilos a day, and over about 20 days it builds them up to 8.

Interviewer: That's just getting them used to it?

Participant: Yeah, getting them used to the grain mainly, the wheat... so as to build up the required bugs in their stomach to handle the feed. Yeah, we've had neighbours who have killed cattle through wheat poisoning, grain poisoning. So, if you give them a big hit at once...

The only other thing is the automatic drafting.

Interviewer: Yeah they're guided to different paddocks depending on what you have to do with them?

Participant: Yeah the different yards

Interviewer: So if you had to give them veterinary treatment...?

Participant: Yeah, veterinary treatment, of artificial insemination, it puts them into the one yard. And if it's a show cow, and we want to give her a bit better treatment we put her into the other yard, with hay and stuff there.

Interviewer: And things like cows that have freshly calved, when they walk in the tag reader will identify them and the computer lets you know.

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Participant: Yep, it will identify them and let us know that they have freshly calved... Yeah, as long as you calve the cow in the computer, but nine time out of ten that happens, so it's fine.

Interviewer: So the computer picks up again, freshly calved ones, slow milking ones it identifies, and also ones that have been treated with umm...

Participant: Yeah Penicillin.

Interviewer: Is there anything else it picks up as well?

Participant: obviously it will tell you if the cows are on a permanent draft, like if she's on that permanent draft for the show cow list. Along with that, you've got to initiate the process of that, so for it to tell you that the cow is fresh you've got to calve the cow, for it to tell you that she's got penicillin in her, you've got to tell the computer to start with. But you only have to do it once, so from then on, it will tell you for the remaining days. And if she's slow, you just write in this is a slow cow, and from then on, she's always gunna be a slow cow, that's her life, she will be slow. So you're employees know to deal with her first... which is good.

Interviewer: Do you utilise an RFID reader at all, and for what purpose? The NSW regulations state that readers are not mandatory.

Participant: Apart from in the dairy, no we don't use them for any other reason, and the calf feeder.

Interviewer: Do you utilise a software application to work with your RFID, or for any other purposes on your farm? If so, how do these applications function (if not specified earlier in Q1 or Q3).

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Participant: Well, we went through that a little bit before, but the software is called Dairy 2000, built in Victoria only for dairy farms. As mentioned, it has all those functions in regards to drafting and feeding, and AI and those sort of functions. It has a lot of functions we don't use, because it's way above what we need.

Interviewer: And that was built by OnFarm Electronics was it?

Participant: Yeah, OnFarm Electronics

Interviewer: What benefits do you believe your use of RFID provides to you?

Participant: Mainly convenience, for feeding, making it so much easier to individual feed, and drafting, making it easier to draft a cow without racing out and going to get her. It's happening automatically nearly. That's the biggest advantage. Makes milking a lot smoother.

Interviewer: The automatic feeder, does it provide the cows that are milking better with more feed, so it just produces more milk.

Participant: It's the same as I suppose any program, as long as you program it in there to start with, it will happen automatically from then on. We herd record, so we measure every cow's milk once a month, and then it goes on that, if she's done 38 litres on that herd record she'll get fed for 38 litres for the following month until we herd record again.

Interviewer: So is the idea to feed them more to get more milk out of them.

Participant: Yeah, to the general statement. As they get further in to their lactation they're going to slow off in their milk anyway. That's just a natural thing. So we've built into ours that over the 300 days of lactation that it will slowly bring them down after 150 days it'll slowly bring them down anyway.

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Interviewer: Do you believe there are any disadvantages that have arisen due to your use of RFID?

Participant: The only disadvantage I suppose is getting old dogs to learn new tricks. Learning how to use the basics of the computer. That, I suppose, for any employer is a bit of a hassle sometimes.

The cost of it, the advantages have outweighed the cost of it, long term. Like, if you're talking only over a year, there's no way you can justify that cost, but if you justify it over 20 years, it's paid for itself well and truly. In regard to saving of feed, saving of headaches, in regard to running around out the dairy trying to catch a cow, just simple things.

Interviewer: Do you feel you are gaining a good enough return on your RFID investment?

Participant: Yes.

Interviewer: Are you considering extending the use of RFID for farm management operations on your farm in the future (such as feed enhancement, gate control etc)?

Participant: Well, we've got that already. The only other little things we'd probably go on are the milk meters, electronic milk meters. It's the only thing, well, not the only thing, but, it's one thing I've thought about which might happen within 10 years. You need the individual identification for that, so...

Interviewer: *Do you find the cost of RFID to be excessive?*

Participant: Well, the initial cost was a big hit. I suppose, at the end of the day it would have been close to \$60, maybe \$65, 000 to put the software and hardware into the dairy. For individual cows it's not expensive, for dairy farmers, because at the moment, well,

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for any sort of farming I suppose it's not expensive, because you need to put the tag in the cow's ear now anyway now to sell it, by law, you need to put it in there. So, it's not excessive. \$4 per animal, roughly, is not an excessive amount. It is when you start doing thousands of them, but, it's not excessive really.

Interviewer: Do you have any concerns regarding the use of RFID in general?

Participant: No, not really. I suppose the only thing when we installing was to keep it away from any other electrical items, because interference was happening and we weren't getting good read range.

Interviewer: Is there an application where you feel RFID would be useful on your farm, or for dairy farms in general, that you haven't as yet heard of?

Participant: Not that I can think of. On another farm, like in sheep farms it would probably be very handy for drafting, mainly on age. If you wanted to get your animals pregnant at a certain age for sheep, and you had them running through a race and it drafted them on age that would be handy. That's the only thing I can think of. Nothing extra on top, for dairies.

Interviewer: Have you considered the use of RFID for monitoring the temperature of animals? Would you adopt such an invention?

Participant: Yes, yes we have. They've thought about it in the U.S., and they've tried to implement it in the U.S. The temperature of a cow is obviously related to if they are in heat - in season to mate - so, if their temperate goes up, they're likely to be in heat. If they do more walking of a day, they're likely to be on heat. If they do less walking they're likely to be sick. Things like that, it's a big help for everyday things. If they made a device that could detect heat, and walking... that was simple, and could run in with the same system that we're running now, well we would have it in two seconds sorta thing, it would make it a lot easier.

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Interviewer: I've heard, currently they've been trialling things with sheep and pigs as well, actually putting in a rumen bolus

Participant: yeah a rumen bolus

Interviewer: Yeah, in that kind of a field they've been working on those, and identifying temperatures and that. So, if a temperature was too high for a cow, that could signify they're on heat, or also it could signify that they're sick as well?

Participant: If the temperature of a cow, yeah, if she is high, that could... but yeah, if it's high temperature, there's something different happening there, so you've gotta check it out.

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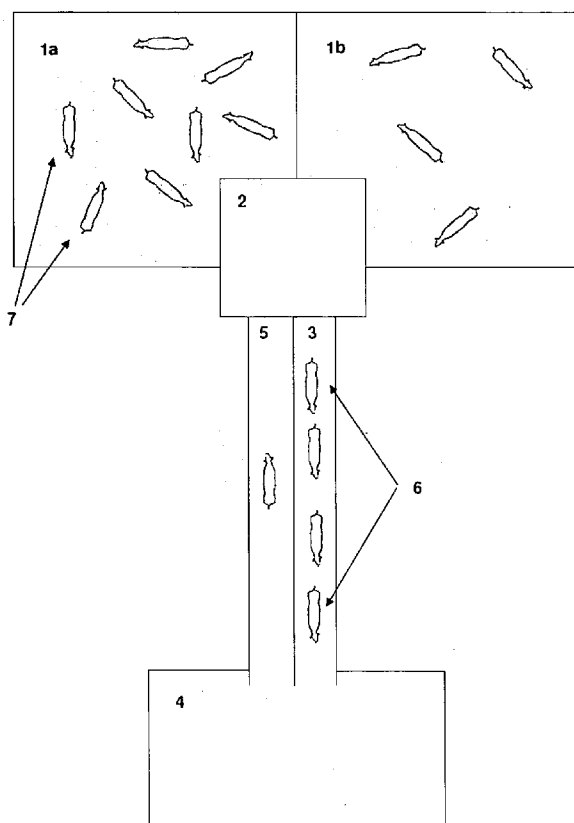
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(54) Title: METHOD, SYSTEM AND/OR APPARATUS FOR OPERATING A SELECTION SYSTEM



(57) Abstract: The invention relates to a system, method and a set of computer executable instructions configured to control an animal's access to a channel leading to a remote resource. The process of the invention is instigated through retrieving a specific animal record based on the output of an identification means. A control signal is then issued by the invention to an animal selection system to allow the animal access to the remote resource if the retrieved animal selection record indicates priority animal status. Additional control logic may also be employed after the assessment of animal status to allow access to the remote resource to non-priority status animals.

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METHOD, SYSTEM AND/OR APPARATUS FOR OPERATING A SELECTION SYSTEM

TECHNICAL FIELD

This invention relates to a method, system and/or apparatus for operating a selection system. Preferably the present invention may be used in conjunction with a selection system to determine whether an animal is ready to join a queue of animals awaiting service by a remote resource. In a preferred embodiment a remote resource may be an automatic milking system (AMS) which milks an animal. However, those skilled in the art should appreciate that other applications for the method of operating a selection system may also be considered, and reference to its use in the above application only throughout this specification should in no way be seen as limiting.

BACKGROUND ART

Milking systems, which automatically milk dairy animals, are known in the field of farming and commonly referred to as automatic milking systems (AMS). The most common dairy animal with which an AMS may be used is a cow. Most AMS can be used with small herds of cows which are housed in barns. The animals live and are fed in a large barn which also houses the automatic milking system. The animals can wander from the end of the barn to the automatic milking system, where the cow is fed and milked at the same time.

This system, however, does not work effectively in situations in which cows are not housed in barns, but are housed in paddocks, where they freely graze from pasture. These animals are usually milked twice a day, using conventional milking systems. The animals can walk considerable distances (sometimes up to 2-3 kilometres) from their grazing paddocks to the milking area. The paddocks in which the animals graze may change regularly to maintain a good feed level and

allow the grass and vegetation in each paddock to recover from grazing and to most effectively utilise the feed that is grown.

Using an AMS with this kind of pasture based farming can be difficult. The animals (usually cows) must rotate which paddocks they graze in, allowing
5 optimum growth of the grass and health of the animals. Implementing an automatic milking system, which will work whichever paddock a cow is in, and includes a long walk to the building housing the AMS, can be difficult.

One way of overcoming this problem is described in New Zealand Patent No. 512521, which discloses a selection system and method for milking animals. This
10 system works by having an attractant at a selection station in a grazing paddock. As the cows are drawn to the attractant, the system identifies each cow using a tag reader. This identification information is then checked against milking records. If a cow meets a predetermined criterion it is then allowed access to a passage or raceway which leads to the milking area, which may include an automatic milking
15 system. If the cow does not meet the predetermined criterion, the cow is directed back to the old or onto a new paddock.

The attractant is usually something that the animal would like to feed from once or twice a day, such as water, feed, or grain. The basic selection system makes a decision based on information from milking records to determine whether the cow
20 should be milked and allows the cow into a race to walk to the automated milking system. This simple predetermined criteria of whether a cow should be milked based on milking records can be limiting, as it does not take into account the animals health, the number of animals in the race or any other discriminating factors such as individual behaviour patterns.

25 The nature of the attractants available in or via the selection system, as well as the diurnal patterns of cows means that many cows may enter the system at the

same time or in close succession. This can create a long queue, in which an animal is required to stand for a long time as it waits to be milked. Long wait times create stress on animals, and result in inefficient use of the system. This can impact on the quality and volume of milk, or the animal health of the animal.

- 5 Long periods of time off pasture waiting to be milked is also a less positive experience for the cow thereby reducing her likelihood of returning to the selection system for further selection for milking, in turn making the complete system less effective. It would be preferable for the animal to remain in the paddock and be able to graze or lie comfortably, rather than stand or lie in a long queue.
- 10 It would also be preferable if there was a way of ensuring priority animals were sent to the AMS for milking. Animals might be designated as a priority due to health reasons, such as temperament or other behaviour reasons, lactation condition or physiological state such as mastitis, lameness or reproductive status.

Similar problems to the above discussed with respect to automatic milking

- 15 systems are also present in relation to pasture management for livestock. Grazing animals need to be shifted from one break of pasture to another over time as the original pasture is depleted. Generally, animals have to travel some distance through a channel or race to the new pasture. It would therefore be of advantage to have a selection system which could preferentially allow some
- 20 animals priority access to new pasture over other animals. It would also be of advantage to have a selection system which could consider characteristics of animals when determining which animals should be allowed access to sources of new pasture.

- An improved system for selection of which animals are enqueued would be
- 25 preferred. Specifically, one that takes into account the amount of animals already in the queue, and the likelihood of an animal returning to the attractant at a later

time. This would allow, the minimal queue to be kept at all times, and animals that are seen to be returning often can be turned away, whereas animals which return only once a day can be enqueued as a priority.

A system which also takes into account whether the animal would be milked by
5 the automatic milking system would also be an advantage.

All references, including any patents or patent applications cited in this specification are hereby incorporated by reference. No admission is made that any reference constitutes prior art. The discussion of the references states what their authors assert, and the applicants reserve the right to challenge the accuracy
10 and pertinency of the cited documents. It will be clearly understood that, although a number of prior art publications are referred to herein, this reference does not constitute an admission that any of these documents form part of the common general knowledge in the art, in New Zealand or in any other country.

It is acknowledged that the term 'comprise' may, under varying jurisdictions, be
15 attributed with either an exclusive or an inclusive meaning. For the purpose of this specification, and unless otherwise noted, the term 'comprise' shall have an inclusive meaning - i.e. that it will be taken to mean an inclusion of not only the listed components it directly references, but also other non-specified components or elements. This rationale will also be used when the term 'comprised' or
20 'comprising' is used in relation to one or more steps in a method or process.

It is an object of the present invention to address the foregoing problems or at least to provide the public with a useful choice.

Further aspects and advantages of the present invention will become apparent from the ensuing description which is given by way of example only.

DISCLOSURE OF INVENTION

According to one aspect of the present invention there is provided a method of operating a selection system, said selection system being adapted to control an animals access to a channel leading to a remote resource, said method being
5 characterised by the steps of;

- i) identifying an animal, and
- ii) allowing the identified animal access to the channel if said animal is identified as a priority animal.

According to another aspect of the present invention there is provided a method of
10 operating a selection system, further characterised by the additional subsequent step of allowing the identified animal access to the channel if the animal is determined able to use said remote resource.

According to a further aspect of the present invention there is provided a method of operating a selection system, further characterised by the additional
15 subsequent step of allowing the identified animal access to the channel if the existing number of animals present in the channel is below a queue threshold value.

According to another aspect of the present invention there is provided a method for operating a selection system, further characterised by the subsequent step of
20 allowing the identified animal access to the channel if the animal's return rate is below a return rate threshold.

According to a further aspect of the present invention there is provided a method of operating a selection system, further characterised by the additional subsequent step of assessing the current value of a remote resource against a

threshold value to determine if an identified animal should be allowed access to said remote resource.

According to yet another aspect of the present invention there is provided a method of operating a selection system further characterised by the additional
5 subsequent step of assessing the current value of a resource presently available to an animal against a threshold minimum value for said resource to determine if the identified animal should be allowed access to a remote resource.

According to yet another aspect of the present invention there is provided an information management system for a selection station, said information
10 management system including

an identification means, and

a data storage means configured to store animal selection records, and

a processing means, and

a control system configured to operate a selection station,

15 wherein the processing means is adapted to process animal selection records stored by the data storage means to determine whether the control means should issue a control signal to operate a selection station.

According to a further aspect of the present invention there is provided a set of computer executable instructions stored on a computer readable medium, said
20 instructions also being adapted to execute steps of;

i) retrieving a specific animal record based on the output of an identification means, and

ii) issuing a control signal to allow an animal access to the remote resource if

the retrieved animal selection record indicates priority animal status.

According to a further aspect of the present invention there is provided a set of computer executable instructions, said instructions being adapted to execute the additional subsequent step of issuing a control signal if the retrieved animal selection record indicates that the animal associated with the record is able to use
5 the remote resource.

According to a further aspect of the present invention there is provided a set of computer executable instructions, said instructions being adapted to execute the additional subsequent step of issuing a control signal if the retrieved animal selection record indicates that an existing number of animals present in the
10 channel is below a queue threshold value.

According to further aspect of the present invention there is provided a set of computer executable instructions, said instructions being adapted to execute the additional subsequent step of issuing a control signal if the retrieved animal selection record indicates that the return rate of the animal associated with the
15 record is below a return rate threshold.

According to a further aspect of the present invention there is provided a set of computer executable instructions further characterised by executing the additional subsequent step of assessing the current value of a remote resource against a
20 threshold value to determine if an identified animal should be allowed access to said remote resource.

According to a further aspect of the present invention there is provided a set of computer executable instructions further characterised by executing the additional subsequent step of assessing the current value of a resource presently available
25 to an animal against a threshold minimum value for said resource to determine if the identified animal should be allowed access to a remote resource.

The present invention may provide a method of operating a selection system. The selection system may be adapted to control an animal's access to a channel leading to a remote resource.

5 A resource may preferably be an automatic milking system (AMS), which allows animals to be milked by a machine without human intervention. However, in alternative embodiments this resource may be a feed station, a station where animals are screened for health problems, or any other kind of area in which animals need to be moved into to receive some form of service from a resource.

10 For example, in one alternative embodiment the present invention may be employed to control access to blocks or breaks of pasture on a per animal basis. In such embodiments the particular characteristics of individual animals may be assessed in decision making logic employed by a selection system to determine whether an animal presenting to a selection station be immediately allowed to access new pasture.

15 Reference throughout this specification will be made to a resource being an automatic milking system. However, those skilled in the art should appreciate that other resources may also be used, and reference to the resource being an automatic milking system only throughout this specification should in no way be seen as limiting.

20 Preferably an animal may be a livestock animal, which is housed remotely from the automated milking system. These animals may preferably be cows, which may graze in a pasture a distance from the automated milking system. Alternatively, animals may be sheep, goats, or any other type of dairy animals which the system is configured to milk which are kept in an area remote from the
25 system.

Reference throughout this specification will be made to an animal being a cow.

However, those skilled in the art should appreciate that other animals may also use the present invention, and reference to its use with cows only throughout the specification should in no way be seen as limiting.

Preferably a channel leading to a remote resource may be provided by a race or
5 fenced in area or path leading from the pasture in which the animal is housed, to the automated milking system. This race may be varied in length and/or configuration, based on which pasture or paddock the animal is housed in.

The present invention may provide a method of operating a selection system, which may either enable or disable access to the race or fenced area. This
10 selection is based on selected criteria of each animal attempting to access said race. This allows a user to prioritise each animal's access to the channel and therefore the animal's access to the remote resource. It allows the selection system to help maintain an optimal number of animals in the race leading to the milking system, therefore optimising the throughput efficiency of said system.

15 Preferably, the present invention may provide a method, system or an apparatus for operating a selection system. An information management apparatus may be used to manage the operation of the selection station.

An information management system may be formed by a computer system associated with the selection station, which processes data and allows the
20 selection station to select an animal based on this data process. Preferably an information apparatus may consist of an identification means, a data storage means, a processing means, and a control system.

Preferably an identification means may be a system which works in conjunction with an identification element connected to an animal to identify the animal.
25 However in alternative embodiments, an identification means may be provided by any other means for identifying an animal moving through the information

management apparatus.

Preferably an animal may be identified by the system reading an identification element connected to the animal. This identification element may consist of an RFID tag which the animal wears, and a corresponding tag reader which then
5 identifies the animal. An ear tag containing an RFID component is commonly used on livestock animals. This tag can identify an animal as the animal passes a tag reader. This identification element can then be used to query a storage means associated with further information on the identified animal. However, in alternative embodiments the animal may be identified through other means, such
10 as other identification tags, infrared tags, or any other means which identifies an animal to the system.

Reference throughout this specification will be made to an identification means being an RFID tag reader. However, those skilled in the art should appreciate that other identification systems may also be used, such as infrared tags, and
15 reference to the identification means being an RFID tag reader only throughout this specification should in no way be seen as limiting.

Preferably a data storage means may be part of a computer's memory (either dynamic or static). Preferably the data storage means stores a number of animal selection records. The system may store the records in a number of ways,
20 allowing a selection system to access the records.

Preferably an animal selection record may consist of information describing an animal. The information is preferably stored in a data storage means, and consists of an identifying portion-identifying the animal, and a number of variables, which relate to this animal, a group of animals, or the overall system. These
25 variables may be used by the information management system to process the animal selection records to determine whether an animal should have access to a

channel leading to a remote resource.

Preferably the information management system may include a processing means.

Preferably this processing means may process the animal selection records to determine whether the control means should issue a control signal to the selection

- 5 station. In some embodiments a processing means may be formed by a microprocessor. The processing of the animal selection records may include retrieving data from these records, and comparing them to predetermined thresholds or identification numbers to determine whether the control means should issue a control signal to the selection station.

- 10 For example, if an identification means identifies an animal, and the processing means matches this identification to a record in the animal selection records which corresponds to a priority animal, then the control system may select an animal. The processing means may preferably be provided by a computer based program which reads the animal selection records as data and then processes these.

- 15 Preferably the computer executable instructions may retrieve a specific animal record based on the output of an identification means. This is preferably executed by when an identification means identifies an animal, the program will then match this identifier to a specific animal record. This animal record may then be processed using the processing means, to treat information from this record
- 20 based on further steps of the program.

Preferably a set of computer executable instructions may form a part of a computer program which is processed by the processing means.

- Preferably a method of operating a selection station may be executed by computer executable instructions, but in alternative embodiments other means for
- 25 executing the method may be considered. Preferably the processing means may be a microprocessor programmed with a set of computer executable instructions.

These instructions may direct the information management system to operate a selection system in accordance with a preferred embodiment of the present invention.

Reference throughout this specification will be made to a processing means being
5 a microprocessor programmed with computer executable instructions. However, those skilled in the art should appreciate that other processing means may also be used, and reference to the above only throughout this specification should in no way be seen as limiting.

Preferably a control system may operate with the selection system. Preferably a
10 control system may provide a control signal to a selection station, allowing that selection station to enable or disable access to a race. The control system would preferably receive information from a processing means, then may issue a control signal to the selection station. The processing means may indicate to the control system that the animal identified should be allowed access to a race, thus the
15 control system will issue a signal allowing a selection station to allow access to the said animal. This signal may be a certain voltage output, indicating a true or false condition, or it may be any other way of providing a signal to a selection station.

Preferably, an animal may be allowed access to a channel if it is determined a priority animal by the information management system. Preferably the animal
20 may be manually labelled as priority by the user. A user may wish to designate an animal as being a priority based on data not maintained by the selection system, such as temperament, health of the animal, or the animal's weight. This may allow a user to manually override the system when desired. For example, in some embodiments a user may wish to flag a particular animal for diversion due to
25 health reasons. They may therefore assign priority status to this animal to ensure that the animal is draughted to the remote resource as soon as it presents to the selection system.

However, in some embodiments at least one automated process may be completed to assign priority status to a particular animal.

For example, in one embodiment an animal may be accorded priority status if the animal has not been milked for a time period exceeding a maximum milking interval. This milking interval can be employed to ensure that all animals are milking regularly and that an animal which has not approached the selection station for some time will immediately be classified as a priority animal and directed towards the remote milking system.

In yet other embodiments different automated processes may be completed to assign priority status when the type of remote resource varies. For example, in one alternative embodiment where the remote resource to be accessed is a new break pasture, priority status may be assigned to a particular animal if that animal is classified as a high productivity animal. In the case of dairy applications, cows which have a high than average yield may be given preferential access to new pasture through the assignment of priority status.

Preferably the animal may be allowed access to the race if it is determined able to use the automatic milking system. This determination may be based on the status of at least one parameter belonging to the identified animal. For example, this parameter may indicate whether this animal is carrying above a certain amount of milk. Other parameters may also be used to determine whether the animal is able to use the system, such as the weight of the animal, the health of the animal, or any other predetermined criteria.

For example, in one preferred embodiment a determination may be made as to the predicted or potential yield of milk currently carried by an animal based on a known or estimated milk secretion rate for that particular animal. A user or users of the present invention may therefore set a minimum yield value as an indicator

regarding whether an animal can use the automatic milking system, with the predicted yield parameter being compared with same to make a decision as to whether the animal should be allowed access to the channel.

5 In yet other embodiments predicted or potential milk yield may be employed in a selection system decision when resources other than remote milking systems are involved. For example, in one alternative embodiment where the remote resource to be accessed is new pasture, current predicted yield may be used to determine whether a cow should be held back from the new pasture. Cows given access to new pasture generally prefer to stay and graze for as long as possible and
10 therefore can delay the completion of a milking cycle. Current predicted milk yield can be used to hold back cows from new pasture which should be milked in the short term.

In such embodiments a further test may be completed with respect to the value or quantity of pasture remaining in an existing or old paddock and/or the value of
15 quantity of pasture present in a new paddock which an animal may potentially be given access to. If a cow is held back from new pasture on the basis of current predicted milk yield, this cow may still be allowed through to the new pasture if the old pasture break is significantly depleted, or the new pasture break has already been depleted by cows already allowed access to same.

20 Preferably an animal may be allowed access to the race if the number of animals present in the channel or race is less than or equal to a queue threshold value. If the channel queue length is above a certain threshold value, then the selection system may prevent a further animal accessing the race.

In a further preferred embodiment the present invention may employ two separate
25 and distinct queue threshold values, being a maximum queue threshold value, and a marginal queue threshold value. In such embodiments the maximum queue

threshold value may function in the same way as that described above, preventing further animals accessing the channel, or preventing non-priority status animals accessing the channel. The marginal queue threshold value may define a range of queue length values in which a further assessment may be made of data parameters associated with an animal to determine whether it should be allowed to access to the queue.

For example, in instances where the marginal queue threshold is five animals less than the maximum queue threshold, once the marginal queue threshold is reached, the system may prevent animals which are not priority animals from entering, and only allow infrequent visitors into the queue. This may avoid long queues building up, thus creating stress on the animals. It also may allow an optimum amount of animals in the queue at all times, thus increasing the efficiency of the remote resource, and the selection system.

This threshold value or values may be variable, based on the length of the channel leading to the remote resource. If the race is longer, the queue threshold value may be higher, allowing more animals into the queue. However, if the race is small and the animals only have a short distance to travel to the milking system, then the queue threshold value may be lower. A queue threshold value may also change depending on a number of variables, such as weather, condition of the animals, time of year, and so forth.

When the number of animals in the queue is below a threshold value, if the identified animal is able to access the resource based on previous selection criteria, then the animal will be allowed access to the queue. However, if the queue threshold value is exceeded, then the animal may not necessarily be allowed access to the queue.

The return behaviour of an animal may describe the number of times an animal

returns to the selection station during a set period of time. If the animal returns only once a day, then it may have a low return rate. However if the animal returns many times during the day, then its return rate may be classified as high. The animals return rate and behaviour may also describe the average time that it takes
5 for an animal to return to the selection station.

The selection station may allow access to the race if the animals return behaviour is below a return threshold rate. This return threshold may be set based on the length of the queue, a queue threshold, or any other variable. If an animal has a return rate below the return threshold rate, the animal may be allowed access to
10 the channel. If however, the queue is above a certain length, or other variables are exceeded, and the animal is known to return to the selection station every two hours, the animal may be turned away as this animal is likely to return at a later time when the channel is not as busy.

For example, in some embodiments when the length of the queue sits between a
15 marginal and maximum threshold value, the return rate of an animal presenting at a selection station may be compared against a threshold return rate. Animals with a low return rate may therefore be allowed access to the channel, whereas animals which return frequently to the selection station may be refused access.

The return threshold rate may be set based on a number of variables, and there
20 may also be taken into account whether this is the animal's first or subsequent return to the selection station during one period of time. The period of time may be a day, or half a day, or some other period, depending on how often the animals are to be milked.

An animal's return pattern may vary over time as an animal's visiting pattern can
25 vary based on weather conditions, lactation condition or the length of the race to the milking system. The selection system may collect return rate data for a herd

of animals, allowing the return rate threshold to also vary based on this information.

In a preferred embodiment the present invention may also be employed to increment a return rate parameter included within an identified animal record after
5 the animal's record has been retrieved. Those skilled in the art should appreciate that computer executable instructions working in conjunction with an associated information management system may be employed to update a return rate parameter once an animal presents itself to gain access to the remote resource.

In a further preferred embodiment, the present invention may also be employed to
10 assess whether an animal should be allowed access to a second resource after having being refused access to a first or primary remote resource. For example, in some embodiments an animal entering a selection station may initially be assessed with respect to gaining access to a remote automated milking system. If access to the milking system is refused the same animal may again be
15 assessed to determine whether the animal should be given access to a new pasture break. A similar set of criteria to that discussed above may be employed to determine an animal's worthiness for access to a second resource.

In a further preferred embodiment an animal may be allowed access to a second resource if that animal has been allocated priority animal status. In the case
20 where the second resource is provided by new pasture, animals with higher than average productivity may be allocated priority status and given access to new pasture earlier than animals with lower productivity. In such embodiments the lower productivity animals may in turn be allowed access to new pasture if a predicted milk yield associated with the animal is below a threshold which
25 indicates the animal can use an associated remote automated milking system. In such instances animals carrying a minimal amount of milk will be allowed to graze on new pasture for extended periods of time.

In yet other embodiments a decision to allow access to a secondary resource consisting of new pasture may be made through an assessment of the value or quantity of the new pasture currently available or the value or quantity of old pasture which an animal originated from. If the old pasture is effectively grazed out, access may be given to new pasture. Conversely, if animals already allowed access to new pasture have substantially depleted same, more animals may be allowed access to this pasture immediately.

The present invention provides an improved way of selecting animals to be allowed access to a race leading to a milking system. This improved system takes the identification of an animal, determines the variables of this animal to a range of predetermined criteria to determine whether the animal is able to enter a race leading to a milking system.

This selection system provides an improved way of enqueueing the animals, which allows the system to maintain a minimal queue at all times. This minimal queue results in less stress on the animal and improved efficiency of the queuing systems. If the animals are in a minimal queue at all times, the automatic milking system can be utilised constantly, resulting in increased efficiency of the system.

Smaller queues also allow animals to relax as they are free to roam in a pasture before entering the race, and if the race contains an increasingly long queue, they may be free to roam longer and are in cramped conditions for less time.

The present invention may provide a number of advantages over the prior art.

The selection system may allow an optimum queue length to be maintained at all times. It may allow a user to prioritise an animal's use of a milking system, and creates less stress on an animal to be milked.

The selection system can also decrease the likelihood of an animal reaching the

milking station, and then being rejected for milking based on the fact that they may not have enough milk, they may have returned recently, or they may be unhealthy. The selection system allows these factors to be considered before the milking station is reached, and therefore an unsuitable animal may be turned away
5 at an earlier stage, thus reducing inefficiency in the system.

The selection system may provide an efficient system for enqueueing animals to be milked by an automatic milking system.

The present invention may also be employed in pasture management applications. The present invention may assess parameters or characteristics
10 associated with particular animals to assess whether access should be given to a new pasture break. In some instances the present invention may be employed to manage pasture in isolation, or in other embodiments may initially assess an animal with respect to access to an automated milking system, and if access is not granted the animal may be assessed with respect to access to a new pasture
15 break.

BRIEF DESCRIPTION OF DRAWINGS

Further aspects of the present invention will become apparent from the following description which is given by way of example only and with reference to the accompanying drawings in which:

- 20 Figure 1 shows a plan view of a prior art selection system; and
- Figure 2 shows a plan view of a selection station system configured in accordance with the present invention, and
- Figure 3 shows a flow chart of the basic steps, executed in accordance with a preferred embodiment of the present
25 invention, and

Figures 4a, 4b show flowcharts illustrating the steps executed in accordance with a further embodiment to select a cow for access to a milking system and/or access to new pasture, and

- 5 Figure 5 shows a plan view of a selection station and associated paddocks provided in accordance with a further embodiment of the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

- Figure 1 shows a plan view of a selection system as seen previously with respect
10 to NZ 512521.

This view shows a holding paddock (1), including a selection station (2), which controls access to a channel configured as a race. This race (3), leads to a remote resource, which in this case is a milking system (4). The animals to be milked (5) are in a queue leading to the milking system (4).

- 15 This system provides no control of the queue length, and therefore there is the potential to form long queues, as is shown.

Figure 2 shows a plan view of a selection station system configured in accordance with the present invention.

- This view shows a holding paddock (1) with an improved selection system (6)
20 leading to a channel (3) leading to a milking system (4). The cows to be milked (5) are waiting in a short queue before entering the milking system area, and other cows (7) are waiting in the holding paddock (1) where they are free to roam, graze, and are not stressed by being in a long queue.

The present invention provides an improved way of selecting the cows to be

enqueued (5), so that a queue is maintained at an optimum length, and further cows to be milked later (7), may roam freely in a holding paddock (1), therefore creating less stress on the animals.

Figure (3) shows an illustration of the basic steps executed by the present invention in one preferred embodiment.

Step 1: An animal is identified by an identification means, or tag reader.

Step 2: The selection station allows this animal access to the race if the information management system determines that the animal is a priority animal.

Step 3: The system may also allow the non-priority cow access to the race if the system determines that the cow would be milked by the milking system. This allows animals that have already been milked that day to be turned away.

Step 4: The system may then determine how long the queue is, and if the queue is longer than a certain threshold it may turn the animal away. If the queue is lower than this threshold, it may allow the animal access to the raceway to the milking system.

Step 5: The system may then determine how often an animal usually returns to the selection station. If this return rate is low, the selection station may allow the cow to access the race.

Step 6: The system may then determine whether an animal fits other priority criteria due to health reasons, such as temperament or other behavioural reasons, lactation condition or physiological state such as mastitis, lameness or reproductive status.

The present invention provides an improved method for determining whether an animal should be allowed access to a race which leads to a milking system. It

may of course be used with a variety of remote resources, providing access and a steady flow of animals to this resource.

The present invention allows a system to operate efficiently, for animals to remain as relaxed as possible. The present invention may work with a milking system to
5 provide an optimum system for using milking systems in farms, where animals are housed a distance from this milking system.

Figures 4a and 4b show flowcharts illustrating the steps executed in accordance with a further embodiment to select a cow for access to a milking system or access to new pasture.

10 Once a cow is initially identified an assessment is made as to whether the cow has priority status through determining whether she is flagged for health reasons or has a milking interval which exceeds the maximum milking interval defined for all members of the herd.

If the cow is not a priority status animal an assessment is next made of whether
15 the cow is due for milking through comparing a predicted yield value associated with the cow at the present point in time with a threshold milking yield value assigned to all members of the herd. This predicted yield value is used to determine if the cow can use the remote milking system. If the cow is determined able to use the remote milking system the current length of the queue giving
20 access to the milking system is compared with a maximum queue size and marginal queue size. A cow will be sent back to a paddock if the maximum queue size has been exceeded or if the marginal queue size has been exceeded and the return rate of the cow is higher than a threshold return rate.

Pseudo code illustrating an instruction set employed to implement the above
25 process is set out below:

```

Identify cow
IF Cow's milking interval > maximum interval OR cow is flagged for health treatment THEN
    Add cow to milking queue list
    Set gates to send cow to milking facility
ELSE
    IF Cow is due for milking THEN
        IF queue size > maximum queue size THEN
            CALL Send cow to paddock (thisCow)
        ELSE
            IF queue size < marginal queue size THEN
                Add cow to milking queue list
                Set gates to send cow to milking facility
            ELSE
                IF cow is frequent visitor THEN
                    CALL Send cow to paddock (thisCow)
                ELSE
                    Add cow to milking queue list
                    Set gates to send cow to milking facility
                ENDIF
            ENDIF
        ENDIF
    ELSE
        CALL Send cow to paddock (thisCow)
    ENDIF
ENDIF

Function "Send cow to paddock (thisCow)"
BEGIN
    IF Cow is recently milked THEN
        Send cow to new paddock
    ELSE
        IF old paddock open time < open time limit THEN
            Send cow to old paddock
        ELSE
            Send cow to new paddock
        ENDIF
    ENDIF
RETURN

```

As can be seen above, the Function "Send cow to paddock (thisCow)" is also defined. The execution of this function is also illustrated in the flowchart of figure 4b. This function is called when a cow is initially refused access to a milking system or facility as illustrated by figure 4a. This function determines if a cow should be allowed access to a second resource such as a paddock with new pasture.

In this function the priority status of the animal is first investigated through determining the cow's milking interval and whether she has been milked recently.

A recently milked cow will be sent to a new paddock. If the cow has not been milked recently, an assessment is made as to how long the old paddock has been grazed to determine the value or capacity of the remaining pasture resource provided by the old paddock. If the pasture in the old paddock has been significantly depleted through an assessment of opening times a cow will be allowed access to the new paddock.

Figure 5 shows a plan view of a selection station and associated paddocks provided in accordance with a further embodiment of the present invention.

In the embodiment illustrated, a selection station (2) provides access to a remote milking system (4) by way of a channel or race (3). Animals (7) in an existing or old paddock (1a) gain access to the milking system (4) through the selection system (2) becoming an enqueued animal (6).

After milking occurs the animal then returns to the same selection station (2) by way of a return race (5).

As discussed with respect to figures 4a and 4b, the selection system may also be employed to determine whether an animal should be given access to a secondary resource such as a block of new pasture (1b). As can be seen from figure 5, animals can be given access to this new pasture block through the selection system (2). Animals presenting to the selection system which have either been milked previously and have a short milking interval can subsequently be allowed access to the new pasture block (1b). Conversely, if an animal from the old pasture (1a) presents to the selection station (2) and is refused access to the race (3), the animal's milking interval or priority status can be assessed to determine whether the animal should in turn be given access to the new pasture block (1b).

Aspects of the present invention have been described by way of example only and it should be appreciated that modifications and additions may be made thereto without departing from the scope thereof as defined in the appended claims.

WHAT WE CLAIM IS:

1. Computer executable instructions adapted to control an animal's access to a channel leading to a remote resource, said instructions being adapted to execute steps of;
 - i) retrieving a specific animal record based on the output of an identification means, and
 - ii) issuing a control signal to an animal selection system to allow an animal access to the remote resource if the retrieved animal selection record indicates priority animal status.
2. Computer executable instructions as claimed in claim 1, wherein said instructions executes the additional subsequent step of issuing a control signal to an animal selection system if the retrieved animal selection record indicates that the animal associated with the record is able to use the remote resource.
3. Computer executable instructions as claimed in claim 2, wherein at least one parameter associated with the animal is assessed to determine whether the animal can use the remote resource.
4. Computer executable instructions as claimed in claim 3, wherein a parameter includes an estimate of the amount of milk the animal is carrying, or a health indicator associated with an animal, or the weight of the animal.
5. Computer executable instructions as claimed in any previous claim, wherein said instructions execute the additional subsequent step of issuing a control signal to an animal selection system if the retrieved animal selection record

indicates that an existing number of animals present in the channel is below a queue threshold value.

6. Computer executable instructions as claimed in any previous claim, wherein said instructions execute the additional subsequent step of issuing a control signal to an animal selection system if the retrieved animal selection record indicates that the return rate of the animal associated with the record is below a return rate threshold.
7. Computer executable instructions as claimed in any previous claim, wherein the animals to have their access controlled to a remote resource are dairy animals.
8. Computer executable instructions as claimed in claim 7, wherein the remote resource is an automatic milking system.
9. Computer executable instructions as claimed in any previous claim, wherein the animal selection system controls an animal's access to the channel leading to the remote resource.
10. Computer executable instructions as claimed in any previous claim, wherein a channel is provided by a race or fenced path.
11. Computer executable instructions as claimed in any previous claim, wherein an identification means works in conjunction with an identification element connected to an animal to be identified.
12. Computer executable instructions as claimed in claim 11, wherein said identification element is an RFID tag.

13. Computer executable instructions as claimed in any previous claim, wherein the identification means queries a storage means used to store animal records.
14. Computer executable instructions as claimed in any previous claim, wherein priority animal status is manually assigned to specific animals.
15. Computer executable instructions as claimed in any previous claim, wherein said instructions increment a return rate parameter of the identified animal's record after said animal's record has been retrieved.
16. A method of operating a selection system adapted to control an animals access to a channel leading to a remote resource, said method being characterised by the steps of;
 - i) identifying an animal, and
 - ii) allowing the identified animal access to the channel if said animal is identified as a priority animal.
17. A method of operating a selection system as claimed in claim 16, further characterised by the additional subsequent step of allowing the identified animal access to the channel if the animal is determined able to use said remote resource.
18. A method of operating a selection system as claim in either claim 16 or claim 17, further characterised by the additional subsequent step of allowing the identified animal access to the channel if the existing number of animals present in the channel is below a queue threshold value.
19. A method of operating a selection system as claimed in any one of claims 16 to 18, further characterised by the subsequent step of allowing the identified

animal access to the channel if the animal's return rate is below a return rate threshold.

20. An information management system for a selection system adapted to control an animal's access to a channel leading to a remote resource, the information management system including

an identification means, and

a data storage means configured to store animal selection records, and

a processing means, and

a control system configured to operate a selection system,

wherein the processing means is adapted to process animal selection records stored by the data storage means to determine whether the control means should issue a control signal to operate the selection system.

21. An information management system as claimed in claim 20, wherein the data storage means is formed from at least a portion of the memory of a computer system.

22. An information management system as claimed in claim 20 or claim 21, wherein the processing means is formed by a microprocessor.

23. An information management system as claimed in any one of claims 20 to 22, wherein a control signal is issued by the control system to operate the selection system if an animal is determined to be able to use the remote resource.

24. An information management system as claimed in any one of claims 20 to 23, wherein a control signal is issued by the control system to operate the selection system if an animal's return rate is below a threshold return rate.
25. An information management system as claimed in any one of claims 20 to 24, wherein a control signal is issued by the control system to operate the selection system if the number of animals present in the channel is less than or equal to a queue threshold value.
26. Computer executable instructions substantially as herein described with reference to and as illustrated by the accompanying drawings and/or examples.
27. A method of operating a selection system substantially as herein described with reference to and as illustrated by the accompanying drawings and/or examples.
28. An information management system substantially as herein described with reference to and as illustrated by the accompanying drawings and/or examples.

FIGURE 1

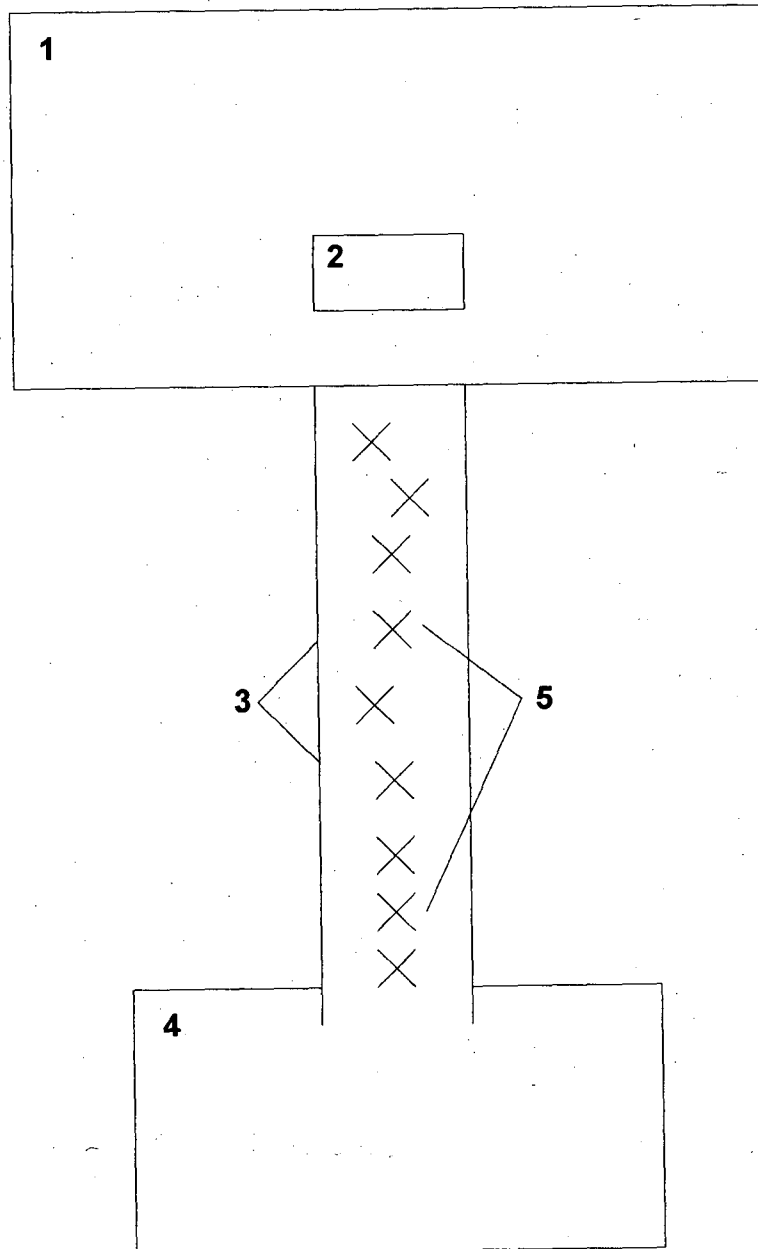


FIGURE 2

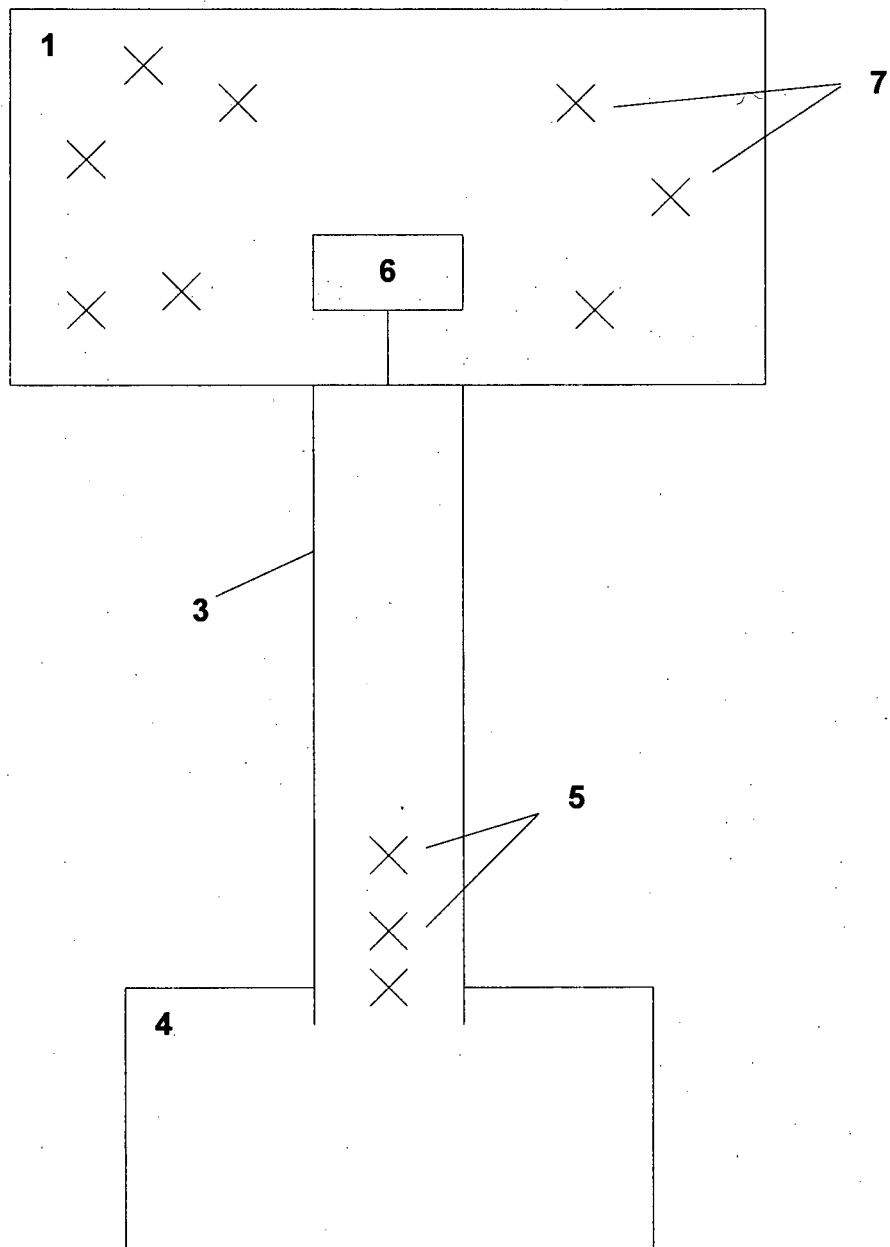
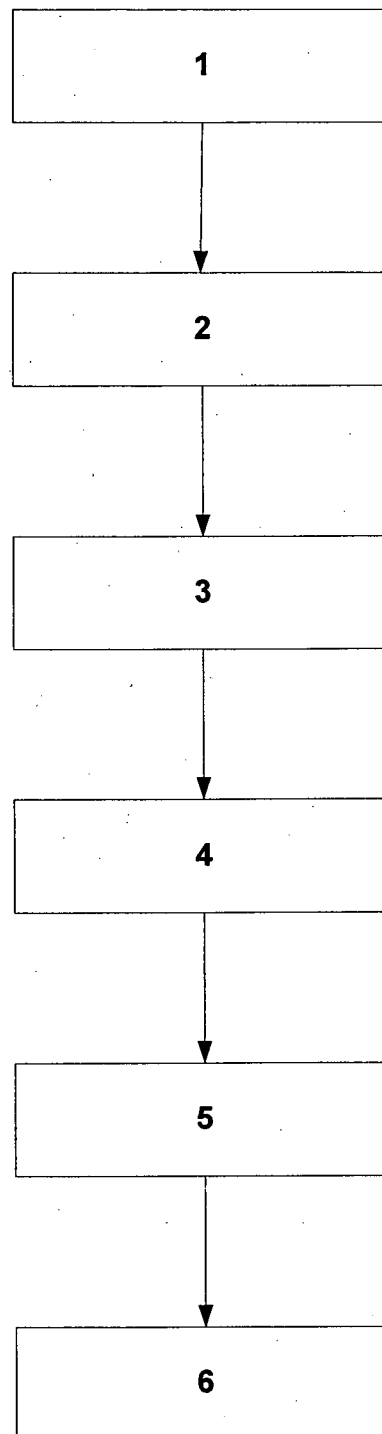


FIGURE 3



3/6

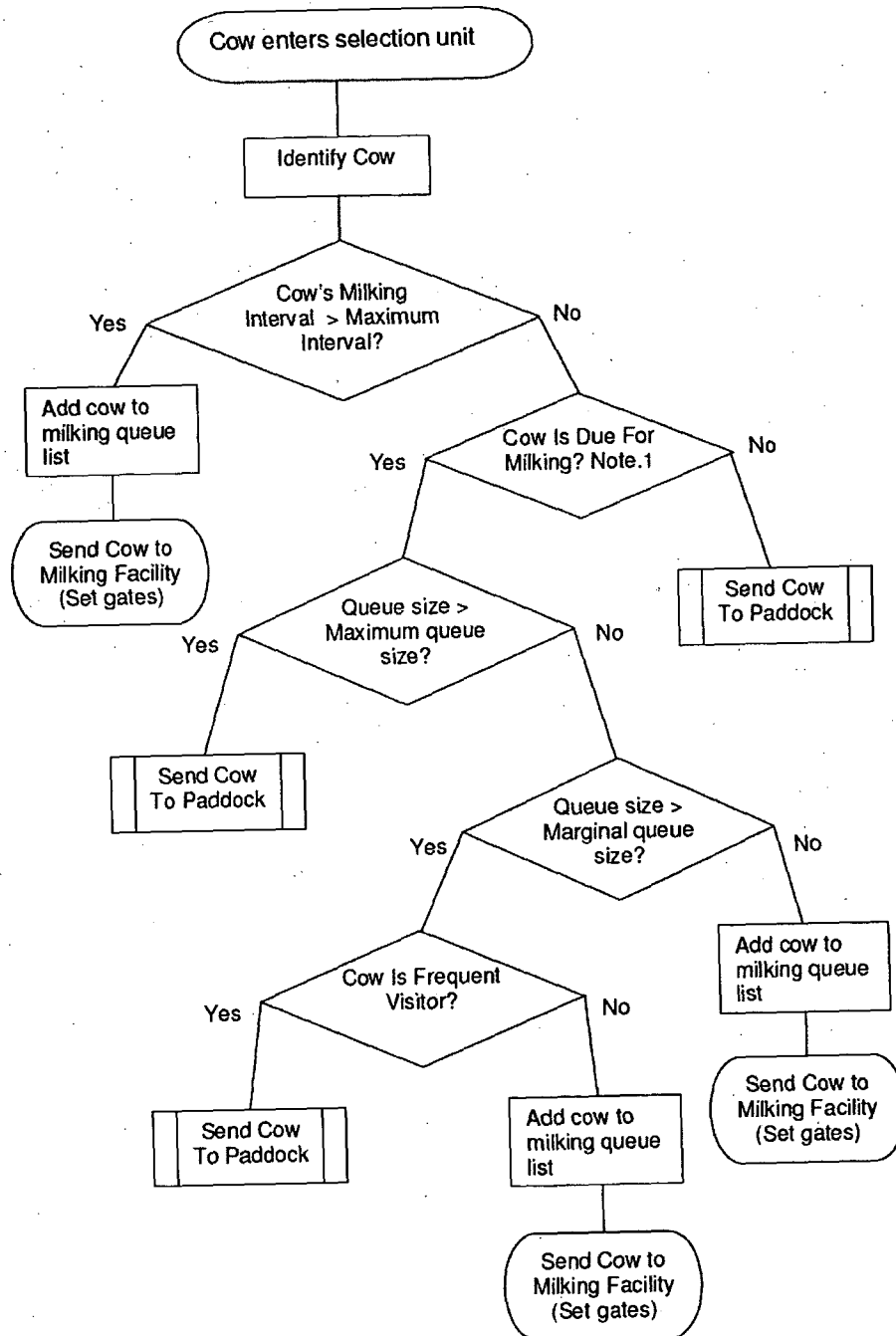
FIGURE 4a

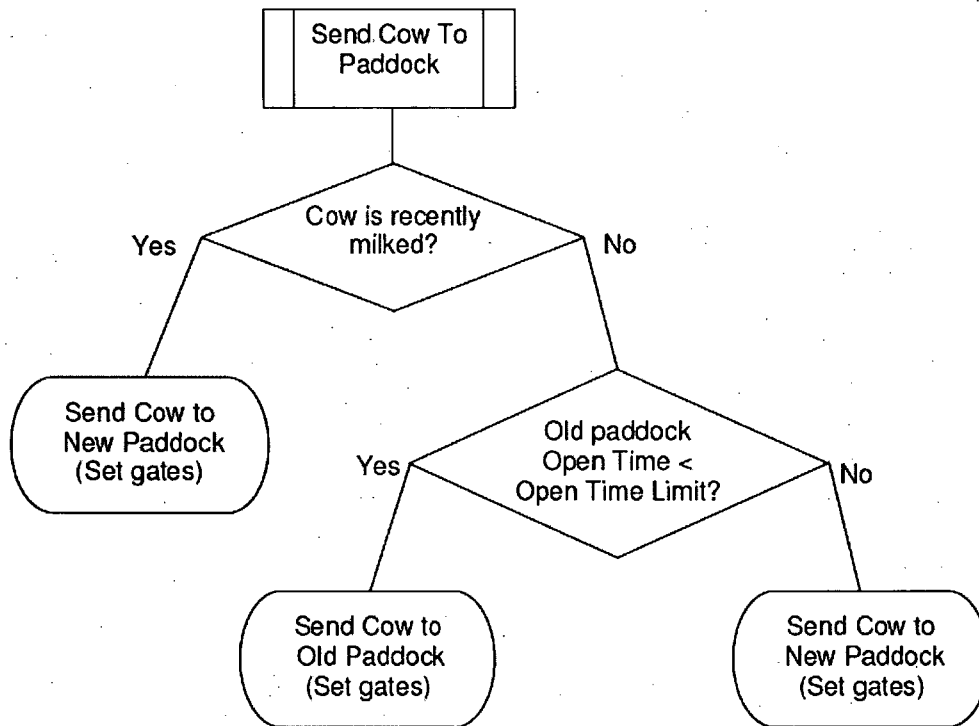
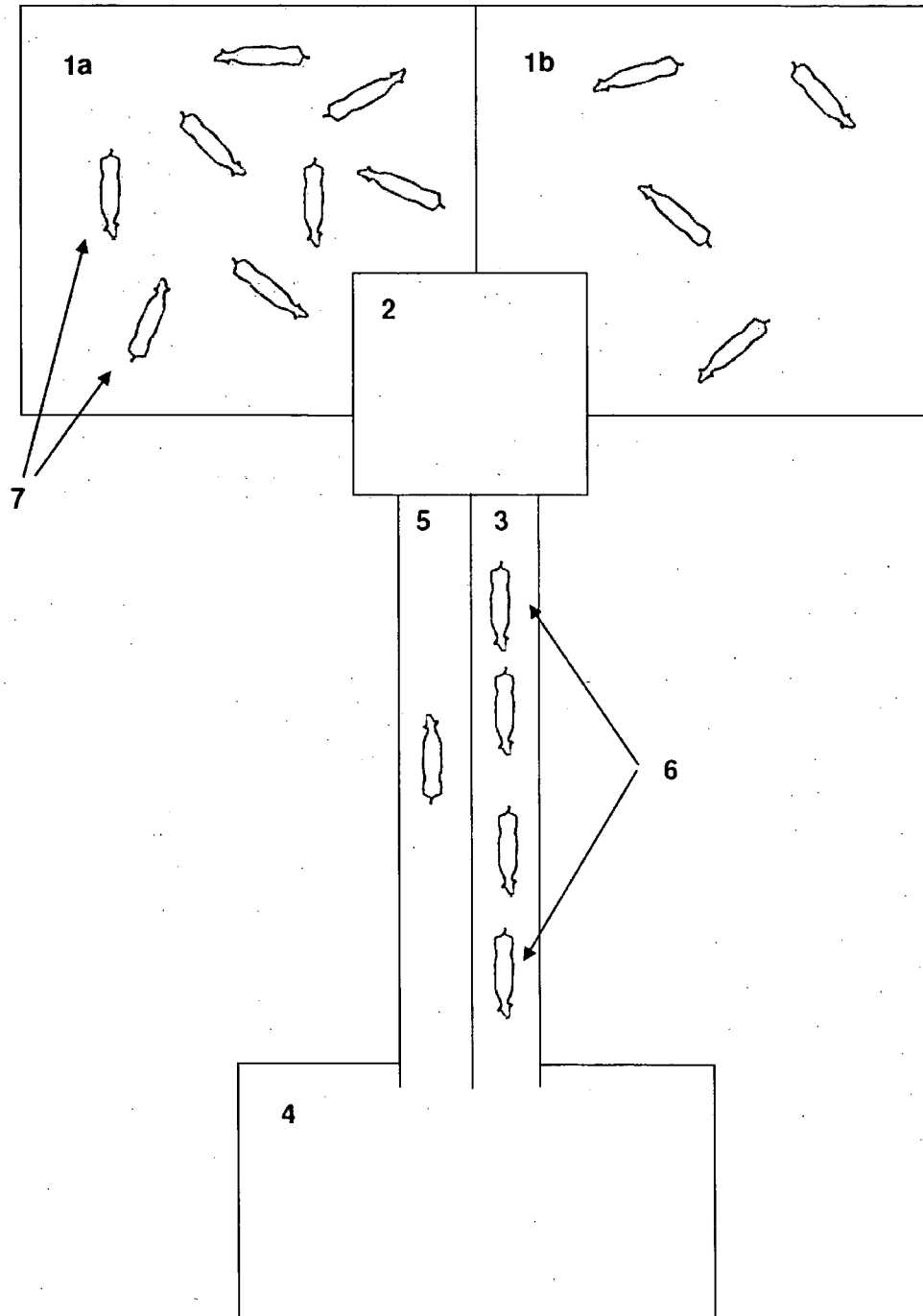
FIGURE 4b

FIGURE 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2007/000286

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. *A01K 15/04* (2006.01) *G07C 9/00* (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI, internet, AusPat, Patent Lens, PCT Gazette, Esp@cenet, GetThePatent "cattle, rfid, gate etc."

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Trevarthen, A., 'The Importance of Utilising Electronic Identification for Total Farm Management: A Case Study of Dairy Farms on the South Coast of NSW', 2005. See url: < http://ro.uow.edu.au/cgi/viewcontent.cgi?article=1000&context=thesesinfo >. Entire document.	1-25
X	WO 2006/059916 A2 (VESTIGO MANAGEMENT LIMITED) 8 June 2006. Entire document.	1-4,7-14,16,17,20-23
X	AU 775809 B2 (MICRO BEEF TECHNOLOGIES, LTD.) 12 July 2001. Entire document.	1-5,9-18,20-23,24
X	GB 2232053 A (G E BAKER (UK) LIMITED) 5 December 1990. Entire document.	1-4,9-13,15-17,20-23
X	WO 2000/001226 A (ALFA LAVAL AGRI AB) 13 January 2000. Entire document.	1-4,6-17,19-24



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
12 March 2008

Date of mailing of the international search report
18 MAR 2008

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/NZ2007/000286

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
WO	2006/059916	NONE					
AU	775809	AU	24768/01	AU	34570/95	AU	78688/98
		AU	2004205259	CA	2161749	US	5573002
		US	5673647	US	5836880	US	6000361
		US	6135055	US	6200210	US	6318289
		US	6516746	US	6579236	US	6805075
		US	2001044579	US	2002050248	US	2003188689
		US	2005000458	US	2007131175	US	2007157888
GB	2232053	NONE					
WO	2000/001226	AU	50746/99	SE	9802356		
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							

APPENDIX ISR02

PATENT COOPERATION TREATY

From the:
INTERNATIONAL SEARCHING AUTHORITY

To:

James & Wells Intellectual Property
Of Private Property Bag 3140,
Hamilton 3240, New Zealand

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing (day/month/year) 1 8 MAR 2008	
Applicant's or agent's file reference 123646PCT/16	FOR FURTHER ACTION See paragraph 2 below
International application No. PCT/NZ2007/000286	International filing date (day/month/year) 2 October 2007
Priority date (day/month/year) 2 October 2006	
International Patent Classification (IPC) or both national classification and IPC Int. Cl. A01K 15/04 (2006.01) G07C 9/00 (2006.01)	
Applicant SENSORTEC LIMITED et al	

1. This opinion contains indications relating to the following items:

- | | | |
|-------------------------------------|--------------|--|
| ☒ | Box No. I | Basis of the opinion |
| ☐ | Box No. II | Priority |
| ☐ | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| ☐ | Box No. IV | Lack of unity of invention |
| ☒ | Box No. V | Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |
| ☐ | Box No. VI | Certain documents cited |
| ☐ | Box No. VII | Certain defects in the international application |
| ☐ | Box No. VIII | Certain observations on the international application |

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. +61 2 6283 7999	Date of completion of this opinion 12 March 2008	Authorized Officer P. THONG AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. (02) 6283 2128
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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/NZ2007/000286

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 - ☒ The international application in the language in which it was filed
 - ☐ A translation of the international application into, _____, which is the language of a translation furnished for the purposes of international search (under Rules 12.3(a) and 23.1(b)).
2. ☐ This opinion has been established taking into account **the rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:
 - a. type of material
 - ☐ a sequence listing
 - ☐ table(s) related to the sequence listing
 - b. format of material
 - ☐ on paper
 - ☐ in electronic form
 - c. time of filing/furnishing
 - ☐ contained in the international application as filed.
 - ☐ filed together with the international application in electronic form.
 - ☐ furnished subsequently to this Authority for the purposes of search.
4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
5. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/NZ2007/000286

Box No. V **Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims 26-28	YES
	Claims 1-25	NO
Inventive step (IS)	Claims	YES
	Claims 1-28	NO
Industrial applicability (IA)	Claims 1-28	YES
	Claims	NO

2. Citations and explanations:

D1 = The Importance of Utilising Electronic Identification for Total Farm Management: A Case Study of Dairy Farms on the South Coast of NSW

D2 = WO 2006/059916

D3 = AU 775809

D4 = GB 2232053

D5 = WO 2000/001226

Novelty (N): Claims 1-25

Claims 1-25:

Citation D1 discloses a computerised system (paragraph 5.1.4) that records/registers and identifies (diagram 5.1, paragraph 5.4.1) animals, allowing animals priority entry via a channel to remote resources (diagram 5.2 – steps 19 and 20, paragraphs 5.3.1, 5.5.2). Therefore, the subject matter of independent claims 1, 16 and 20 lacks novelty. The citation also discloses the features of dependent claims 2 to 3, 7 to 13, 17 and 21 to 23 (chapter 5), 4 (paragraphs 5.2.2.6, 5.2.2.9), 5, 18 and 25 (paragraph 5.2.2.8), 15 (paragraphs 5.5.1, 5.5.3), 6, 19 and 24 (paragraph 5.3.4) and 14 (paragraphs 5.2.2.3, 5.4.2).

Claims 1-4,7-14,16,17,20-23:

Citation D2 (page 10 lines 31 to 33, page 11 lines 11 to 16, page 17 lines 9 to 11, page 21 lines 16 to 26, page 18 lines 17 to 28, figure 3, figure 5 etc.) discloses drafting priority animals for milking or feeding, rendering the subject matter of the claims not novel.

Claims 1-5,9-18,20-23,24:

Citation D3 discloses a computerised system (page 69 line 35) that records/registers (page 22 lines 6 to 8, page 22 lines 21 to 25, page 77 lines 1 to 8) and identifies (page 80 lines 30 to 34) animals, allowing animals priority entry via a channel 22 (having a queue threshold - figure 5) into sort pens 30 leading to one of several remote resources (figure 7, page 94 line 1 to page 95 line 36) like feed pens A to D of a feedlot (page 28 lines 15 to 19). Citation D3 (page 23 lines 24 to 30, page 4 line 3 to page 25 line 28) also discloses a similar approach (identification, queuing) within a feedlot (figure 2). Therefore, the subject matter of independent claims 1, 16, 20 and that of the dependent claims cannot be considered novel.

NOTE: Continuation in Supplemental Box.

Supplemental Box

Claims 1-4,9-13,15-17,20-23:

Citation D4 discloses a computerised system (page 3 line 23) that records/registers (page 1 line 25) and identifies (page 3 line 24) animals, allowing animals priority entry via a channel to remote resources (figure 2, page 4 lines 12 to 19). Therefore, the subject matter of independent claims 1, 16 and 20 lacks novelty. The citation also discloses the features of dependent claims 2 to 3, 17 and 21 to 23 (page 4 lines 12 to 19), claim 4 (page 1 line 28 - animal of weaker health), claims 9, 10 (figure 1), claims 11 to 13 (page 4 lines 7 to 12, page 1 lines 12 to 18) and claim 15 (page 1 lines 21 to 26).

Claims 1-4,6-17,19-24:

Citation D5 discloses a computerised system (page 9 line 10) that records/registers (page 8 lines 21 to 22, page 10 lines 10 to 16, page 10 line 24) and identifies (page 10 lines 18 to 20) animals, allowing animals priority entry via a channel to remote resources (page 8 lines 10 to 14). Therefore, the subject matter of independent claims 1, 16 and 20 lacks novelty. The citation also discloses the features of dependent claims 2 to 3, 17 and 21 to 23 (page 8 lines 10 to 14), claims 4, 6, 15, 19, 24 (page 11 lines 4 to 11), claims 7 to 13 (page 9 lines 24 to 28, figure 1, page 9 line 11, page 11 lines 8 to 16) and claim 14 (page 11 lines 1 to 4).

Inventive Step (IS): Claims 1 to 28

Claims 1 to 25:

As above.

Citation D3 (which relates to beef cattle) is immediately applicable to dairy cattle. Hence, the subject matter of dependent claim 7 lacks an inventive step in view of the disclosures in this citation.

Claims 26 to 28:

The subject matter of the claims lacks an inventive step because it merely involves the application or implementation of a commonly known as well as a disclosed (citation D1 for example) technology to a specific dairy farm/floor layout.

APPENDIX GIPSON01

Diphasic Analysis of Lactation Curves in Dairy Goats¹

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ABSTRACT

Milk production data on 5084 Alpine, 2052 LaMancha, 7024 Nubian, 2194 Saanen, and 2339 Toggenburg does were grouped into 90 subclasses: five breeds $\times$ three parities (1, 2, and 3) $\times$ two seasons of kidding (early, December to March; late, April to July) $\times$ three measures of 305-d milk production within breed (low, medium, and high). Subclass means of milk production for 100 3-d groups were smoothed and used to estimate parameters of a diphasic function, which is the sum of two logistic functions. Characteristics for each phase of the lactation curve (initial, peak, and 305-d yields, time of peak, and duration of phase), which are functions of parameters of the diphasic function, were then analyzed using a linear model including breed, parity, season, and mean of measure of production as a covariate, weighted by the number of observations in each subclass. Breed had little effect on the shape of the lactation curve in dairy goats. Parity affected primarily characteristics of the second phase of lactation. Season of kidding had the most consistent effect on the lactation curve: affecting characteristics of each phase. Measure of production affected characteristics of the second phase more than those of the first phase. First phase, with its proximity to overall peak and short duration, could be interpreted as a "peak" phase. Second phase, affected

largely by parity, could be interpreted as a "persistency" phase.

INTRODUCTION

Knowledge of the lactation curve allows one to predict total milk yield from a single test day (23) or from several test days early in lactation. Knowledge of the curve also allows the dairy producer to make management decisions based on production of an animal early in lactation; it helps to identify sick animals before clinical signs appear, such as those with decreased milk production from subclinical mastitis; and it helps to identify animals that need special attention, such as high producing animals with a higher dietary demand than average producing animals (1, 2, 11).

Several mathematical functions have been used to model the shape of the lactation curve in dairy cattle, the most popular being the incomplete gamma function (20). Parameters of the incomplete gamma have a biological interpretation relative to pathways of energy utilization in lactation (24), yet are difficult to interpret relative to the shape of the curve. The incomplete gamma is known to underestimate milk yield in midlactation and to overestimate it in early and late lactation in dairy cattle (4, 17). This function requires estimated milk yield to be zero at parturition, which is unappealing biologically because an animal has the ability to produce milk even before parturition (7). Calculation of 305-d yield from the incomplete gamma must be approximated, because no closed form expression exists.

Other mathematical functions have been used to remedy shortcomings in modeling the lactation curve with the incomplete gamma. One such function is the multiphasic logistic (10), parameters of which have been interpreted biologically for the analysis of growth curves (9, 13, 14). It is postulated that parameters of the multiphasic function also have biological interpretation for the analysis of lactation

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²Reprint requests.

curves (10). Several genetic and environmental factors affect the lactation curve in dairy cattle, such as breed (8, 26), season of calving (8, 21, 22, 25), and measure of milk production (12, 25). There has been little research, however, on the lactation curve in dairy goats. Objectives of this study are to model lactation curves in dairy goats using a multiphasic logistic function and to study the effects of breed, parity, season of kidding, and measure of milk production on the shape of the lactation curve and on the phases of lactation.

MATERIALS AND METHODS

Data

Test-day (kg milk/d) and 305-d lactation (kg milk) records on dairy goats were obtained from the Dairy Records Processing Center in Provo, UT via the USDA Animal Improvement Programs Laboratory in Beltsville, MD. Data were edited so that each record was for 1) a doe from one of the five major dairy goat breeds in the United States (Alpine, LaMancha, Nubian, Saanen, and Toggenburg), to exclude crossbred and experimental does; 2) a normally terminated lactation, to ensure that lactation was started and terminated in the same herd and that it was not terminated by abortion, death, or sale; 3) a test-day sample taken from d 6 through d 305 of lactation; 4) a date of kidding between December 1 and March 30 (early season of kidding) or between April 1 and July 31 (late season of kidding); 5) a lactation number (parity) greater than zero and less than 4; 6) a lactation initiated during early season of 1981 through late season of 1987; and 7) a test-day yield less than or equal to 13.6 kg, to ensure that the record was not from a cow. After editing, data comprised milk production records on 5084 Alpine, 2052 LaMancha, 7024 Nubian, 2194 Saanen, and 2339 Toggenburg does.

Within breed, records were grouped into three measures of milk production (low, medium, and high) based upon 305-d yield; each measure of production had nearly equal numbers of observations. For Alpine, Saanen, and Toggenburg, low was less than 690 kg with a mean of 500 kg; medium, 690 to 1000 kg with a mean of 800 kg; and high, over 1000 kg with a mean of 1150 kg, approximately. For LaMan-

cha and Nubian, low was less than 550 kg with a mean of 400 kg; medium, 550 to 800 kg with a mean of 650 kg; and high, over 800 kg with a mean of 950 kg, approximately.

Test-days for each doe were assigned to one of 100 3-d periods over the course of lactation. Each period was called a test-day group and comprised test-days from different does. For example, a test taken during d 6, 7, or 8 of lactation was assigned to test-day group 7, and a test taken during the period of d 303, 304, or 305 was assigned to test-day group 304. This grouping strategy ensured that endpoints were equidistant from the midpoint for each group and from endpoints of adjacent groups, without interpolation or extrapolation.

Mean milk production for does in each test-day group was computed for each of 90 breed-parity-season-measure of production ($5 \times 3 \times 2 \times 3$) subclasses and then smoothed by LOWESS (3), a procedure to remove random noise associated with each datum and to give a representation of the underlying smooth curve. LOWESS is nonparametric regression that smooths in a two-step process. The first step of LOWESS is locally weighted regression, using a subset of "nearest neighbors"; the statistical weight is a tricube function, $(1 - u^3)^3$, where u is the inverse of the absolute distance of each neighbor from the datum being smoothed. Thus, neighbors farther away from the datum being smoothed received a smaller weight than neighbors closer to the datum; data outside the subset of nearest neighbors received a weight of zero.

The second step of LOWESS is robust regression, using the same subset of nearest neighbors; the statistical weight is a biweight function, $(1 - u^2)^2$, where u now is the inverse of the absolute value of each residual. Residual is the deviation of the observed datum from the predicted (smoothed) datum of the first step. Again, data outside the subset of nearest neighbors received a weight of zero. Figure 1 represents a lactation curve based on actual and smoothed means of test-day groups for Alpines in first parity, early season of kidding, and low production.

Both steps of LOWESS are iterated together until the smoothed points stabilize, i.e., until smoothed values do not change from round to round. Number of iterations was set to two

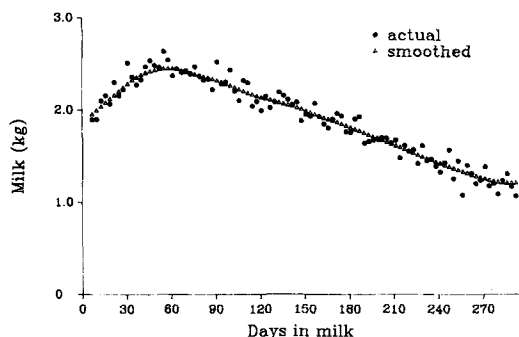


Figure 1. Lactation curve of actual (●) and smoothed (Δ) mean test-day groups for Alpines at first parity, early season of kidding, and low production.

because this number was usually sufficient to stabilize the smoothed points (3). The fraction of data used as a subset of nearest neighbors was set to .20, so that for each mean of the 100 test-day groups, 20 nearest neighbors were used for smoothing. For examples, for test-day group 7, the mean itself and means of the subsequent 20 test-day groups were used; for test-day group 100, the mean for group 100, means of the previous 10, and means of the subsequent 10 test-day groups; and for test-day group 304, the mean and means of the previous 20 test-day groups. If smoothed points represent the underlying function, then least-squares estimates of parameters based on smoothed data will be nearly unbiased and have smaller mean squared error than least-squares estimates of parameters based on actual data (19).

Model

A multiphasic function, which is the sum of logistic functions, models the lactation curve in dairy cattle better than the incomplete gamma function, in terms of smaller and more random residuals (10). The diphasic function was considered sufficient to model the lactation curve because a third phase provided little additional information (10). The diphasic logistic function is:

$$y_t = \sum_{i=1}^2 \{a_i b_i [1 - \tanh^2(b_i(t - c_i))]\}$$

where y_t is milk yield (kg) at time t (days in milk; $t = 7, 10, 13, \dots, 304$), $\tanh$ is the hyperbolic tangent, and for each phase i : $a_i b_i$ is peak yield, c_i is time of peak yield, and $2/b_i$ is duration, defined as days required to attain about 75% of asymptotic total yield during that phase. Data were smoothed because analysis of actual data for breed-parity-season-measure of production subclasses, especially for those with few observations, resulted in convergence to nonsensical parameter estimates, i.e., negative values for a_i or b_i .

Nonlinear regression [PROC NLIN (18)] was used to estimate parameters of the diphasic function from smoothed data via a derivative-free secant algorithm (16). Functions of estimates of parameters for each phase, including initial, peak, and 305-d yields, time of peak, and duration [see (10) for formulae for initial and 305-d yields] were then analyzed assuming a linear model, weighted statistically by the number of observations in each subclass:

$$y_{ijkmn} = \mu + b_i + p_j + s_k + \beta(l_{m(i)}) + e_{ijkmn}$$

where y_{ijkmn} is a function of estimates of parameters for each subclass and phase; μ is overall mean; b_i , effect of breed i ; p_j , effect of parity j ; s_k , effect of season of kidding k ; β , the linear regression coefficient for $l_{m(i)}$, the mean measure of milk production m within breed i ; and e_{ijkmn} , the random error.

RESULTS AND DISCUSSION

Number of observations by breed, parity, season of kidding, and measure of production are in Table 1. Nubians were 37% of total observations; Alpines, 27%; Toggenburgs, 13%; Saanens, 12%; and LaManchas, 11%. First parity had more observations (51%) than second (31%), which had more than third (18%). Early season of kidding had more observations (56%) than late season (44%). For high measure of production, more than twice as many does kidded in early season than in late season.

First-order autocorrelation of actual data ranged from $-.35$ to $.26$; about 80% of the

TABLE 1. Number of observations by breed, parity, early or late season of kidding,¹ and low, medium, or high production.²

Breed and parity	Early			Late			Overall
	Low	Medium	High	Low	Medium	High	
Alpine							
1	478	468	261	766	461	127	2561
2	162	340	473	167	194	224	1560
3	96	179	344	86	107	151	963
Total	736	987	1078	1019	762	502	5084
LaMancha							
1	203	241	141	307	175	54	1121
2	71	127	218	47	67	69	599
3	40	70	127	32	21	42	332
Total	314	438	486	386	263	165	2052
Nubian							
1	593	625	415	1054	701	252	3640
2	251	449	632	217	272	309	2130
3	181	229	452	104	138	150	1254
Total	1025	1303	1499	1375	1111	711	7024
Saanen							
1	174	237	97	318	183	59	1068
2	68	129	211	76	102	109	695
3	49	75	155	43	43	66	431
Total	291	441	463	437	328	234	2194
Toggenburg							
1	228	225	101	373	207	49	1183
2	62	163	255	77	97	78	732
3	34	74	175	35	52	54	424
Total	324	462	531	485	356	181	2339
Overall	2690	3631	4057	3702	2820	1793	18,693

¹Early = December 1 through March 31; late = April 1 through July 31.

²Alpine: low = <685 kg; medium = 685 to 975 kg; high = >975 kg; LaMancha: low = <580 kg; medium = 580 to 840 kg; high = >840 kg; Nubian: low = <510 kg; medium = 510 to 765 kg; high = >765 kg; Saanen: low = <690 kg; medium = 690 to 1025 kg; high = >1025 kg; Toggenburg: low = <690 kg; medium = 690 to 980 kg; high = >980 kg.

values ranged from $-.16$ to $.16$. An autocorrelation outside of the range $-.16$ to $.16$ indicates a significant first-order autocorrelation for 100 test-day groups and six parameters (15). Time series analysis of daily milk yield of an individual cow has shown the existence of a significant 7-d cycle in daily milk production (5). In our study, however, individual test-days were about 30 to 45 d apart, well beyond the 7-d cycle. Thus, adjacent means of test-day groups were expected to be uncorrelated.

Values for functions of estimates of parameters for first parity are in Table 2 for first phase and in Table 3 for second phase. Entries under "initial" and "305-d" yields are contributions of yields for that phase to overall yields. Esti-

mated differences and regression coefficients from weighted analysis of covariance for functions of estimates of parameters are in Table 4. For first phase (Table 4), initial yield was similar for breed and for parity, less for early season of kidding (.57 kg) than for late season (1.49 kg), and increased almost 1 g/kg 305-d yield with increasing production for LaManchas, Nubians, and Saanens. Peak yield was similar for breed and for parity, less for early season (.93 kg) than for late season (1.95 kg), and increased about .6 g/kg 305-d yield for Alpines and about 1.3 g/kg 305-d yield for LaManchas, Nubians, and Saanens. Total 305-d milk yield for first phase was similar for breed and for parity, less for early season (95.1 kg) than for late season (263.6 kg), and increased

TABLE 2. Values for functions of estimates of parameters for first phase in first parity.

Breed and season ¹ of kidding	Measure ² of production	Initial yield	Peak ³ yield	305-d yield	Time ⁴ of peak	Duration ⁵ of phase	
		(kg)		(d)			
Alpine	Early	Low	.4	.7	73.2	51	132
		Medium	.8	1.0	126.8	45	171
		High	1.0	1.7	199.6	56	144
	Late	Low	1.4	1.6	244.1	41	222
		Medium	1.1	1.5	210.1	55	179
		High	1.5	2.2	331.3	62	190
LaMancha	Early	Low	.2	.4	51.7	68	139
		Medium	.2	.4	43.2	57	123
		High	.4	.9	97.1	57	119
	Late	Low	.5	1.0	113.1	62	131
		Medium	1.0	1.8	241.8	65	164
		High	1.7	2.5	342.6	58	177
Nubian	Early	Low	.1	.2	19.1	48	90
		Medium	.4	.6	62.3	48	118
		High	.3	.6	59.6	56	121
	Late	Low	.9	1.1	149.0	47	179
		Medium	1.7	1.8	305.0	37	274
		High	2.2	2.7	413.8	50	222
Saanen	Early	Low	.3	.5	48.2	45	109
		Medium	.8	1.3	158.7	55	157
		High	1.6	2.3	346.1	60	192
	Late	Low	1.2	1.6	198.6	44	165
		Medium	.4	1.1	116.9	67	122
		High	1.7	2.2	338.9	57	204
Toggenburg	Early	Low	.8	1.1	171.2	56	222
		Medium	.4	.8	93.4	63	133
		High	.4	.9	77.6	50	104
	Late	Low	.7	1.3	158.9	61	149
		Medium	1.5	2.0	285.1	54	187
		High	1.7	2.6	348.6	56	174

¹Early = December 1 through March 31; late = April 1 through July 31.²Alpine: low = <685 kg; medium = 685 to 975 kg; high = >975 kg; LaMancha: low = <580 kg; medium = 580 to 840 kg; high = >840 kg; Nubian: low = <510 kg; medium = 510 to 765 kg; high = >765 kg; Saanen: low = <690 kg; medium = 690 to 1025 kg; high = >1025 kg; Toggenburg: low = <690 kg; medium = 690 to 980 kg; high = >980 kg.³a,b₁.⁴c₁.⁵2/b₁.

TABLE 3. Values for functions of estimates of parameters for second phase in first parity.

Breed and season ¹ of kidding	Measure ² of production	Initial yield	Peak ³ yield	305-d yield	Time ⁴ of peak	Duration ⁵ of phase	
		(kg)			(d)		
Alpine Early	Low	1.5	1.9	502.1	116	476	
	Medium	2.1	2.8	733.5	122	455	
	High	2.2	3.8	974.8	156	417	
	Late	Low	1.0	1.2	350.5	199	870
		Medium	2.1	2.4	657.1	115	606
		High	2.2	2.9	833.7	202	714
LaMancha Early	Low	1.6	1.7	448.0	65	571	
	Medium	2.3	2.7	688.4	96	455	
	High	2.7	3.5	920.0	122	455	
	Late	Low	1.5	1.5	404.9	18	800
		Medium	1.6	1.7	500.3	135	1000
		High	1.5	2.5	668.1	267	714
Nubian Early	Low	1.7	1.8	436.0	53	476	
	Medium	2.0	2.4	613.9	95	465	
	High	3.1	3.4	911.3	84	588	
	Late	Low	1.1	1.1	320.2	28	1000
		Medium	1.2	1.3	380.1	113	952
		High	1.0	2.3	557.7	289	606
Saanen Early	Low	1.6	2.1	538.5	113	444	
	Medium	1.8	2.7	707.8	143	435	
	High	1.9	3.5	910.0	189	645	
	Late	Low	.9	1.4	385.0	189	588
		Medium	2.7	2.8	766.4	70	667
		High	2.3	3.2	884.3	181	606
Toggenburg Early	Low	1.3	1.5	407.4	119	606	
	Medium	2.5	2.9	747.6	96	476	
	High	3.2	4.1	1077.2	116	455	
	Late	Low	1.4	1.5	428.8	104	1111
		Medium	1.5	2.0	573.1	189	645
		High	1.8	3.2	841.3	221	556

¹Early = December 1 through March 31; late = April 1 through July 31.²Alpine: low = <685 kg; medium = 685 to 975 kg; high = >975 kg; LaMancha: low = <580 kg; medium = 580 to 840 kg; high = >840 kg; Nubian: low = <510 kg; medium = 510 to 765 kg; high = >765 kg; Saanen: low = <690 kg; medium = 690 to 1025 kg; high = >1025 kg; Toggenburg: low = <690 kg; medium = 690 to 980 kg; high = >980 kg.³a,b.⁴c.⁵2/b.

TABLE 4. Estimated differences and regression coefficients for functions of parameter estimates for each phase, based on weighted least squares.

Source	Initial yield	Peak yield	305-d yield	Time of peak	Duration of phase
First phase					
Estimated differences					
	(kg)			(d)	
Breed ¹					
Alpine	.20	.06	16.8	-7.3**	15.2
LaMancha	-.08	-.08	-10.7	1.5	-9.9
Nubian	.24	.04	-22.1	-9.5**	20.6
Saanen	.05	-.02	-7.8	-5.4	-8.6
Parity ²					
First	-.17	-.12	6.9	12.4**	15.0
Second	.04	.02	8.9	.6	8.4
Season ³					
Early	-.92**	-1.02**	-168.5**	-.1	-60.6**
Regression coefficients					
	(g/kg)	(kg/kg)		(d/kg)	
Production					
Alpine	.14	.62*	.08	.02**	-.02
LaMancha	.99*	1.32**	.19*	.00	.04
Nubian	.98**	1.32**	.21**	.01**	.04
Saanen	.84*	1.24**	.20**	.02**	.05
Toggenburg	.32	.57	.06	.00	-.02
Second phase					
Estimated differences					
	(kg)			(days)	
Breed ¹					
Alpine	-.13	-.04	-6.8	22.7	-33.1
LaMancha	.00	.03	5.9	-9.4	-34.7
Nubian	-.08	-.14	-30.6	-.5	4.9
Saanen	.07	.12	19.2	10.0	-136.9*
Parity ²					
First	-.66**	-.43**	-37.4	64.1**	102.2*
Second	-.22	-.15	-17.2	22.5	35.7
Season					
Early	.60**	.74**	147.7**	-27.0**	-271.5**
Regression coefficients					
	(g/kg)	(kg/kg)		(d/kg)	
Production					
Alpine	2.03**	2.94**	.81**	-.01	-.16
LaMancha	1.10*	2.29**	.66**	.18**	-.11
Nubian	1.29**	2.07**	.65**	.19**	-.07
Saanen	1.28**	2.30**	.70**	.05	.12
Toggenburg	2.09**	3.14**	.83**	.06	-.32*

¹Expressed as deviation from Toggenburgs.²Expressed as deviation from third parity.³Expressed as deviation from late season of kidding.**p* < .05.***P* < .01.

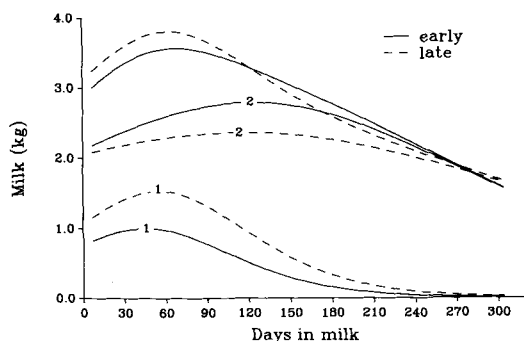


Figure 2. Lactation curves for phases 1 (1), 2 (2) and overall (unnumbered) in Alpines at first parity, early (—) and late (----) season of kidding, and medium production.

about .2 kg/kg 305-d yield for LaManchas, Nubians, and Saanens. The lower initial, peak, and 305-d yields for first phase of early season compared with those functions for first phase of late season are seen in Figure 2, which shows lactation curves for Alpines in first parity, early and late seasons of kidding, and medium production.

Time of peak was earlier for Alpines (43.4 d) and Nubians (41.2 d) than for Toggenburgs (50.7 d), later for first parity (54.9 d) than for third parity (42.5 d), similar for season, and about .02 d/kg 305-d yield for Alpines, Nubians, and Saanens. Duration of first phase was similar for breed, for parity, and for measure of production and shorter for early season (123.2 d) than for late season (183.8 d). For first phase, the shorter duration of early season is seen also in Figure 2.

For second phase (Table 4), initial yield was similar for breed, less for first parity (1.94 kg) than for third parity (2.60 kg), more for early season (2.6 kg) than for late season (2.0 kg), and increased about 1 to 2 g/kg 305-d yield with increasing production. Peak yield was similar for breed, less for first parity (2.48 kg) than for third parity (2.91 kg), more for early season (3.08 kg) than for late season (2.34 kg), and increased about 2 to 3 g/kg 305-d yield. Total 305-d yield for second phase was similar for breed and for parity, more for early season (764.6 kg) than for late season (616.9 kg), and increased about .75 kg/kg 305-d yield. The higher initial, peak, and 305-d yields for second

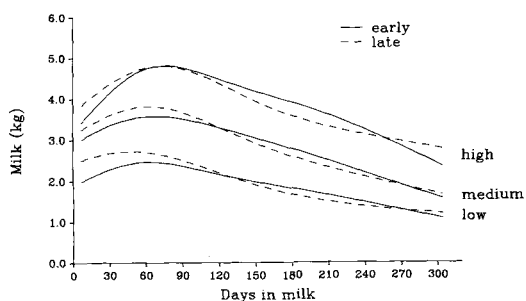


Figure 3. Lactation curves in Alpines at first parity, early (—) and late (----) season of kidding, and low, medium, and high production.

phase of early season compared with those functions for second phase of late season are seen also in Figure 2.

Time of peak was similar for breed, later for first parity (143.5 d) than for third parity (79.4 d), earlier for early season (94.7 d) than for late season (121.7 d), and increased almost .20 d/kg 305-d yield for LaManchas and Nubians. Duration of second phase was shorter for Saanens (482.5 d) than for Toggenburgs (619.4 d), longer for first parity (633.6 d) than for third parity (531.4 d), shorter for early season (441.6 d) than for late season (713.1 d), and similar for production. For second phase, the shorter duration of early season is seen also in Figure 2.

Figure 3 presents an overall lactation curve for Alpines in first parity in each season and measure of production, and is representative of that of other breeds. Early season has lower initial yield than late season. Curves for early season are more linear from time of peak to d 305 than those for late season.

For the data analyzed, first phase had shorter duration than second phase for each breed-parity-season-measure of production subclass (Figure 4). Time of peak of first phase was usually between d 30 and 60 of lactation and near overall time of peak in the lactation curve, whereas time of peak of second phase was usually after d 120 of lactation. First phase, with its shorter duration and its proximity to overall time of peak, could correspond to a "peak" phase in lactation. In contrast, the second phase, with its longer duration, could correspond to a "persistence" phase. Duration for

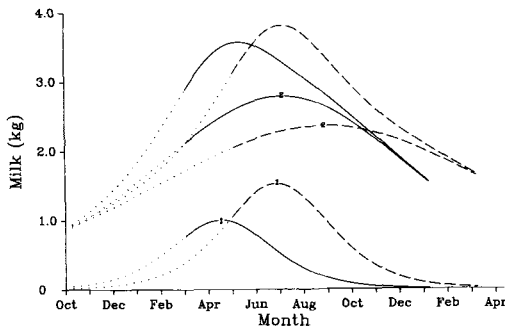


Figure 4. Lactation curves for phases 1 (1), 2 (2), and overall (unnumbered) in Alpines at first parity, early (—) and late (----) season of kidding, and medium production and for prepartum milking ability (....) from October until parturition.

first phase was not different for parities, whereas duration for second phase or “persistence” decreased significantly with increasing parity. This is consistent with results found in dairy cattle by Grossman and Koops (10), who noted the inverse relation between duration of second phase and parity and proposed that duration of second phase could be used as a measure of persistency. Duration of second phase tended to decrease also with increased production (Table 4), indicating that persistency decreased with increased production. The negative relations between persistency and parity and between persistency and production have been noted also in dairy goats (6), using a different measure of persistency.

CONCLUSIONS

Breed had little effect on the shape of the lactation curve in dairy goats of this study. Parity affected primarily second phase of lactation. For first phase, first-parity does had later time of peak than third-parity does. For second phase, first-parity does had lower initial, peak, and 305-d yields, later time of peak and longer duration than third-parity does. Season of kidding had the most consistent effect on the lactation curve: for first phase, does kidding in early season (December 1 through March 30) had lower initial, peak, and 305-d yields, and had shorter duration than does kidding in late

season (April 1 through July 31). For second phase, does kidding in early season had higher initial, peak, and 305-d yields, earlier time of peak, and shorter duration than does kidding in late season. Measure of production had varying effects on the lactation curve: increased production was associated with increased initial, peak, and 305-d yields and time of peak for each phase, with the increase being greater for second phase than for first. Selection for higher milk production probably affects characteristics associated with second phase of lactation more than those of the first phase. First phase, with its proximity to overall peak and short duration, could be interpreted as a “peak” phase. Second phase, affected primarily by parity, could be interpreted as a “persistence” phase. More research on individual animals is needed to validate this interpretation.

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APPENDIX GIPSON02

Note to Contributors

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– book reviews – news and announcements.

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VOL. 3 NO. 4

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The Cheghu (Pashmina) goat of the Himalayas

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(Accepted 23 May 1989)

ABSTRACT

Koul, G.L., Biswas, J.C. and Bhat, P.N., 1990. The Cheghu (Pashmina) goat of the Himalayas. *Small Rumin. Res.*, 3: 307–316.

Various breed characteristics including size, conformation, colour, habitat, fibre production and reproduction pertaining to Cheghu goats are described. The body weights at birth, 1 and 3 years were 2.1, 16.6 and 39.9 kg for males and 2.0, 14.5 and 27.8 kg for females, respectively. Body length, height at withers and chest girth at birth, 1 and 3 years were 28.5, 28.9 and 31.5 cm, 54.4, 50.6 and 64.5 cm, 72.9, 66.2 and 84.7 cm for males and 28.4, 28.9 and 31.5 cm, 53.0, 48.5 and 57.0 cm and 65.5, 58.1 and 73.9 cm for females. In the age groups of 0–1, 1–2, 2–3 and above 3 years pashmina (cashmere) yields averaged 62.3, 98.9, 192.9 and 168.6 g in males and 64.0, 100.1, 118.7 and 125.4 g in females, fibre length 5.0, 5.8, 7.7 and 7.0 cm in males and 4.9, 6.0, 5.8 and 5.8 cm in females, and fibre diameter 11.3, 12.0, 12.0 and 12.8 μm in males and 11.7, 11.9, 12.0 and 12.0 μg in females.

INTRODUCTION

Certain goat breeds, originating in and around the Himalayan mountains at altitudes above 3666 m, produce an undercoat of fine lustrous fibre beneath the outer coat of long hairs. This is known as 'pashmina' or 'cashmere'. The fibres grow in winter when the ambient temperature is very low and are shed or combed out in spring. Kaura (1943) gave an account of Kashmiri goats, found in the hilly tracts of Kashmir and Tibet. His description was restricted to coat colour and some physical conformation traits. He did not specifically mention the breed which he described. Similarly, Khot and Jalihal (1963) described the pashmina goats of Ladakh from the Changthang area, and the description conforms to the Changthangi breed of pashmina goats. The first attempt to describe Cheghu goats was made by Sen (1944) but his description was inadequate. Acharya (1982) also described the Cheghu breed of pashmina goats based on earlier reports, but did not cover all aspects. It is important that this valuable breed be described in detail.

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Lactation curves in dairy goats: a review

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(Accepted 26 May 1989)

ABSTRACT

Gipson, T.A. and Grossman, M., 1990. Lactation curves in dairy goats: a review. *Small Rumin. Res.*, 3: 383–396.

Only a few dairy goat studies have modeled lactation curves using a mathematical function. Among them, the multiphasic function provides the most useful information on characteristics of the lactation curve including scale (initial and maximum yields) and shape (time of maximum yield and persistency). Factors that affect such characteristics include breed, parity, season of kidding and level of production. Breed affects scale of the curve; parity affects scale and shape; season of kidding mainly affects shape (persistency); and level of production affects scale and shape (persistency). The multiphasic function warrants further consideration as the model for lactation curves in dairy goats. Further genetic and physiological research is needed to understand fully the biological properties of phases of the lactation curve in dairy goats and to ascertain their usefulness in management and in selection.

INTRODUCTION

Lactation curves are valuable tools to dairy producers for management decision-making and selection. Knowledge of lactation curves allows to predict total milk yield from a single test day (Wood, 1974) or from several test days early in lactation (Goodall and Sprevak, 1985). With such knowledge, dairy producers can make management decisions early in lactation based on individual production (Hyde, 1975; Dudouet, 1982; Brooke, 1983; Doyle, 1983; Auernhammer et al., 1987).

Genetic improvement in dairy cattle has been achieved for many aspects of milk production. Genetic improvement in most American dairy goat breeds over the last 20 years, however, is almost nonexistent for milk and fat yields (Mohammed and Grossman, 1984; Wiggans et al., 1988). Understanding genetic influences on the lactation curve can provide dairy producers with a firm basis on which to select animals for a specific production goal.

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One such goal could be to select does that have peak level of production early in lactation and maintain that peak over the course of the lactation, i.e., to select does that are more persistent. Selection for a more persistent doe is appealing for several reasons. The amount of milk available year-round is fairly constant, which is an important economic consideration if dairy goats are seasonal milk producers. The physiological stress of negative energy balance in early lactation could be reduced, which may decrease the number and severity of metabolic and reproductive disorders. The doe can be fed a more constant diet and the proportion of roughage in the diet could be increased, which may reduce the cost of feeding (Sölkner and Fuchs, 1987).

Few studies have been reported on lactation curves in dairy goats, compared to the many studies in dairy cattle (Masselin et al., 1987). The objective of this paper is to review the literature on lactation curves in dairy goats, especially with respect to mathematical functions that describe characteristics of the lactation curve including scale (initial and maximum yields), shape (time of maximum yield and persistency), and factors that affect such characteristics.

MATHEMATICAL FUNCTIONS

Most studies of lactation curves in dairy goats have plotted a measure of average weekly or monthly milk production versus time after kidding. These studies show patterns of the lactation curve but do not describe the curve in terms of a mathematical function (Table 1). It should be noted that most studies on lactation curves in dairy goats have been conducted on a small number of observations and that many of the same records were involved in different studies (e.g., Gipson and Grossman, 1987, 1989; Gipson et al., 1987).

Among the mathematical functions that have been used to study the lactation curve in dairy goats are the general exponential, the inverse polynomial, the grafted polynomial and the multiphasic.

General exponential

The general function is of the form:

$$y_t = at^b e^{-(c+dt)t} \quad (1)$$

where equation (1) is the exponential function (Brody et al., 1923), when $b=0$ and $d=0$; the parabolic exponential function (Sikka, 1950), when $b=0$; or the incomplete gamma function (Wood, 1967), when $d=0$; and where y_t is milk production at time t and a , b , c and d are parameters. Functions of these parameters describe characteristics of the lactation curve, including initial yield ($t=0$), maximum (peak) yield and time of peak yield.

For the exponential, which describes only post-peak production, initial yield is a , which is also peak yield. For the parabolic exponential, initial yield is also a , peak yield is $a(\exp(c^2/4d))$ and time of peak yield is $-c/2d$. For the

TABLE 1

Summary of studies on the lactation curve in dairy goats

Breed ¹	Factors studied	Reference
Local (44)	parity	Bonnekamp, 1939
Alpine (1899), LaMancha (696), Nubian (2293), Saanen (837), Toggenburg (857)	breed, parity	Gipson and Grossman, 1987
Alpine (1643), LaMancha (558), Nubian (1962), Saanen (776), Toggenburg (864)	breed, parity, level of production	Gipson et al., 1987
Alpine (6525), LaMancha (2379), Nubian (8672), Saanen (2742), Toggenburg (3042)	breed, parity, season of kidding, level of production	Gipson and Grossman, 1989
Czech milk goat (230)	parity, month of kidding, measure of persistency	Horak and Pindak, 1969
Malabari (65), Saanen-Malabari cross (24)	breed	Mukundan and Bhat, 1983
Alpine and Poitevine (700), Saanen (272)	breed, parity	Ricordeau, 1963
Norwegian milk goat (1100)	parity, season of kidding, stage of lactation	Ronningen, 1967
Barbari (97), Jamunapuri (87)	breed, parity	Sachdeva et al., 1974
? (298)	level of production	Sauvant and Fehr, 1975
English milk goat (24), Alpine (1983), British (63), Saanen (110), Toggenburg (47)	breed, parity, season of kidding	Watkin and Knowles, 1946

¹Number of does in parenthesis.

incomplete gamma, initial yield is zero, peak yield is $a(b/c)^b e^{-b}$ and time of peak yield is b/c . Wood (1967) proposed another characteristic, persistency, measured as $-(b+1)\ln(c)$. These three special forms of the general exponential function also have been used to study dairy cattle lactation curves.

Assuming additive errors, non-linear regression procedures can be used to estimate parameters of function (1). Assuming multiplicative errors, function (1) is intrinsically linear and a log transformation will result in the log-linear form $\ln(y_t) = \ln(a) + b\ln(t) - ct - dt^2$. Thus, linear regression procedures can be used also to estimate parameters (regression coefficients).

Gipson and Grossman (1987) analyzed mean daily milk production for five breeds and four parities (first, second, third and fourth or greater), using the log-linear form of the incomplete gamma. Estimates of parameters for first and for second or greater parities are in Table 2, pooled over breeds.

TABLE 2

Estimates of parameters and coefficients of determination (R^2) for general exponential and inverse polynomial functions used to model the lactation curve

Breed	Parameter ¹				
	$\ln(a)$	b	c	d	R^2
Gipson and Grossman, 1987					
	incomplete gamma				
Pooled ²	0.48	0.21	0.004	—	> 0.90
Pooled ³	0.84	0.23	0.005	—	> 0.90
Mukundan and Bhat, 1983					
	exponential				
Malabari	1.07	—	0.033	—	0.86
Saanen half-breds	1.88	—	0.029	—	0.95
Pooled	1.32	—	0.023	—	0.88
	parabolic exponential				
Malabari	1.24	—	0.071	0.002	0.92
Saanen half-breds	1.88	—	0.029	0.000	0.95
Pooled	1.45	—	0.054	0.001	0.90
	incomplete gamma				
Malabari	1.32	0.007	0.024	—	0.91
Saanen half-breds	1.86	0.031	0.020	—	0.95
Pooled	1.51	0.003	0.186	—	0.88
	inverse polynomial ⁴				
	β_0	β_1	β_2	R^2	
Malabari	0.46	0.461	0.0094	0.99	
Saanen half-bred	0.09	0.119	0.0074	0.99	
Pooled	0.29	0.346	0.0036	0.99	

¹ $\ln(y_t) = \ln(a) + b \ln(t) - ct - dt^2$.

²First parity, over Alpine, LaMancha, Nubian, Saanen, and Toggenburg.

³Second and greater parities, over Alpine, LaMancha, Nubian, Saanen, and Toggenburg.

⁴ $t/y_t = \beta_0 + \beta_1 t + \beta_2 t^2$.

TABLE 3

Values for characteristics of the incomplete gamma function, based on estimates of parameters in Table 2

Breed	Peak yield ¹	Time of peak yield ²	Persistency ³
Gipson and Grossman, 1987	kg milk	days from kidding	
Pooled ⁴	3.0	53	6.68
Pooled ⁵	4.4	46	6.51
Mukundan and Bhat, 1983	kg milk	weeks from kidding	
Malabari	3.6	0.03	1.44
Saanen half-bred	6.3	1.55	4.03
Pooled	4.5	0.02	1.69

¹ $a(b/c)^b e^{-b}$.

² b/c .

³ $-(b+1)\ln(c)$, unitless.

⁴First parity, over Alpine, LaMancha, Nubian, Saanen, and Toggenburg.

⁵Second and greater parities, over Alpine, LaMancha, Nubian, Saanen, and Toggenburg.

Values for characteristics of the incomplete gamma, including peak yield, time of peak yield and persistency are in Table 3, based on estimates of parameters in Table 2.

Mukundan and Bhat (1983) analyzed weekly milk data for two breeds, using the linear forms of function (1). For that study, it is not known if does were of the same parity or age or if they were of different parities or ages, which were ignored as a source of variation in describing the lactation curve. It should be noted also that only a relatively small number of does were used in this study. Estimates of parameters for general exponential functions are in Table 2 by breed. These estimates were from weekly data (unit for time is weeks) and cannot be compared easily with those from daily data (unit of time is days) of Gipson and Grossman (1987). Values for characteristics of the incomplete gamma are shown in Table 3, based on estimates of parameters in Table 2.

Inverse polynomial

The inverse polynomial (Nelder, 1966) is another function that has been used for dairy cattle, but only once for dairy goats:

$$y_t = t / (\beta_0 + \beta_1 t + \beta_2 t^2) \quad (2)$$

where y_t and t are defined as above, and β 's are regression coefficients. For the inverse polynomial function, initial yield is defined as zero. Function (2)

is also intrinsically linear and can be linearized by an inverse transformation, resulting in $t/y_t = \beta_0 + \beta_1 t + \beta_2 t^2$.

Mukundan and Bhat (1983) also used the linear form of function (2) and concluded that the inverse polynomial provided the best fit (Table 2), based on coefficient of determination (R^2). Similar transformations of data and comparisons of R^2 have been made in dairy cattle studies (Yadav et al., 1977; Singh and Bhat, 1978; Batra, 1986; Batra et al., 1987). It has been noted, however, that when functions for different transformations of the data are used, R^2 is not a valid criterion for comparing functions (Grossman and Koops, 1988). Estimates of parameters for the inverse polynomial function are also in Table 2 by breed.

Grafted polynomials

Grafted polynomials (Fuller, 1969), which are segmented polynomial sub-models that are continuous over the range of the data and have continuous first derivatives, have been used in a study of lactation curves in dairy goats (Gipson et al., 1987), but not yet used in dairy cattle. The grafted polynomial used was:

$$y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 d_1^2 + \beta_4 d_2^2 \quad (3)$$

where y_t and t are defined as above, d_1 has value $t - 52$ when t is greater than 52 and has value 0 otherwise; d_2 has value $t - 85$ when t is greater than 85 and 0 otherwise; and β 's are regression coefficients. Gipson et al. (1987) analyzed means of test-day samples for five breeds, four parities (first, second, third and fourth or greater) and five levels of production (based upon milk production early in lactation).

Multiphasic

Recent research has demonstrated the usefulness of a multiphasic function, which is the sum of logistic functions, to model the lactation curve in dairy cattle (Grossman and Koops, 1988; de Boer et al., 1989). This function also has been used to model the lactation curve in dairy goats (Gipson and Grossman, 1989) and is of the form:

$$y_t = \sum_{i=1}^n \{a_i b_i [1 - \tanh^2(b_i(t - c_i))]\} \quad (4)$$

where y_t and t are defined as above, $\tanh$ is the hyperbolic tangent, and for each phase i : $a_i b_i$ is peak yield, c_i is time of peak yield and $2/b_i$ is duration, defined as days required to attain about 75% of asymptotic total yield during that phase. The multiphasic function is nonlinear; therefore, parameters of the multiphasic must be estimated using nonlinear regression procedures.

Using the multiphasic function, Gipson and Grossman (1989) analyzed means of test-day samples for five breeds, three parities (first, second and third), two seasons of kidding (early, December to March, and late, April to

July) and three levels of production (low, medium and high, based on individual total 305-day milk yield). Averaged over breed, parameter estimates for each phase of the diphasic function ($n=2$) are in Table 4, for first and for second or greater parities, for two seasons of kidding and for medium level of production (500–1200 kg 305-day milk). Values for characteristics of each phase of lactation, including initial and peak yields, time of peak yield and duration of phase are in Table 5.

FACTORS AFFECTING THE LACTATION CURVE

Several factors have been cited as affecting characteristics of the lactation curve in dairy goats and, thus, the milk production for the lactation. These factors include breed, parity, season of kidding and level of production.

Breed

Differences in breeds of dairy goats have been observed to affect peak yield, time of peak yield and persistency.

For peak yield, LaManchas and Nubians had lower peak yields than other breeds, by about 1 kg (Gipson and Grossman, 1987). Purebred Malabaris had lower peak yield than did half-bred Saanens (Table 3).

For time of peak yield, Saanens peaked at about 50 days of lactation, which was 10 days later than for other breeds studied (Gipson and Grossman, 1987). Malabaris peaked almost immediately in lactation, two weeks before half-bred Saanens (Table 3). From empirical observations, Saanens peaked at 15 to 45 days of lactation, about 30 days earlier than Alpines and Poitevines (Ricordeau, 1963). English milk goats and Toggenburgs peaked at about 50

TABLE 4

Estimates of parameters for each phase of diphasic function¹, for first and second or greater parities, for two seasons of kidding, and for production between 500 and 1200 kg 305-day milk (Gipson and Grossman, 1989), averaged over breed

Parity	Season ² of kidding	Phase 1			Phase 2		
		a_1	b_1	c_1	a_2	b_2	c_2
1	Early	55.9	0.0157	53	610.9	0.0042	104
	Late	156.5	0.0109	50	649.3	0.0026	124
≥2	Early	66.6	0.0167	41	788.0	0.0045	78
	Late	202.0	0.0113	42	747.5	0.0034	93

¹ $y_t = a_1 b_1 (1 - \tanh^2(b_1(t - c_1))) + a_2 b_2 (1 - \tanh^2(b_2(t - c_2)))$.

²Early = 1 December through 31 March, late = 1 April through 31 July.

TABLE 5

Values for characteristics for each phase of diphasic function, for first and for second or greater parities, for two seasons of kidding, based on estimates of parameters in Table 4

Parity	Season ¹ of kidding	Phase 1		Phase 2					
		Initial ² milk yield (kg)	Peak ³ milk yield (kg)	Time ⁴ of peak (days)	Duration ⁵ of phase (days)	Initial milk yield (kg)	Peak milk yield (kg)	Time of peak (days)	Duration of phase (days)
1	Early	0.47	0.88	53	127	2.13	2.57	104	476
	Late	1.28	1.71	50	183	1.52	1.69	124	769
2	Early	0.72	1.11	41	120	3.14	3.55	78	444
	Late	1.84	2.28	42	177	2.30	2.54	93	588

¹Early = 1 December through 31 March, late = 1 April through 31 July.

² $a_i b_i (1 - \tanh^2(b_i(t - c_i)))$, $t = 0$.

³ $a_i b_i$.

⁴ c_i .

⁵ $2/b_i$.

⁶ $2/b_i$.

⁷ $2/b_i$.

⁸ $2/b_i$.

⁹ $2/b_i$.

¹⁰ $2/b_i$.

¹¹ $2/b_i$.

¹² $2/b_i$.

¹³ $2/b_i$.

¹⁴ $2/b_i$.

days of lactation, which was earlier than for Alpines, Saanens and the British dairy goat, each of which averaged 70 days (Watkin and Knowles, 1946).

For persistency, Malabarais were less persistent than half-bred Saanens (Table 3). English milk goats and Saanens were more persistent than other breeds (Watkin and Knowles, 1946), but Ricordeau (1963) found no difference in persistency between Saanens and Alpine-Poitevines.

For each phase of a diphasic lactation curve, breed did not affect initial or peak yields, time of peak, nor duration of phase (Gipson and Grossman, 1989). Duration of second phase was their measure of persistency and will be discussed further under parity.

In most cases, breed differences were usually unimportant in accounting for variation in the shape of the lactation curve, but were important for variation in the scale of the curve. The lactation curve for higher producing breeds was similar in shape to the curve for lower producing breeds, except for an upward shift of the curve for higher producers.

Parity

There appear to be two almost universal observations regarding the effect of parity on scale and shape of the lactation curve. The first observation is the positive relationship between scale and parity. Initial and peak yields for first-parity does usually were lower than for later-parity does (Watkin and Knowles, 1946; Ricordeau, 1963; Horak and Pindak, 1969; Sachdeva et al., 1974).

The second observation is the negative relationship between shape and parity. Time of peak yield generally was later in lactation for first-parity does, at about 50 to 80 days of lactation, than for later-parity does (Bonnekamp, 1939; Watkin and Knowles, 1946; Horak and Pindak, 1969; Sauvante and Fehr, 1975; Gipson and Grossman, 1987; Gipson et al., 1987).

Persistency, which can be defined as the ability of a doe to maintain peak yield, was greatest in first-parity does and decreased with increasing parity (Table 3) (Watkin and Knowles, 1946; Ricordeau, 1963; Sachdeva et al., 1974; Gipson and Grossman, 1987; Gipson et al., 1987; Gipson and Grossman, 1989).

According to grafted polynomial analysis, persistency was affected negatively by parity. The linear slope from peak yield to the end of lactation (β_1), which was a measure of persistency, ranged from -4.2 g milk/day for low-yielding, first-parity does to -20.5 g milk/day for high-yielding, third-parity does (Gipson et al., 1987).

Gipson and Grossman (1989), who used the diphasic function to analyze lactation curves, observed that parity had little effect on characteristics for the first phase of lactation, i.e., initial and peak yields, duration of phase and time of peak, but greatly affected those characteristics for the second phase. It is known that first-parity does are more persistent than later-parity does. First-parity does had lower initial and peak yields, with longer duration and later time of peak, than later-parity does for the second phase. It was con-

cluded, therefore, that the second phase of lactation in dairy goats could be viewed as the "persistence" phase and its duration as its measure, i.e., the longer the duration of the second phase, the more persistent the lactation. This conclusion for dairy goats agrees with dairy cattle by Grossman and Koops (1988), who used duration of the second phase as a measure of persistence.

For the overall lactation curve, time of peak is between the time of peak for each phase, although it is closer to the time of peak for the first phase than for the second phase (Gipson and Grossman, 1989). Because time of peak for each phase is later for first-parity does than for later-parity does (Table 5), we would expect time of peak for the overall curve to be later for first-parity does than for second or greater-parity does.

Similar to studies in dairy cattle, Horak and Pindak (1969) studied three measures of persistence in dairy goats. They concluded that the most convenient measure was production in the second hundred days of lactation, taken as a percentage of production in the first hundred days. This measure of persistence was 91% in first parity, decreasing to 84% in fifth parity. Does kidding in March were 95% persistent, averaged over parity, whereas does kidding in May averaged to be only 83% persistent.

In general, parity had a large effect on variation in the scale and shape of the lactation curve: initial and peak yields increased with increasing parity until about third or fourth parity, and then decreased. Time of peak yield was earlier and persistence was less with increasing parity.

Season of kidding

Most goats are usually seasonal breeders, entering estrus in the fall and kidding in early spring. Season of kidding has been observed to affect initial and peak yields and persistence.

For the overall lactation curve (Gipson and Grossman, 1989), does kidding early (December through March) had lower initial and peak yields than those kidding late (April through June). Overall milk production in late lactation, however, was greater for does kidding early than for those kidding late. This is reflected in the first phase by lower initial and peak yields and in the second phase by higher initial and peak yields, for does kidding early compared with those kidding late.

In England, does kidding February through May reached peak yield at about 9 to 12 weeks of lactation, whereas does kidding June through January reached peak yield earlier, at about 5 to 8 weeks of lactation (Watkin and Knowles, 1946). Also, does kidding February through May had higher initial yield and were more persistent than does kidding June through January. In Norway, Ronningen (1967) found contradictory results: does kidding December through February were more persistent and peaked earlier than does kidding March or April.

Generally, does kidding during the main kidding season (December through

May) were more persistent than does kidding out of main season, and does kidding early in the season (December through March) were less persistent than does kidding late in the season (April and May).

Level of production

Few studies have examined the relationship between level of production and the lactation curve in dairy goats. Sauvant and Fehr (1975) and Gipson et al. (1987) found that as level of production increased, persistency decreased. Gipson and Grossman (1989) found as level of production increased, initial and peak yields increased and duration for each phase decreased, especially for the second phase of lactation.

Thus, level of production affected the scale and shape (persistency) of the lactation curve. Higher producing does were less persistent than lower producing does, resulting in a steeper decline in milk production after peak yield.

PRACTICAL APPLICATION

Dudouet (1982) discussed practical applications of the lactation curve in dairy goats, based on the usefulness of the lactation curve as a management tool. Dudouet presented theoretical examples of how environmental factors, such as mastitis, insufficient feed, changes in housing, kids left to suckle does and coccidiosis could affect actual milk production, and how these factors could be detected by the deviation of the actual total herd production curve from the theoretical curve. Dudouet assumed a constant 90% level of persistency for each parity and level of production, which is now known not to be the case (Gipson and Grossman, 1989).

Comparing actual to theoretical herd production could be a useful management tool for assessing problems in the herd, only if a large percentage of animals were affected. However, if only one or two does were affected, say with sub-clinical mastitis, then Dudouet's whole-herd approach would not detect the problem. To detect deviations on an individual basis, milk production for each doe should be compared to a theoretical lactation curve appropriate for its condition, i.e., breed, parity, season of kidding and level of production. These theoretical curves can be calculated easily using estimates for parameters of a mathematical function.

CONCLUSION

Mathematical function allows the lactation curve to be expressed in terms of a set of parameters to be estimated. Various functions have been used to study the lactation in dairy cattle and in dairy goats. Each function has advantages and disadvantages. The recently proposed multiphasic function enables

the lactation curve to be partitioned into phases and provides estimates of characteristics of the lactation curve that are of interest to the dairy producer.

Many factors affect characteristics of the lactation curve in dairy goats. Generally, differences in breed produce a change in scale, or an overall shift in the curve. Parity affects scale (initially and peak yields) as well as shape (persistence), with the greatest difference between first and later parities. Season of kidding mainly affects shape (time of peak yield and persistence) and level of production affects scale and shape (persistence).

An understanding of the lactation curve in dairy goats should enable more efficient selection and management decisions, because a farmer will be able to compare individual milk production of does in the herd against a "standard" curve.

We believe that the multiphasic function warrants further consideration as the function to model the lactation curve in dairy goats. Further genetic and physiological research is needed to understand fully the biological properties of phases of the lactation curve in dairy goats and to ascertain their usefulness in management and in selection.

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APPENDIX SCOTT01

Use of Lactation Curves for Analysis of Milk Production Data

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ABSTRACT

Nonlinear equations were compared with categorical analysis to account for DIM effects on milk production. Five different models for lactation curves were evaluated. Derived from a multiphasic lactation curve, the selected lactation curve appeared to result in random residuals and performed more consistently than the multiphasic curve. Residuals from the fitting of lactation curves were then used for split-plot analysis (continuous model) to estimate treatment effects. Statistical performance of this model was compared with split-plot analysis based on a discrete model with regularly spaced intervals to account for DIM effects (discrete model).

The fitting of lactation curves accounted for herd, lactation number, and interaction effects of herd and lactation number and accounted for 34.1 and 44.3% of variance among cows for primiparous and multiparous cows, respectively. The continuous model detected interactions of genetic and management factors with treatment of multiparous cows that were not detected by the discrete model.

No statistically significant differences were detected between the two modeling approaches. The continuous model appeared to violate fewer assumptions regarding data distribution than did the discrete model, which reduced the risk of introducing bias during the estimation of treatment effects. The continuous model seemed to be more sensitive to subtle interactions of treatment and other factors.

(**Key words:** lactation curves, data analysis, milk production)

Abbreviation key: BCSC = body condition score at calving, IG = incomplete gamma (Wood's) lactation curve model, IP = inverse polynomial lactation curve model, LCSP = lactation curve fitted prior to split-

plot model, LHG = lactation within a herd group, M1 = monophasic lactation curve model, M2 = diphasic lactation curve model, MC = monophasic lactation curve model with additive constant, SCSP = split-plot model using DIM subclasses.

INTRODUCTION

Production of milk and milk components varies with stage of lactation or DIM (8, 14, 21). Improper models for the effects of DIM may fail to remove autocorrelation from the residual error. When production among a group of cows is not measured using the same DIM, the use of discrete intervals to account for DIM effects may introduce biases in the estimation of treatment responses (13). Additionally, when cows are not simultaneously placed on trial, models for time-related effects can be complicated by the presence of multiple time series. In particular, time effects can confound the relationship among predictors and milk production (13).

The DIM account for a substantial amount of the variation in the production of milk and milk components within the lactation of a single cow. This time series may differ substantially among lactations and herds; however, DIM effects usually follow a pattern that is similar for all cows in the same lactation within a herd group (LHG) (10, 22, 23). Primiparous cows are more persistent, and lactation curves are flatter than those for multiparous cows (22). Lactation curves of multiparous cows are similar, except that the estimate of daily milk production is multiplied by a slightly higher factor for cows in third and greater lactations (10).

The incomplete gamma function (IG) is the predominant lactation curve used to model milk production of dairy cows; however, the inverse polynomial (IP) has outperformed IG in some situations (1). Both IG and IP have similar limitations: milk production at 0 DIM is forced to 0, milk production during early lactation is overpredicted, peak milk production is underpredicted (1, 8, 15), residuals are autocorrelated (7, 8), and model parameters are highly correlated, suggesting an overparameterized model (3).

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The multiphasic lactation curve (8) appears to overcome some of the problems inherent to both IG and IP. Initial milk production is not forced to 0, and, if the diphasic or triphasic variant of the model is used, residuals are not autocorrelated with one another. Both the diphasic and triphasic variants of the model have been shown to be the optimal version of the multiphasic model (2, 6, 8). The primary limitation of the multiphasic lactation curve is failure of the model to satisfy the convergence criteria when unadjusted data are analyzed.

Two additional time series, season of calving and season of the year in which each observation occurred, also contribute to the variance observed for daily milk production. Effects of season of calving might uniformly increase milk production throughout an entire lactation (9, 23) or also might influence the shape of the lactation curve (11). Seasonal effects, such as first-crop haylage and heat stress also might influence the shape of the lactation curve (23). Wood (23), but not Keown et al. (11), accounted for the variation in daily milk production that was associated with season of observation. Because season of calving and season of observation may be interdependent, unbalanced designs may not properly estimate the effects of season of calving and season of observation.

Split-plot models permit the partitioning of variance found in experimental observations for within-cow variance (DIM, season of observation) and among-cow variance [treatment, predicted producing ability, season of calving, herd, lactation number, management and nutrition effect, and body condition score at calving (BCSC)]. Proper allocation of experimental variance for the portions within and among cows improves the accuracy of estimation of whole-plot effects. Improper assignment of these variance components may result in overestimation or underestimation of whole-plot error and, thus, inaccurate hypothesis testing. (Whole-plot error is used for both F and t testing.) Additionally, improper partitioning of these variance components may result in nonrandomly distributed error terms, invalidating all hypothesis testing.

The objective of this research was to evaluate the use of nonlinear equations to account for DIM effects prior to analysis using general linear models. Improved estimation of treatment responses may result from decreases in standard errors of treatment means, the elimination of biases associated with considering continuous nonlinear effects as discrete intervals, or both. Nonlinear models for DIM effects may also help fulfill most of the statistical assumptions about error distribution that are inherent to hypothesis testing of parameter estimates.

MATERIALS AND METHODS

Data

Five commercial Holstein herds were selected based on rolling herd averages for milk production >9000 kg/yr per cow. All herds were milked three times daily. Each herd was scheduled to be sampled every 14 d by Wisconsin DHIA. Actual test intervals varied between 12 and 31 d; the mean interval was 15.6 d. Cows calving between July 1, 1989 and March 15, 1990 were on trial for the first 180 to 200 DIM ($n = 443$). Only 383 (86.5%) cows had ≥ 7 observations for milk production and composition. Four percent FCM was utilized as the production variable of choice because 4% FCM more closely reflects energy needs for milk production than does actual milk (19).

These data were obtained from a field trial designed to evaluate the effects of dietary calcium salts of long-chain palm oil fatty acids on production, health, and reproductive parameters (16). Cows were assigned randomly to control and treatment populations based on date of calving. Calcium salts of long-chain palm oil fatty acids were added to the control ration at the rate of 0.45 kg/d per cow for the first 180 to 200 DIM and were fed to 220 of the 443 cows on trial. Control rations contained 3.7 to 4.8% supplemental fat.

Lactation Curve Models

Models were fit to both individuals and each LHG. There were 15 LHG: five herds and three lactation numbers (first, second, and third or greater). The following three lactation curve models were compared.

IG (21):

$$y_t = At^{be^{-ct}},$$

IP (14):

$$y_t = t(\beta_0 + \beta_1 t + \beta_2 t^2)^{-1},$$

and the multiphasic lactation curve model (8):

$$y_t = \sum_{i=1}^n a_i b_i [1 - \tanh^2(b_i(t - c_i))]$$

where y_t = expected milk production on DIM t ; A , b , c , β_0 , β_1 , β_2 , a_i , b_i , and c_i are curve parameters; and n = number of phases in the multiphasic lactation curve.

Three variants of the multiphasic curve were compared. Model variants were diphasic (**M2**; $n = 2$),

monophasic (**M1**; $n = 1$), and monophasic with an additive constant (**MC**). An additive constant was included in MC to allow increased model flexibility in selecting the appropriate segment of the hyperbolic tangent curve. The triphasic form of the multiphasic model was not evaluated because the 10 observations of 4% FCM production that were needed to fit the model were greater than the number available in this data file.

Statistical Analysis

The analysis was completed in three distinct phases. Lactation curve models were fitted by the Marquardt method using PROC NLIN of SAS (18). Starting grids were specified such that all solutions fell within the outer limits of the search grid. Models were not transformed to their linear approximations prior to iteration. The original models equally weighted all observations; however, the logarithmic transformation used to determine the linear approximation reduced the weight placed on high milk production (15). Individual lactation curves were estimated only for individuals with ≥ 7 DHIA sample days (383 of 443 cows in the data). All five models for lactation curves were also fit for pooled data for milk production within each of the 15 LHG.

Selection of the optimal model for lactation curves was based on error sums of squares, error range, variance of the errors, and the mean absolute value of errors. The Durbin-Watson test was also estimated; however, the usefulness of this statistic is severely limited by its lack of sensitivity when testing for autocorrelation for models based on <15 observations (4). Model coefficient of multiple determination is not a good criterion for evaluating goodness of fit for nonlinear models because residuals may be autocorrelated (8).

Using the residuals from the fitting of the optimal lactation curve to each LHG, lactation curves for split-plot models (**LCSP**) were developed. Results from the LCSP model were then compared with conventional split-plot analysis of the unadjusted data using DIM subclasses within the split plot to account for DIM effects (**SCSP**; subclass split plot).

Under SCSP, intervals of 5, 10, 15, and 20 d were analyzed to determine the effect of length of DIM interval on performance. Unless otherwise noted, the SCSP was based on 10-d intervals for DIM. The 10-d interval was selected as a compromise to prevent multiple observations of the same cow from falling within the same subclass and yet to maintain the highest possible number of observations within the

subclass. The whole-plot error term was cow as a random effect.

Type III sums of squares (18) were used to determine significance. Probability values $<10\%$ were considered to be significant for whole-plot effects, and the significance level for split-plot effects was $P < 0.05$. General linear models were developed separately for 4% FCM production, milk production, and fat percentage. Identical models were derived from both forward selection and backward elimination stepwise procedures. All main effects and two-way interactions were considered when the final general linear models were developed for LCSP and SCSP. If a two-way interaction was significant for the final model, all three-way interactions involving the two-way interaction were also evaluated. No three-way interactions were significant.

RESULTS AND DISCUSSION

The discussion is divided into four sections. In the first section, the selection of the optimal model for the lactation curve is described. The impact of using lactation curves (LCSP), compared with using discrete intervals for DIM effects (SCSP), on the selection of significant main effects and interactions is considered in the second (whole-plot model) and third (split-plot model) sections. Finally, selection of the optimal model is discussed.

Lactation Curve Model

When fit to individuals, comparisons among the five models evaluated were similar, regardless of the error measurement examined. Only the mean absolute value of the errors and the variance of the error term are reported in Table 1. Ranking of the models, from best to worst, was M2, MC, IG, IP, and M1. The diphasic lactation curve always outperformed IG, IP, and M1 and outperformed MC in 94 to 97% of the lactation curves calculated, depending upon the error measurement used for comparison. The monophasic model with an additive constant always outperformed M1 and improved fit for 88.5% of individual lactation curves compared with either IG or IP; the exception was that MC always resulted in a better model than IP when the error sum of squares was used to determine fit.

The MC reduced the magnitude of the mean absolute value of errors by 7.3 to 10.8% over that of IG, IP, and M1. The diphasic curve resulted in an additional decrease of 8.2% in the mean absolute value of errors over MC. Curve fit, measured either by error sum of squares or variance of the error, improved an average

TABLE 1. Goodness of fit measurements for all lactation curve models fit to 4% FCM for each cow with at least 7 sample days.

	Lactation curve model				
	IG ¹	IP	M1	MC	M2
Mean absolute error, kg					
X ²	2.0 ^a	2.04	2.10	1.87	1.73
SD ³	0.41	0.44	0.39	0.35	0.40
Error variance, kg ²					
X	8.6	8.8	9.2	7.4	6.7
SD	3.2	3.4	3.2	2.7	2.9
Direct comparison of individual models ⁴					
M2 > ⁵	100.0	100.0	100.0	94.0	
MC >	88.5	88.5	100.0		
M1 >	30.6	32.6			
IP >	52.2				

¹IG = Incomplete gamma model, IP = inverse polynomial model, M1 = monophasic model, MC = M1 plus constant, and M2 = diphasic model.

²Mean of error measurement for each model across all individuals.

³Variance of error measurement for each model across all individuals.

⁴Based on mean absolute error.

⁵Percentage of 383 lactation curves in which the model in the left column reduced mean absolute error over the model in the column containing the percentage.

of 13.3 to 19.4% for MC over IG, IP, and M1; M2 reduced variance of the error by an additional 10.9% over MC.

The M2 was not always superior to MC. Regardless of the error measurement examined, MC performed more consistently than M2. The variance and maximum of each error measurement was smaller for MC than for M2. Thus, although MC resulted in a higher mean for each error measurement, this mean was more uniform across all cows compared. Conversely, M2 fit a number of cows very well without uniform improvement in fit across the entire population. At least a portion of these differences resulted from the ability of M2 to fit lactation curves with two peaks. Because treatment was initiated by calving, only a single peak was expected for the lactation curve, and curves with two peaks were considered to be aberrant. Curves with multiple peaks most often occurred from cows that had one or two occurrences of depressed FCM production, relative to preceding and subsequent FCM production, after peak production. Often those cows were clinically ill during the affected time period. Those cows that appeared to be healthy might have been afflicted with a subclinical health problem or might have had aberrant test day production. Therefore, we concluded that a single peaked curve was the desired model for lactation curves. Additionally, M2 failed to meet convergence criteria for 54% of the curves fitted to individual cows. Curve smoothing techniques might increase the probability of model

convergence, but might also introduce bias when populations contain only a few observations (5).

Both IG and IP overpredicted milk production prior to peak (70 DIM) and after 160 DIM and underpredicted midlactation milk production (Figure 1). Although only the first 200 DIM were analyzed, these results were parallel to those reported in studies (1, 8, 15) evaluating residual patterns of these two models over an entire 305-d lactation. The residual pattern for M1 was opposite that of IG and IP, resulting in underprediction of milk production during early and late lactation and overprediction of midlactation milk production (Figure 2). This observation was in direct contradiction to the determination of Grossman and Koops (8) that M1 overpredicted early lactation, underpredicted midlactation, and accurately predicted late lactation. These differences may have resulted from differences in either the length or the persistency of the lactation curve. Because milk production >200 DIM declines linearly, the model would have been shifted further to the right on the hyperbolic tangent curve, resulting in flatter peaks (underprediction) and higher initial production (overproduction). Neither MC nor M2 displayed any apparent pattern for residual measurements over time. First-order autocorrelation of residuals within a single lactation was not detected for any model by the Durbin-Watson test; however, this statistic had a large inconclusive region when <15 observations were available (4). Individual cows had a mean of only 10

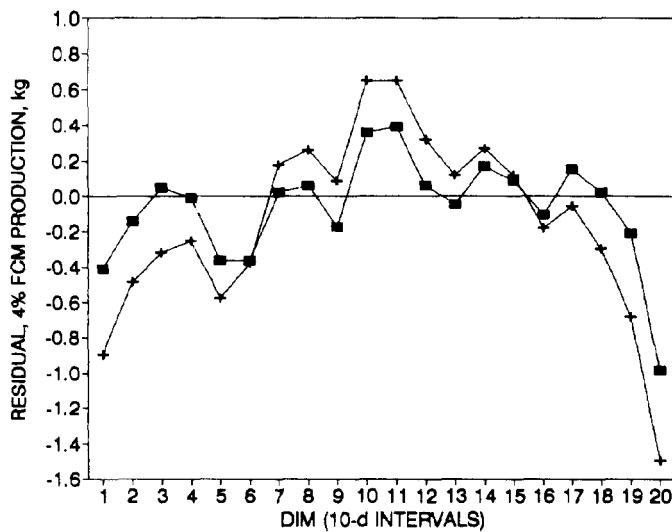


Figure 1. Mean residual plotted by DIM for the incomplete gamma (■) and inverse polynomial (+) models for lactation curves.

to 11 observations (range, 7 to 14) for 4% FCM production.

Residual plots for all five models for lactation curves suggested that a higher order autocorrelation process might have been present. Unfortunately, the asymptotic tests used to evaluate higher order autocorrelation processes required ≥ 30 observations before meaningful results could be calculated.

When data were grouped by LHG prior to fitting each model, differences in performance of IG, IP, M1, MC, and M2 were minimal. Each model accounted for 0 to 22% (mean of 11%) of the variability in the unadjusted data within each LHG. Lactation curves were expected to account for only a small portion of the variability within each LHG because the data were not adjusted for other variables prior to grouping. Based on the mean absolute value of errors, MC outperformed both IG and IP for 12 of the 15 LHG and always outperformed M1. The diphasic curve performed inconsistently when lactation curves were analyzed for each LHG. For three of the LHG, M2 led to no improvement over linear regression. The diphasic curve did not meet convergence criteria for any LHG, and MC failed to converge for 4 of the 15 LHG.

The three variants of the multiphasic model were also evaluated by *F* test to determine the significance of the added parameters within each LHG (17). The additive constant in MC contributed significant information ($P < 0.001$) for 14 of the 15 LHG. The additive constant was significant ($P < 0.05$) for the remaining LHG. Compared with M1, the second phase

of M2 also contributed information ($P < 0.001$) for 13 LHG. Significance levels were $P < 0.05$ and $P < 0.10$ for the remaining two groups. The second phase of M2, compared with the additive constant of MC, was significant ($P < 0.05$) for 12 of the 15 LHG.

Based on these results, MC was regarded as the best model. Because the original design of this trial was to detect responses in milk production to supplementation of 0.45 kg of calcium salts of long-chain palm oil fatty acids/d per cow, the possible introduction of bias between control and treatment populations, secondary to fitting the data to MC, becomes important. There was no suggestion that MC resulted in any bias between treatment and control populations (Table 2). The model may have fit the treatment population slightly better, but the magnitude of this difference was small.

Combining Lactation Curves with General Linear Models

Whole plot. Whole-plot independent effects accounted for the variance among cows in the production of milk and milk components. The significance for each independent effect and interaction for 4% FCM models (LCSP and SCSP) is in Table 3. Continuous fixed effects included predicted producing ability (PPA) for 4% FCM (0.4 PPA for milk production + 15 PPA for fat production), body weight at calving, and BCSC. Effects of BCSC and body weight at calving on production data appeared to be linear

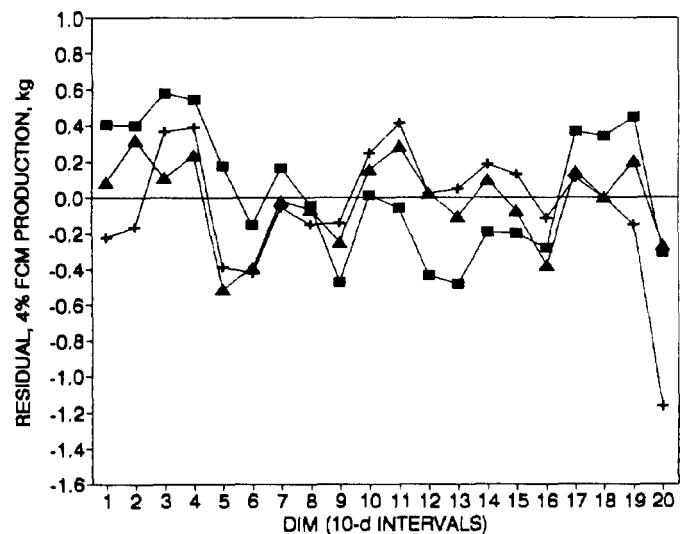


Figure 2. Mean residual plotted by DIM for the three variants of the multiphasic lactation curve: monophasic (■), monophasic with an additive constant (+), and diphasic (▲).

TABLE 3. Comparison of models for 4% FCM whole plots resulting from the lactation curve method of analysis (LCSP) versus conventional analysis (SCSP).

Effect	Lactation 1		Lactation ≥ 2	
	LCSP	SCSP	LCSP	SCSP
	P^1			
Predicted producing ability (PPA)	<0.01	<0.01	<0.001	<0.0001
Season of calving (SC)	0.07	0.08	<0.0001	<0.0001
Herd	...	<0.0001	...	<0.0001
Management and nutrition (MNE)	0.09	...	0.63 ³	...
Herd within MNE	<0.001	...	...	...
Fresh BW	<0.0001	<0.0001	...	...
Body condition score at calving (BCSC)	...	...	<0.0001	<0.0001
Treatment (T)	0.08	0.07	<0.01	0.02
PPA $\times$ T	...	...	0.10	...
PPA $\times$ BCSC	...	...	0.09	...
MNE $\times$ T	...	...	<0.01	...
MNE $\times$ SC	...	...	0.03	...
MNE $\times$ BCSC	0.09	...	...	...
Herd $\times$ SC	...	...	...	0.08
Lactation number	...	...	...	0.37 ³
Lactation number $\times$ BCSC	...	...	...	0.06

¹For Type III sums of squares.²Not significant ($P < 0.10$) for fully reduced model.³Main effect included in model because interactions including main effect were significant ($P < 0.10$).

(not shown). Discrete fixed effects included season of calving and season of observation (2-mo intervals), herd, lactation number (first, second, and third or greater), treatment, management and nutrition effect (blocking variable to separate herds based upon magnitude of treatment response), and DIM (10-d intervals). Predicted producing ability, season of calving, BCSC, and body weight at calving had similar coefficients and significance, regardless of analysis technique.

For multiparous cows, the process of fitting lactation curves to each LHG accounted for herd, lactation number, and all interactions of these fixed effects with other whole-plot variables. Therefore, herd, lactation number, and all interactions with herd and lactation number were eliminated from the whole-plot model. Because the generation of each lactation curve removed one degree of freedom from the whole-plot error term, the degrees of freedom associated with herd, lactation number, and interactions of herd with lactation number were not available to be added to error degrees of freedom. Herd, lactation number, and their interactions with other variables, particularly treatment, were significant in the general linear model with SCSP.

For multiparous cows, the use of lactation curves prior to split-plot analysis separated the five herds into two populations, based on the observed response to calcium salts of long-chain palm oil fatty acids.

Four of the five herds did not respond to calcium salts of long-chain palm oil fatty acids (low response), but, in one herd, 4% FCM production increased by 2.88 kg/d per cow when calcium salts of long-chain palm oil fatty acids were fed (high response). This factor was accounted for by the inclusion of a blocking factor, effect of management and nutrition, in the whole-plot model for multiparous cows. Because only one herd (experimental unit) was in the high response group, factors contributing to differences in treatment response among herds could not be determined. Possible causes of the discrepancy in estimates of treatment response among herds are discussed by Scott et al. (16). The single herd in the high response block for effect of management and nutrition could not be differentiated from the other four herds when SCSP was utilized.

TABLE 2. Comparison of error measurements, peak 4% FCM production, and days to peak production for the monophasic model with an additive constant for control cows versus cows fed calcium salts of long-chain fatty acids (Ca-LCFA).

	Control	Ca-LCFA
Mean absolute error, kg of 4% FCM	1.88	1.86
Error variance, (kg) ² of 4% FCM	7.43	7.31
Peak of 4% FCM production		
kg	41.9	42.5
d	70.8	75.4

The advantage of including blocking for effect of management and nutrition with LCSP must be qualified. Because only one herd was included in the high response block for effect of management and nutrition, the ability of LCSP to detect the effect of management practices may simply have resulted from one herd being markedly different from the remaining four herds. Because only one experimental unit was included in one level of the predictor variable for effect of management and nutrition, the variable might not represent a true cause and effect relationship.

Two significant interactions, predicted producing ability with treatment and BCSC with treatment, were detected by LCSP. Milk production and fat percentage did not demonstrate a significant interaction of predicted producing ability with treatment ($P < 0.25$ and $P < 0.77$, respectively), but 4% FCM ($P < 0.10$) and fat production did ($P < 0.10$). Milk production and fat percentage exhibited significant interactions of BCSC with treatment ($P < 0.07$ and $P < 0.02$, respectively). Because decreased BCSC was associated with increased milk production and decreased fat percentage when cows were fed calcium salts of long-chain palm oil fatty acids, this interaction was not significant when 4% FCM was analyzed. These interactions were not significant under SCSP. The difference between LCSP and SCSP might have resulted from either confounding or collinearity of variables under SCSP.

Few differences were detected between LCSP and SCSP when data from primiparous cows were analyzed. Because an interaction of management and nutrition with herd was still present under LCSP, the inclusion of effects of management and nutrition and of herd within management and nutrition in the LCSP model was nearly the same as the use of herd as a blocking effect with SCSP. The only difference in models for 4% FCM that were generated by the two systems was the ability of LCSP to detect an interaction of management and nutrition effect with BCSC that was not detected with SCSP ($P < 0.09$). Because calcium salts of long-chain palm oil fatty acids were not fed to these cows prior to calving, this interaction reflects a difference in BCSC between the high response herd for management and nutrition effect and the remaining four herds rather than a treatment effect.

Combining Lactation Curves with General Linear Models

Split plot. With general linear models for analysis of production data, the split-plot portion of the model

accounts for variance within cows, such as DIM and season of observation effects. When 4% FCM was analyzed for multiparous cows, LCSP successfully accounted for all DIM effects and interactions prior to fitting the general linear model. Season of observation, and its interactions with other independent variables, was the only parameter to retain significance under LCSP. Interactions of season of observation with herd and lactation number were not eliminated by LCSP. These interactions were not expected to be accounted for by lactation curves because the models that were used accounted for effects of DIM and not season of observation. These effects were assumed to be randomly distributed across treatments within each LHG and to have little impact on estimation of treatment response.

When milk production or fat percentage was analyzed with LCSP, LCSP did not completely account for all DIM effects within the split-plot model. Two factors might have influenced the differences in LCSP performance between 4% FCM and milk production and fat percentage. First, the lactation curve model used was developed specifically for 4% FCM production and might not have been the optimal model for lactation curves for either milk production or fat percentage. Second, lactation curves for 4% FCM production were more consistent among cows in each LHG than were lactation curves for either milk or fat percentage. Production of 4% FCM converged because of the negative correlation between milk production and fat percentage (12). Production of 4% FCM was more similar for two individual cows than either milk production or fat percentage because cows with high milk production tended to have lower fat percentage than cows with lower production. Lactation curves for 4% FCM were typically flatter than lactation curves for milk because the lowest fat percentage frequently occurred near peak milk production.

Selection of the Optimum Model

Differences in the ability of LCSP to fit data for primiparous and multiparous cows appeared to be related to differences in the lactation curves of these two groups. Although a lactation curve fit to each LHG accounted for one-third of the split-plot variance for multiparous cows, the lactation curve only slightly outperformed a straight line for primiparous cows (Table 4), either because of the lack of well-defined peaks (high persistency) or because of the high degree of variability in time to peak production for primiparous cows. Multiparous cows peaked from 40 to 100 DIM, but several primiparous cows had not yet

peaked by the end of the study (200 DIM). Primiparous cows in one herd peaked at 145 DIM, on average. Patterns were similar for milk production: 27% (primiparous cows) and 41% (multiparous cows) of split-plot variance was explained by lactation curves.

For 4% FCM and milk, lactation curves accounted for 34% (primiparous cows) and 40 to 45% (multiparous cows) of whole-plot variance (Table 4). Whole-plot variance was accounted for by the elimination of differences in mean production for each LHG and by the removal of DIM effects unique to each LHG. Because a unique curve was fit to each LHG, most of the interactions of herd and lactation number with other variables were accounted for also.

Lactation curves accounted for similar amounts of split-plot variance for both primiparous and multiparous cows (41 and 36%, respectively) when fit to fat percentage. However, only a small portion of whole-plot variance was explained by lactation curves (12 and 10%, respectively), suggesting that LCSP did little to increase the sensitivity of analysis to detect treatment differences in fat percentage. This result might have been related to smaller differences in fat percentage between LHG than 4% FCM and milk production. Whole-plot variance accounted for only 51% (primiparous cows) and 39% (multiparous

cows) of the total variance in fat percentage, but whole-plot variance accounted for 60 to 67% of the total variance in 4% FCM and milk production. Because the model for the lactation curve was developed based upon 4% FCM, another possible explanation for these differences was that the curve utilized was not an adequate model for fat percentage.

Predicted treatment responses for both 4% FCM and milk production differed substantially for multiparous cows between LCSP and SCSP. Conventional split-plot analysis using DIM subclasses overestimated 4% FCM treatment response by 50% (1.00 and 0.66 kg/d per cow for SCSP and LCSP, respectively) and milk treatment response by 110% (0.86 and 0.41 kg/d per cow, respectively) compared with those for LCSP. At least a portion of the differences in the estimation of treatment response was a function of two distinct, nonrandom distributions found within the data.

Based on individual lactation curves, peak 4% FCM production increased 0.6 kg/d for the treatment population (Table 2). This value was similar to the treatment response of 0.66 kg of 4% FCM/d estimated by LCSP (Table 4). No differences in persistency were detected between the control and treatment populations. Differences in mean of 200-d cumulative amount of FCM production, estimated by fitting MC

TABLE 4. Comparison of variance explained by general linear models for 4% FCM resulting from lactation curve method of analysis (LCSP) versus conventional analysis (SCSP).

	Lactation 1		Lactation ≥ 2	
	LCSP	SCSP	LCSP	SCSP
Estimate of treatment difference, kg FCM/d ¹	1.01	0.96	0.66 ²	1.00
P ³	0.06	0.06	0.001	0.02
Between cow variance (BCV) explained by				
	(%)			
Lactation curve	34.1	44.3 ⁴	44.3	...
General linear model	16.2	48.5	35.2	79.5
Error	49.7	51.5	20.5	20.5
BCV MSE ⁵	106.1	100.1	85.7	83.5
BCV adjusted R ² , %	41.0	44.3	76.8	76.8
Total variance explained by BAV	67.0	67.0	60.5	60.5
Within-cow variance (WCV) explained by				
Lactation curve	6.2	...	33.0	...
General linear model	15.5	27.8	10.7	43.2
Error	78.3	72.2	56.3	56.8
WCV MSE	7.9	7.7	15.1	15.5
WCV adjusted R ² , %	18.7	20.7	42.1	40.6

¹At population means for all other independent effects.

²Weighted equally for all five herds to facilitate comparison with SCSP.

³Treatment difference.

⁴Not applicable.

⁵Mean square error.

to each individual, between treatment and control populations were 290 and 109 kg for primiparous and multiparous cows, respectively. These results compared favorably with the estimated daily treatment response from LCSP multiplied by 200 d (202 and 132 kg of 4% FCM for primiparous and multiparous cows, respectively). Based on daily treatment responses as estimated by SCSP, differences in 200 d cumulative amount of 4% FCM production were 192 and 200 kg, respectively.

Observations from the treatment group were clustered near peak milk production (45 to 104 DIM), and control observations were clustered during early (<15 DIM) and late (>174 DIM) lactation. This unbalanced distribution caused SCSP to estimate the effect of DIM improperly, resulting in inflated estimates of treatment effects and biased estimates of production.

The distribution of observations within each DIM subclass further affected the estimation of treatment effect. Prior to peak production (75 to 84 DIM), cows in the treatment population were observed, on average, 0.1 d later in lactation than were control cows. Conversely, after 114 DIM, treated cows were observed on average 0.4 d earlier than were control cows. Thus, the treatment group had the benefit, on average, of an extra 0.1 d to increase milk production prior to peak production; also, these cows were observed 0.4 d earlier after peak production when daily production was declining. During midlactation, 4% FCM production declined 0.1 to 0.2 kg/d.

The use of discrete intervals to analyze nonlinear continuous effects might have also introduced other biases into the estimation of treatment response. Not all cows were observed within each DIM interval because of ongoing recruitment, illness, culling, uneven sampling intervals, and other factors beyond experimental control, which might have contributed to inaccurate estimation of treatment effects because different populations were used to calculate the effect of DIM within each interval.

Similarities in the magnitude of split-plot error sums of squares for both LCSP and SCSP were related to the length of the interval selected for each DIM subclass (10 d).

CONCLUSIONS

For fitting 4% FCM production over the first 200 DIM, the best model for lactation curves was MC. The MC consistently outperformed IG, IP, and M1. The M2 generally outperformed MC; however, MC performed more uniformly across the entire population.

Because lactation curves are not symmetrical near peak production, replacement of DIM with the fourth root of DIM might be beneficial for derivatives of the model of Grossman and Koop (20).

The fitting of a unique lactation curve to each LHG to determine the effect of DIM prior to conventional split-plot analysis reduced biases introduced by non-random distribution of production data across DIM and other predictor variables. When compared with the classification of DIM effects into a number of discrete intervals, lactation curves fit production data in a manner more representative of actual patterns of lactation production. The elimination of bias should result in more accurate estimation of treatment effects.

For multiparous cows, the fitting of lactation curves prior to analysis increased the ability of general linear models to detect interactions of treatment response with independent variables by repartitioning the variance from herd and lactation number. By accounting for the effects of herd and lactation number and their interactions with other effects in the model, the use of a unique lactation curve for each LHG increased the ability of general linear models to detect important interactions.

Improvement of the general linear model for primiparous cows was minimal when lactation curves were fitted to analysis, which might have resulted from the more persistent lactation curves for production during first lactation.

The development of models capable of analyzing effects of both DIM and season of observation through the use of continuous nonlinear equations should help reduce biases that are secondary to chance imbalances in data distribution across predictor variables. When combined with lactation curves, such equations should more accurately predict treatment effects from production data from field trials. The use of such equations might also permit the detection of smaller treatment differences or the use of fewer observations for the detection of significant treatment effects.

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