

THE DAIRY RESEARCH FOUNDATION'S

2015 SYMPOSIUM

Answering the Call - growing the dairy industry



FACULTY OF
VETERINARY
SCIENCE



THE UNIVERSITY OF
SYDNEY

**CURRENT TOPICS IN
DAIRY PRODUCTION**

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DAIRY RESEARCH FOUNDATION

CURRENT TOPICS IN DAIRY PRODUCTION

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WELCOME TO THE DAIRY RESEARCH FOUNDATION 2015 SYMPOSIUM

This year we are bringing the Dairy Research Foundation Symposium home to Camden, NSW.

We have welcomed the opportunity to take dairy science on the road over the past two years and the commissioning of our AMR at Corstorphine Dairy late last year has provided the opportunity to return to Camden to showcase our research.

We are excited to see the NSW dairy industries come together once again to hold their meetings in line with the Symposium. We welcome the collaboration of NSW Farmers Association – Dairy Section, Dairy Connect and Dairy NSW whom are all staging meetings over the duration of the event.

For 2015 we have a brilliant line-up of speakers, headed by Professor Ephraim Maltz from the Agricultural Research Organization, Volcani Center at the Institute of Agricultural Engineering, Israel. Professor Maltz is an internationally acclaimed expert in technology application in systems that push the boundaries in terms of productivity per cow and per farm. His talk is guaranteed to have delegates putting on their thinking caps.

The Symposium will continue its journey through the eyes of farmers who have grown their operations through quite different pathways.

Hear the rationale behind their decisions. After lunch we will look into ‘Turning Science into Milk’ before our last session titled ‘Making Money and Connections with Consumers’.

The Field Day will take us to Corstorphine Dairy where delegates will get to view the University’s own Robotic Rotary. In keeping with tradition the real focus of the Field Day will be our Emerging Scientists - the best and brightest of our next generation researchers. Bring your voting hats as they vie for first place in the 2015 DRF Emerging Scientist Award.

We trust that you will enjoy the Symposium again in 2015 as we have planned a program we hope will excite you about the future but that will also give you some tools to take home and implement on your own operations.

Thanks you for attending our 2015 event!

Assoc. Professor Kendra Kerrisk

Programming Committee Chair,

Dairy Research Foundation Symposium 2015

DAIRY RESEARCH FOUNDATION 2015 SYMPOSIUM

ORGANISING COMMITTEE

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Mr Mike Logan, Dairy Connect	A/Prof John House, University of Sydney
Ms Joanna Baker, Dairy Connect	

THE EMERGING DAIRY SCIENTISTS' PROGRAM

The Dairy Research Foundation is pleased to showcase the talents of Australia's emerging dairy scientists at the 2015 event.

Their presentations are the focus of our Field Day program and all have been paired with a senior consultant or scientist to create a highly interactive series of discussions.

The intent behind this encounter is to offer an opportunity for professional development for these emerging scientists.

Here we introduce them to and assimilate them with our industry. The program is in the form of a competition, where we ask you, the audience, to assess the quality, relevance and interest of each presentation – with the audience scores combined to determine a winner. This is announced at the conclusion of the Field Day.

The program clearly identifies those competing in the Emerging Scientists' Program – and we encourage your full participation which will do much towards encouraging our next generation of dairy scientists.

DAIRY RESEARCH FOUNDATION 2015

SYMPOSIUM SPONSORS

The Dairy Research Foundation would like to acknowledge and sincerely thank the following organisations and companies for their support.

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ADVANCED TECHNOLOGIES TO SUPPORT PRECISION DAIRY FARMING

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ABSTRACT

Technological developments in the dairy industry are strongly motivated and enhanced by industry's trend of development. Namely; increasing herd size, production per cow, cow's economic value, expenses (food, labour) as well as socioeconomic progression that include animal welfare public concerns. Primarily, it involves sensors that replace the farmer's inspection and interpretation of the individual cow physiological status. These sensors generate data that after proper analysis and modelling, provide meaningful physiological information to support decision making, both, diagnostic (health, reproduction) and managerial (feeding, milking, grouping). The fact that these sensors record and store on-line data from each cow in the herd, led to precision dairy farming (PDF). It can be defined as systems that by responding on-line to performance and behavioural changes enable the management of the smallest production unit in the dairy (the individual cow if possible) to allow it to express its genetic potential in accordance with economical goals and animal wellbeing.

Expected perceived benefits of PDF technologies include increased efficiency, reduced costs, improved product quality, minimized adverse environmental impacts, and improved animal health and wellbeing.

To be applicable, PDF has to include the following components: sensors that generate data, models that gives physiological interpretation of the data, a management decision making process, and finally decision execution.

The PDF systems can be divided into two categories: for diagnostic purposes (timing critical) and for management (timing tolerate). The same sensor can serve both purposes, to alarm on one hand, and/or elucidate a physiological process or status which improves management on the other hand.

This presentation scans operational sensors and their practical management applications for diagnostic and managerial purposes.

INTRODUCTION

The dairy industry leads the technology in precision livestock farming. This process is driven by increasing herd size and production per cow as well as the economic value of the cow and increased expenses (especially food). Growing public concern to animal wellbeing also motivates this process. Technological progress advances the development and use of sensors that can provide detailed on-line data about the individual cow in the herd regardless of herd size. With proper physiological labelling and interpretation this data can be translated into information which in turn, can support management decision making on the level of the individual cow - PDF down to individual cow level.

The definition of PDF is to manage the smallest production unit (the individual cow if possible) in order to enable the cow to express its genetic potential in accordance with economic goals and animal wellbeing. This approach is expected to improve animal health, wellbeing and profitability of the dairy operation. The 'smallest' unit can be the entire herd, a group of cows with common physiological and performance characteristics or the individual cow. The 'size' of this unit is determined by the sensors, facilities involved and availability of automation and operational ease.

A PDF system is constructed of the following components: A sensor that generates data, a model that gives a physiological interpretation of the data, a management decision making process and finally decision execution. The PDF systems can be divided into two categories: those used for diagnostic and those used for management. The same sensor can serve both categories. For example a decline in milk yield can indicate estrous, a health problem or even a nutritional problem. Nevertheless, for all categories data have to be labelled and analysed in order to convert it into meaningful information. Sensors are useless data generators unless there is a model that transfers these data to meaningful physiological information. Both diagnostic and managerial PDF systems are designed to alarm or elucidate a physiological event or status which improves management decision making. The difference between diagnostic and managerial PDF systems is that the former has to alarm in advance or very close to the event it supposes to detect (estrous, calving) and the latter can be more time tolerant like change of concentrate supplementation. Most of the PDF appliances of diagnostic nature relate to health and reproduction and the motivation for their development was to replace human senses as well as to economize on the dairy operation.

This paper scans long-standing and novel-technologies and sensors with emphasis on data-information-decision making process and practical applications and possibilities. Special attention will be given to: body weight scales, on-line milk composition analyser, behaviour, location (in and out the milking parlour) and rumination sensors.

Long-Standing Sensors

The oldest sensor in the dairy industry is probably the 'jar' milk meter that measured the individual cow milk production but records had to be done manually. Electronic milk meters did not change this situation until individual cow identification (ID) was developed, and opened the age of on-line performance recording. But the real revolution came when personal computers penetrated into the dairy operation. The ID, computing and records-storing power were the key for further sensor development. The ability to identify a cow in a certain location enables the download of data on one hand and execution of management decisions on the other hand. The electronic milk meter soon became, in addition to its original task, also a diagnostic tool for health and reproduction solitarily or with other sensors that came into practice like milk conductivity for udder health detection and activity tags for estrous detection. In some cases, research preceded application of sensors and in some cases it was the other way around like with activity estrous detection sensors (steps – S.A.E. Afikim, Israel and neck – SCR, Natanya, Israel) that spread in the industry because of their apparent performance success. Another sensor that intensive research (Rajkondawar *et.al.* 2006, Dyer *et.al.* 2007) preceded its application was the BouMatic StepMetrix® lameness detector. A nice illustration how technology and computing power turn existing technologies into a sensor can be the milking parlour facilities that are now acting as 'a sensor' for milking parlour and milkers performance by adding timing to each milking parlour device (Maltz *et.al.* 2004, see below).

BODY WEIGHT – WALK THROUGH SCALES

The first walk-through weigher for dairy cows was developed in 1979 in the National Institute of Agricultural Engineering, Bedford, GB and suggested that routinely monitoring the body weight (BW) of individual cows, combined with daily milk yield (MY) recording, may improve management strategies (Filby *et.al.* 1979). The natural BW daily fluctuations caused an inner resistance among farmers and researchers alike to use this parameter for management purposes. Indeed, BW does fluctuate diurnally (Peiper *et.al.* 1993), daily and periodically (Maltz *et.al.* 1997, Maltz 1997, Van Straten 2008), but this was resolved by technology and methodology.

The initial system we constructed in the Volcani Center, in Israel, coupled ID with electronic scales (under an adequate plate length with a slowdown step before it) no labour involved (Peiper, *et.al.* 1993). The system was located in the outlet path of the milking parlour thus creating the potential to obtain the weight of each cow in the herd after each milking. The capture of BW several times daily at the same time under the same routine enables the calculation of daily or weekly averages minimizing the typical diurnal fluctuations. In addition, BW data smoothening and standardizing techniques help to expose and illuminate physiological events and status that can be used for PDF on the individual cow level (Maltz *et.al.* 1997, Maltz 1997, van Straten *et.al.* 2008).

Significance of BW, patterns and changes for a variety of management aspects is reflected by the number of recently publications. The association between body weight and milk urea (Hojman *et.al.* 2005), Association of daily body weight patterns and reproduction variables (van Straten *et.al.* 2008, 2009) and somatic cell counts (van Straten *et.al.* 2009). Heritability of daily BW and correlations with yield (MY), dry matter intake (DMI) and body condition (BC) (Toshniwal *et.al.* 2008), BW changes in relation to health (Ostergaard and Grohn 1999, Moallem *et.al.* 2002) and calving problems (Berry *et.al.* 2007), feeding in relation to BW changes (Bossen *et.al.* 2009, Bossen and Weisbjerg 2009, Maltz *et.al.* 2009). Today walk-through weighing systems are off-the-shelf products of many dairy equipment companies and some milking robot producers incorporate scales into the milking stall. The automatic weighing systems are probably the most economic sensor in the industry. One system can serve the whole dairy in a conventional milking parlour or about 60 cows in a robot milking system.

Visual Analysis: Body Weight Curves - Energy Balance changes throughout Lactation

Normally BW changes can be associated with changes in energy balance when loss of weight indicates negative and weight gain, positive energy balance. For the high yielding dairy cow this is an oversimplification. The milk production driving force increases MY at a rate that exceeds DMI energy compensation. DMI increase from 7.2 to 16.2 kg DM within two weeks after calving (Silanikove *et.al.* 1997) and may reach over 30 kg DM within 4-5 weeks (personal knowledge). Considering that each kg DM is accompanied in the gastrointestinal tract by 8-10 kg of water, the effect of BW changes reflect two processes with contradictory effects over it. The mobilization of body reserves decreases and gastrointestinal enlargement and fill increase it. This process, in changing levels of magnitude and direction, is ongoing throughout lactation.

Bearing this in mind, visual observation of the BW curves in relation to those of the MY can identify several phases. In transition time a moderate BW decline or no change when the MY increases, indicates that mobilization of body reserves is accompanied by a sufficient increase in DMI and gastrointestinal fill (Fig. 1 cow 5520). A steep BW decline after calving may indicate an approaching of a lactation curve collapse (Fig 1. cow 333). In late lactation an increase in body weight indicates body reserves deposition. After peak

production the decline in MY indicates less energy invested in MY, but it is not clear in which stage DMI changes contribution to BW from positive to zero and finally at late lactation to negative.

In several works where BW and body condition (BC) were measured in parallel (Bar Peled *et.al.* 1995) (Walsh *et.al.* 2008), it could be seen that for several weeks past nadir BW, BC keeps declining or did not change while BW is increasing. In general we can conclude: until BW nadir and at late lactation BW changes correlates linearly with BC and reflects, qualitatively, those of body reserves handling. Between these two stages no conclusions, even quantitative, can be withdrawn regarding body reserves handling from BW changes.

Body Weight and Body Condition Scoring

Body condition (BC) is an important variable for research and management and 'Ongoing research into the automation of body condition scoring suggests that it is a likely candidate to be incorporated into decision support systems in the near future' (Roche *et.al.* 2009). Mizrach *et.al.* (1998), Bewley *et.al.* (2008), Halachmi *et.al.* (2008) are only few examples in this attempt. However, until this is materialized it may be possible to model BCS by using data from available working sensors. Maltz *et.al.* (2001, 2002) suggested the use of on-line MY and BW data and the relationship between them to develop a model for estimating the BC throughout all lactation stages. As described above, linear relationships between BW and BCS from calving until nadir BW, BW decline reflects also BC decline and in late lactation when BW increase indicates BC increase. Between these two periods the relations between BW and BC changes are not linear. Therefore, it was suggested to model BC in two stages separated by the phase from which the energy investment in MY starts to decline i.e. peak production. This model requires only a single BC scoring after calving. The preliminary results were quite encouraging (Maltz *et.al.* 2002). Recently an on-line milk composition analyser was developed (Katz *et.al.* 2007, see below). It is expected that when milk energy value will be incorporated into the model it will improve its performance.

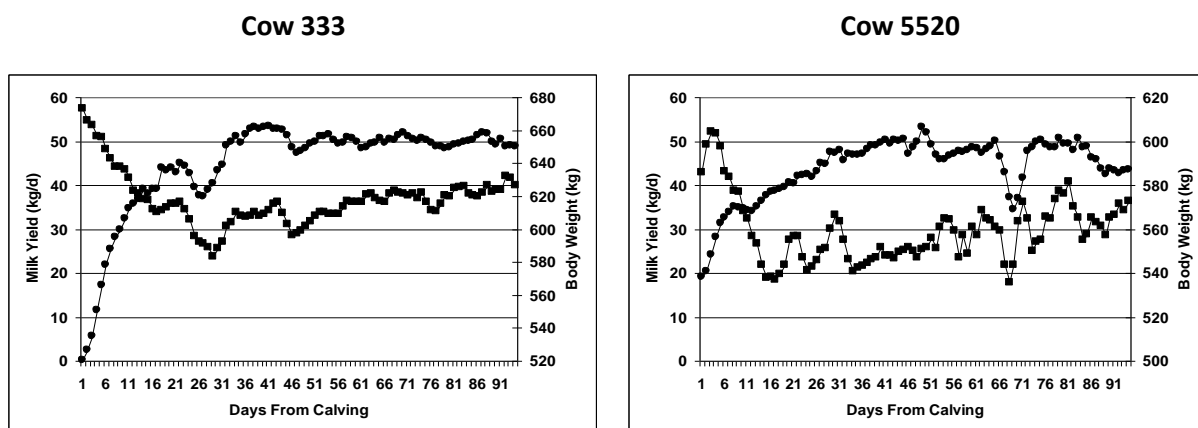


Figure 1. Milk yield (●) and body weight (■) 3 day running average of daily values of 2 cows. cow 333 – steep post calving decline (nadir – 86% of post calving weight) and cow 5520 – moderate BW post calving decline (nadir - 91% of post calving weight).

Body Weight and Dry Matter Intake and Nutrition

Individual dry matter intake is a desired parameter for feeding decisions especially when applying individual concentrates supplementation that is a must under robot milking conditions. Daily individual DMI also provides the information about the economical contribution of any cow in the herd at any given time. Individual DMI formulas published by Halachmi *et.al.* (1997, 2004) showed that DMI can be modelled out of

daily MY and BW data. In the NRC (2001) an individual DMI formula was published which also calculates DMI out of performance (MY, milk fat, BW) and time after calving. In addition, Spahr *et.al.* (1993) showed the significance of cow potential (the ratio of MY to BW at peak production) for cows grouping. On-line BW data may have a significant contribution also in group feeding.

Body Weight and Reproduction

Van Straten *et.al.* (2008, 2009) found correlations between BW changes/cycles in early lactation and reproductive performance. A preliminary attempt was performed to use BW changes at estrous as an indication of emerging from negative energy balance to improve first insemination performance (Kaim *et.al.* 2009). The criteria of emerging from negative energy balance were that MY is decreasing or increasing by no more than 0.5 kg/d (an indication of past or reaching peak production) and BW is increasing by 0.1% or more of post calving weight when the values are calculated as 3d running average for 7d prior to estrus detection (Fig. 2 left panel). The results of this preliminary study were that 42% of the heifers that showed estrous between 57-85 days after calving and 37% of the cows that showed estrous between 47-65 days after calving (out of 55 and 54 inseminations for heifers and cows respectively) conceived after first insemination that was carried out after BW and MY performance analysis, compared to 35% (out of 84 inseminations) and 20% (out of 137 inseminations) for heifers and cows respectively that showed estrous after 85 and 65 days after calving (heifers and cows respectively) that was practically performed in that dairy.

Body Weight and Health

The effect of health problems over BW changes was described in several works (Maltz *et.al.* 1997, Ostergaard and Grohn 1999, Moallem *et.al.* 2002). The loss of appetite due to health problem or discomfort is immediately reflected by a body weight loss (see above) sometimes even preceding that of MY decline or milk conductivity response when measured in whole milk (personal knowledge). Figure 2(right panel) demonstrates a case where the BW decline precedes that of MY but was ignored because decisions were taken according to MY and the MY change on day 52 was considered as a 'normal' fluctuation. The decline on day 54 led to the cow being presented to the vet.

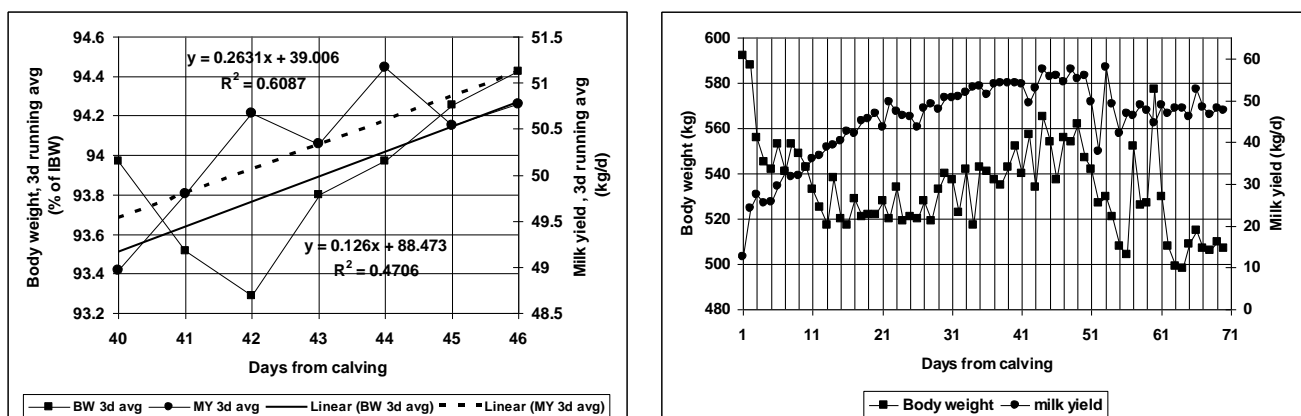


Figure 2. Data collection and insemination decision for one cow showed estrous 46 days after calving (left panel). Daily BW change as a result of a health problem. The cow was presented to the vet and treated on day 54 (right panel).

MILK COMPOSITION ANALYZER

This novel sensor (Afilab®) was recently introduced into the industry (Katz *et.al.* 2009) and not a moment to early. Milk fluctuations within milking, between milkings and between days change remarkably as lactation progresses. The periodical milk test analysis has only a limited benefit to PDF on a daily or even weekly decision making because routinely the periodical milk test is performed once a month. Besides the obvious benefit that this analyser has for feeding and health (see below), it turns up the possibility for diverting the milk from any cow (even during milking of a single cow) to different tanks according to the milk processing needs. Under the conditions of robotic milking where cows may be sampled at non-regular hours and it is possible that not the entire daily MY was sampled, a milk composition analyser is even more significant for PDF then in the case of conventional milking parlours.

Milk Composition Analyser and Feeding

For frequent feeding decisions, a monthly milk composition value has limited value especially during early lactation (Maltz *et.al.* 2009). Figure 3 demonstrates the difference between a daily and a monthly value of milk composition during the first 100 days after calving. The daily milk composition data improved decision making regarding computer controlled individual concentrates supplementation by encouraging cows with a desired milk composition and depressing MY of those that their milk had a low economic value (Maltz *et.al.* 2009). In any feeding system that supplements concentrates individually such as with robotic milking, the milk composition analyser is a significant contribution.

Milk Composition Analyser and Diagnostic Indication

Among the typical health problems, those that occur after calving can affect the entire lactation. Heuer *et.al.* (1999) described the association between milk composition of the first milk test and a variety of health problems. An on line milk composition analyser can be a useful tool in this respect monitoring on-line both the fat content and fat protein ratio (Tomaszewski and Cannon, 1993, Heuer *et.al.* 1999). Milk lactose elevation was associated with mastitis (Schlinsen and Bauer, 1992). Together with the milk conductivity sensor, on line lactose measured by the analyser can improve mastitis detection. The economical benefits of this sensor are so obvious that it is likely it penetrates into practical use before scientific trials show it.

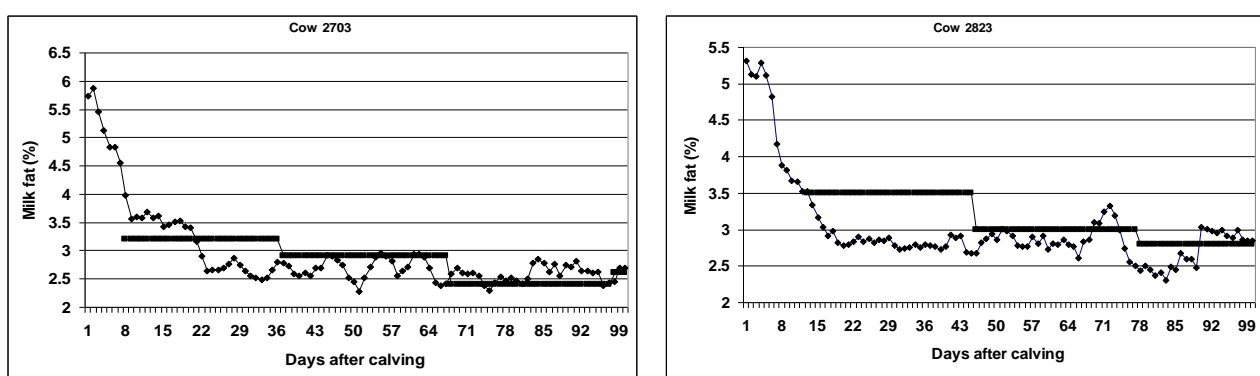


Figure 3. Two cows demonstrating the difference in depending on milk fat values achieved through periodical milk test (■) were one measurement dictates to rely on the same value for about a month until next milk test, and data achieved daily (3 days running average) by the milk composition sensor (▲). (From Maltz *et.al.* 2009, Precision Livestock Farming '09)

BEHAVIOUR SENSOR

An animal manifests its feeling by its behaviour. Therefore, any environmental or physiological status or discomfort will be expressed by its behaviour and our challenge is to decipher behaviour and behavioural changes to enhance managerial decisions. This is successfully done for diagnostic purposes in estrus detection where the increasing activity of the cycling cow is detected by increasing number of steps (S.A.E. Afikim, Afifact®) or neck movements (SCR, H-Tag®, Heatime®). Estrus was recently associated also by a remarkable change in lying behaviour (Livshin *et.al.* 2005). Monitoring the behaviour of the dairy cow has potential applications for animal welfare, and a variety of diagnostic purposes that will improve animal well-being, management and profitability.

Behaviour Sensor and Animal Welfare

'Optimal biological functioning of an organism occurs only when it lives in the most appropriate surrounding. ...under such conditions, and only under such conditions, the best overall biological functioning of the organism is assured and the maximum quality of its life is reached' (Hurnik, 1992). Under such conditions the animal should be free to carry out its normal behaviour.

Rest and activity are fundamental and complementary components of animals' behaviour. In ruminants in general, and dairy cows in particular, lying behaviour reflects the rumination activity as well as resting. It may be effected by daily routine (feeding, milking), individual temper, and is often considered as an indicator of cow comfort when different housing environments are compared (for references see Livshin *et.al.* 2005).

A leg-mounted sensor to monitor and register lying times was developed in The Institute of Agricultural Engineering, the Volcani Center. A trial was conducted using this sensor where diurnal lying behaviour was compared under two different housing systems (Fully roofed barn with no stalls and free stall barn, Livshin *et.al.* 2005) it was found that:

- Under stable daily management routine the cows adapt a very constant pattern of lying behaviour (Table 1).
- Housing system effects lying behaviour (Table 1).
- When cows were moved from one housing system to the other they adapted the behaviour typical to that particular housing system.

Routine management practice may affect the pattern and the time of lying. Allowing sufficient lying time may be particularly significant under hot climate conditions where cows are moved several times a day between milking to the milking parlour waiting area, and/or tied in the feeding alley for forced cooling. This is common and is often in addition to the before milking cooling. All these activities are time consuming and may impair lying behaviour of the high yielding dairy cow.

Table 1. Lying time (mean \pm SD) in between-milking diurnal intervals of 8 cows in a no-stalls barn and 8 cows in free-stalls barn (from Livshin *et.al.* 2005).

Time interval	Lying time (min)		Lying time in free-stall, % of no-stall	Significance (P<)
	No-stall	Free-stalls		
04:30 - 12:30	157 \pm 42	120 \pm 43	76.4	0.01
12:30 - 20:30	118 \pm 50	108 \pm 49	91.5	Ns
20:30 - 04:30	258 \pm 51	199 \pm 50	77.1	0.001
24h total	533 \pm 87	427 \pm 90	80.1	0.001

Behaviour Sensor and Diagnostic Aspects

Since resting and activity are complementary components of animals' behaviour then lying behaviour may have a significant contribution to estrus detection especially under conditions whereby activity is limited (free stall) or prevented (tied stalls). Its potential in this respect was indicated by Brehme *et.al.* (2004) and Livshin *et.al.* (2005).

Motivated by the potential benefits that were presented by Livshin *et.al.* (2005) S.A.E. Afikim developed a behaviour sensor that measures number of steps, lying time and lying bouts, which was recently introduced to the dairy industry. It is common knowledge that the behaviour of the cow changes prior calving. It was found that calving time can be detected 24 hours before happening by analyzing the day to day changes of number of steps, lying time and lying bouts (Maltz and Antler 2007). The performance of this sensor is significantly improved when analyzing, in addition to diurnal data, also separately day time and night time behaviour (Maltz, unpublished data).

In addition to the activity sensor, feeding behaviour was analysed as an additional indicator for approaching calving. In a preliminary trial where dry cows before calving were caged in a 'finishing group' equipped with two computer controlled self-feeders and rationed daily 5 kg of concentrate in addition to finishing ration fed in the common feeding trough. The daily concentrates ration was fed in equal portions in four six-hour feeding windows. Feeding behaviour of feeding window consumption and number of visits to the self-feeders were analysed in addition to the normal behaviour variables of number of steps, lying time and lying bouts analysed in day, and night time and diurnally.

A reduced number of visits and missing a normally used feeding window, was often associated with calving within the following few hours. Missing two feeding windows, in most cases indicated that the animal is calving. These preliminary results illustrate that technology that was developed for one purpose, concentrates rationing, can serve as a sensor and be incorporated into PDF in a way the producers never originally anticipated.

MILKING PARLOR PERFORMANCE DATA – HUMAN ANIMAL INTERACTION

Combining cow ID with electronic milk meter was a major step towards PDF, the ability of on-line timing milk flow rate of each meter at any part of the milking process on one hand, and all the parlour activities (gate close and cow release, cluster attachment and detachment) on the other hand, enables the evaluation of milkers performance, milking routines, and cows response to routines and milkers behaviour.

Milking parameters were monitored using ID, MM, timing and software (AfiFlo, S.A.E. Afikim, Israel) in three commercial dairies of about 400, 550 and 850 Holstein cows with different pre-milking preparation routines. Milk flow rates for 0-15, 15-30, 30-60 and 60-120 s after cluster attach, and also duration and magnitude of peak and low milk flow were measured for each milking. Milking records on about 30,000 milkings of five normal consecutive days were analysed for regular milking parameters, prior to an exceptional milking.

Milking efficiency data presented in Table 2, show that the most successful milk letdown was achieved in the dairy with most extensive pre-milking preparation routine (dairy 1).

Table 2. Milking efficiency in the three dairies with different milking routines¹

Dairy	Preparation Routine	Milk ² (kg/cow)	AMT ³ (min)	Milk flow rates (kg/min)				Low flow (% of AMT)
				0-15s	15-30s	30-60s	60-120s	
1	Extensive	13.5a	4.8a	1.6a	2.7a	1.9a	4.1a	18.6a
2	Standard	13.1a	5.1b	0.5b	2.4b	1.9a	3.5b	18.3a
3	None	11.5b	5.7c	0.4c	2.0c	1.3c	2.8c	26.2c

¹Sessions' averages for five consecutive days, ²Average milk yield per cow per milking session

³AMT – average milking time, abc - Different superscripts indicate significant differences between rows (within parameter; P<0.001)

An exceptional morning milking was identified when compared to previous morning milkings (Table 3.). The reason for the differences looms from the result in all milk let down parameters as well as well as parlour performance ones. The cows were harried into and in the milking parlour, which affected both, milk let down as well as milk yield.

Table 3. Milk yield of morning milking (MY), Average milking time (AMT), average peak flow, and parlour performance parameters, of an exceptional morning milking compared to the same parameters of the regular previous morning milking. All differences are significant (P < 0.05)

Milking	MY (kg)	AMT (min)	Peak flow (kg/min)	Between loads (min)	First to last ID in load (min)	Loads per hour	Milking time (h)
Normally average 47.2% of cows flow <1 kg/min in the first 15 sec after attach							
Regular	11.9	5.20	2.29	5.4	3.2	8.23	4.13
Exceptionally 65.9% of cows flow <1 kg/min in the first 15 sec after attach							
Exceptional	11.4	5.52	2.07	4.3	2.6	8.87	3.83

The conclusion is that incorporating timing into the existing milking parlour sensors can evaluate milk let down parameter, hence milkability and cows' readiness for milking related to milking routines. This system can also identify changes in routine and milkers performance.

RUMINATION SENSOR

A sensor that measures rumination time was recently introduced to the industry by SCR (SCR, Natanya, Israel). Rumination time can be stored and analysed in 2 hour intervals in 2 minutes resolution. The potential benefit of this sensor lies in the fact that it can serve both in nutrition management, and as a health and cow's welfare sensor. In a recently conducted trial (Adin *et.al.* 2009) differences in both rumination time and pattern were recorded on group level for cows fed different TMRs. This trial indicated the significance of this sensor for both nutritional research and management. The potential benefits of this sensor for diagnostic purposes like health and predicting calving time is demonstrated by the producer. The close association of rumination, to any nutritional aspect or gastrointestinal occurrence may put it into practical use before research is producing proofs to justify its use.

MULTI SENSOR ACTING IN PRECISION FEEDING

The emerging of the new technologies and increase in feed cost has led to increasing interest in feeding cows individually according to individual performance differences dictated by different genetic dairy merits in order to achieve better performance efficiency and economics together with balanced feeding to maintain health and welfare. This attitude gains interest also in pasture based farming (see Hills *et.al.* 2015). With the technology in hand, the question is: what are the criteria according to which to feed the cows in order to achieve these goals. A trial was conducted to evaluate individual precision feeding (IPF) and nutrient utilization according to individual energy balance at early lactation compared to the control which was the traditional total mixed ration (TMR) feeding strategy (Maltz *et.al.* 2013).

Fifty-eight Holsteins cows were blocked by parity and production during the pre-treatment period and then randomly assigned at 21 d postpartum to a control TMR diet (n = 29; 16.2% CP, 1.64 Mcal NEL, 22% starch, and 19% forage NDF) or a diet with caloric density manipulated weekly (precision diet, n = 29, 16.2% CP, 1.59 to 1.68 NEL, 18 to 26% starch, and 16 to 22% forage NDF) to promote a calculated positive energy balance of 5 Mcal/day. Diets were fed as total mixed rations and precision cows had their diets adjusted individually once a week, by grain supplementation from 0 to 25% of daily DM offered, according to energy balance of the preceding week. Daily energy balance was calculated out of measured DM intake and data provided by commercial sensors (milk meters, on-line milk composition analysers and walk through scales for body weight measurement).

The study lasted from wk 3 to 19 postpartum. Compared with controls, precision cows had similar DM intake (24.3 kg/d), but NEL intake tended to be greater primarily between wk 4 and 8 postpartum. Yields of milk (45.2 vs. 41.9 kg/d), milk components, 3.5% fat-corrected milk (44.0 vs. 40.8 kg/d), and energy-corrected milk (43.4 vs. 40.2) were all greater for precision than control cows, resulting in greater energy-corrected milk production per kg of diet DM consumed (1.79 vs. 1.72). Precision cows produced more milk calories per kg of metabolic weight (0.227 vs. 0.213 Mcal of NEL/kg), although the amount of consumed calories partitioned into milk (82.3%) and measures of energy status did not differ between treatments throughout the study.

These results clearly indicate the feasibility of precision feeding employing computer controlled concentrates self-feeders. This was already indicated in previous studies (Maltz *et.al.* 2009). However, there is still one

difficulty in applying this technology and this is the absence of a food intake sensor. Until such a sensor is available, we can only use models (NRC 2001, Halachmi *et.al.* 2004) to evaluate individual food intake. The sensors that measure the variables that compose the model are commercially available. We continue to try and improve the food intake model by incorporating a new variable into the model which is the time the cow spends with her head in the feeding trough.

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UNITY IN DAIRY

Mike Logan

CEO, Dairy Connect NSW

The NSW Dairy Industry has an enormous opportunity. All it needs is a unified approach.

THE BIG PICTURE

If we look at the Global Economy right now we can see two major changes.

1. The US economy is recovering and the US dollar has strengthened. Or, our dollar has weakened and that makes us more competitive in the global dairy market.
2. Growth in China has slowed from an unsustainable 14% to around 6%. That is still pretty high, but at 14% someone was going to get hurt. Unfortunately, the two that got hurt are iron ore and dairy.

GLOBAL DAIRY SUPPLY & DEMAND

It doesn't matter what the question is, the answer is China. But China is only a continuation of what has happened in Asia – although at a larger scale. Already Japan, South Korea, Taiwan, Singapore and others have grown remarkably since the 1970's. Now it is China and after that will be Vietnam, Thailand, Philippines, Malaysia, Indonesia and Burma. That is one heckova lotta people.

China's consumption of dairy is forecast to grow at a sustainable rate. As Jim Begg of Dairy UK said at the Global Dairy Conference in Japan last year, 'the world is supply constrained'. There is more demand than there is production. Demonstrably, if we take the opportunity grow more dairy product there is a sustainable market to buy it.

However, Australia has not yet responded to the changed global demand for dairy. On the other hand, New Zealand has adapted. The growth in the New Zealand dairy production is a mirror reflection of the changed demand in China. They have actively swapped sheep for dairy cows, attracted investment and developed the market.

PRICE

It is often said that the Australian dairy industry's farmgate pricing is driven by global markets. This is not true. For the most part, Australia is not in the global market and the local market has been heavily perverted by the supermarket channel. It is not too late to take the opportunity to enter the global market.

VALUE CREATION

Interestingly, New Zealand has focussed on the export commodity market. That is mostly Whole Milk Powder as well as a range of other products. Only in the last two years have they begun to more actively engage in the branded product space.

Australia on the other hand, has focussed on branded products into a mostly domestic market. The percentage of Australian dairy products that has been exported has continually dropped since 2000 while

production has also dropped. It is logical to assume that although the New Zealand dairy industry has focussed on volume we have focussed on value. This too is not true.

New Zealand have created more value from a lower value product than Australia has from the higher value and branded product. In the last financial year we left US\$1.15 billion on the table in lost value. Even in NSW terms, we left US\$90 million sitting there. Our opportunity is to learn to regain that value.

COSTS OF PRODUCTION

To add insult to injury, New Zealand has a lower cost of production for dairy in both the farm and manufacturing scales. We have higher energy, labour and infrastructure costs.

Our only solution is to be creative and innovative.

PLANNING

We have no National or NSW plan for agriculture (or dairy). Of course, with the DRF we are working on developing a NSW plan for dairy. Both New Zealand and Tasmania have clear and concise dairy plans and both have benefited from the new global circumstances. Our opportunity is to do the same.

WE HAVE

1. Good demand for our product
2. Limited capacity to meet that demand through a lack of investment in manufacturing
3. High costs of production
4. Strong branded products with good reputations
5. Disaggregated marketing approach that is costing over \$1billion each year
6. Disaggregated value chain where each sector thinks it is in competition with the other
7. Good R&D that we need to drive harder

WHAT DO WE NEED?UNITY

1. A plan to grow and add value
 - a. in R&D and
 - b. in the wider industry to attract investment and skills
 - c. that uses a branded approach to unify the value chain
2. To aggregate our marketing so that it
 - a. Adds value to our brands and our reputation for quality, nutrition and safety (don't ever mention the words 'clean and green'!)
 - b. Overcomes the high costs of production
 - c. Works within or around the restrictive Competition and Consumer Act

PATHWAYS FOR GROWTH IN THE NSW DAIRY INDUSTRY

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Population-based increases in dairy product requirement as well as providing milk to fill potential shortfalls arising from exiting dairy businesses in this state and in Queensland provide a market need and opportunity for NSW dairy business to expand in both scale and output. This need for growth will be further accentuated if some of the manufacturing opportunities currently considered in NSW eventuate. While the industry has been exposed to somewhat mixed messages with respect to production expansion in recent years, the current dairy environment is generally favourable for growth with additional processors competing for product in most regions, and a number of these giving clear signals that they have demand and capacity to utilise additional supply if provided. Existing or new entrants to the NSW dairy industry can take some confidence that continued strong demand for additional product is likely to arise from a combination of natural attrition of existing NSW farms; an expanding milk-drinking population in this state; and the potential for continued decline in production in Queensland in the face of increasing population and demand in that state. With current production in NSW relatively stable at around 1 billion litres per year, even moderate growth of 2% per annum implies additional requirement of milk of around 20 million litres per year for this state alone. To account for this growth as well as continued expansion of demand by the manufacturing sector in southern NSW, natural attrition and increasing interstate opportunities, business growth and development will need to account for significantly more milk than that projected above.

Key constraints for growth in NSW include:

- High value of land, particularly coastal and peri-urban land
- Lack of confidence in milk pricing impacting both appetite for expansion and additional risk as well as willingness of finance sector support to fund growth
- Increasing layers of red and green tape
- Mismatch between processors desire to seek product that is close to manufacture and availability of suitable sites that are amenable to growth
- Apparent lack of suitably skilled upper and lower level labour to facilitate growth
- Aging facilities and infrastructure in many enterprises that constrains expansion from existing platforms
- General rising input costs and long term reduction in dairy terms of trade
- Diminution of appropriately skilled and directed extension providers and services
- Inconsistent or absence of processor competition for supply in some regions

- No desire by many producers to grow due to 'stage of career', strong equity positions and no financial need to grow or lack of succession opportunities
- Seasonal rainfall variability
- Competition for, and availability of high security water for both irrigation and stock use
- Lack of 'self-confidence' in the NSW industry

To varying extents, many of these constraints are real. However there are still a number of mechanisms by which dairy businesses can choose to grow that can either manage or circumvent some of these either real or perceived challenges to growth. Critically, any plan for expansion should involve careful whole-of-business planning with particular reference to financial management and monitoring, with key reference as to how growth and expansion is to be funded at the front end, and then serviced by the changes in business structure and liabilities that ensue.

Dairy businesses can expand by a number of mechanisms:

1) **Improvement in per cow productivity and efficiency from the existing herd**

There is significant scope to expand productivity in most herds by increasing per cow productivity. In most herds, a realistic target of production of body weight of milk solids per cow per 305 day lactation should be achievable with a number of herds already exceeding this benchmark. With the NSW industry reporting per cow production in 2013/14 at approximately 7.2% combined solids at 5000 litres per head or 360kgs milk solids per head, there would appear to be considerable scope in many herds to grow per cow production substantially. Much of this gain could be achieved with combined improvements in management and feeding.

Sometimes this will require investment in infrastructure on farm to couple with efficient use of feed resources but in many instances significant gains can be made through changes in practice, improved timing and prioritisation of farm activities and minor changes in existing facilities and infrastructure. Importantly, growth through this mechanism does not greatly increase risk associated with increased stocking rates and is likely to improve feed conversion efficiency substantially as an increasing proportion of total nutrient grown or purchased to feed to cows is able to be diverted to production. With the majority of costs on most farms associated with either growing or purchasing feed, improving feed conversion efficiency is likely to be highly correlated with farm economic performance.

This mode of growth can often be managed to a point without changing existing milking plant, with minimal change to farm infrastructure such as laneways and tracks and water supply, and with minimal interruption to existing labour structures. However, it is important that labour and infrastructure 'bottlenecks' are identified and addressed as these can be important constraints themselves in improving per cow productivity. Adoption of new technology is highly conducive to this mode of growth. Growth by increasing per cow production generally minimizes requirement to secure additional cattle reducing risk of biosecurity breakdowns. An exception to this is if the genetic base of the herd is rapidly altered by destocking and restocking, for example, when a mixed breed/mixed cows size herd is consolidated into a single breed/more uniform cow size.

2) **Increased intensification to increase herd size and productivity from existing site**

Increasing herd size and stocking rate on the existing platform can lead to significant increases in per farm output and productivity. This should be considered once achievable and sustainable per cow production targets have first been met. This strategy is ideal in businesses that have underperforming

assets and unutilised capacity. Farm businesses need to carefully review their existing resource and infrastructure base to determine if major changes in management practices and infrastructure are required to match increasing stocking rates and risk. Development needs to be planned to ensure that infrastructure and staffing skill or levels are adjusted to meet the needs of a larger herd. Critically, agronomic management and realistic projections for home grown fodder production need to be assessed (prior to expansion!), allowing either appropriate adjustment of practices or shifts in targets for purchased feed requirements to be carefully considered and appropriate steps taken to accommodate additional input requirements and input price risk. In our experience, gradual herd expansion using existing replacement cattle or small purchases of cattle with appropriate attention to biosecurity can be preferable as it may allow infrastructure, agronomic performance and general management to slowly adjust to the increased stocking rate.

It can also be less challenging for farm cash flow. Expansion that requires large capital investment to help manage increased herd size and risk, for example construction of new dairies or feedpads, and adoption of significant new technologies such as robotics may require external funding. Business planning needs to ensure that partial budgeting or financial analysis that balances the income changes from expansion with additional costs including provision for funding infrastructure repayments as well as changes in labour, farm inputs and repairs and maintenance that may be required under higher stocking rates and changed farm capital. Additional resource requirements of expanded dry and replacement herds also need to be considered.

3) Local expansion from the same site using existing land or locally acquired land (either purchased or leased) to increase herd size and productivity

In this model, an existing dairy business expands production from its existing site using either, or a combination of the two modes above, supported by use of existing internal land that may be underperforming or being used for other purposes; or by acquiring land 'next door' by purchase or leasing. In high-land-value areas such as coastal NSW, leasing strategic parts of neighbouring properties may be more economically viable than purchasing additional land where agricultural returns and total business scale may not justify additional land ownership. Additional land if easily accessible to the milking area may allow improved feeding of the existing herd to increase overall production (per cow and farm), particularly in farms that are already overstocked.

Alternatively, if stocking rate across the whole property is held constant and mirrored on the leased land, productivity may be increased on a pro-rata basis for the extra cattle that can be run on the new land. Critical farm infrastructure and funding considerations include provisions for additional access routes including laneways and crossings, additional requirements for stock water provision, fencing and gating upgrades and pasture renovation and upgrades in newly acquired land. Variable costs associated with herd size and increased areas being farmed need to be accounted for. Energetic and time costs associated with cattle walking long distances or protracted milking times also need to be factored in. If accompanied by a significant increase in herd size, key stock handling, milk harvesting, supplementary feeding and effluent infrastructure and management systems need assessment, planning, funding and construction and the ongoing costs associated with these need to be assessed in light of the whole farm business plan.

4) Local or distant land acquired by purchase or leasing to grow fodder and/or rear young stock.

This option can be considered as a component of the three previously discussed options or as a stand-alone option aimed at either improving input (reducing feed costs) or outcome (heifer growth targets,

feed quality) security and control. Importantly, unless coupled with a full business plan to grow whole-business output, it can increase business costs, risks and complexity.

Additional land may be either purchased or leased in this model. This can be in the same region as the existing enterprise, or in a distant region that may provide alternative opportunities for diversification or management of climate risk. For example, a coastal business that acquires an inland holding to produce hay or grain or grow out heifers. In some cases speculative land investment with a view towards capital growth may be the prime motivating factor in land acquisition with a view to having agriculture 'pay the rates'.

The costs and risks associated with this form of growth require careful consideration, particularly if debt-funded, as the combined costs of servicing debt, as well as covering other fixed and variable operating costs may exceed costs of equivalent purchased fodder or agistment, as well as carrying substantial performance risk. The labour and social costs of farming and travelling to satellite properties should also be considered. Careful whole business modelling is required to assess the financial and other impacts of this form of expansion, particularly if it is not matched with a substantial shift in underlying business performance. While we have seen this form of expansion succeed, particularly on leased land in close proximity to the dairy business, we have also seen it place intense financial stress on a number of businesses when not coupled with a whole farm financial plan that considers the effect of climate variability and seasonal failure, input and milk price volatility and the effect of increasing managerial loadings on business owners.

5) Relocation of enterprise to a new or existing dairy site

There are a number of examples in NSW where businesses have fully relocated to alternate sites, or to different regions. This has generally involved some form of business migration from coastal to inland areas but there are a few examples of movement in the opposite direction, or up and down the coast. Businesses that have found their growth constrained due to property size and land values, and have not been able to lease, fund or justify purchase of additional neighbouring land have made the decision to realise existing land value to fund development of new 'greenfield' dairy developments or acquire and expand existing dairy enterprises. The attractions of setting up new enterprises based on the inland irrigation systems have included lower land costs, access to irrigation water, being closer to major inputs and feed opportunities, reduction of the effects of summer humidity and perception of reduced problems associated with development in peri-urban areas. While in many cases, these benefits and others have manifested, there have also been a number of 'road-bumps', anticipated or otherwise, that have made the transition more challenging than expected. These have included unexpected difficulties with local councils and neighbours, seasonal challenges including droughts, floods and locusts, temporary and permanent changes to water access and allocations, lack of local dairy-orientated supporting infrastructure, service providers and extension services, challenges with local labour, and increased tendency of processors to shift the costs of milk transport back to producers and processor decisions to exit some areas of supply. This aside, the potential for medium to large scale dairy development in the inland regions is still significant and, as a result of competition for land and land values, is a more likely region for significant growth and development than on the coast.

The following farmer papers set out some real-life stories of 'growth' and business change from NSW and beyond. Aspects of all the above have been utilised as these businesses continue to sustainably grow and expand their horizons to meet the demand for milk.

GROWTH WITH NO MORE COWS- 'DOING IT BETTER'.....HOPEFULLY!

Robert and Zak Hortin

'Hortin Grazing Company', Torbay

South-West Western Australia (Between Denmark and Albany)

Table 1. FARM DETAILS - PHYSICAL

Hortin Farm Details	
Farm Size (ha)	1,650ha
Mixed Beef/heifer rearing/silage	1,430ha
Milking Area (ha)	220ha
Annual Rainfall (mm)	1,200mm
Irrigation area (ha)	No irrigation
Dairy type	Rotary 50 stand
Herd	
Milking Cow numbers (incl dries)	550-600
Heifer numbers	500-550 calves reared each year, 150 brought into the herd. All bulls and crossbred calves reared
Stocking rate (cows/milking ha)	2.5 cows/ha
Breed	Holstein-Friesian
Calving System	Split 30/70 July 28 th to September 22 nd /Decembers 1 st to June 1 st
Production	
Annual Milk Production (2013/2014)	3,650,000
Ave Milk Fat %	4.1%
Ave Milk Protein %	3.1%
Ave SCC (x1000 cells/ml) Average	Average 160,000 Always under 200,000
Production per cow (L/cow)	6,700
Milk solids per cow (kg/cow)	481
Milk solids per ha (kg/ha)	1,202
Labour	
Labour inputs (FTE's – 50 hr. week)	6
Litres per labour unit	608,333
Kg MS per labour unit	44,100
Cows per labour unit	92
Nutrition	
Concentrate inputs (grain & protein meals – tonne/cow/year)	2.2 – 2.4 t (7-10kg/day) fed in dairy 2013-2014 – Barley, Wheat, Lupin

BACKGROUND AND OUR FARMING SYSTEM

Our dairy enterprise is located at Torbay, between Denmark and Albany in South West Western Australia. This dairy business is integrated with a beef farming enterprise co-managed on our other pastoral holdings in the region. With Zak, coming into the business, we are now onto the 5th generations of mixed beef and dairy farming with 3 generations active on the farm. Our goal is to continue to see our integrated businesses grow so that they can be passed on to the next generation in better shape again.

Our dairy production system has utilised a typical Western Australian hybrid feeding strategy based on grazing rain-fed pastures that grow from autumn through till early summer supplemented with dairy feeding of concentrates, and supplementary feeding for the rest of the year with pasture silage made on both the milking area and run-off blocks during spring. Our pasture system is predominantly annual rye grass based with clovers and kikuyu growing into summer in favourable seasons. Our forage conservation is based on making 3000 round bales of silage and additional hay. We use round bales as we have the equipment for this and it suits our spread-out farming system and challenging silage making seasons. The wet weather means we often need to work on paddocks with wet subsoils that can be very difficult to traffic with heavy machinery and we need to get in and out quickly on often limited acreages during breaks in the weather.

PROBLEMS WITH THE OPERATION AS IT WAS

Silage was traditionally fed back to the herd on the ground resulting in significant wastage. Despite availability of a mixing wagon, we were reluctant to feed concentrates with the silage. This capped potential intake of concentrates to what could be safely fed in the dairy. We have a very favourable concentrate: milk price ratio and have not been able to exploit the benefits of this in previous years for the reasons mentioned above. This, in combination with variable and generally moderate forage quality has limited production, particularly during the late summer and autumn.

The calving system on the property is spilt with cows calving between December and June and between late July and the end of September. The predominantly Holstein herd is bull bred with high genetic merit bulls sourced from well-respected Western Australian studs. We have never been able to exploit the full benefit of this genetic base with our cows traditionally producing between 450 and 500 kgs milksolids/head/lactation.

OUR MOTIVATION AND DRIVE FOR CHANGE

We have a business goal to increase the productivity and profitability of the farm. However, we do not want to milk more cows at this stage as we feel that the farm infrastructure, milking shed and current labour structures suit the current herd size and our management style. We know that the herd does not consistently milk to its potential and we would like to improve productivity by improving per cow production. We believe that cows should be able to produce their body weight in milk solids and as such we can see that there is potential for at least a 20% increase in productivity without the stress and risk of milking more cows. We are also aiming to improve profitability by maximising margin over feed costs and minimising wastage. We have identified that the most room for improvement exists in production during summer, autumn and early winter. Improving productivity at that time of year is likely to improve production during the core grazing season as well. Lifting milk production in the non-grazing season is also beneficial to our supplier Lion who would like more milk at that time of year and have given appropriate pricing signals to chase it at that time.

THE CHANGES WE HAVE MADE

We identified that silage was being fed either fully or partially in combination with pasture for at least 60% of the year. This had been being fed on the ground resulting in significant wastage and paddock damage. We were also very reluctant to mix concentrates in TMR, despite having a very good mixing wagon and as such, our production was capped at well below its potential. To help improve this situation we constructed a 500 cow concrete feedpad in 2014. We also upgraded to a larger feed wagon. It was hoped that we could use this combination to feed efficiently and without wastage giving more flexibility in our feeding system and ingredient options. We constructed the feed pad on an arterial lane-way to get additional value out of concreting a high traffic area. We also set the feedpad up in an area that was close to paddocks in the sandier, free draining parts of the farm and shelter belts so the cows had safe loafing areas nearby so they could move freely to and from the feedpad.

In combination with this we also converted our old milling system to an upgraded disc mill and mixing system to improve both quality of processing and accuracy of concentrate mixing.

We knew we would benefit from some technical advice in helping fine tune our feeding management, but had never really sought this, mainly due to a lack of local services in the area. An opportunity arose through Western Dairy to get access to a nutritionist as part of a project designed to manage and monitor the change from our old to our new system and then present this story to the WA dairy industry at our annual Dairy Innovation Day in April this year. We grabbed this opportunity and have been very happy with what it brought to the business. Critically this experience highlighted the following issues:

1. To get the most out of our feeding system, we needed to greatly improve silage quality – in the short term we needed to use more nitrogen; in the longer term we had options to use later heading ryegrass cultivars to widen harvest windows of vegetative rather than reproductive forage. We also needed a subjective silage grading system at the accumulation phase to help manage feed out.
2. That we could also improve grazing management in spring to improve pasture quality and yield.
3. That feed budgeting after forage harvest would allow us to better budget and plan the feed out, plan for gaps and improve potential for controlling concentrate cost with forward budgeting.
4. That favourable concentrate pricing provided opportunities to feed more in the current milk price environment - our access to lupins was a great tool for managing diet protein and carbohydrate fermentability.
5. That we needed to shift from a reward to a challenge feeding system with our automated feed system.
6. That our feedpad needed modification to improve access to the centre of the pad from the loafing areas to make it easier for the herd to feed at leisure during the dry season.

Much of these changes are discussed in the attached report prepared for our DID day earlier this year.

CHALLENGES AND HURDLES SO FAR

We have had minimal issues during the construction phase and implementation has been relatively stress free. The changes in management suggested by our consultant were relatively simple to execute and imposed minimal additional workload and cost on the enterprise. The additional nitrogen inputs were justified by much higher silage yields, increased proportion of leaf and improved quality and a terrific seed-set after silage was cut. Early in the summer we encountered some acidosis issues as we transitioned out of our pasture phase but we worked with our nutritionist to resolve this by shifting more concentrate into the TMR to try and force the cows to eat the diet more aggressively with safety - this resolved quite quickly. Cow traffic issues on the pad were fixed with a few strategically employed 'bungy'-cords. We are still working on fine tuning options with the automated feed system and making sure it is well aligned with milk solids data as well as milk volume.

ESSENTIAL FACTORS FOR SUCCESS

Doing our homework prior to construction of the feed pad was critical in the effectiveness of its design. We looked at a lot of pads and spoke to a lot of people before proceeding with construction. We chose to compromise with some costs vs function by using troughs on of a concrete pad rather than a wider fully formed pad that would require more concrete but this is still working very well. At around \$500 per cow, it is a long term investment and the concrete base is essential in our wet environment for both cow comfort and health and traffic with machinery.

Seeking expert advice with the feed management and then following this has also been important. It is critical to work with credible specialists that you trust and then work with the advice that is given. Ongoing communication and support between farm visits is very important and much easier in the 'electronic age'.

IF WE HAD OUR TIME AGAIN

In short, we would have made these changes a lot sooner! Our management style is fairly laid-back and we have not been as diligent with financial performance monitoring as we could be but it very clear the changes are making a huge difference to our output and our profit. Our nutritionist encourages us to monitor our milk solids production per cow to assess how the cows are going and we regularly review our margins over feed costs to see how the numbers are stacking up. With minimal shift in inputs we are seeing consistently higher milk solids produced per cow (25/5/15- 2.1kgs/cow/day) and per hectare.

WHERE TO NEXT

Our feedpad effluent is not well managed at the moment and we know we need to improve this aspect of our system. We would like to install a flood-wash and separation system to allow us to get away from scraping the pad and to allow us to better utilise the effluent as a nutrient source. We would also like to explore underground water options with the view of considering some irrigated maize in summer in combination with the effluent. We still have a way to travel with fine tuning with what we have but at this stage things look promising.

A NEW FEEDPAD AT THE HORTIN'S DAIRY

Robert and Zak Hortin

Kronkup dairy, Hortin Road, Torbay

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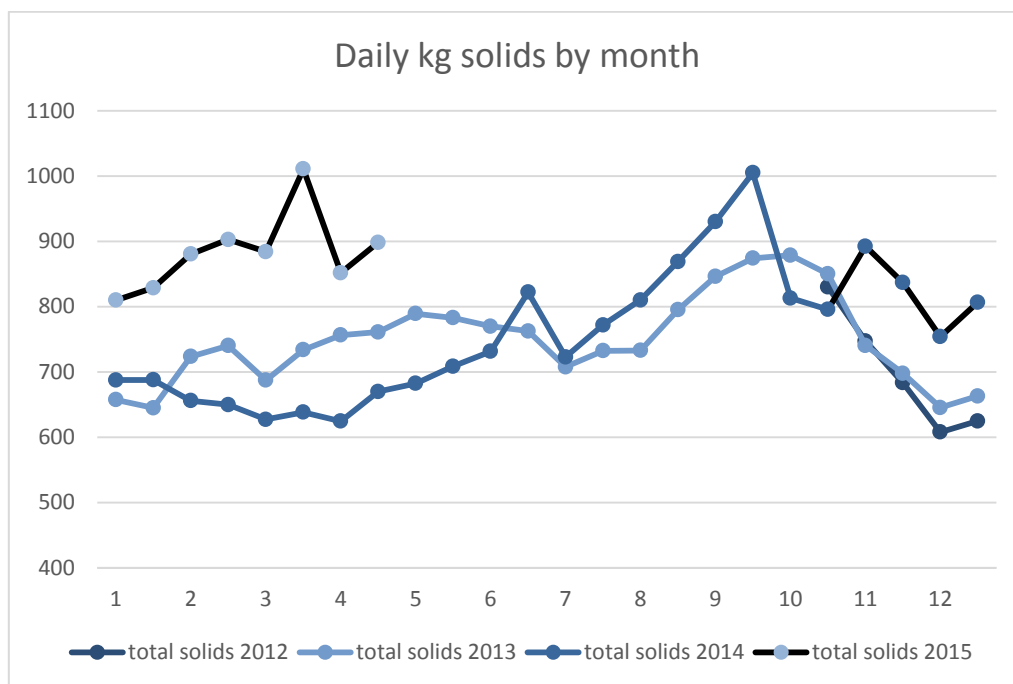
KEY POINTS EXTRACTED FROM WA DAIRY INNOVATION DAY PAPER

- Silage is the predominant source of fodder for the farm for much of the year making up 100% of the fodder for 3-4 months and up to 50% of the fodder for a further 4-5 months. ***Silage quality should be of paramount focus for the enterprise.*** In the short term this can be manipulated by Improving fertility, particularly nitrogen levels in an effort to increase protein, yield, proportion of leaf and to reduce NDF%. Increasing nitrogen application rate would also increase grazable pasture and lengthen the grazing season assuming adequate soil moisture was present. It was recommended that nitrogen application rates were lifted to supply 1.5kg/ha of N per day and that an application of 30kg/ha of N was made immediately to help boost silage cuts in 3 weeks' time.
- ***A more aggressive approach to spring grazing management was recommended to help improve/maintain pasture quality.*** This focussed on shortening the grazing rotation to target closer to 2-2.5 leaf ryegrass in spring to try and maintain a more vegetative sward for longer. Rotation length was to be dropped from 26 days back to 20 days initially and then later to 15 days. Up to 3000 bales of silage are made each year. Logistically it is important to be able to sort silage into similar quality lines to make it accessible. Using feed tests to do this is ideal but impractical in the short term as baled silage should not be moved after wrapping until feeding. A subjective grading system based on proportion of leaf was established. Silage can then be stacked in lines and classed as either A (high quality, high leaf), B (average type silage) or C (higher proportion of stem, low leaf). Silage quality was later tested and found to be highly correlated with the classification system.
- Once silage harvest was complete, ***a comprehensive feed plan and forage budget*** was to be developed to help manage: the staging of the feeding out of the varying grades of silages; to minimise risk of running out of high quality silage too early and being exposed to the need to purchase fodder; to allow any fodder purchases to be forecast and acted on in a 'buyers' rather than a 'sellers' market; and to forecast grain and protein requirements. A copy of this feed plan is attached to this paper.
- Favourable grain and lupin pricing and good milk price point to ***making the most of the concentrate feeding opportunities*** to use these with a higher degree of safety and less wastage through the feed pad. Higher levels of concentrate feeding were to be considered once the cows had no access to pasture and the TMR was fully operational. Lupins were

identified as the most suitable protein source for the system but some preference for additional use of canola was flagged for future years.

- The automatic feed system had been set up to feed responsively to production. This was **altered to challenge feed cows to a targeted intake level and** hold them at that level for at least 50, and later 80 days before production feeding commenced. Further manipulation to hold cows at peak allocation for longer while TMR feeding is to be trialled.
- The feed pad has been well constructed. The key issue was the restricted access at the end of each pad and the long filling times for the herd. **Installing some additional gates and concrete access adjacent** to the central water troughs was suggested to improved access to the pad from the loafing areas.
- Future silage (and pasture) planning is very important to address strategically. The region has a high likelihood of extended growing seasons. There is considerable value in **selection of much later heading ryegrass cultivars** to take advantage of this, particularly on grazing areas and more fertile or heavier country.

Results to date are promising!



Graph 1. Daily farm milk solids production October 2012-April 2015

Table 1. Graded silage results for 2014 season

Sample details	% DM	% ADF	% DDM	MJ/kg ME	% WSC	% NDF	% CP
1. Dairy A	36.2	23.8	74.9	11.2	14.0	40.4	16.8
2. Dairy 2C	43.9	28.4	68.4	10.3	10.3	50.6	13.9
3. 3A	44.5	26.2	71.3	10.7	14.3	46.0	12.9
4. 4A	38.2	26.5	71.7	10.8	12.2	44.5	15.8
5. 5A, Mitch Rd	40.4	26.3	71.4	10.7	14.6	44.0	16.1
6. 6B, Thom Rd BB	49.1	27.6	69.1	10.4	14.2	49.1	14.3
7. 7B Carinya Nich	35.3	28.3	69.7	10.5	13.3	49.8	14.0

CHANGE THROUGH EFFICIENCY GAINS

Heffernan Family

1589 Myrtle Mountain Road

Candela NSW 2550

FARM DETAILS - PHYSICAL

Lindsay Farm Details

Farm Size (ha)	438ha
Milking Area (ha)	245ha
Annual Rainfall (mm)	700mm
Irrigation area (ha)	42ha bike shift
Dairy type	Herringbone 22 double up

Herd

Milking Cow numbers (incl dries)	420 (incl dries)
Heifer numbers	120 calves reared each year
Stocking rate (cows/milking ha)	1.7 cows/ha
Breed	Holstein-Freisian 60%, Jersey 40%
Calving System	all year round calving heifers batched quarterly about 30 each time

Production

Annual Milk Production (2013/2014)	2,369,132
Ave Milk Fat %	4.3
Ave Milk Protein %	3.4
Ave SCC (x1000 cells/ml) Average	180,000, always under 220,000
Production per cow (L/cow)	5,640
Milk solids per cow (kg/cow)	422
Milk solids per ha (kg/ha)	724

Labour

Labour inputs (FTE's – 50 hr. week)	6
Litres per labour unit	394,855
Kg MS per labour unit	29,572
Cows per labour unit	70

Nutrition

Concentrate inputs (grain & protein meals – tonne/cow/year)	2.4tn (8kg/dairy) 6.5 kg wheat 1.5kg supplementary pellets minerals buffers & Incl. approx. 100tonne/year of Canola pellets or lupins to adjust the protein when required
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When Greg and Ian (his cousin) joined their fathers (Roger and David) in the family dairy operation 6 years ago they were buying into a farm with traditional operations, annual cycles of endless ploughing, big paddocks and some extremely persistent weeds. There was a strong reliance on bought in high quality feed to supplement the 'feast or famine' operation. At the insistence of their fathers, Greg and Ian were forced to leave the farm to get trades but even throughout his apprenticeship and carpentry career, Greg couldn't help himself with weekend relief milking giving him an opportunity to experience a variety of management practices on different farms. After 5 years of carpentry Greg got a job as an assistant farm manager on a farm near Bega. He re-entered the family business just as the drought was breaking creating the opportunity to buy the lease block across the road which gave them a total land holding of around 1500 acres.

THE OPERATION PRIOR TO THE CHANGE

Prior to Greg and Ian buying into the operation, it was a traditional family farm working with traditional methods, not at all progressive and really not going too far, too fast. In the past 6 years there have been two core stages to growing the business.

The first came about with a Bega Cheese grant to plant some shelter belts which created an opportunity to reassess the farm layout with a focus of improving the fodder management. Previously the farm had large paddocks – 7 days grazing per paddock meant a lot of regrowth was lost at the cows progressed through the paddock while backgrazing previous allocations. Many paddocks couldn't be grazed at night because the layout meant it was extremely challenging to get cows out of the paddock for the morning milking. Nowadays (after re-fencing most of the farm) generally only 2 grazings are had in each paddock, meaning the pasture growth and utilization has increased dramatically, quality is improved as post-grazing residuals are closer to targets and weed management is improved.

The second stage involved the upgrade of the dairy. When the original 8-aside herringbone was replaced some years ago, his father and uncles had the foresight to build an 18-aside dairy with capacity to grow. Just prior to Christmas 2014 the dairy facility was converted from a 18-aside HB low-line double up to a 22 aside, mid-line with dual pulsation. The dairy also has auto cup-removal, electronic cow ID, milk meters and in-bail feeding. The dairy conversion has dramatically improved the efficiency of the milk harvesting process with improved teat condition and udder health, reduced cups on time and less time in the dairy. With the younger generation on farm the morning milkings start earlier which creates plenty of time for farm development during the day.

THE MOTIVATION FOR CHANGE

Having the new generation come into the farming operation brought with it an enthusiasm for operational improvements. Greg and Ian had been exposed to a variety of farming practices and took every opportunity to challenge the fodder management practices in an attempt to improve the quality and quantity of home grown feed. Sometimes it took much convincing but with all partners on board they often 'tried' a practice change to give their fathers the confidence to trust that the change was beneficial. In an operation in which many acres were ploughed and replanted in early Autumn each year Greg set aside 17 acres, sprayed it for two years of fallowing and then planted it with improved pastures. In the meantime, paddocks side by side were subjected to Autumn planting at the same time, with identical planting rates and varieties (one sprayed and left to fallow prior to planting, one ploughed and planted) – showing that the spraying/fallow strategy resulted in much improved pastures, much reduced weed infestations and many, many less hours sitting on

tractors. The focus is to grow more feed which puts more milk in the vat. In turn this makes more money available to carry out further improvements and reduce debt.

The ultimate goal is to improve the entire 'home' farm so that the block across the road (also improved) can act as a feed factory for most of the year. This will allow the herd to grow to 450 cows quite comfortably – the herd is being grown as the pastures are improved.

THE PROCESS FOR CHANGE

The first step was to deal with succession planning. It took almost 12 months to work out how Greg and Ian could enter the business. The farm currently has 7 families living on it (in 7 separate houses) and over the years has been home to 29 grandchildren (Greg and xx are two of them). Knowing this, you start to get a feel for how many people need to be kept happy with regards to succession of the farming operation. With the current partnership it was agreed that nutritional and agronomic consultants should be employed to guide the partners and challenge them with their existing management practices. This also helped to give the fathers sufficient confidence in some of the ideas being put forward by Greg and Ian. Ultimately the proof was in the pudding – further reinforcing the confidence levels.

THE FINANCIAL CONSIDERATIONS

Plenty of 'back of the envelope' calculations are done to justify changed management practices. It was relatively easy to calculate the costings for ploughing vs. spraying but anticipating the increase in feed production was more challenging as on-farm practices are constantly being refined. The Heffernan's thought they were on a winner with the staged autumn planting (across through stages) which meant that feed quality was not compromised with large areas ready to graze at the same time. This has been further refined with the most recent practice involving actually planting paddock-by-paddock after grazing which dramatically improved the feed wedge going into winter.

The family participates in the Farm Monitor Project and whilst they recognize that they are below average in many of the KPI's – they are far from the worst. However, when it comes to the bottom-line they are within the top 5% for profit. They run a simple system without too many bells and whistles. Their real focus is improving the home-grown feedbase so that they can reduce their reliance on bought in feeds.

THE CHALLENGES/HURDLES FACED ALONG THE WAY

The greatest challenge has been convincing their Dad's to let Greg and Ian to implement change. To be fair Roger and David have given the boys opportunities to adopt change, but not without discussion and justification.

THE ESSENTIAL FACTORS OF GROWTH SUCCESS

One of the most beneficial/valuable things implemented on farm was the reduction of paddock sizes – allowing the management of smaller areas which has resulted in increased quantity and quality of forages. The system has remained simple but the operation has sufficient gear to ensure that they can control their own destiny. If pasture gets away on them during a flush they have no issues with cutting and baling silage from a single paddock with just 10 bales. Often it wouldn't be worth bringing in a contractor but with their own gear they have this added flexibility, allowing them to conserve high quality silage and maintain high quality pastures. That said, it is also recognized that there are times that it makes good sense to use a contractor.

WHAT WOULD BE DONE DIFFERENTLY IF THEY HAD THEIR TIME AGAIN?

There are no rights or wrongs – just different ways of doing some things. Whatever we do from here will improve our business, even though the Dad's create a level of resistance the family is never scared to try something new. In fact they are even happy to go back to more traditional practices if they perceive that they are the best fit for the operational objectives of the day.

One of the things the family is now working on is the fertilizer management/plan. Historically they confess that they haven't been particularly good at being proactive with soil testing and targeted fertilizer applications. It is perceived that there has been lost opportunity in this area and they are definitely looking to improve this aspect of the operation. The Heffernans know they need to look after the soils and they see that the number of earthworms is significantly improved with the reduction of ploughing. Greg in particular gets great satisfaction from learning more about soil health and investigating soil management options.

WHERE TO NEXT?

There is an overarching 'grand plan' which likely contributes significantly to the success of the Heffernan farming operation. They are proactive in setting goals and reassessing progress in relation to their targets. The first two stages of the 'grand plan' have been executed (reconfiguration of the paddocks and the upgrade of the dairy) and next on the 'agenda' is a mini-feedpad which will allow them to reduce silage wastage. This year they purchased a new tractor and ensured that it was big enough to tow mixer wagon that will be purchased sometime in the future. They see the need for this will arise as the quantity and quality of feed on the home farm improves – this will position the family to really focus on using the block across the road as a feed factory to support the milking operation. The more immediate objective is to improve the reticulation and location of stock water on the farm.

With the efficiency gains being captured in the dairy they find that they have a good 6 hour window each day where everyone is out of the dairy and the focus is put to development, paddock work and feed management. They have chosen to use those efficiency gains to really push for operational improvements across the system – keeping everybody busier than ever!!

VMS: A STEP FORWARD OR JUST TOO MANY MOVING PARTS

Wayne and Paul Clarke

Dobies Bight, Richmond Valley, Northern NSW

FARM DETAILS - PHYSICAL

Clarke Farm Details	
Farm Size (ha)	124 Ha plus 50 ha leased
Effective Dairy Area (ha)	95Ha
Milking Area (ha)	85Ha
Annual Rainfall (mm)	1150mm
Irrigation area (ha)	40 ha bike shift & 40 ha travelling boom
Dairy type	Herringbone 20 swingover
Herd	
Milking Cow numbers (incl dries)	365
Heifer numbers	160
Stocking rate (cows/milking ha)	4 cows/Ha
Breed	50 % Holstein Friesian, rest X-bred
Calving System	year round
Production	
Annual Milk Production (2013/2014)	1,663,429
Ave Milk Fat %	4.08
Ave Milk Protein %	3.21
Ave SCC (x1000 cells/ml) Average	170,000
Production per cow (L/cow)	4,557
Milk solids per cow (kg/cow)	332
Milk solids per ha (kg/ha)	1,332
Labour	
Labour inputs (FTE's – 50 hr. week)	4
Litres per labour unit	415,857
Kg MS per labour unit	30,306
Cows per labour unit	91
Nutrition	
Concentrate inputs (grain & protein meals – tonne/cow/year)	1.3 t/cow/yr. fed on feed pad

THE EVOLUTION OF THE FARMING SYSTEM

My brother Paul & I returned to the family farm at Casino in northern NSW in 1994. Three incomes from 64 ha, (12 of which is river bank) meant production per ha was critical & labour-saving equipment a distant second in those early days, a trend which has stayed with us through the years.

The transformation from a 120 cow farm to the current 300 cow operation came about as follows. A runoff block was purchased, irrigation was installed and a basic fodder factory created with silage grown and carted to the dairy.

An existing herd of 100 cows was leased, our heifers agisted, resulting in a doubling of milk production. A succession plan was put in place which saw our parents retire. The neighbouring 60 ha farm was put up for auction so the run off block was sold to pay for its purchase.

This was laser levelled and irrigation was installed. The leased cattle were gradually replaced with our own cows and the herd grown to 300 milkers. Meanwhile, the agistment was terminated so all replacements & dry stock were kept on farm. Another adjoining dryland property of 60 ha, planted to seteria has been leased in recent times, to complete the growth in land available for the enterprise.

THE OPERATION AS IT WAS

Typically we milk 300 cows all year round. The 45 ha of kikuyu surrounding the dairy (under bike shift irrigation), provides the basis of our grazing system. It gives us the resilience required to withstand wet and dry conditions. There is 20 ha of dry land seteria that is used to extend the summer grazing rotation.

In autumn the kikuyu is over sown to annual rye grass and a further 20 ha is planted to high density Persian clover and grazed during the day. In summer the same 20 ha is used to grow corn for silage.

We have always been interested in achieving high pasture utilization and make use of dry stock daily to graze pasture after the milkers to ensure residual levels are at the desired levels. As such a dedicated milking platform is not a focus of our management program, with more importance placed on whole farm management.

THE MOTIVATION BEHIND IT ALL

The twenty aside swing over dairy we currently use was built thirty years ago, originally as a 10 aside. It has been modified a number of times but in the end it is a time consuming, unpleasant place to be for the cows and us. It definitely has been the major source of inefficiency in terms of time and labour use, tying up 16 hrs of labour a day.

While we have spent considerable time and money upgrading infrastructure on the farm over the years, the act of replacing the dairy has for various historical reasons not made it to the top of the pile. Now, we have put up with its inefficiency for so long the thought of any conventional dairy isn't palatable when the robotic alternative exists. The added attractions include the reduced physical demands, especially given our workload in the past, the ability to be timelier in other strategic management practices and providing some flexibility about when we undertake them.

THE CHANGE PROCESS

The real change is the dairy. The installation of 4 VMS, with four smart gates allowing the cows voluntary access to three pasture allocations, as well as the existing feed pad. The knock-on effects start with our commodity storage shed, as it houses the new dairy.

In the past all grain was fed through the mixer wagon on the feed pad. So now we have chosen to mix our grain ration which has meant the purchase of the appropriate plant to mix, deliver and store the cows concentrate mix. We were lucky in that as the farm was well setup to accommodate the three way grazing system, some revitalising of existing fencing was all that was required. The only other change is converting the existing cropping area (20ha) to pasture so the cows don't have to walk so far, and swapping 20ha existing pasture at the extremity of the farm to the cropping area. The need for rejigging our calf rearing area is also a consideration.

DOING OUR HOMEWORK – THE DECISION MAKING PROCESS

Although the decision was possibly a forgone conclusion right from day one, before it was actually agreed upon and articulated, we went through a number of steps. The first was a complete review of the existing business, nothing was spared & considerable cost cutting was achieved with \$40k in ongoing savings identified.

The discussion was then begun with various AMS companies about what they had to offer and what level of service they could provide. At the same time we began reviewing all of the information put out by FutureDairy and talked to some of the people involved.

Next was visiting existing AMS farms in QLD, NSW, Victoria & Tasmania. We kept refining discussions with AMS companies and we then put together a comprehensive ten year business plan based on our own experience and the information we had collated.

After consultation with our accountant & bank manager, the decision was made to proceed. It was decided to fund the robots via equipment finance over a seven year period, as it suited both tax implications and was more feasible from a cash flow perspective. Costs of the building modification were funded through a bank loan.

THE CHALLENGES AND HURDLES (SO FAR)

There have been two major hurdles so far. Both were predictable but still onerous and difficult to manage. The first is making numerous decisions about a production system that you have only limited knowledge about and virtually no experience in; you have limited idea about the ramifications and won't know until things get going.

The second is trying to maintain the current production system while taking the time to do the necessary research and spending the time required implementing the project. It definitely has affected the timeliness of some of the current operating procedures and has come at an additional financial cost to the business.

ESSENTIAL FACTORS FOR SUCCESS

Whilst we are yet to actually implement the actual change to VMS and all sorts of scenarios are still racing through our minds as to what will or won't work, we are hopeful that the following will bias things in our favour.

Cows will be happier anywhere away from the old dairy and given the herd is used to being slightly under fed; has a 50% cross bred component of the herd; regularly move to three pasture allocations a day: normally walk 4-5km a day and have use of 5km of sandstone laneways, they should be able to traffic. We have access to a pasture metre for accurate feed allocation and the change to individual feed allocation for the concentrate ration should also help. In addition, a determination to do whatever it takes to make it work economically should help.

IF WE HAD OUR TIME AGAIN

While possibly a bit early to look back with total objectivity, one thing would be to decide on which AMS company we were going to deal with a lot earlier than we did. Deciding which one to use was possibly the hardest decision we had to make, but it definitely would have simplified the overall process. One other thing was the decision not to explore the option of solar power. The thought of adding another layer of complexity to the decision making process made us leave it alone. In hindsight maybe we should have pushed through the pain barrier.

WHERE TO NEXT?

In reality, we just want to get the show on the road, and see how it works on our farm under our seasons. Check out the upper limits, see what is and isn't possible and hopefully develop an operating system we are happy with in terms of risk management and being financially rewarding. Then we can look at our options.

FROM FOOTBALL TO DAIRY FARMING

Ian & Lisa Hindmarsh

Cowra, NSW

Hindmarsh Farm Details	
Farm Size (ha)	160ha
Mixed Beef/heifer rearing/silage	160ha
Milking Area (ha)	140ha
Annual Rainfall (mm)	600mm
Irrigation area (ha)	120 Ha Pivot, Solid Set & handshift. 487 ML, permanent water right
Dairy type	Herringbone 18 D/U rapid exit
Herd:	
Milking Cow numbers (incl dries)	330
Heifer numbers	270 all up, all running on the farm
Stocking rate (cows/milking ha)	2.4 cows/ha
Breed	Holstein- Friesian, Illawarra, Jersey
Calving System	Year round
Production	
Annual Milk Production (2013/2014)	3,200,222; 224,000kg milk solids
Ave Milk Fat %	3.8%
Ave Milk Protein %	3.2%
Ave SCC (x1000 cells/ml) Average	Average 110,000
Production per cow (L/cow)	8,500
Milk solids per cow (kg/cow)	595
Milk solids per ha (kg/ha)	1,600
Labour	
Labour inputs (FTE's – 50 hr. week)	5.5
Litres per labour unit	600,000
Kg MS per labour unit	45,000
Cows per labour unit	60
Nutrition	
Concentrate inputs (grain & protein meals – tonne/cow/year)	2.7t/cow grain & canola meal Maize silage, wheaten hay, Lucerne silage, cereal silage

THE FARMING SYSTEM

My intention from the start was to run the farm as a high input intensive feeding system milking up to 600 cows in freestall barns, growing most of the fodder under irrigation on the farm. We calve year round and feed cows a Total Mixed Ration on a feedpad. I am currently running two herds, with the fresh cows being milked 3 times per day. All the replacements are run on the farm, so stocking rate is high.

THE OPERATION AS IT WAS

We built a fairly simple rapid exit lowline herringbone dairy, with no feeders, able to be handled by 1 person. We built the feedpad beside it, but couldn't afford to build the freestalls at that time, so just have loafing paddocks nearby. I had accumulated 150 cows, and bought 2 other herds to start off. We used sexed semen and kept all the heifers, so built up numbers to 400 fairly quickly.

THE MOTIVATION BEHIND IT ALL

I grew up on a dairy farm in the Southern Highlands of NSW, and always had ambitions of running my own farm. My other interest was rugby league, which I played professionally for ten years. Lisa and I bought the farm in 2002 while I was still playing football; it was a Lucerne and fat lamb production farm. I finished my football career in 2007 and began the conversion of the farm to dairy.

The motivation was always there to set up my own farm; playing football gave me the means to do it. I love breeding and showing cows. I love the challenge of farming; I am very competitive and want to succeed with everything I do. Moving from the highlands to the central west gave me the chance to set up an intensive dairy system, and grow high tonnages of fodder.

THE CHANGE PROCESS

The biggest change for me and my family was moving from professional sport (I played in France for my last year), back into farming. From there, it was learning about farming in the central west, and setting up the farm to be as productive as possible.

DOING OUR HOMEWORK – THE DECISION MAKING PROCESS

I sought advice from Ian Lean to plan the new farm; we did budgets based on other feedlot systems in the region. When you are starting from scratch, you need to do your homework as everyone wants to sell you something.

THE CHALLENGES AND HURDLES (SO FAR)

Lack of water for irrigation – we hit drought in our first year and had zero allocation, so only grew 2tDM/ha. This blew our budget from day 1 as we had to purchase a lot of feed when hay was expensive. We have had 4 years out of 10 now with zero allocation. This changed my thinking on cow numbers, and I have reduced back to around 300 cows, and rely less on purchased feed.

Adapting cows from pasture based highlands to feedpad in hot, dry Cowra – we had a lot of environmental mastitis in the herd and lost quite a few cows. Adjusting the cows to a varied diet has also been a challenge; incorporating TMR with grazing on some days depending on what feed is available on the farm.

Growing ryegrass successfully has been a challenge, I have now given up on it and am returning the farm to Lucerne and crops for silage, including maize, forage sorghum, wheat and oats. I had originally set the farm up for rotational grazing, but couldn't get consistency of intake, so have reverted to a mostly cut and carry system with feeding a ration on the feedpad.

Finding and managing staff has been an issue, and is a limiting factor in being able to leave the farm.

ESSENTIAL FACTORS FOR SUCCESS

We employ a farm secretary to manage the accounts and meet with our bank manager monthly to monitor and review our position. This gives some rigour to keep on top of the business.

I am improving the infrastructure and bringing in protocols and systems to make it easier for staff to understand roles and expectations.

We always try to grow as much feed as possible from the farm with the water available, and purchase temporary water if it pays. I am constantly working out feed costs and comparing sources of feed. I have recently split the herd into two based on days in milk, and have started to milk the fresh cows 3 times a day and feed them better.

IF WE HAD OUR TIME AGAIN

The farm business has not been as profitable as I had hoped; you can't get the return that is commensurate to the hours and effort put in. Selling surplus heifers for export has helped maintain cashflow when milk prices have dropped and costs gone up; however feeding heifers to achieve the required growth rates is expensive.

If we had time again, I would have built the freestall barn at the start; I think it would provide better control and consistency over cows' diet and management. I would also have stuck to growing Lucerne and corn and not persevered with establishing ryegrass pasture.

WHERE TO NEXT?

The challenge now is to find the sweet spot in the business where we grow the right combination of forages that suit the farm and cope with the unreliability of water supply; and balance this with the right number of cows and milk production to minimize the reliance on purchased feed.

I am prepared to accept lower returns to achieve the lifestyle we want and have time with the family. We have two kids, Dakota aged 9 and Flynn aged 8.

GENOMIC SELECTION FOR ACCELERATED GENETIC GAIN IN DAIRY CATTLE AND PASTURES

Ben Hayes

Ben Hayes^{1,2,3}, Jennie Pryce^{1,2,3}, Zibei Lin^{2,3} and Hans Daetwyler^{1,2,3}.

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WHAT IS GENOMIC SELECTION?

Genomic selection refers to selection decisions (e.g. which bull to use, which heifers to keep) based on genomic breeding values (GEBV). The GEBV are calculated as the sum of the effects of DNA markers across the entire genome, thereby capturing the effect of genetic mutations that cause differences between animals or plants in key traits (such as fertility in dairy cattle, yield in pastures) (Meuwissen *et al.* 2001). To be able to calculate the effects of all of the DNA markers, a large reference population is required of individuals with both DNA marker genotypes and the traits of interest recorded (for example a large number of dairy cattle with good fertility records that are genotyped for 50,000 DNA markers). The DNA markers are in the form of Single nucleotide polymorphisms (SNP), which are genotyped with DNA chip technology. So a genotyping test that genotypes 50,000 SNP at once is termed a '50K SNP Chip'.

GENOMIC SELECTION IN AUSTRALIAN DAIRY CATTLE

In dairy cattle GEBVs are now being used to identify and market the best bulls in many countries around the World (Pryce and Daetwyler, 2012). The main advantage in using genomic breeding values comes because bulls with outstanding genetic merit can be identified and used early (two years of age), rather than having to wait for a progeny test (seven years of age). This reduces the generation interval and can lead to double the rate of genetic gain than conventional progeny-testing systems (Schaeffer, 2006).

The Australian Dairy Herd Improvement Scheme (ADHIS) calculates genomic breeding values (termed Australian genomic breeding values, ABVg) for forty traits, including fertility, survival, temperament, milk production, mastitis resistance and feed saved (a measure of feed conversion efficiency). ABVg are calculated for both Holstein and Jersey cattle. More than 1500 young bulls are genotyped per year, and those with the highest ABVg for Balanced Performance Index, Health Weighted Index and Type Weighted Index are published in the Good Bulls Guide (<http://www.adhis.com.au/v2/downv2.nsf/%28Permalink%29/BreedingValuesGoodBullsGuide-April2015?OpenDocument>). The reliability of the ABVg for these young bulls was increased significantly by adding 10,000 Holstein and 4000 Jersey cows to the reference population (in April 2012). These cows were from commercial herds and had excellent records for fertility and other traits. The addition of the cows led to a 4-8% improvement in the reliability of breeding values depending on trait. Reliabilities of ABVg for young bulls, with no daughters now range from 64% (production) to 40% (for traits like fertility and survival).

How well do these ABVg actually predict performance of a bull's daughters? Genomic breeding values (ABV(g)s were introduced in Australia in 2011. Now some of these bulls have daughters milking, so we can compare the performance of these daughters predicted by their sires' ABVgs, and their actual performance. If you selected the top 10 Index bulls using ABV(g)s in 2011, the group would have averaged a predicted \$254 index units (adjusted for base changes). It turns out that this group now averages \$195, based on their daughters performance for milk yield, fertility, and other traits in the index. In comparison the bottom 10 bulls started at an average \$115 in 2011 and now have an average of \$72 from their daughters performance. So the performance of the bull's daughters has lined up well with their ABVg before they had daughters. If we assume that the average number of lactations is around 4, then the difference in lifetime profitability between the 2 groups is around \$500/cow.

GENOTYPING HEIFERS

Genomic breeding values can also be obtained for heifers, in order to select those with the highest genetic merit to remain in the herd. The cost of genotyping heifers has been reduced by the development of low density SNP arrays (7K, 9K and 26K) (e.g. Boichard *et.al.*, 2012). These tests are now available commercially at a considerably cheaper price than the 50K SNP panel.

The benefit of genotyping heifers has been assessed in terms of the impact on rate of genetic gain through increasing the reliability of selection in female selection pathways (e.g. McHugh *et.al.*, 2011). Reliabilities of greater than 60% are now being achieved for many traits; this is equivalent to a cow with 3-4 lactation records and much higher than a heifer's reliability without genomic selection (e.g. parent average which is approximately 30% depending on trait).

We have investigated the cost benefit of genotyping heifers in a real Australian dairy herd. In this herd, thirty six heifers were genotyped at a cost of \$50 (approximately the cost of the current test). Twenty five heifers were selected on ABVg as herd replacements and eleven were culled or sold. Based on difference in the level of ABVg of retained versus culled heifers and taking into account the reliability of ABVg (after accounting for total cost of genotyping) per heifer retained was \$60.

In addition to genetic gain, there are several other reasons why females should be genotyped. This includes parentage discovery, avoidance of inbreeding, and avoiding mating carriers of genetic defects.

Genomic tools to discover the parentage of calves are now available with close to 100% certainty when the low density arrays are used and 99.5% certainty when more than 150 SNPs are genotyped on an animal and its sire (Hayes, 2011). Parentage discovery means potential parents do not have to be nominated; rather the calves' genotype is compared to a large data base (at ADHIS) of potential sires. Calves can also be assigned to its dam provided the dam has also been genotyped. Using genotyping to resolve parentage may be particularly useful for herds with large numbers of calves being born over relatively short periods, where it is often logistically not possible to work out the sire and dam of a calf. The value of this is likely to be in reducing stress and reliance on staff around calving when many calves are born over a short-period. This has been commercialised as the parentage discovery service offered by Holstein Australia.

Control of inbreeding is another advantage of genotyping heifers. Inbreeding leads to loss of performance, particularly for fertility. Pryce *et.al.* (2011) showed that controlling inbreeding using a genomic relationship matrix (built from the SNP data) could reduce the rate of inbreeding by 1 to 2% with very little loss in genetic gain in profit. However, pedigree did a reasonably good job as well, reducing inbreeding by around half the

amount obtained when using a genomic relationship matrix to control inbreeding when assessed on the genomic scale. Because pedigree information is 'free', the value of controlling inbreeding using genomic relationships rather than pedigree relationships is small and by itself does not justify genotyping females. A 1% reduction of inbreeding, valued at AU\$5 per annum or AU\$14.20 when discounted over four lactations can be achieved. More recently, we have found genomic regions, that when inbred, have an unfavourable impact on calving interval (a measure of fertility) of 7 days, which is 1 genetic standard deviation (Pryce *et al.* 2014).

For farmers using large groups of genomically tested sires, it may be difficult to manually work out which cow to mate to which bull i.e. avoiding matings between relatives. This could mean that computerised mating plans become more common. These mating plans could also avoid mating carriers of lethal recessive defects. Such defects include genetic mutations that lead to embryonic loss, including Holstein haplotype 1, 2, and 3 and Jersey Haplotype 1. The SNP which cause these defects have in many cases been discovered (Sonstegard *et al.* 2013, Daetwyler *et al.* 2014), and are now included on the low density SNP chips. Avoiding mating carriers of such defects is particularly important in ET programs.

To summarise this section, relatively low cost genotyping of heifers is now possible, in order to obtain ABVg for selection. The economic benefit of genotyping heifers depends on the proportion that will be retained on the herd, but if this is less than 60% of the heifer drop, the benefit is about \$60 net per heifer. Added benefits are parentage discovery, avoidance of inbreeding, and avoidance of matings of sires and cows carrying lethal recessive defects.

THE FUTURE OF GENOMIC SELECTION IN DAIRY CATTLE

Genomic breeding values at present are based on 50K SNP genotypes. These SNPs track the mutations affecting traits like fertility from one generation to the next; however this tracking is not perfect – only 60% of the genetic variation for fertility is captured by the 50K SNP chip (Haile-Mariam *et al.* 2013). Having the entire genome sequences of bulls may help to increase the reliability of ABVg further, as the actual mutations affecting the traits could be identified. The idea behind sequencing key ancestors of cattle breeds is that we will have the causative mutations in the data set, i.e. we will be able to capture more of the genetic variation in a trait. The 1000 bull genomes project has started with an aim to provide researchers with a large database for genomic prediction and genome wide association studies in all cattle breeds (<http://1000bullgenomes.com/>, Daetwyler *et al.* 2014). The combination of the sequence data, and addition of 30,000 more cows to the reference population (which is happening as part of the Info project run by the Dairy Futures CRC), should increase reliability of ABVg towards 70%.

GENOMIC SELECTION IN PASTURES

The genomic selection technology which has been so widely adopted in dairy cattle is starting to be applied to increase the rate of genetic gain in pastures. Forage grasses and legumes provide important targets for genomic selection, as many of the key traits such as yield, persistence and quality are difficult or expensive to assess, and are measured late in the breeding cycle. There are some considerable challenges in applying genomic selection to pastures, including massive genetic diversity, and the fact those traits such as yield must be measured in swards made up of genetically diverse individuals (measurements on single individuals in pots do not translate well into the field!). We have developed strategies for implementing genomic selection in rye grass which take these challenges into account (Hayes *et al.* 2013). We have applied

genomic selection at the cultivar level (i.e. less related than full and half-sib) in both simulated genomic selection studies, and now in real field trials. In the empirical field trial data and using genetic markers from candidate genes as well as a transcriptome-based genotyping-by-sequencing approach, the accuracy of genomic selection was moderate to high within cultivar for heading date but it was reduced for biomass yield (Daetwyler *et.al.* 2015). Our simulations of commercial perennial ryegrass breeding programs show that genetic gain per year can be at least doubled for moderate heritability traits (e.g. biomass yield) and significantly increased for low heritability traits (e.g. persistency) (Lin *et.al.* 2015). So genomic selection is a very promising approach for improving important traits in forages!

CONCLUSION

Genomic selection is leading to increased genetic gain in dairy cattle, through early identification and use of young bulls of very high genetic merit. Selection of heifers on genomic breeding values is also possible, with the cost-benefit depending on replacement rates. Extra value can be gained by genotyping heifers including parentage discovery, avoidance of inbreeding, and avoidance of mating of carriers of lethal recessives. Efforts to improve the reliability of genomic breeding values using whole genome sequence data are well underway. Genomic selection also has enormous potential for improvement of pastures, and results from early field trials are promising.

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FARMERS - CUSTODIANS OF THE LAND

James Walker

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Farm: Camden Park (near Longreach) and Wakefield (near Isisford)

Region: Longreach and Isisford, Central Queensland

Commodity: Wool sheep, agistment cattle

Farming area: 36,500 hectares

Rainfall: 150-380 mm per year

James Walker farms at Wakefield Station (western Queensland) 90 kilometres south of Longreach and about 90 kilometres south of the Tropic of Capricorn. Wakefield Station is approximately 60,000 acres, 240-odd square kilometres with core business of cattle and wool sheep.

The station was purchased by James' grandfather 66 years ago and with James taking over management 13 years ago. He predominantly lives on another property near Longreach.

The station is home to about 12,000 sheep but numbers do fluctuate quite a bit with seasonality. Generally there are about 4000 ewes and 5000 wethers. The ewes are joined in a large mob for rotational purposes but are dispersed into smaller mobs for lambing.

In addition to Wakefield Station, James also has Camden Park, 17,000 acres of open Downs country with predominant grasses being Mitchell, Flinders and a little bit of buffel grass. Currently, they have 4000–5000 agistment cattle on there for 3 months.

WORKING WITH WESTERN QUEENSLAND'S CLIMATE

The station receives about 17–18 inches (about 450 mm) of rainfall a year, but this varies between 5 and 40 inches, and that's just in James' time.

Such variation in rainfall creates a real feast or famine situation so that one year there is an abundance of feed and the next there are real feed limitations. Managing the feed supply in conjunction with climate and price signals is a skill in itself.

The station does get some frosts but it is recognised that significant problems would arise if there were heavier frosting.

Earlier in 2013, the station was exposed to 10 days in excess of 40 °C heat. The relentless heat affected grass quality, and wilted a lot of it.



If the station were exposed to a month of extended heat, all of the grass would be destroyed with all nutritional value being removed.

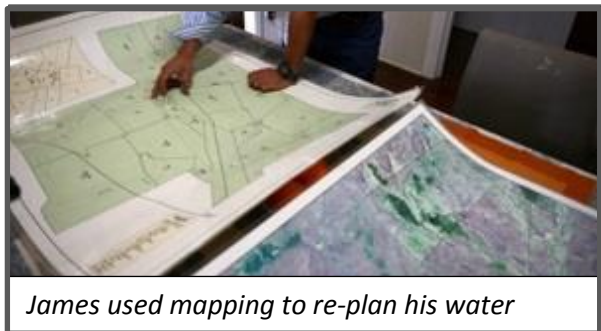
CHANGING MANAGEMENT PRACTICES ON FARM

Three key management practices have been changed with James' management of the operations. These are outlined here:

Reducing distances between feed and stock water

Wakefield Station and Camden Park both used to operate with traditional grazing and watering systems. Livestock had to walk in excess of 5–10 kilometres (away from water) to eat. This has all been changed and now the furthest distance between water and feed is 2 kilometres which has resulted in much improved animal health.

At Wakefield, there are permanent surface water dams which were the only livestock watering points. Traditionally, at the start of the season all the dams were full, but towards the end of the season the water quality had diminished significantly which affected livestock wellbeing and performance. To add to low water quality, the cattle were walking in excess of 2 kilometres from water to feed. This resulted in them expending any energy they had ingested (through foraging) to walk back to water.



James used mapping to re-plan his water

When James took over the management of the station he drew 2 kilometre–radius circles adjacent to each other on a property map.

Then through the circle centres, he drew a line which was to be the 63 kilometres of poly pipe that was needed to accommodate the 2 kilometre–spacing.

Now, the livestock drink and graze in relatively close proximity. When the feed in the vicinity of a watering point is depleted the livestock are rotated to the next 'watering point'. This has resulted in a dramatic increase in the useable acreage. From a central point, the water is reticulated through two loops, which creates more volume and pressure of water for the livestock.

The 75 mm polypipe goes for 20 kilometres in one direction and 45 kilometres in the other. In total the 65 kilometres of pipe holds 0.4 mega litres - the equivalent of over 1.1 million schooners of water (in university terms).



This is the central point for Wakefield's water reticulation

Fencing to manage grazing density and pressure

Since James took over the management of Wakefield (over 13 years ago), they've done 42 kilometres of internal fencing and 43 kilometres of boundary fencing.

They fenced off the creek system so that the grazing density and pressure can be altered throughout the year. Taking stock off the creek systems when they're vulnerable and putting them out into open grazing areas prevents them hugging the creek systems and the associated destruction.

The outcome has been really rewarding; checking all the water points used to take 2–3 days to check all the water points, but now with the water run it can be done in 2–2.5 hours.



Rotational grazing to repair pasture

A lot of people set stock – particularly in the beef and sheep industries. Set stocking requires forecasting to match stock numbers to times of lowest pasture quantity and quality. Often decisions are made as much as 8 months in advance – trying to pre-empt feed levels to allow decisions to make on stocking levels.

The strategy at Camden Park is to put agistment cattle on for 3 months (about 4000–5000 head). When the stock comes off, the country repairs itself. Stock is bought on when the feed is most abundant; at the end of the season there won't be as much feed available. In practice, they say, 'We've got good feed and good water, so we're going to stock it to the hilt, manage that feed to a set level and then take the cattle off.'



Cattle at Camden Park (Left)

USING FORECASTS FOR PROFITS

The semi-arid region creates an ebb and flow; a boom and bust cycle, for the operators. The more information James can get on rainfall patterns and potential forecasts, the better he can manage his business and the more money he can generate for the economy.

Last year as a part of the Climate Champion program he learned about the dynamical forecast model called POAMA. He'd never been exposed to it before, and believes that in farming many operators are guilty of not cross-checking forecasts in the medium-to-long term.

In western Queensland there's no consistency in rainfall patterns; it is so sporadic. There's no system that can be truly banked on. To make informed decisions they have to look at shorter dynamical modelling.

Last year James noticed, for his region, that POAMA was in a neutral pattern with no strong conviction either way for rainfall. If it became a positive pattern, that would be fine, but James needed to make decisions based on the information he had at hand at that time.

Because it was neutral, the probability of a significant negative pattern was relatively high. James knows from experience that if it swings to a down side, there's a fairly steep slope where feed, grass and water reserves can be depleted very quickly.

James took the decision to sell down most of the cattle in their enterprise. They actually did end up getting the rain, but most of his region and most of north-western Queensland didn't.

The outcome was that whilst everybody else ran out of feed and flooded the market with 'forced' stock sales or agisting out cattle. James was in a position of having an abundance of feed and he avoided the loss in capital with the livestock enterprise. This was the first time that such a big move had been made based on forecasting. The fact that the James was using dynamic forecasting (in conjunction with other indicators) – rather than historical modelling gave him the confidence to action his decision and come out with a 'win'.



James knows that a lot of farmers just won't buy into the concept that you can predict rain, but he believes that the POAMA modelling and the work that the Bureau of Meteorology are doing is getting more and more refined and polished. Having faith in the technology made a big difference to the profitability of the enterprise profitability through allowing James to make informed decisions based on the climate and what those forecasting models showed him at the time.

The climate has always been variable, and I think we're already managing for it. In terms of managing climate change, it'll be a progressive change over many years.

LEADING ADAPTATION IN SEMI-ARID REGIONS

James knows that they really have to be on top of climate management to successfully manage the enterprise. The one factor that varies in their business is rainfall and it's a very important aspect of the business to be able to manage that.

James spoke after a senior climatologist at the University of California, Berkley, in 2012 who said that when rainfall shifts closer to the poles and high temperatures increase in farming areas, it's going to make all current farming operations, as they stand, unviable and the practices will have to alter.

However, James believes that farmers are a lot more adaptive than the climatologist suggested. Farmers change their practices now (inter-seasonally reacting to price signals, and overnight to adapt to technology, policies and markets).

Semi-arid regions are already at the forefront of managing climate shifts because they are already so accustomed to the huge variances in rainfall experienced from year to year.

Climate change will be an evolution. It'll not catch people by surprise and, least of all, farmers. Farmers are very resilient and James truly believes that they're already adapting to it under the terms of commercial enterprise.

DIVERSIFYING ENTERPRISES

One of the keys to success of James' enterprise has been diversification, and it's probably different to most other farmers as they like to trial and research innovations.

If they get a price signal on a particular commodity or a particular innovation they'll look at it very seriously and adapt to change. They explore all those opportunities, adapt, and just keep an open mind; he believes that's what you have to do when you're in farming or agriculture.

- James has had crossbred **sheep**. The area out here is traditionally a Merino wool-producing area. They're into meat sheep that don't require shearing as a low-maintenance, low-labour measure.
- They've tried exporting sheep to South-East Asia but 5 years ago they moved back into Merino sheep for the **wool**. They did that because when it's dry, getting wool off sheep is a surer guarantee than the production of a calf or a lamb.
- **Cattle** have come in the last 10 or 15 years as a fairly big industry for this area.

- The development of **infrastructure for water** was aimed at improving the security for the animals, and increasing their health because they've got access to better feed and also better quality water at the end of the year.
- Another innovation is a little bit of **tourism** - showing people the systems out here, and educating them on what we do and why we do it. It's very rewarding.
- Another diversification is **hay baling**, capturing the opportunity of the abundance of grass while it's there.
- The **intensive (short-term) agistment** is another diversification for the enterprise. Stock consumes the feed while the grass is still in its ripening stage but are removed before the grass is wilted. By enlarge destocking occurs prior to the end of the year.



Baled hay (Left)

Making hay to manage drought

One of the more recent innovations is haymaking with native grasses. They've been doing it 4 or 5 years now, and it's a big part of the business. The returns are comparable to cropping, or 8 times the return in cattle or sheep for the acreage.

You have to have the right land type, contractor to do the work and shed storage to do hay.

During a period of feed abundance 5 years ago James decided to baling 'a bit of hay'. By the end of the first year they had 10,000 baled and sold. Now they're into their fifth year, and they've sold about 60,000 bales.

They make sure the contractors leave enough grass in the system to keep the plants healthy. Baling is typically done in the middle of the wet season which allows the plants to regenerate if there's rain during the wet season. In March of 2015, after hay had been made they were almost in a position to bale and harvest as a result of receiving 6 inches of rain. In this case though the decision was made to preserve the grass for livestock.

Making hay allows the enterprise to manage the abundant feed when it is available, to harvest it in good seasons, and to secure a bit of cash and capital for periods of low cash flow through a drought. In agriculture and managing climate variability James knows that a lot of outsourcing is necessary if they are to be in a position to harness opportunities that come and go quickly. This means that the lack of labour or skill base doesn't limit them with these opportunities.

ESTABLISHING BIODIVERSITY

Ideally, James' country would be naturally occurring, lightly shaded grasslands. The different trees that establish when endemic gidyea scrub (*Acacia cambagei*) is removed are highly valuable because they create micro-ecosystems and biodiversity.

With a bit of lateral thinking a lot of different habitats for animals and creatures can be created; there's a whole heap of activity happening in there and it also improves the soil quality.

For instance, in some places, the scrub is thick and the ground is bare underneath it. When rainfall comes, it hits the ground and sheets off, creating erosion. It could be an option to clear strips of scrub to create a different habitat between the tree lines. It'll take a while for the grass to establish because the soil is so barren of seeds but it will happen over time.



CONTINUING LONG-TERM SUSTAINABILITY

James sees farmers as custodians of the land. He believes that every farmer has a responsibility to leave the land for the next generation in a condition that is at least as good as it was received in. He knows that his grandfather would look at what they've done and wouldn't be able to believe it. He is confident that they are going to leave it in an enhanced state.

James looks forward to the day when the connection happens for the general public. He would like them to realise that farmers manage the land and animals looking at long-term sustainability and preparing it for the next generation. He knows first-hand that taking a long-term sustainability approach is in the best interests of the enterprise. If they take too much out of the soils, the ecosystems or even the livestock this year, their enterprise will suffer the following year. It's all a 'balance for abundance' in this game.

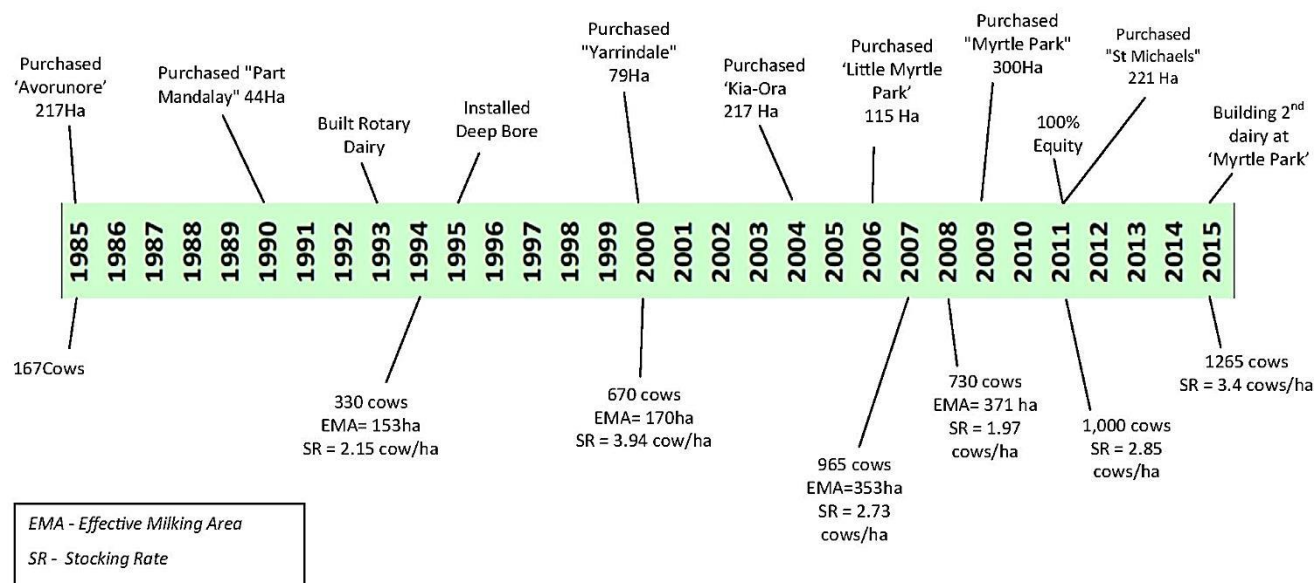
Whilst James believes that successful farmers are good custodians he also knows that they don't feel compelled to headline their sustainability, they just sort of get on with it, and although it's a buzz word in corporate and commercial spheres at the moment, sustainability is just part of 'normality' for them.

James has been awarded the Central West Industry excellence award for Sustainability for his development with Wakefield Station. In 2012 he was awarded a Nuffield scholarship and is continually improving sustainable agricultural management for stakeholders founding Agrihive.com and Agrihive.org. In 2015 James was chosen to attend the Challenge of Rural Leadership in the UK after founding the 'Big Night Outback' - CEO Business Summit and is connected with extension for Agriculture through inventing initiatives including the Kidworth Case Study Competition, the CEO Dairy Business Summit and developing tools and initiatives to improve financial literacy in Agriculture in Australia and Internationally.

OUR JOURNEY OF GROWTH

Ruth and Neville Kydd

*It all depends on us – if we want to achieve something it's up to us to make it happen.
It won't happen unless we make it happen.*



Neville started as an apprentice and moved into share farming before buying our own farm. I was nursing and milking cows on days off. We couldn't afford to buy in Gippsland so we moved away from our family to somewhere we could 'nearly afford'.

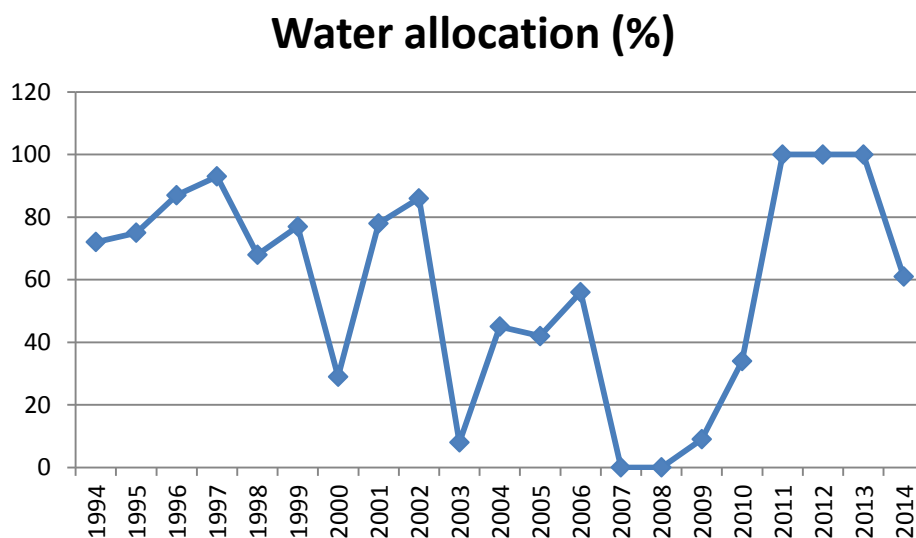
We purchased a rundown irrigation farm at Finley in 1985 with 40% equity. We could see that the farm had potential to allow us to grow the business. We dreamed of milking 250 cows doing 250kg of fat/cow.

Since then we have grown to 1260 cows doing about 500kg solids/cow and 7 million litres/yr. in a pasture based system with 1.3 t grain fed per cow. Production per cow is not high but our aim is to make an overall profit; to maximise the difference between milk price and expenditure without compromising our long term sustainability. Managing pasture is the key to our system.

We run a seasonal calving, three-way crossbred herd which cope well with the distances they have to walk and are a hardy and economical cow for our farm, not too heavy on the clay based soils, low cell counts, high fertility and generally 'tough'. We have bred for high fertility, easy calving, low cell counts, easy milking and good temperament. Breed is not important to us. Maintaining premium quality milk throughout the year is critical. The three-way crossing gives us the benefit of the hybrid vigour and a simple breeding system.

Over the years through the benefits of the challenges that life imposes on us like droughts, floods, interest rates and changing government policy we have learnt to be prepared and to be flexible. We like to keep at least 12 months-worth of silage stored on the farm so that we don't have to purchase feed at high prices. We know storing silage is expensive but it gives us the confidence to plan ahead and removes the risk of having to purchase feed when it is simply not profitable. With an average of 425 mm rainfall we are heavily dependent on our irrigation scheme as part of our feed cost. Our allocation is decided on an annual basis

and if it doesn't rain in the mountains we don't have water. The graph shows our historical water allocations over the past 20 years. We need to be flexible to manage such a volatile commodity.



We are not particular about how many cows we milk. If the sums don't add up we will sell cows or choose to take a production cut to achieve long term viability. Having a high fertility rate allows us to rebuild numbers quickly when seasons permit.

We have been completing a comprehensive annual analysis since 1994 so we can compare our performance from year to year and to monitor for any trends that might be creeping up on us. Brian Crockart analysed our data for a project for the Future Ready Farms project and Peter Havrlant has updated the info for the last few years.

Our two sons work in the business with us and we employ another 3 full time staff and 2 part timers. We use contractors for silage making, some fertiliser applications; weed spraying, land forming etc. The staff is mostly back packers or agriculture trainees wanting to gain experience. We try and fit the job to the person. Steven is a mechanic so he does all the mechanical work on the farm and a lot of the tractor work, Daniel is really good with the cows and pasture management. The staff starts with milking and are then given more responsibility as they prove their interest and skills. We encourage them to do any training they want and we attend most industry initiatives in our region.

In 1996 we did an Australian Institute of Management Course. This gave us a better view of our business and taught us that if we want something to happen we have to make it happen. If we want to be profitable it's up to us to make it happen. We have to learn the skills, do the research and analyse the figures on every part of our business to make it profitable. We do lots of mini budgets to analyse the cost/benefit of each decision, full budgets on big decisions and annual analysis. The benchmarking gives us a good comparison of how we are going compared to ourselves but it is retrospective; budgets are used for looking forward.

We are in the process of building a new dairy on the Myrtle Park property. We are concerned that the stocking rate is getting too high on the dairy farm and that it is putting too much pressure on the cowshed, laneways, cows and staff. It makes us vulnerable. Also to get a good return on the money we have invested in developing the property, we need to get a better return than just grazing and fodder production. We are hoping to build an economical dairy which will pay for itself in 5 years. With the insecurity in the water

market we need to make sure we don't over capitalise our investment and ensure that we have options if we can't secure enough water to run the farm as a dairy farm.

Building relationships with our suppliers and other dairy farmers is critical to our business. Their support, understanding and commitment to our business helps us to be successful and in-turn we hope that they will be successful. We also have many dynamic dairy farmers in the area that support each other, all operating different businesses but sharing knowledge for the betterment of the industry.

Living at Finley has many challenges but it has allowed us to grow our business so we can have our sons and their families work with us on the farm and to live the lifestyle we choose.



TALKING TO YOUR CONSUMERS – NAVIGATING THE FEAR OF COMMUNICATING WITH THE ‘ENEMY’

Ann Burbrook

Concise Communication

How do you speak to your consumers?

How do you find a common language?

How do you navigate your way through the difficult conversations?

How do you find common ground to discuss the issues that can make a difference?

The extraordinary Charlie Arnot, the founder of CMA says... ‘If you are not prepared to show what you do, then maybe you shouldn’t be doing it.’

The question is... how does that apply to us in Australia? How does this apply to you as farmers and producers? In a climate where animal rights issues, food pricing, organics and GMO products, to name a few, can influence the way our customers choose and buy their food, how do you step into the conversation and who should you talk to?

How important is transparency and gaining trust? What do consumers need to know in order to make the ‘right choice’? And should you even bother trying to engage with them?

The Australian television industry is a prime example of an industry that forgot about its consumers. That industry decided its consumers were too stupid to want intelligent, challenging productions on their television each night. Instead the industry provided a diet of light weight programs, reality TV, current affairs shows with no moral fibre... and what has been the consequence of these decisions? You only have to look at the popularity of Netflix to realise that viewers are quite capable of voting with their feet... or in this case their remotes.

We ignore our customers at our peril. If we don’t respect them, if we don’t engage with them, if we ignore their values and issues then we can’t be shocked and surprised when they turn away from us.

We can no longer avoid having the conversations with our consumers. With the divide between the rural and urban landscape ever shrinking we need to accept that farmers and consumers now live on each other’s doorsteps. We are neighbours, and as such, we are able to peer into each other’s backyards and see what’s going on. Coupled with this is the fact that information now travels faster and further than ever.

There can be no more secrets. There can be no more spin. There can only be open, respectful discussion and debate.

Farmers, producers and consumers can all share the same discussions... but if only we make the effort to learn the same language.

‘YOU FEEL BETTER KNOWING IT COMES FROM A BETTER PLACE’: UNDERSTANDING AUSTRALIANS’ ‘ETHICAL’ FOOD CHOICES

Dr. Heather Bray

*Department of History, School of Humanities, Faculty of Arts
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Australians appear to be considering the ethical implications of their food choices at an increasing rate. The rising sales of ‘organic’ food, new product categories within supermarkets with ‘higher’ standards of animal welfare, and the growth of farmers markets selling locally-produced food are all seen as indicators that consumers are ‘voting with their dollar’ for more sustainable and ethical ways of producing food.

But are they really? And what is ethical food anyway?

Ethical food refers to food that is produced in a way that is ‘better’ than conventional food for others who count morally. These moral others are not ourselves and families, but may be other people, communities, animals or the environment.

Within the marketplace, ethical food has become synonymous with categories such as organic, locally-produced, sustainable, humane, fair trade etc. Our interest in these categories is not whether the claims of being ‘better’ are actually true, but more in how consumers think about these categories, why they buy them (or not), and what ethical might mean to them.

For most ethical food categories, Australia seems to be about midway between the EU and the USA. We have much lower rates of vegetarianism than in the UK, for example and have very high meat consumption rates. Organic food sales are still relatively low compared with the UK. Our attitudes to genetically-modified food appear to be midway between the EU and the US. We are a multicultural, highly urbanised nation, with food insecurity and obesity simultaneously affecting sectors of our population. We have low levels of agricultural literacy among children and adults.

Our research was undertaken in Adelaide over the last 3 years using focus groups and interviews with consumers. We used qualitative approaches where we recorded what people said and then analysed the text because we are more interested in the deeper, richer data this generates than surveys that give percentage agreement with statements. With this approach, researchers use ‘saturation’, the point where we just hear the same things over and over, as an indication that our findings are representative.

Our findings suggest that there are a range of reasons why people may choose to buy an ‘ethical’ food over another, and that many of these don’t relate to being ‘better’ for that moral other. For example, many consumers told us that the products were better quality; they were ‘fresher’, tastier and more nutritious than other foods.

Local food in particular was more likely to be chosen because of concerns about food safety and hygiene or to support local businesses (arguably an ethical choice) than about the reduction of greenhouse gas emissions due to food transport.

Overall ethical food choices seem to be fluid and flexible: people will choose ethical in some circumstances and not others. Even those who create rules for themselves find that at times they do not make the best 'ethical' choices given the complex of reasons associated with food choice ways to break them. And people with lower incomes found it difficult to shop ethically, even if they felt they should.

It does seem that the assumption that people are choosing ethical food to vote with their dollar is narrow at best and that ethical consumption is a complex issue.

BUILDING TRUST IN OUR MODERN FOOD SYSTEM

Greg Mills

B.SC. Dip. Sc. Ag. MAIA

Food Integrity Solutions

In Jan 1988 Time Magazine made the bold statement on the cover; '*1968 - The year that shaped a generation*'. Both Martin Luther King, Jr. and presidential candidate Bobby Kennedy Jr. were assassinated in '68. Both in the United States and in Australia the Vietnam War was the first televised war that brought the realities of war into our homes and protest onto our streets.

While 1968 may not have been a precise date, or maybe the year was different for Australia, but the changes which started in this era can be seen in the social environment in which agriculture finds itself today. The camera on the battlefield in Vietnam and the new style of reporting brought people onto the street and the respect of government changed as it became the norm to question the status quo.

As people took to the streets and the media became more questioning, the authority that was granted primarily by office and your position was eroded. Where once society saw government as the final arbitrator and decision maker it was people that could build relationships with the community that gained power as people felt more empowered to question the government decisions of the day.

The community held the view that progress was seen as inevitable before 1968, this became more questioning and progress was now seen as possible. The community no longer had a single social consensus, and a great diversity of views from many voices was becoming the norm. Communication that was formal and indirect moved to become more informal and direct with the evolution of 'masses of communicators' rather than 'mass communication'.

As we now move forward 40 years the changes started in the sixties continue to gain momentum. In 2006 we saw Facebook® and Twitter® appear in the communication landscape. Now everyone has both a camera and a television screen in their pocket. Anyone can now start a conversation, comment on an issue and input their perspective independent of government and the mainstream media. Agriculture now finds itself in a world of activism, extremism and a consuming public who can get information from an almost infinite number of sources.

No longer does the government alone dictate agricultural practices through legislation, regulations and codes of practice. Once we would have seen long consultation processes run by government with wide representation and public comment periods and long implementation periods for industry to adjust to the changes. Now the supply chains can respond to public pressure in board rooms, making decisions impacting on farmers with limited if any consultation. While agriculture must continue to lobby and build relationships with government, the decision process now prevalent in our modern food system means that farmers need to personally play a greater role in the new conversation about how food is produced.

Over the past 40 years, we have seen consumers dramatically change their attitudes about food. What started out with trust and respect for farmers has now morphed into a growing hatred for 'big food' and fear and questioning of modern farming methods. While people trust farmers, they are now not sure what we

are now doing is farming. The solution is often that we need to 'educate' consumers about where their food comes from. When the reality is that our typical consumer is busy, does not want to be told how to think and food is always on the shelf so there is no need to know how food is produced. It is irrelevant to them. The front of mind issues for most consumers revolves around financial security and other family issues. Whilst some consumers show great interest and many show interest on specific topics or products, few consumers have the time or inclination to be educated about modern food production. It is only when issues are brought to their attention that food issues become front of mind for most consumers.

Whilst consumers do not want to be educated they do want to have their questions answered openly, honestly and transparently when they arise. Consumers want to engage in a conversation when they have questions. If a farmer is not available to answer the question or provide relevant information there is any number of organizations who will provide their interpretation of the issue. Consumers questions create a vacuum that will be filled at the speed of Twitter®.

Like a camera on the battle field in Vietnam was a catalyst for change in the sixties, social media can be seen as the camera on the battlefield of modern food. If we are to create an environment where agriculture and food can grow, prosper and remain competitive in a global market, farmers need to engage with consumers, where they are, when they have questions. If we are to renew the trust once enjoyed by agriculture and the food system, farmers need to promote their practices and be willing to be fully transparent and take every opportunity to engage with consumers.

We often forget how little our friends, family and local community know about what we do and why we do it. Once we would have relied on government or our industry bodies to deal with the public while farmers got on with farming. The new discussion about our food system will rely on farmers playing a new role in this discussion.

The new discussions of food often happen on social media. It is increasingly important for farmers to build a presence on social media platforms and not leave it to our detractors to answer our consumer's questions. But simply setting up Twitter® or Facebook® and arguing with activists is not of any assistance to building trust in farming or helping engage with the real consumers of our products. The key interest of consumers is often not the facts or the science of agriculture but a desire to know that there is a trustworthy farmer who is producing their food who has the interest of the consumer, their animals and the planet at the core of its values.

Launching into the online world can be daunting for many farmers, but it is now critical that farmers become involved and stop other people telling our story. Training opportunities are increasing for farmers to learn how to build a social media presence. However, a social media presence is as much about knowing when and how to engage, and more importantly when not to engage.

The rise of social media means that farmers now need to decide who they would like to tell their story. There is no doubt the story of farming will be told, the question is who will be the storyteller.

PERFORMANCE IMPROVES WHEN YOU KNOW WHERE YOU STAND

Neil Lane

Dairy Australia

Twelve months ago two good mates took up golf. I caught up with them separately a few weeks later after a recent round and asked them both how the golf was going.

Friend number one said he enjoyed being outside and whacking the ball down the fairway. He loved going to the driving range and hitting a bucket of balls with the driver.

'How did you go today?' I asked.

'Really good,' he said, 'I had a great time.'

'What did you score?' I said.

'Oh I don't keep score,' he said.

'Ok,' I replied a little puzzle.

Friend number two used to give me the same answers until I asked him about his latest round.

'90 shots off the stick which gave me 34 stableford points which meant I missed out on winning the comp by two points,' he said.

But then he pulled out his scorecard and continued.

'I hit my driver really well today, long and straight, but my putting cost me. I three putted five times so I've got a lesson booked in as well as a couple of sessions on the putting green.'

These conversations have continued over the past 12 months. However, one friend has dropped his handicap to single digits through practising the weaker parts of his game while the other still enjoys the walk but wonders if he is getting better or not at the end of 18 holes.

The question I have now is when it comes to dairy farming and running a dairy farming business, which one of the golfers do you most resemble?

There is no right or wrong in this discussion, yet the golfers had little more than their time at stake.

If your aim in running a dairy business that you really enjoy is to stay in business, not go broke and ideally grow sufficient wealth over the journey, then keeping score and focussing on all parts of your game will increase the chances significantly.

This is where Dairy Australia's new farm business management tool DairyBase comes into play.

DairyBase is a web-based tool that enables dairy farmers to measure and compare their farm business performance.

It helps farmers analyse the resources they have and the way they are using them. Through comparative analysis it allows farmers to track their own performance over time and compare with other similar farms according to factors such as farm size, region, production system, and rainfall/irrigation availability.

DairyBase enables farmers to:

- Compare their own farm business over time
- Create annual reports and forecasts
- Identify opportunities to drive profit and reduce risk
- Make more informed business decisions
- Generate benchmarks according to farm size, region and production system

The key benefit of DairyBase is that it gives farmers and their advisors the information and analysis they need to have well-informed discussions about farm performance.

It's about having a better understanding of the numbers in the farm business particularly how the physical aspect of the business relates to the financial.

By using DairyBase and knowing the business a farmer can then discuss topics such as achieving short and long-term goals, opportunities to improve operations, whether their farm expenses are in line with similar farms and what decisions need to be made to improve their position.

Visit dairybase.com.au to find out how keeping score on your farm can shed light on your performance.



DairyBase Q&As

What is DairyBase?

DairyBase is a new web-based tool developed by Dairy Australia which aims to:

- Provide dairy farmers with a tool to enable them to measure their annual business performance and compare their business – against others and themselves over time.
- Provide dairy farmers, service providers and industry with a national database of Dairy Farm Monitor project (DFMP) data and other datasets from other Dairy Australia funded activities consultants and other service providers.
- Standardise terminology used in physical and financial reporting within the dairy industry and to ensure consistency in calculations and terminology to describe Farm Business Performance.

DairyBase will allow farmers and their advisors to have a better understanding of their business so they can identify:

- › Opportunities to improve their business
- › The strengths and weaknesses of the business
- › What decisions can be made to reach goals and targets

DairyBase is NOT a cash flow tool - it is a tool that provides an annual assessment of farm performance based on real data entered by farmers and or their advisors.

Why use DairyBase?

DairyBase is a free web-based tool which will equip dairy farmers to better understand the physical performance of their farm – Cows, Feed, Labour and link it to the financial performance – Cash, Profit, Wealth. DairyBase will provide the industry with access to a national database of accurate physical and financial information.

Dairy farmers will be able to measure their business performance over time providing the evidence and measures needed for budgeting and planning

Dairy farmers will be able to compare themselves against the Dairy Farm Monitor Project (DFMP) industry data

DFMP data will be able to be filtered based on a range of factors, such as farm size, region, feed input level and other farm system drivers allowing a 'like for like' comparison.



To find out more visit dairyaustralia.com.au/DairyBase

When will DairyBase be available?

DairyBase will 'go live' on 25 May 2015.

How much does DairyBase cost to use?

DairyBase is a free tool provided by Dairy Australia for dairy farmers and advisors.

How do I access DairyBase?

Dairy Australia has created a website dairybase.com.au which will include:

- › The DairyBase Login
- › DairyBase User Guides
- › Contact details for further support if needed
- › Farm Business Management information and resources
- › News and snapshot data derived from DairyBase analysis and research.

What will I see when I first log in?

When you first log in to DairyBase you will be asked for information that will establish you as a user and provide the information needed to allow you to securely access DairyBase. This is only required on the first occasion.

A 'how to get on to DairyBase' guide will be provided at dairybase.com.au

What kind of device and web browser can I access DairyBase from?

DairyBase is a web based tool that you can access from your computer, laptop or tablet. DairyBase works well on Google Chrome for Windows computers and Safari on Apple computers. Alternatively, DairyBase will work on the latest Internet Explorer Browser version (IE 11) and the latest Firefox version (35.0.0).



How easy is DairyBase to use?

DairyBase is straightforward for people with a reasonable level of computer skills who are used to working with on-line tools. It provides a user friendly web-based interface for data entry, data editing and report generation. An Excel data entry spreadsheet is under development and will also be available.

DairyBase includes two key sections:

- › Physical data: Land, Livestock, Milk Production, Feed, Fertiliser, Water, Labour
- › Financial data: Income, Variable Costs, Overhead Costs, Finance and Capital Costs, Assets and Liabilities

I'm worried about privacy around my personal information, can you reassure me it's safe?

Yes, user privacy and data security has been a primary objective of the DairyBase development and is assured. The following points are relevant to the question of privacy and security.

- › No private user data will be made available through the DairyBase website – all benchmarks will be based on Dairy Farm Monitor data
- › All data entry, retrieval and reporting will be done behind a secure login
- › There is no private user or farm information kept in the DairyBase database (name, address, and other detail identifying users or farm location will be kept in a secure database "Salesforce" controlled by Dairy Australia)
- › Users can set the privacy levels of their Farm Datasets to:
 - Completely private (no access to any unapproved person)
 - Private but available for use in industry data aggregation (farm benchmarks)
 - Available for use in Dairy Australia approved research projects
- › Users control who has access to the farm data sets they have created
- › Farm owners control who can see and assign farm data to their farm.

What information do I need before I begin?

You need your farm financial information, your profit and loss from your cashbook and your farm physical information such as land area, cow numbers, milk production, irrigated water costs and feed quantities used/purchased and costs.

How long does DairyBase take to complete?

Like all things, the more prepared you are, the quicker it is. If you have a full set of data to enter it should take one to two hours. However, you do not need to have a complete set of data to get started and you will be able to see some results if only partial information is available.

To find out more visit dairyaustralia.com.au/DairyBase

Can I complete a DairyBase analysis by myself or do I need expert help to input the information?

Anyone can enter the data into DairyBase. Although you might work with your advisor or other support to work with DairyBase. You can also give permission for your farm advisor or accountant to upload your data into DairyBase.

Is there any training or support available to learn how to use DairyBase?

Yes, Dairy Australia has been working with Regional Development Programs in all regions to provide the capability in each region to support farmers. Over the coming months there will be information provided to farmers, and also to discussion groups.

If you want help you can contact your Regional Development Program to look for support activities in your region. Contact details for Regional Development Programs can be found at dairybase.com.au where you can also find the DairyBase User Guide.

Can I enter my data retrospectively?

Yes, you can enter historical data.

I've done similar analysis in the past, can I take my data across from those analyses?

We are working toward being able to do that. If you have been a part of the Dairy Farm Monitor Project or Queensland dairy Accounting Scheme your data will be part of DairyBase.

I'm entering the data myself and I'm having trouble what can I do?

Go to dairybase.com.au – it will have options for support available in your region.

So, I've entered my data what happens then?

The DairyBase program allows you to develop reports based on your farm information. It will allow you to compare your own performance over time. You can also select various parameters to compare your farm versus other operations.

DairyBase gives you the questions that should be asked about your business and equips you to gather the evidence needed to find answers.

Should I benchmark?

Benchmarking against other farms is a way of getting a better understanding of your business, however, benchmarking is always limited by the fact that every farm operation and farmer is different, not to mention the conditions different farms are operating with.

Are there resources to support DairyBase?

Yes there are a number of resources on dairybase.com.au

What is the best time of the year to complete DairyBase?

The best time is when you are planning for the next season. For many farmers this is June or July given it is a time when farm financial information is being finalised in many cases. Good data collection throughout the year will help make this an easy process.

Why should I choose DairyBase over another benchmarking tool?

It's free and easy to use, flexible, offers a database of past and present data, gives instant results and is a new industry standard. It also provides the chance to compare against Dairy Farm Monitor Project data, which provides very high quality data.

Is Taking Stock still available?

Taking Stock was a process of review that included a tool for collecting farm performance information. DairyBase follows the same principles as Taking Stock but offers better reporting and gives better levels of insight into the business. While it will not be further upgraded you can still access and use the Taking Stock tool at dairyaustralia.com.au

What if my internet connection is slow?

Internet speeds can be an issue in regional areas, and has been considered in the design of DairyBase. An excel data entry spreadsheet will be available although you won't be able to do the reporting.

Where do I go for more information?

Visit dairybase.com.au or contact your Regional Development Program – their contact details are provided on the DairyBase web site.

To find out more visit dairyaustralia.com.au/DairyBase



DairyBase

Data entry resource list

Below are the items we suggest you have in front of you before completing a DairyBase analysis

Physical data

Land

Farm map or other documents that provide details of land areas, including owned, leased, usable, unusable, milking, support, irrigated and dryland.

Livestock

Opening and closing livestock numbers for all age groups.

Grazing records to calculate the time spent by each livestock class on the milking area, support area or agistment.

Milk Production

Milk production details for milk supplied to the factory for the financial year.

Feed

Opening and closing feed quantities for all feed types.

Quantities of supplements made on the milking area and on the support area.

Quantities of supplements purchased off farm and their purchase price.

Quantities of each feed fed on the milking area and quantity fed on the support area.

Fertiliser

(this is optional in DairyBase)

Quantities of fertiliser types used including a breakdown of the quantity applied to the milking area.

Rainfall and Irrigation

Annual average rainfall for your farm and the measured rainfall for the year.

Megalitres of water applied for irrigated farms.

Labour

Number of paid part time and full time staff and the hours they worked.

Number of unpaid staff (family) and the hours they worked.

Financial data

Financial statements including Profit and Loss (Income and Expenses), Balance Sheet (Assets and Liabilities) and Livestock Trading Account (Opening and Closing livestock plus sales and purchases).

You may want the Profit and Loss (GST Exclusive) from your own accounting program to provide further detail on the breakdown of income and expenses.

Milk Income statement from your milk processor to ensure all payments, including any step-ups, that match the production for the financial year are included.

An estimate of the market value of your Land, Water, Vehicles and Plant and Equipment Assets.



To find out more visit dairyaustralia.com.au/DairyBase

2015 EMERGING SCIENTISTS PROGRAM

THIS HIGHLY ACCLAIMED
PROGRAM IS THE PERFECT
SHOWCASE FOR
AUSTRALIA'S UP AND
COMING DAIRY
SCIENTISTS



ALYSIA PARKER

I grew up in Wilton, NSW on a 30acre property with horses, dogs and chooks. I attended Wollondilly Anglican College during years 7 to 10. In order to study agriculture I changed to Elderslie High School for years 11 and 12. I graduated year 12 in 2009. Following my high school education I studied Bachelor of Animal and Veterinary Bioscience at The University of Sydney. My honours project looked at the antimicrobial activity of Manuka honey against MRSA and *Pseudomonas aeruginosa* isolated from horses. I graduated in 2013 with first class honours. In 2013 I got married in Bowral and moved to the stunning Wollongong area. In 2014 I began my PhD looking at *Mycoplasma* infection in Australian dairy herds. I have a love for animals and really enjoy working within the dairy industry. My hobbies include horse riding, bushwalking and going to the beach.

MEAGHAN DOUGLAS

Meaghan is a Dairy Nutrition Research Scientist at the State Governments Ellinbank Centre for Dairy Research in Gippsland. Outside of work, she helps out on the farm at home with her partner Will, milking a herd of autumn-calving cows on a sharefarm property in West Gippsland.

Meaghan graduated from the University of Melbourne in 2014 following the completion of a Bachelor of Science, with First Class Honours. Her honours thesis investigated the relationship between milk protein concentration and reproductive performance in Holstein-Friesian cows in a pasture-based, seasonally calving dairy system. This research investigated nutrient and energy partitioning, milk production and physical development during early lactation in primiparous cows, with Meaghan based at Ellinbank for the duration of her honours year.

Following the completion of her university degree, Meaghan began working as a Research Scientist with the research group at Ellinbank. Her current research is in the Novel Strategies to Breed Dairy Cows project, focussing on identifying cows with low methane production and improved heat tolerance, and she is also currently working on the publication and dissemination of the results from her honours thesis. Meaghan thoroughly enjoys undertaking research within the dairy industry, and wishes to continue providing knowledge through her research that would greatly benefit Australian dairy farmers.





JESSICA ANDONY

I was born and raised on my parents' first generation dairy farm in Harvey, Western Australia. From a young age I had a passion for the farm, and especially the animals. I was always very involved in all aspects of the farm, particularly animal health and genetics. Completing my AI Technician course in 2011, I began working closely with my Dad in AI and selection of sires.

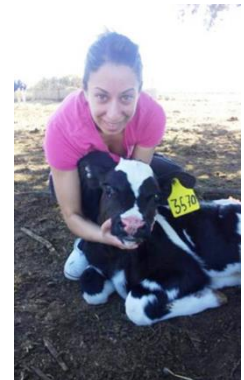
In 2010 I began working in a veterinary clinic at the age of 17 and loved working with animals. When I finished high school I got accepted into Murdoch University to study Animal Science, while maintaining my job at the vet clinic for the first 3 years while I was studying.

I specialised in dairy science in my fourth year of university, with an honours project that looked at subclinical ketosis in early post-partum dairy cows. Animal health is still something I am very passionate about, and working in the dairy industry is where I want my career to go. I am definitely keen to undertake further study in dairy science.

I am currently working for the Department of Agriculture WA in the dairy research team where we are undertaking a feeding experiment. Along with that I work as the Young Dairy Network Coordinator for Western Dairy, which involves planning and coordinating educational and social events for young farmers in WA.

MARY ABDELSAYED

I have just moved to Melbourne from Sydney where I grew up and did all my study. I studied animal and veterinary bioscience at the University of Sydney from 2006-2009 where I majored in quantitative animal genetics. I then went on to do a PhD in 2010 to 2014 with the University of Sydney and was also a part of the Dairy CRC where my research focus was on the quantitative genetics of extended lactation and persistency in Australian dairy cattle on pasture based systems. I have been currently appointed as the project manager on the health data for healthy cow's project and working at Holstein Australia.



ADAM LANGWORTHY



Adam Langworthy graduated from the University of Tasmania with a Bachelor of Agricultural Science (First Class Honours) in 2012, and was awarded the Agriculture Institute of Australia Medal. An interest in pasture agronomy and physiology led to opportunities for Adam to participate in a number of research projects, including the Dean's Summer Research Scholarship and the Tasmanian Institute of Agriculture Summer Studentship. These programs provided an introduction to the saline and waterlogging tolerant legume, narrowleaf trefoil (*Lotus tenuis* Waldst. & Kit. ex Willd.), which formed the focus of Adam's honour's project. It was a work placement on a dairy farm as an undergraduate student that sparked Adam's passion for the dairy industry, motivating him to successfully apply for the Dairy Manufacturing Scholarship (Dairy Australia) after graduation. This scholarship proved to be invaluable in providing a perspective of the whole dairy value chain, giving him a holistic approach to his current research. The scholarship exposed Adam to the negative impacts of a heat

wave on pasture production in South-West Victoria, which led to an interest in the heat tolerance of pasture species. Shortly after concluding the scholarship, Adam commenced a PhD project with the Tasmanian Institute of Agriculture Dairy Centre entitled 'Can we beat the heat in southern Australian dairy pastures?'

After completing his bachelor degree, Adam has looked for opportunities to incorporate research into on-farm practices. This is evidenced by his position as a student representative for the Agriculture Institute Australia Tasmania Division Committee. Adam also assisted in hosting the 22nd International Grassland Congress 'Temperate Grasslands in Tasmania – Diversity and Management' Pre-Congress Tour.

RACHAEL RODNEY

Rachael Rodney is a PhD candidate at the University of Sydney and SBScibus. Her studies focus on relationships between nutrition and fertility in the dairy cow, particularly around transition. Rachael completed a Bachelor of Animal and Veterinary Bioscience with honours through the University of Sydney in 2010. She spent two years working as a Sustainable Agriculture Policy Officer at the federal Department of Agriculture before returning to her home town of Camden, NSW to undertake her PhD.



MAJID KHANSEFID



Majid is a PhD student of The University of Melbourne and Dairy Futures CRC. He is a researcher with the Dairy Futures CRC's Animal Improvement program and aims to increase feed conversion efficiency in cattle which is important to the Australian dairy industry because it has a direct effect on profit.

He did his BSc in Animal Science and MSc in Animal Breeding and Genetics, both at The University of Tehran, Iran. Although he had the chance to continue his studies in Iran as a distinguished MSc graduate, he preferred to do his PhD overseas and chose Australia because of the high calibre of the scientists.

Majid has chosen this field of research because he really enjoys biology and also working with huge amounts of data, statistical models and data analyses. He thinks it is really hard and challenging to be a good computational biologist because it needs profound knowledge in several fields!

ASHLEIGH WILDRIDGE

I grew up in the Camden area, have spent my whole life around motor racing and four wheel driving. I got my first 4WD/restoration project in March, hope to have it blinged up and back on the road soon! I got my first horse when I was in year 6 and have had one ever since.

As a little person I loved visiting my grandparents 'farm' in Goulburn where they had a handful of beef cattle on about 300 acres. Always loved the idea of farming (particularly dairy) but I never really had much exposure to it.

I went to university in Wagga straight after year 12 and did a Bachelor of Animal Science (Honours) which I finished in 2013. I worked with beef cattle in my uni honours year looking at the use of proximity loggers.



Until I started my PhD last year, I had not really had any exposure to the dairy industry other than what I learnt in high school.

My PhD is now looking at managing heat stress in AMS's to improve cow health and welfare, as well as reduce production decreases associated with summer conditions. When I finish my PhD I would love to stay in the dairy industry and one day get a job that allows me to work with and help farmers.

ALEX JOHN



Alex John is a Tasmanian expat, originally from the North-West coast of the apple isle. His early exposure to agriculture involved visiting his uncles cropping farm, where he and his cousin would nick carrots from the paddock and sell them on the side of the highway at bargain prices. Though this seemed quite lucrative at the time, it was Alex's later experiences as a part time farm hand on a local dairy farm that sparked his interest in agriculture and in particular dairy production.

Choosing to combine his interests of agriculture and science, Alex completed his Bachelor of Agricultural Science (Hons) at the University of Tasmania in 2013, with his honours project 'Pasture Management in Two High Performing Automatic Milking Systems.'

Choosing to follow on with his research into AMS, Alex moved to Camden in 2014, where he is currently completing his PhD with the FutureDairy group at the University of Sydney. Alex is now looking to improve robot utilisation throughout 24 hours in pasture-based automatic milking systems through a better understanding of how feed allocation impacts cow visitation to the robotic milking unit. Through this work Alex hopes to help new and existing farmers gain a better understanding of the technology so they are able to maximise their success.

RUAIRI MCDONNELL

Originally from Ireland, I am currently working as a Dairy Research Officer from the Department of Agriculture and Food, Western Australia (DAFWA). I came to Australia in 2011 after having spent a year in New Zealand working in the dairy industry over there. My background is in ruminant nutrition. I have a Master's degree from University College Dublin (Ireland), where my project looked at the effects of divergent phenotypic selection for residual feed intake on methane emissions in heifers. Upon completion of my thesis in 2008, I worked for a year as a research assistant in UCD on the research farm, before moving to New Zealand.



I have a strong passion for dairy farming, coming from a farming background myself. My main research interests lie in the areas of ruminant and pre-ruminant nutrition, pasture management and in particular, looking at ways to improve the financial performance of dairy farms. Our current main project at DAFWA is titled Flexible Feeding Systems Western Australia, which commenced in 2012 and involves the investigation of ways to improve the efficiency of grain supplementation on dairy farms in Western Australia. This is my second time participating in the DRF symposium, having also taken part in last year's emerging scientist competition, and I am very much looking forward to this year's event.

MILK ACIDIFICATION TO CONTROL *MYCOPLASMA BOVIS* GROWTH IN INFECTED MILK

Alysia Parker

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ABSTRACT

Milk with varying bacterial load is routinely fed to calves yet poses a risk for disease, impacting calf growth and survival. Milk acidification involves lowering the pH of milk to eliminate and/or prevent the growth of harmful bacteria. The objective of this study was to evaluate the efficacy of milk acidification using Salstop® (acidification agent) on the growth of Mycoplasma bovis in milk.

Five 100mL groups of bulk tank milk were inoculated with a prepared M.bovis broth to achieve an average starting concentration of 1.33×10^6 cfu/mL. Using Salstop®, four treatment groups were adjusted to an approximate starting pH of 6, 5, 4 and 3.5. The fifth group was left as the untreated control. All groups were kept at an average room temperature of 23.6°C (± 0.03). Triplicate samples were taken at 1, 2, 4, 6, 8 and 24hrs post treatment and transferred onto Mycoplasma agar and into broth (4mL) as an enrichment step to determine viability of the organism following treatment. The pH was also recorded for each triplicate. A colony count was determined on the Mycoplasma agar plates after 5 days incubation. All broths were incubated for 4 days followed by plating, 5 days incubation and subsequent colony counting. To confirm results the trial was repeated.

The pH of all treatment groups remained stable over 24hrs to give an average pH of 7.13 (control), 5.99, 5.18, 4.08 and 3.65. Viability results are shown in Figure 2. These results demonstrate that milk acidification using Salstop® is effective at eliminating M.bovis growth in milk if the appropriate pH and exposure time is maintained.

INTRODUCTION

Mycoplasma bovis is currently recognized as one of the most significant Mycoplasma pathogens in cattle. It has been demonstrated as the causative agent of mastitis and arthritis in adults (Wilson *et al.*, 2007) as well as pneumonia, arthritis and otitis media (inner ear infection) in calves (Fraser

et al., 2014; Maunsell *et al.*, 2012; Stipkovits *et al.*, 2005). Cow to calf transmission of *M.bovis* can occur through the ingestion of infected milk (Maunsell *et al.*, 2012). Current options to reduce this risk of transmission include feeding milk replacer or pasteurized whole milk. Heat pasteurization of milk is an effective method of eliminating *M.bovis* without discarding milk; however it involves a large initial cost to purchase the appropriate equipment which may not be a financially viable option for smaller dairy

producers (Butler, Sickles, Johanns, & Rosenbusch, 2000).

While milk replacer may be less of an initial financial cost it can be costly over time and past evaluations have suggested that milk replacer may provide a poorer nutrient composition compared to whole pasteurized milk (Godden, Fetrow, Feirtag, Green, & Wells, 2005). While both options provide a liquid feed, which is free from viable *M.bovis*, it does have the potential to become re-inoculated if placed into collection and feeding equipment which may be contaminated with the organism. A treatment approach which may combat this issue is milk acidification which involves lowering the pH of milk to a level which is unsuitable for bacterial growth and survival (Anderson, 2008). This provides a continued preservative effect provided that the pH remains at an appropriate level, and is a cost effective alternative for smaller producers.

A pilot trial in 2005 indicated that the total bacterial count in raw bulk tank milk is reduced when the pH is lowered to 4.1 with the addition of formic acid (Anderson, 2005b). However very little information is available on specific contact times required to inactivate specific bacterial species. Several calf performance trials with acidified milk have suggested that milk intake may be affected initially due to milk palatability, however calves soon become accustomed to the taste with feed intake and efficiencies as well as calf growth not being significantly affected (Guler, Yanar, Bayram, & Metin, 2006; Metin, Yanar, Guler, Bayram, & Tuzemen, 2006). Furthermore the authors' recorded significantly lower faecal consistency scores and incidences of diarrhoea in calves fed acidified milk. Due to a lack of cell wall as well as its sensitivity to heat and disinfectants, it is likely that *M.bovis* is sensitive to changes in pH (Butler *et.al.*, 2000; Enger, Fox, Gay, & Johnson, 2015). The objective of this study was to evaluate the efficacy of milk acidification using Salstop® (acidification agent) on the growth and survival of *Mycoplasma bovis* in milk over 24hrs. Current milk

acidification recommendations suggest pH 4 to 4.5 should be achieved to kill several bacteria of interest in the dairy industry (Anderson, 2005a; Anderson, 2008). However to the best of the author's knowledge the effects of milk acidification on *Mycoplasma* have not been investigated. Consequently the pH treatment levels 6, 5, 4 and 3.5 were chosen for analysis in this trial as they provide a broad range of investigation.

MATERIAL AND METHODS

Mycoplasma bovis (ATCC® 25523™) was grown in Mycoplasma broth (Supplied by Elizabeth Macarthur Agricultural Institute (EMAI), NSW Department of Primary Industries, NSW, Australia) over 48hrs. Bulk tank milk was heat treated at 63°C for 30minutes to reduce any bacterial load which may have been present and affected *M.bovis* growth.

Five treatment groups were prepared in sterile glassware with 100mL of heat treated bulk tank milk. Each milk treatment group was spiked with the prepared *M.bovis* broth to achieve an average starting concentration of 10⁶ colony forming units per mL (cfu/mL). Prior to pH treatment the starting concentration of *M.bovis* in milk was estimated for each group. This was done by removing an aliquot and performing a 10-fold serial dilution in phosphate buffered saline (PBS). Each dilution was then plated out in triplicate 10uL volumes onto Mycoplasma agar (EMAI). Three 2mL aliquots were also removed from each treatment group to measure the starting pH. Using small quantities of Salstop® each treatment group was adjusted to a desired starting pH of 6, 5, 4 and 3.5. The milk was thoroughly mixed to ensure all additive was dissolved.

After the addition of Salstop®, an aliquot was taken to test the pH. Once the desired pH was reached the pH was measured in triplicate aliquots. The fifth treatment group was left as the untreated control.

All treatment groups were placed in a hood at room temperature. Following treatment commencement, sampling intervals included 1hr, 2hrs, 4hrs, 6hrs, 8hrs and 24hrs of treatment exposure. At each sampling interval for each treatment the following were performed. The air temperature was recorded. The treatment group was gently swirled and three 2mL aliquots were removed. For each aliquot, 10uL was transferred onto Mycoplasma agar to evaluate growth and 10uL was transferred into Mycoplasma broth (4mL) as an enrichment step to evaluate viability. The pH of each aliquot was measured.

All Mycoplasma agar plates were incubated in candle jars (obligate anaerobic conditions) at 37°C for five days. Following plate incubation the number of colonies grown were counted if possible or otherwise labelled 'Too Many to Count' (TMTc). All broths were incubated at 37°C for 4 days with the addition of a positive and negative control. Following incubation, each broth was plated, incubated and counted as described above. To confirm results the trial was then repeated.

RESULTS

The mean room temperature over 24hrs was 23.6°C (± 0.03). The mean pH (\pm SE) of all treatment groups at each sampling point are shown in Figure 1. All treatments remained stable over 24hrs. Efforts were made to achieve similar pH treatments for trial 'a' and 'b' with an average pH of 7.13, 5.99, 5.18, 4.08 and 3.65 for the control, treatments pH6, pH5, pH4 and pH 3.5 respectively. For treatment group pH5, trial 'a' had a slightly higher average pH of 5.29 compared to trial 'b' with an average pH of 5.07.

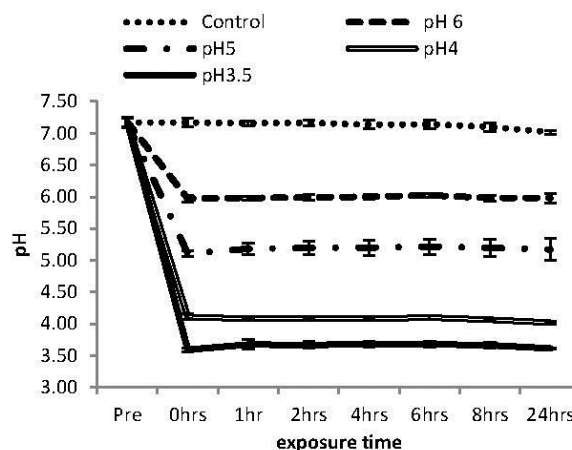


Figure 1. Mean pH (\pm SE) of milk following treatment with Salstop®

The survival of *M. bovis* in milk for each treatment over 24hrs is shown in Figure 2. The mean starting concentration of all treatments was log 6.13 cfu/mL (\pm log 4.69 cfu/mL). For each time point if the number of colonies grown were TMTc the starting concentration for that treatment was assigned. The results for the control, pH 6, pH 4 and pH 3.5 were very similar for trials 'a' and 'b' with pH 5 showing minor differences. For treatment pH 4 and 3.5, there was no growth from 1hr onwards for both trials.

For treatment pH 5, trial 'a' showed a reduced concentration at 4hrs and 6hrs to log 3.45 cfu/mL (\pm log 2.82 cfu/mL) and log 2.43cfu/mL (\pm log 2.49 cfu/mL) respectively and no growth thereafter. In trial 'b' which had a slightly lower average pH, the concentration was reduced at 2hrs to log 3.35 cfu/mL (\pm log 2.88 cfu/mL) and no growth thereafter.

For treatment pH 6 there was reduced growth at 8hrs to log 4.39 cfu/mL (\pm log 3.08 cfu/mL) and log 3.88 cfu/mL (\pm log 2.71 cfu/mL) for trial 'a' and 'b' respectively and no growth thereafter. For the control growth was reduced at 24hrs to log 3.60 cfu/mL (\pm log 1.76 cfu/mL) and log 2.22 cfu/mL (\pm log 2.18 cfu/mL) for trial 'a' and 'b' respectively. Following enrichment in broth, *M. bovis* death was confirmed for all results which showed no growth with one exception. In trial 'b' pH6 showed no growth at 24hrs however following broth

enrichment growth was recovered (results not shown).

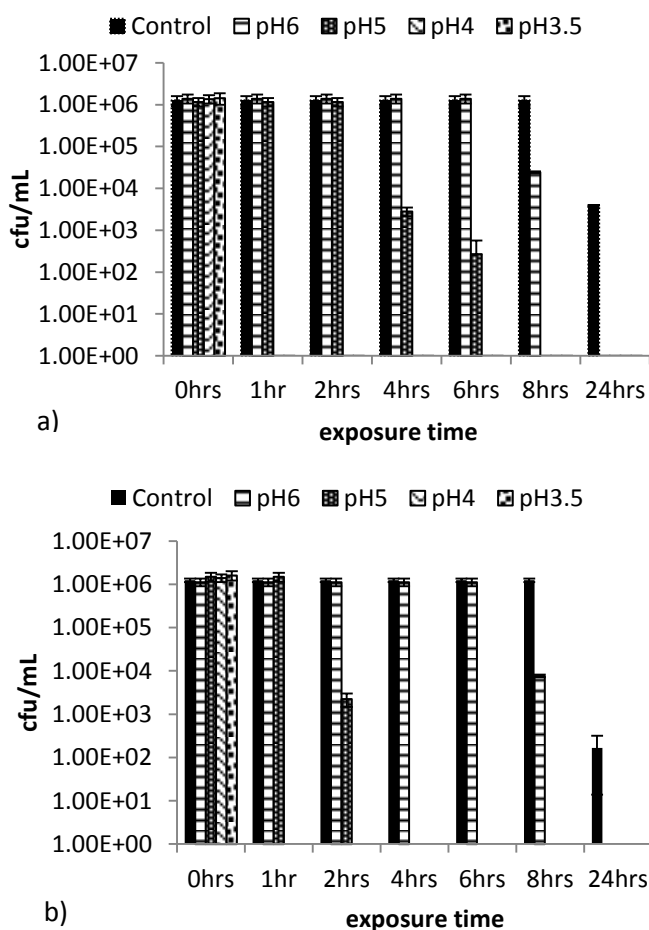


Figure 2. Mean (\pm SD) concentration of *M.bovis* in milk following treatment exposure during trial a) and trial b).

DISCUSSION

Over the 24hr sampling period the pH for each treatment remained stable and did not drop or raise once the desired pH was achieved. This is an important aspect for two reasons. Firstly it has been suggested that when a pH below 4 is reached, calves find acidified milk less appealing (Anderson, 2005a). It is therefore important that the pH does not continue to drop once the milk has been adjusted to the desired pH. Secondly, if the pH raises this may affect the duration of exposure needed to kill *M.bovis*. This is particularly important if the milk becomes re-

infected with *M.bovis* after acid treatment as the treatment may not be as effective as expected due to a higher pH.

For treatments pH 4 and 3.5 *M.bovis* growth was eliminated after just 1hr of exposure time. This is not surprising as an ideal pH range for the growth of *M.bovis* in broth is 7.8 ± 0.3 (Nicholas, Ayling, & McAuliffe, 2008). This was confirmed in a previous study looking at porcine *M.hyorhinis* which found significantly less growth when broth pH was reduced to just 6.5 (Dinter & Taylor-Robinson, 1969). These results also suggest that *M.bovis* may be more sensitive to changes in pH than bacteria more commonly found in bulk milk. A previous pilot trial looking at acidified milk with formic acid demonstrated no bacterial growth after 3-21 hours of contact at a pH of 4.2 (Anderson, 2005b).

For treatment pH 5, there were slight differences in results between trials 'a' and 'b'. In trial 'a' growth was decreased at 6hrs, with no growth at 8hrs onwards. However in trial 'b' growth was reduced at 2hrs with no growth at 4hrs onwards. This may be due to the slight difference in the actual mean pH for each trial. Trial 'a' had a slightly higher mean pH of 5.29 while trial 'b' had a mean pH of 5.07. While this difference in pH is only minor it suggests that pH5 may be a critical level with only slight fluctuations causing changes in the necessary exposure time required for *M.bovis* death.

To be confident that acidification will kill *M.bovis* in milk in a short period of time it therefore may be necessary to decrease the pH to 4. By dropping milk to pH4 it may have the added benefit of being effective against several other bacteria of interest in the dairy industry including *E.coli*, *Salmonella spp* and *Staphylococcus aureus* which thrive at a neutral pH range yet exhibit limited survival at a pH less than 4.5 (Anderson, 2008). As previously described, this theory was investigated in a previous pilot trial however was only investigated with total plate counts of bulk tank milk (Anderson, 2005b). Therefore very little

information is available on specific contact times required to inactivate specific bacterial species. To our knowledge this is the first study of its kind to look at *M.bovis*.

Interestingly, in both trials the control sample also decreased in the concentration of viable *M.bovis* over 24hrs. This suggests that *M.bovis* may not be able to proliferate in milk, but rather milk may facilitate proliferation of infection as a transport media. This is also confirmed by the observation that milk has a lower than optimal pH for *M.bovis* growth. However, with the exception of 0hrs to confirm the starting concentration, dilution series were not performed at the other sampling points and colonies were only counted if possible.

There is therefore the potential that prior to 24hrs *M.bovis* did increase in concentration in the control before exhausting the nutrients and decreasing. Furthermore, it is also possible that by heat treating milk prior to inoculation there may be some impact on nutrients in the milk that *M.bovis* may utilize for growth. However this step was considered necessary to ensure that other bacteria, which grow much faster, did not affect the growth and survival of *M.bovis* in milk which would have affected the results of this trial. It is therefore necessary that further investigations are conducted with *M.bovis* inoculated into raw bulk tank milk which has not been heat treated. This will also mimic a more realistic scenario which may be encountered by dairy producers.

CONCLUSION

While it has not been established if *M.bovis* proliferates in milk, it has been demonstrated as the causative agent of mastitis and is therefore frequently isolated in milk from infected farms (Justice-Allen, Trujillo, Goodell, & Wilson, 2011). When fed to calves, infected milk can then act as a transport media for the pathogen allowing cow to calf transmission, resulting in otitis media and arthritis (Maunsell *et al.*, 2012). It is therefore necessary that this milk is treated prior to calf

consumption to kill all viable *M.bovis* organisms. This study has demonstrated that milk acidification using Salstop® is effective at inhibiting *M.bovis* growth in milk if the appropriate pH and exposure time is maintained. The ideal pH to achieve these results in a short amount of exposure time is pH4. This consistently results in no growth of *M.bovis* after just 1hr with the pH remaining stable over 24hrs. Further research is needed to investigate the effects of milk acidification on other types of bacteria of interest in the dairy industry.

ACKNOWLEDGEMENT

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EARLY LACTATION MILK PRODUCTION AND ENERGY PARTITIONING IN PRIMIPAROUS HOLSTEIN-FRIESIAN COWS WITH HIGH OR LOW MILK PROTEIN CONCENTRATIONS IN A SEASONALLY-CALVING, PASTURE-BASED HERD

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ABSTRACT

A strong positive association between milk protein concentration (MP%) and reproductive performance has been reported in many countries, but little has been done to elucidate and exploit the underlying mechanisms. The current research had the aim of comparing milk production, nutrient and energy partitioning, and physical characteristics between cows with high or low MP% in early lactation. Milk yield and composition, blood plasma metabolite and hormone concentrations, and body condition score (BCS) were measured in a group of 85 primiparous Holstein-Friesian cows at DEDJTR, Ellinbank Centre Victoria, during the first 123 days of lactation. Results from cows within the quartiles with highest (Hi) and lowest (Lo) MP% are presented. Hi MP% cows had greater concentrations of milk fat, protein and lactose, but lower daily milk volume compared with Lo MP% cows. There were no significant differences in daily yield of milk solids (milk fat plus protein) or in daily net energy apportioned for milk production. Hi MP% cows had greater blood plasma concentrations of glucose, insulin, insulin-like growth factor-1 (IGF-1) and leptin and maintained a greater BCS during early lactation. Overall, results were consistent with Hi MP% cows partitioning more nutrients and energy to body condition at the expense of milk yield, except that this was not entirely supported by calculations of total energy output in milk. Further research is necessary to better understand causes of the positive association between MP% and reproductive performance in dairy cattle.

INTRODUCTION

The declining fertility of dairy cattle in many countries over several decades has been associated with a focus on increasing per cow milk production and an increase in the proportion of

Holstein-Friesian genes from sires of North American origin (Buckley, O'Sullivan, Metges, Evans & Dillon, 2003), but causal inter-relationships between these variables are poorly understood. In pasture-based, low-input dairying

systems of south-eastern Australia and elsewhere, seasonally-concentrated calving patterns are used to increase pasture utilisation by matching peak energy requirements with peak pasture growth rates (Auld, O'Brien, Cole, Macmillan & Grainger, 2007). In such systems and others, low fertility results in substantial costs to dairy farmers, including high rates of cow wastage due to cows failing to conceive (Borman, 2004).

The InCalf studies conducted mainly in Victorian herds in 1998 and 2009 showed that one of the factors having the greatest impact on the probability of conception within 6 weeks following the mating start date was the cow's milk protein concentration (MP%) (Morton, 2000, 2011). This positive association between MP% and dairy cow fertility has also been shown in the United Kingdom, Ireland and the Netherlands (Buckley, O'Sullivan, Metges, Evans & Dillon, 2003; Xu & Burton, 1996), yet it is strongest in cows with moderate milk volumes, typical of those managed in pasture-based production systems of south-eastern Australia (Morton, 2000). If the factors underpinning this association could be understood and exploited, there could be substantial benefits for the Australian dairy industry, especially when viewed in the context of milk protein being more than twice as valuable as milk fat under the milk payment systems that predominate in many Australian processing companies.

Differences in the way cows partition energy in early lactation, when energy demands for lactation exceed energy intake, provide one possible explanation for the association. Post-partum negative energy balance (NEB) in dairy cows causes decreased MP% due to a shortage of glucose for milk protein synthesis in the mammary gland (de Vries & Veerkamp, 2000). Negative energy balance, as indicated by a marked loss in body condition in early lactation when the energy requirements for milk production and maintenance exceed dietary energy intake, is associated with poor

reproductive performance (Butler, 2003; Reist *et al.*, 2003). However, Fahey, Morton & Macmillan (2003) demonstrated a positive association between the reproductive performance of non-lactating heifers and their MP% in their first lactation, although it was not as strong as in multiparous cows. This nevertheless indicates that the biological determinants underpinning the association are not restricted to lactation-specific factors such as post-partum NEB.

The objective of this experiment was to compare milk production, body condition score (BCS) and blood plasma concentrations of selected metabolites and hormones between primiparous Holstein-Friesian cows with either high (Hi) or low (Lo) MP%, in order to gain an understanding of the mechanisms behind the association. The hypotheses tested were: (1) that, in comparison with Hi MP% cows, Lo MP% cows have blood plasma metabolite and hormone concentrations that indicate preferential partitioning of nutrients and energy towards milk synthesis in early lactation at the expense of body condition; and (2) that milk energy output in early lactation is greater for Lo compared with Hi MP% cows due to increased milk yield.

MATERIAL AND METHODS

Data was collected from 85 primiparous Holstein-Friesian cows from the research herd at DEDJTR, Ellinbank Victoria. Cows were managed as a single, seasonally-calving herd, with a mean calving date of August 1 2013. All cows experienced a common nutritional and management regimen. Their diet consisted of grazed perennial ryegrass pasture, an average of 3.7kg DM/day of grain (wheat and/or canola meal) fed in the dairy during milking, and pasture hay and silage fed in the paddock in summer and autumn. Cows were milked twice daily at c. 0600h and 1500h. All experimental procedures were approved by the DEDJTR Agricultural Research and Extension Animal Ethics Committee.

Milk volume was measured at each milking using a DeLaval Alpro milk metering system (DeLaval International, Tumba, Sweden), while a composite milk sample (p.m. plus a.m.) was taken using in-line milk meters once per week until November, and fortnightly thereafter. These samples were tested for concentrations of protein, milk fat (MF%) and milk lactose (ML%) using a near-infrared milk analyser (model 2000, Bentley Instruments, Chaska, MN, USA). Daily milk energy yield for each cow was estimated by calculating the daily yield of milk protein, fat and lactose, and assigning these components net energy contents of 24.1 KJ/g, 38.3 KJ/g and 16.5 KJ/g, respectively (Sjaunja, Baevre, Junkkarinen, Pedersen & Setala, 1990).

Blood samples were collected weekly from calving until November, and thereafter at monthly intervals. Two 10ml blood samples were collected via coccygeal venepuncture into vacutainers containing powdered lithium heparin, and potassium EDTA (BD Vacutainer System, Belliver Industrial Estate, Plymouth, UK). Samples were gently inverted, stored on ice, and processed within 60 minutes of collection. Blood samples were centrifuged (Clements SG 400[®], Clements, Sydney, NSW, Australia) at 1800 g for 10 minutes at 4°C, the plasma was aspirated into two 5ml sample tubes, and then stored at -18°C prior to analysis. These blood samples were analysed for glucose, non-esterified fatty acids (NEFA), urea and β -hydroxybutyrate (BHBA) using commercially-available kits on an Olympus AU400 Clinical Chemical Analyser at the Animal Health Laboratories (Department of Agriculture and Food, Western Australia). Analyses for insulin, IGF-1, leptin and somatotropin were conducted using similar methodologies on a gamma counter (Packard Cobra-II, Auto Gamma) at the School of Animal Biology, University of Western Australia.

Cow BCS was assessed by trained technical staff at weekly intervals during early lactation using the 8-point scale of Earle (1976).

Statistical analyses

The cows were separated into quartiles based on their average MP% during early lactation (up to 123 days in milk for each cow), and only data from cows within the highest (Hi; 3.22 to 3.40%) and lowest (Lo; 2.87 to 3.00%) MP% quartiles were analysed, using GenStat 17 (2014).

Statistical analysis of the milk production and composition data, milk energy yield, cow BCS, and blood plasma metabolite and hormone concentrations was conducted by averaging the daily or weekly data over the early lactation period, and conducting univariable regression analyses between MP% and each variable.

RESULTS

Mean daily milk volume was greater for Lo compared with Hi MP% cows during early lactation. Cows with Hi MP% also had greater MF% and ML% than Lo MP% cows, however the daily yield of milk solids (milk fat plus protein) did not differ significantly between quartiles (Table 1). Cows with Lo MP% had greater daily lactose yield compared with Hi MP% cows. There was also no significant difference in daily milk energy yield between the MP% quartiles (Table 1).

Pre-partum plasma metabolite and hormone concentrations were not significantly different between Hi and Lo MP% cows, indicating no difference in the nutrient status of these cows prior to their first lactation. Following parturition, cows with Hi MP% had greater plasma concentrations of glucose, insulin, IGF-1 and leptin (Table 1), and numerically lower average plasma concentrations of NEFA, urea, BHBA and somatotropin.

Pre-partum BCS did not differ significantly between Hi and Lo MP% cows (4.63 and 4.60 units, respectively). However, during early lactation, Hi MP% cows maintained a greater BCS in comparison to Lo MP% cows (Table 1).

Table 1. Selected variables for cows with high (Hi) or low (Lo) milk protein concentration (MP%) in early lactation (calving to 123 days in milk)

	Hi	Lo	SED ¹	P-value
Milk yield (L/day)	20.0	22.8	0.98	0.007
MP%	3.27	2.94	0.02	<0.001
MF% ²	4.14	3.74	0.09	<0.001
ML% ³	5.19	5.13	0.03	0.027
Milk solids ⁴ (kg/cow/day)	1.49	1.52	0.07	0.658
Milk energy yield (MJ/cow/day)	66.1	67.9	3.09	0.566
Glucose (mmol/L)	3.36	3.27	0.04	0.030
Insulin (μ U/ml)	5.27	4.37	0.27	0.002
IGF-1 ⁵ (ng/ml)	16.20	11.39	1.14	<0.001
Leptin (ng/ml)	0.58	0.52	0.02	0.006
BCS ⁶ (units)	4.11	4.03	0.04	0.049

Values are the means for all cows in each quartile; ¹SED = standard error of the difference; ²MF% = milk fat concentration; ³ML% = milk lactose concentration; ⁴Milk solids = milk fat plus protein; ⁵IGF-1 = insulin-like growth factor-1; ⁶BCS = body condition score

DISCUSSION

The positive association between MP% and dairy cattle fertility has been demonstrated in a number of studies and is well accepted (Buckley, O'Sullivan, Metges, Evans & Dillon, 2003; Pryce & Veerkamp, 2001). Despite this, the association is not helping to increase the profitability of dairy farming as the underlying mechanisms are not understood and so are not being exploited. This

experiment has provided the first step in understanding the physiological and endocrinological differences between primiparous Holstein-Friesian cows with Hi and Lo MP% in a seasonally calving, pasture-based herd.

One possible explanation for the association is that there may be differences in the ways that Hi and Lo milk protein cows partition energy during early lactation. When milk yield reaches a peak some 6 weeks after parturition, energy demands of lactation are greater than the amount of energy that can be obtained from the diet and cows begin mobilising body tissue reserves in order to meet energy requirements (de Vries & Veerkamp, 2000). This state of NEB is known to reduce fertility, and has also been shown to result in reduced MP% (de Vries & Veerkamp, 2000) due to a higher proportion of available amino acids being used for gluconeogenesis and a reduction in their availability for milk protein synthesis (Auld, Thomson, Mackle, Hill & Prosser, 2000). Hence, it is logical to expect that MP% and fertility may be related in this way.

In the current experiment, blood plasma concentrations of selected metabolites and hormones were consistent with Lo MP% cows partitioning more energy to milk production and less to body condition, and thus being in a more severe NEB than Hi MP% cows. For example, lower concentrations of glucose, insulin, IGF-1 and leptin have all been used previously as indicators of NEB (Delany *et al.*, 2010). Thus our first hypothesis is accepted.

The suggestion that Lo MP% cows were in greater NEB is also consistent with these cows having higher milk volumes but lower BCS than Hi MP% cows in early lactation. This was demonstrated through lower plasma IGF-1 and leptin concentrations in Lo MP% cows, while the greater plasma insulin concentrations in Hi MP% cows would have promoted the uptake of glucose by peripheral tissues (Lucy, 2006), hence resulting in a greater BCS for these cows. Overall these observations indicate that Lo MP% cows may have

greater difficulty conceiving during the first 6 weeks of the seasonally concentrated breeding program than Hi MP% cows (Butler, 2003), though it was not the objective of this experiment to assess this.

Despite the indications that Lo MP% cows were partitioning more energy towards milk production than Hi MP% cows, an examination of milk composition and milk energy content did not support this contention. Although milk volume was greater in Lo MP% cows, our results indicate that there were not large differences in daily yields of milk solids (fat plus protein, not including lactose) between Hi and Lo MP% cows. Similarly, when the daily milk energy yield was calculated using known energy values for the major milk components (this time including lactose), there was no significant difference in milk energy between Hi and Lo MP% cows. Our results suggest that differences in milk energy yield in early lactation are not the only cause of the differences in fertility between cows with divergent early lactation MP%, thus the second hypothesis is not supported.

The lack of difference in milk energy yield between the two MP% quartiles shows that, while some of the association between MP% and fertility may be related to differences in the way cows partition energy between milk and body tissue, there are other important factors that currently remain unclear. This is consistent with Fahey, Morton & Macmillan (2003) that the capacity of primiparous heifers to conceive when they were yet to commence lactation was significantly associated with their MP% in their subsequent lactation. It is also consistent with the observation of Morton (2000) that the association between MP% and dairy cow fertility persists at all stages of lactation, including mid and late lactation when cows have typically regained a positive energy status.

CONCLUSION

Overall this experiment has shown that Lo MP% cows have lower blood plasma concentrations of glucose, insulin, IGF-1 and leptin, reduced BCS in early lactation, and higher early lactation milk volume than Hi MP% cows. Collectively these observations suggest that Lo MP% cows proportion more energy to milk production at the expense of body tissue than Hi MP% cows. Nevertheless, estimates of the amount of milk energy produced by each quartile are not supportive of greater energy partitioning to milk synthesis by Lo MP% cows. We conclude that while differences in energy partitioning in early lactation may partially underpin the positive association between MP% and fertility in dairy cattle, other important factors are involved. Further research is required to fully elucidate these mechanisms so that the potential benefits of the association for the dairy industry can be captured.

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COMPARISONS OF A COW SIDE TEST WITH KINETIC AND COLORIMETRIC ASSAYS FOR B-HYDROXYBUTYRATE FOR DIAGNOSIS OF SUBCLINICAL KETOSIS IN EARLY LACTATING DAIRY COWS

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ABSTRACT

Forty early lactating Holstein Friesian cows (multiparous, DIM: 7 ± 3) were sampled on farm for blood β -hydroxybutyrate (BOHB) concentrations using the Optium Xceed meter (OX) and milk BOHB concentrations using PortaBHB™ ketolac strips). Plasma BOHB concentrations were also measured using kinetic and colorimetric laboratory assays. Whole blood BOHB concentrations (OX meter) and plasma BOHB concentrations (kinetic and colorimetric methods) were highly correlated ($r=0.953$ and $r=0.972$ respectively). Furthermore, concordance (the level of agreement between two variables) between plasma (kinetic method) and whole blood (OX meter) BOHB concentrations was high ($ccc=0.92$). A further 174 early lactating cows from five herds were sampled for blood BOHB concentrations (OX meter) on farm. A multivariate linear regression was performed on log BOHB data. The most commonly used cut point for SCK is generally accepted at $\geq 1.4\text{mM}$ of blood BOHB concentration (kinetic assay). The prevalence of cows with blood BOHB concentration $\geq 1.4\text{mM}$ in this study was 6.4%. However due to the small number of herds in this study ($n=5$) and number of samples obtained from each herd, this should be interpreted with caution. The high concordance between the kinetic assay and OX meter indicates that the cut-point of 1.4mM can be considered as reliable threshold for the diagnosis of SCK in lactating dairy cows when using the OX meter, validating its use in diagnosing SCK in Australian dairy herds.

INTRODUCTION

Subclinical ketosis is characterised by increased concentrations of circulating ketones, such as β -hydroxybutyrate (BOHB) and acetoacetate (AcAc) in the absence of clinical signs (Andersson, 1988). The reported prevalence of subclinical ketosis varies between studies, which may be due to the use of different diagnostic tests and different thresholds for each test. Diagnosis of subclinical ketosis is primarily conducted through measurement of blood BOHB concentrations. This

ketone body is more stable in blood than acetone or AcAc (Työppönen and Kauppinen, 1980). The normal range for blood BOHB is below 1.2-1.4 mM and the most commonly used threshold for subclinical ketosis is $\geq 1.4\text{mM}$ of blood BOHB concentration using a kinetic laboratory assay (Oetzel, 2004, Gordon, *et.al.* 2013, Carrier, *et.al.* 2004 and Iwersen, *et.al.*2009). Early lactation cows with blood BOHB concentrations above this level are at a threefold greater risk to develop clinical ketosis, increased risk of metritis, cystic

ovarian disease and reproductive problems (Duffield *et.al.*, 1998), and cows with BOHB concentrations above 2mM are at risk for reduced milk production (Duffield, 1997).

The two most quantitative laboratory diagnostic tests that are commonly used for the measurement of BOHB concentrations in blood of lactating dairy cows are the colorimetric and kinetic assays, however these methods are expensive and time consuming (Oetzel, 2004) As a result many cow-side tests using blood, milk and urine samples have been developed for diagnosis of subclinical ketosis (Oetzel, 2004).

Although not as convenient as milk samples, whole blood BOHB concentration is recognised as the accepted standard for determining subclinical and clinical ketosis (Gordon, *et.al.* 2013). Current blood tests for measuring ketones on farm are limited to Precision Xtra and Optium Xceed, which are human diabetes and ketone monitoring meters. The range of BOHB concentrations in diabetic humans is lower than that observed in ruminants where ketones can reach concentrations of 12mM and are often greater than 3mM (Pethick and Lindsay, 1982). Therefore the Optium Xceed meter needs to be standardised on the lower range of BOHB concentrations observed in ruminants. The current sensitivity and specificity measured for the Precision Xtra meter is approximately 95% (Oetzel, 2004), but it is not commercially available in Australia.

The first aim of this study was to validate the Optium Xceed meter for use in the diagnosis of subclinical ketosis in Australian dairy herds. On validation of the Optium Xceed blood ketone meter, the second aim was to use this on farm test as a method for rapid and reliable diagnosis of subclinical ketosis in Australian dairy herds.

MATERIALS AND METHODS

A blood sample was collected from forty seven early postpartum lactating Holstein-Friesian dairy cows, from an initial herd in Mundijong, Western

Australia from February to May of 2014, (multiparous, DIM: 7 ± 3). Samples were collected from the coccygeal vein by venipuncture using an 18 gauge needle and 2 x lithium heparin blood tubes. Seven cows were excluded from analysis in the study as they were not within the required DIM at the time of sampling.

A further one hundred and seventy four early postpartum lactating Holstein Friesian dairy cows (multiparous, DIM: 7 ± 3) were selected for blood sampling from five dairy farms in the South West of Western Australia and these were used in separate statistical analysis. These cows had 1 x lithium heparin blood sample taken from the coccygeal vein by venipuncture using an 18 gauge needle.

Cows were identified following the morning milking and sampled 2 hours after receiving grain-based concentrate in the dairy shed. Cows remained in the same herd and received the same diet as other cows on the farm during the experimental period. Cows were selected based on their parity and DIM when the sampling days were scheduled.

A sample of whole blood (0.1ml) from one of the collection tubes was extracted from the tube using a pipette for the determination of BOHB at the time of sampling. The remaining samples were then taken back to the laboratory, spun in a Clements 2000 centrifuge for 15 mins at 3500rpm and had the plasma extracted. A kinetic (Stormont Veterinary Laboratory, Belfast procedure as per McMurray *et.al.* 1984) and colorimetric laboratory assay (Cayman Chemical Company Kit, 2013) was then performed on the plasma from the initial 40 cows only.

The kinetic and colorimetric laboratory assays were based on the reaction catalysed by BOHB dehydrogenase, in which BOHB was converted to AcAc with the concomitant reduction of NAD^+ to NADH. The increase in absorbance associated with NADH was used to determine the concentration of BOHB in the sample. The variation in the two

methods was the way in which NADH was measured and which buffer was used. The colorimetric assay was measured via dye reduction at a visible wavelength (450nm), while the kinetic assay directly measured NADH at a non-visible near UV wavelength (340nm).

A composite milk sample from each cow in the initial herd was collected immediately after blood collection, and using PortaBHB milk ketone test strips the BOHB concentration was recorded for each cow.

Statistical Analyses

A regression analysis was performed on the concentrations of BOHB measured from the Optium Xceed meter, kinetic and colorimetric assays to evaluate significant differences. Concordance correlation coefficients (CCC) were measured to find the agreement between the different laboratory techniques and the cow-side test (Lin, 1989). The CCC determined the extent of deviation of the data from a line of perfect concordance (a line at 45° angle on a square scatter plot of data), by combining measures of precision and accuracy. The accuracy of the data was described as the proximity of the data's reduced major axis to the line of perfect concordance. The precision of the data was described as the tightness of the data about its reduced major axis. The CCC increased in value as the accuracy and precision of the data increased. Limits of agreement (LOA) were also estimated based upon Bland and Altman's procedure (1986). The LOA assessment which looks at the degree of agreement is considered complimentary to the relationship-scale approach of Lin (1989) P values and Z transforms from the confidence interval (CI) were also calculated.

Of the 174 cows that were sampled in the secondary herds, one animal was not herd recorded, and 23 were not included in the statistical analysis. The data was log transformed to achieve a normal distribution curve for further statistical analysis. A cut point of 1.4mM of blood

BOHB was used for analysis of the data. A descriptive statistic was performed using linear regression, using the 1.4mM cut point as the dependent variable, and milk production (milk volume, milk fat % and milk protein %) as the independent variable. A backwards stepwise regression method was used to determine which variable was significant.

RESULTS

The colorimetric, kinetic and Optium Xceed (OX) blood BHOB concentrations were all very well aligned, showing a strong correlation between the three determinants of BOHB (Table 1). The kinetic assay and Optium Xceed showed a strong correlation (0.95) between BOHB values (Table 1), the colorimetric assay and the Optium Xceed also had a strong correlation (0.97) between BOHB values (Table 1). The kinetic laboratory assay and colorimetric laboratory assay were also strongly correlated for BOHB concentrations of 0.96 (Table 1). A Pearson's r value greater than 0.9 with a p-value of 0 is highly correlated, showing a strong correlation between the each of the tests. This is the first indication that the Optium Xceed blood ketone meter is measuring very closely to the laboratory tests.

Table 1. Correlation (and 95% CI) for the concentrations of BOHB measured using Optium Xceed™ test (blood), colorimetric and kinetic (plasma) methods.

Assay procedures	Correlation & 95% CI (N= 40)	P value
Whole blood (Optium Xceed™ Meter)		
Kinetic-Plasma	0.953 (0.920 – 1.00)	<0.001
Colorimetric-Plasma	0.972 (0.952 – 1.00)	<0.001
Kinetic - Plasma		
Colorimetric-Plasma	0.959 (0.931 – 1.00)	<0.001

The concordance correlation coefficient (CCC) for the Optium Xceed and kinetic BOHB concentrations was 0.92 with a standard error of 0.020 (Table 2).

Table 2. Concordance (and 95% CI) for the concentrations of BOHB measured using Optium Xceed™ test (blood), colorimetric and kinetic (plasma) methods

Assay procedures	Concordance & 95% CI (N= 40)	P value
<i>Whole blood (Optium Xceed™ Meter)</i>		
Kinetic- Plasma	0.916 (0.877-0.954)	<0.001
Colorimetric- Plasma	0.819 (0.745-0.893)	<0.001
<i>Kinetic – Plasma</i>		
Colorimetric- Plasma	0.755 (0.660-0.849)	<0.001

As depicted by Bland and Altman, 1986, a CCC above 0.90 is classed as moderately significant and above 0.95 is classed as highly significant. The CCC between the Optium Xceed and colorimetric assay was 0.82 with a standard error of 0.038 (Table 2). This CCC for the colorimetric assay of BOHB is not significant compared with the kinetic results. The CCC and LOA between the laboratory assays and the Optium Xceed were estimated and displayed in Table 2 and Figures 1-2.

The CCC shows the strength of a relationship between two variables, but not the agreement between the two variables (Bland and Altman, 1986). There is perfect agreement only if the points lie along the line of equality, and there is perfect correlation if the points lie along any straight line (Bland and Altman, 1986).

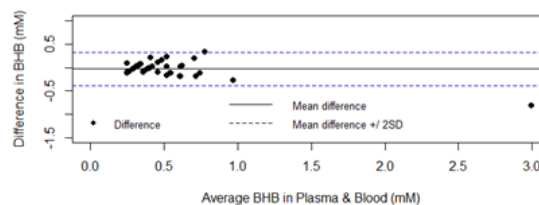
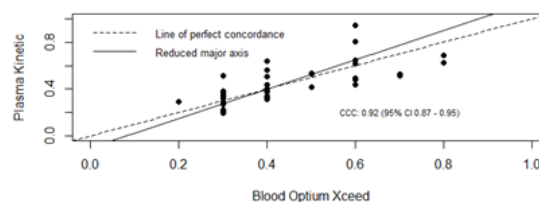


Figure 1. Concordance Correlation Coefficient and Line of Agreement between OX and Kinetic methods for BHOB concentrations.

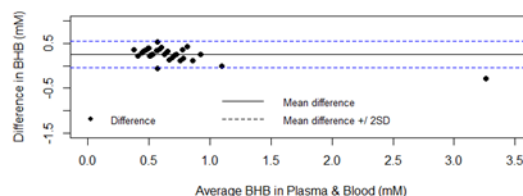
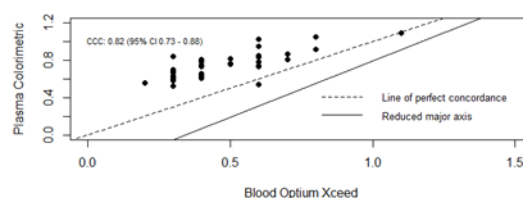


Figure 2. Concordance Correlation Coefficient and Line of Agreement between OX and Colorimetric methods for BHOB concentrations.

The data for the Optium Xceed and kinetic laboratory assay sits within 2 standard deviations from the line of perfect concordance, as seen in Figure 1. In Figure 2, the precision of the data is not as good; however the accuracy of the data is still good. The kinetic data is moderately accurate and precise as shown in Figure 1. When plotted both laboratory methods also produced very good standard curves, with a R² value of 0.997 for the kinetic assay and 0.993 for the colorimetric assay. Initial descriptive statistical analysis showed that BOHB concentration data for the secondary herds

that was measured using the Optium Xceed™ method was not normally distributed, therefore a log transformation of the data was used for the statistical analysis.

The data for this was categorised on a 1.4mM blood BOHB threshold. However there were not

significant relationships between the Optium Xceed concentrations obtained on farm and the production parameters of milk volume, milk fat percentage and milk protein percentage.

Table 3. Summary of production data (\pm SD) for cows below and above the cut-point of 1.4mM of blood BOHB.

	OX BOHB	Log BOHB	Litres/Cow/Day	Milk Fat %	Milk Protein %	Age
Mean						
\pm SD	1.36 \pm 0.28	0.29 \pm 0.2	37.75 \pm 7.07	4.06 \pm 0.64	3.03 \pm 0.14	5.92 \pm 2.29
Min	1.1	0.1	21	2.8	2.8	3
Max	1.9	0.64	51.3	5.3	3.4	13

DISCUSSION

In this study three methods were established for BOHB analysis in blood. The data was determined by comparing a cow-side test; Optium Xceed, and to two laboratory tests; the kinetic and colorimetric assays. The Optium Xceed meter was strongly correlated to the laboratory tests, 0.95 and 0.97 respectively (Table 1). These correlations established the accuracy and reliability of the Optium Xceed meter relative to established laboratory tests, in particular for the kinetic assay (CCC of 0.92), which is the 'gold standard' test throughout the industry (Geishauser, *et.al.*, 2000). In this data subset, the Optium Xceed meter showed moderate levels of agreement with the kinetic laboratory assay, and a low level of agreement to the colorimetric laboratory assay (CCC of 0.82). The moderate CCC between the Optium Xceed and kinetic laboratory assay was an encouraging result, and provided confidence for the use of this meter as an accurate cow-side test. The repeatability of this cow-side test was also established over a range of BOHB concentrations, proving it will be a reliable indicator of BOHB

concentrations, consistent with values for diagnosis of subclinical ketosis, BOHB greater or equal to 1.4mM in blood.

The colorimetric assay was based on the measurement of reduction of a reducing dye. Any non-specific reducing agents present in the samples could have also reacted with the dye to consistently increase the final absorbance reading. This outcome will give a false high reading for BOHB in the samples, which may explain the lower CCC found for the colorimetric assay. Therefore studies that use the colorimetric method will produce greater estimates of the incidence and prevalence of ketosis if not corrected for the interference of these non-specific reducing agents. Consequently, the kinetic assay remains the more reliable of the laboratory methods, and in this study provided the greater concordance correlation coefficient.

Performing a kinetic laboratory analysis of the plasma collected for the secondary herds to determine the BOHB concentrations, in addition to the Optium Xceed BOHB determination, would add confidence to the use of Optium Xceed as a reliable, repeatable on farm diagnostic tool.

The time lag of approximately 3 weeks between collection of the blood samples for BOHB using Optium Xceed and the collection of the herd production data was a flaw in this field study, and possibly contributed to the fact that the herd recording data did not show any relationship to the Optium Xceed BOHB concentrations, or progression of ketosis, in both the initial and secondary herds.

CONCLUSION

The kinetic laboratory assay is the preferred diagnostic indicator of BOHB concentrations and hence degree of ketosis. However, the moderately significant CCC between the Optium Xceed meter and the kinetic laboratory assay allows us to conclude that the Optium Xceed meter is a rapid, reliable and repeatable means of assessing BOHB concentrations on farm.

The sample size and herd numbers were too small to provide enough information to build statistical models about the prevalence of SCK and its impact on production parameters in WA. Nevertheless this data on BOHB and production parameters should provide a foundation for a future larger study to more accurately define and document prevalence of ketosis in Western Australian Dairy herds using cow-side tests.

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COLLECTION OF DATA FOR THE GENETIC IMPROVEMENT OF HEALTH TRAITS IN AUSTRALIAN DAIRY CATTLE

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ABSTRACT

There is growing interest in the Australian dairy industry in the genetic improvement of the health of dairy cows. In Australia, there is minimal storage or export of health data off some on-farm software systems into industry databases to assist in the research or reporting of health traits. The Health Data for Healthy Cows (HDHC) project aims to get a better understanding of the extent of health data recording in the Australian industry by collecting health data from the 100 Ginfo (genomic reference) herds. Health data obtained from herd test centres totalled 275,729 records from just 46 out of the 100 herds. The four most recorded health diseases identified were mastitis, reproductive problems, lameness and metabolic disorders. Mastitis having the highest incidence with 20% of cows affected, followed by reproductive problems (12%), lameness and metabolic disorders (5% and 3% respectively). This project has provided an insight into what health information is actually being collected on farm and that there is a source of health data available which can be accessed and potentially used for the genetic improvement of health traits in Australian herds.

Introduction

Great improvements have been made genetically in milk production in dairy cows over the last 60 years. However unfavourable genetic relationships between milk production and most disease traits, such as mastitis, lameness, reproductive problems and metabolic disorder health traits have become apparent as milk production has increased (Pryce *et.al.* 1997; Rauw *et.al.* 1998; Koeck *et.al.* 2012).

A growing concern for dairy farmers is the improvement of dairy cow health through genetic selection. Healthy cows are more productive, easier to manage, require less intervention, have improved animal welfare and contribute to

profitability by reducing production costs.

However, in many countries, including Australia, industry collection of data on common health events has been sub-optimal or absent, which means there is no ability to provide breeding values and apply genetic selection for common health disorders. Also, such traits are low in heritability, meaning that although genetic progress is feasible, it will be slower. While many farmers may collect some of this information on farm, there is likely to be variation in the completeness of these data sets.

In Australia, there is little storage or export of such information from some on-farm software

packages into industry databases for research or reporting purposes.

Before any work can begin on providing Australian farmers with breeding values for common health disorders, it is important to quantify what data is already being collected on farm and in veterinary practices. As a result of this challenge, the health data for healthy cows (HDHC) project has commenced to help improve our understanding of the extent of health data recording in the Australian dairy industry.

The HDHC project will use infrastructure through the Dairy CRC in the form of the 100 'Ginfo' (Genomic information) herds to collect all health data that is currently being amassed on farm. The Ginfo data is being used as a genomic reference population for genomic breeding values. One of the advantages of having a genotyped population is that it opens up new opportunities for new breeding values, such as dairy health traits.

Therefore the objectives of the HDHC project are:

1. Investigate and identify health data sources available within the herds participating in the Ginfo project
2. Assimilate health data into a database in order to summarise health data status
3. Estimate the incidence of common diseases and health occurrences on dairy farms
4. Estimate antibiotic usage on farms
5. Calculate provisional genetic parameters for health traits where incidence is high enough
6. Estimate the accuracy of genomic selection achievable for data identified health traits

For this paper the first three objectives are covered.

MATERIALS AND METHODS

Health data sources

On farm health data collected from the 100 Ginfo participating herds.

Survey

A survey was used to get an understanding of the health data collection and storage methods that occur on farm. Before participating in the survey, privacy consent and data release authority documents were also provided to the participants to comply with privacy laws.

Obtaining health data

Once the survey, data release authority and privacy consent forms were returned by the farmers; an email was sent to each of the herds respective herd test centres to request all of the data collected for that farm, including the health data interchange format file.

Data analysis

Each of the herds' health data files were merged together to create a master health data file which contained the national cow ID, herd ID, health event, health treatment, date of health treatment, calving date, breed and cow date of birth. Statistical and graphical summaries of the surveys and master health data file were produced using Microsoft office Excel 2013 and the statistical program R version 3.1.1.

Disease incidence calculation

For the calculation of disease incidence the following equations were used:

Number of disease cases (disease occurrence) =
No. of disease cases / No. of cows

Number of cows with cases (%) = No. of cows with cases / Total No. of cows

RESULTS AND DISCUSSION

To date 51 of the Ginfo participants have returned surveys. Out of these, 46 herds have health data recorded, while 5 had no health records.

Therefore, the results currently presented include 46 of the herds out of the total 100 participating in the HDHC project. The total number of raw health records (before any quality control)

obtained only from herd test centres is 275,729 records from 42,056 cows.

Survey

The main form of recording of health data on farm is electronically. Health events are mostly recorded daily across the Ginfo herds.

Figure 1 illustrates the health diseases that dairy farmers regard as most important and what they stated that they recorded on farm.

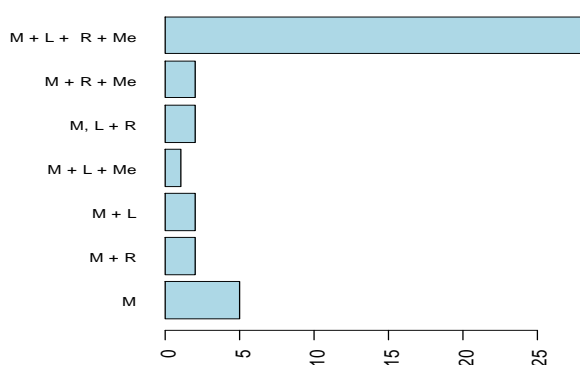


Figure 1. Health diseases farmers ‘say’ they record and what they regard as important. Mastitis (M), Reproductive (R), Lameness (L) and Metabolic (Me)

Data analysis

Analysis of the data indicates that the general health events being mostly recorded are mastitis, reproductive problems, lameness and metabolic disorders (Figure 2). This is fairly consistent with the survey conclusions on what farmers indicated they record and what they think is most important (Figure 1). In relation to other recorded health event traits, mastitis recording accounts for approx. 63% of the health event data set. Reproductive problems accounts for 22% of the data set. Lameness accounts for approx. 9% of the data set and metabolic disorders accounts for approx. 6% of the data set.

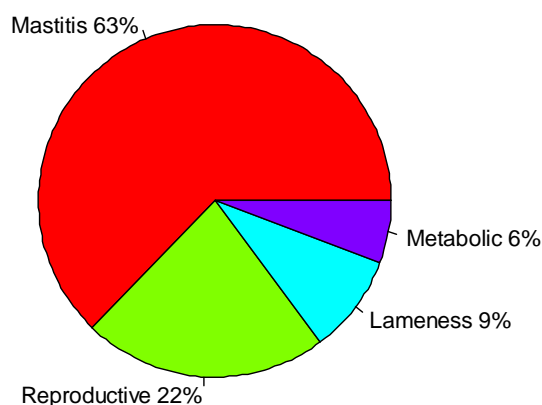


Figure 2. Health data that is actually being recorded on farm.

More mastitis health event data being identified and made available for analysis purposes will assist in improving the reliability of the mastitis resistance breeding value. With fertility being one of the most significant issues facing the dairy industry, knowing that reproduction disorder health data incidences are actually being recorded indicates that farmers are seeing the value and importance of such a trait to the health and production of their cows. Therefore, having a large health event data set would potentially increase the ability for farmers to improve their fertility, and in return profit, through the incorporation into a multi-trait genetic analysis model to improve the reliability and confidence of the fertility breeding value.

Identifying what health event data is actually recorded on farm opens up new avenues of genetic analysis for potential new traits such as lameness and the development of new individual or integrated breeding values to become available to the industry.

Disease incidence

Disease incidence for the top four most recorded health events; mastitis, reproductive problems lameness and metabolic disorders were calculated (Table 1).

Table 1. Disease incidence of the most recorded health traits, total number of cow's with each disease and the total number of cases for each health trait. Mastitis (M), Reproductive (R), Lameness (L) and Metabolic (Me)

Disease	No. of cows	Total no. of cases	Disease occurrence	Cows with cases (%)
M	8495	21611	2.54	20%
R	4972	7730	1.55	12%
L	2237	3124	1.40	5%
Me	1425	1951	1.37	3%

From identified cows that are nominated within the health event data set, individual mastitis health events are recorded about 3 times over the lactation and affects 20% of cows, while reproductive problems are occurring twice and affecting 12% of cows. At a lower level, lameness and metabolic problems in nominated health event cows occurs about once with 5% and 3% of health event recorded cows being affected respectively. Incidences from this data set are less than those previously reported in other studies (Clarkson *et.al.* 1996; Espejo *et.al.* 2006; Clarkson *et.al.* 1996; Parker-Gaddis *et.al.* 2012). Number of cow cases for lameness, reproductive and metabolic problems were lower than previously reported while mastitis cow cases was fairly similar to findings reported in Norway (Osteras *et.al.* 2007).

CONCLUSIONS

In Australian herds, mastitis, reproductive disorders, lameness and metabolic diseases are the most recorded health events. Mastitis is the most occurring disease in dairy herds, followed by reproductive disorders and at a lower occurrence is lameness and metabolic problems. As a result these findings provide clearer decisions on future research priorities, and contribute a reference data set that may be applied for genomic correlation purposes.

ACKNOWLEDGEMENTS

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CAN WE BEAT THE HEAT IN SOUTHERN AUSTRALIAN DAIRY PASTURES?

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ABSTRACT

Heat waves are forecast to increasingly challenge home-grown feed production in southeast (SE) Australian dairying regions. It is estimated that on average between 60% and 70% of a dairy cow's diet in SE Australia is derived from perennial ryegrass (*Lolium perenne* L.), which has a low tolerance to high ambient temperatures (>30°C). There is an increasing need to identify temperate perennial forage species that are better adapted to heat wave conditions. To address this research objective a controlled environment study was undertaken to compare the responses of ten perennial forage species to optimal and heat wave temperature regimes (day/night ambient temperatures of 23/15°C and 38/26°C). The effect of soil moisture availability (optimal watering or no water) and the recovery capacity of plants grown in optimal conditions (day/night ambient temperature regime of 23/16°C; optimal watering) for 18 d after treatments ceased were also examined. Chicory (*Cichorium intybus* L., cv. Grasslands Puna) proved most tolerant, evidenced by its' capacity unlike perennial ryegrass (cv. Samson) to recover from exposure to heat stress and soil moisture deficit applied for 18 d. Results indicate chicory may enable a relatively high level of home-grown feed production to resume following an extended heat wave, that is not possible with perennial ryegrass under dryland conditions.

INTRODUCTION

Dairying in temperate southeast (SE) Australia has remained economically viable against declining terms of trade, due to the competitive advantage of favourable climatic conditions for growing low-cost home-grown feed (Chapman, Kenny, & Lane, 2011). Heat waves increasingly challenge this advantage, with two of the region's most severe heat waves in the last century having occurred since 2009 (BOM, 2014). During the January 2009 heat wave, daily maximum ambient temperatures

(T_{max}) exceeded 35°C and in many cases 40°C for three or more consecutive days, at locations typical of the key Victorian dairying districts (East Sale, Kerang, and Warrnambool). Despite no universal definition, heat waves are typified by a period of consecutive abnormally hot days. Heat waves are subsequently not restricted to summertime; however this study does not consider seasonally anomalous events. Regardless of definition it is accepted that the frequency, duration, and intensity of heat waves will increase during the 21st century (Parker, Berry, & Reeder, 2014). In Tasmania the frequency of heat waves is

forecast to significantly increase in the Midlands and Derwent Valley (White *et.al.*, 2010); two regions currently experiencing an expansion in dairying.

SE Australian dairy farming systems are particularly vulnerable, due to 60-70% of the dairy cow's diet being derived from perennial ryegrass (*Lolium perenne* L.) (Chapman, Kenny, Beca, & Johnson, 2008). Shoot growth inhibition of ryegrass occurs at an ambient temperature of 35°C under fully-watered conditions (Mitchell, 1956). Detrimental high temperature effects on ryegrass involve the imbalance of photochemical and biochemical processes via reduced rubisco activity, which is an enzyme involved in carbon fixation.

Excess electrons are diverted to hydrogen peroxide (H₂O₂) production, a toxic product able to damage many cellular structures (Soliman, Fujimori, Tase, & Sugiyama, 2012). Summer-active forage species capable of withstanding heat wave conditions are subsequently required; however there has been a lack of research regarding the heat tolerance of existing forages.

To address this need, the tolerance of a range of forage species to simulated heat wave conditions with and without irrigation was assessed. Tolerance was defined as a species' ability to support high growth rates during or shortly after the cessation of stress. This differs from previous research that has focused on survival via summer dormancy. Only temperate grazeable perennial species were considered.

MATERIAL AND METHODS

Plant material: Eight species were evaluated, viz. two forbs, chicory (*Cichorium intybus* L., cv. Grasslands Puna) and plantain (*Plantago lanceolata* L., cv. Ceres Tonic); three grasses, prairie grass (*Bromus willdenowii* Kunth., cv. Ceres Atom), cocksfoot (*Dactylis glomerata* L. cv. Megatas), and tall fescue (*Festuca arundinacea* Schreb., cv. Quantum II MaxP™); and three

legumes, birdsfoot trefoil (*Lotus corniculatus* L., Tas 2951), lucerne (*Medicago sativa* L., cv. Sardi 5) and stoloniferous red clover (*Trifolium pratense* L., cv. Rubitas). Diploid perennial ryegrass cv. Grasslands Samson was included as a standard; with diploid rhodes grass (*Chloris gayana* Kunth., cv. Katambora) used as a positive control. For the purposes of this paper only key ryegrass and chicory results are presented.

Growing conditions and establishment: This study was undertaken in two independent zones within a climate controlled glasshouses facility, at the Tasmanian Institute of Agriculture, Burnie, Australia. Day length was maintained at a minimum of 14 h, with day/night temperatures set at 20/10 ± 2°C during establishment.

Plants were grown from seed in 3.8 L pots (5 plants/pot), coloured white to minimise pot heating. Potting media was composed (v/v) of 50% composted pine bark, 30% coarse sand, and 20% *Spaghnum* sp. moss. Legumes were inoculated once all seedlings were at the unifoliate leaf-stage. During establishments pots were arranged in a randomised complete block design containing four blocks. Intra-block variability was minimised by re-randomising pots within blocks at least every 31 d.

During establishment pots were watered at 1-3 d intervals until 85 days after sowing (DAS), with water delivered by an automated drip irrigation system for the remaining 170 d. Plants were defoliated to a 50 mm height at 54, 91, 127, 164, 199, 231, and 250 DAS. Non-limiting nutrient levels were maintained by regular fertilizer applications.

Experimental design: Treatments were imposed 256 DAS in a randomised split-plot design, with the combination of block and temperature regime the main-plot, stress durations assigned to subplots, and the combinations of species, moisture availability and recovery time distributed within subplots in a completely randomised design. In total 960 pots were

included (4 blocks x 2 temperature regimes x 3 stress durations x 10 species x 2 moisture availability levels x 2 recovery periods).

Temperature and stress duration: Temperature regimes consisted of an optimal and heat wave treatment (denoted *O* or *H*). *O* mean ambient temperatures were 23°C for 14 h (day) and 15°C for 10 h (night). *H* mean ambient temperatures were 38°C for 14 h (day) and 26°C for 10 h (night). Temperature regimes were maintained for short (6 d), medium (12 d), or long (18 d) durations (denoted *S*, *M*, or *L*). Each zone contained only one main-plot at any time; to avoid pseudo-replication, main-plots were rotated between zones at 3 d intervals so that each main-plot by stress duration spent equal time in both glasshouse zones.

Irrigation and recovery period: Moisture availability levels were optimal watering (daily to through drainage) or no water (denoted, *Irr* or *Dry*) for the total stress duration. At the conclusion of a stress period plants were removed and harvested or returned to an optimal temperature [mean ambient temperature of 23°C for 14 h (day) and 16°C for 10 h (night)] and watering regime for 18 d (denoted, *RO* or *R18*).

Combined treatments are here on coded, e.g. heat wave treatment by short stress duration by optimal watering by no recovery is given as *HSIrrRO*.

Harvests and measurements: At the end of each duration by recovery period treatment all herbage above 50 mm was harvested, dried to constant weight (60°C), and weighed.

Statistical analysis: Data was analysed as a split plot design. Yield data from the final establishment defoliation was included as a covariate. Quantile-quantile plots of residuals were examined to assess distributional assumptions, with a square root transformation selected.

All data were analysed using the PROC MIXED procedure of SAS (SAS for Windows Release 9.3, SAS Institute, NC, USA), with comparisons of means using appropriately constructed contrasts. Associated P values were adjusted using PROC PLM (Edwards & Berry, 1987). All estimated mean and standard error values presented have been back-transformed. Differences were considered significant when $P < 0.05$, with differences discussed in following sections significant at this level.

RESULTS

The interaction of main plot (block by temperature regime) by stress duration by species by moisture availability by recovery period was significant ($F_{18, 677} = 2.04$; $P < 0.01$).

Both species were able to recover (*RO* vs. *R18*) from water deprivation (*Dry*), regardless of stress duration (*S*, *M*, or *L*) (Table 1). However, ryegrass was unable to recover from the cumulative stress of water deprivation (*Dry*) and heat wave (*H*) temperatures, when applied for *M* and *L* durations (Table 1).

In contrast chicory was able to recover from the combined stress irrespective of duration, yielding 57% and 23% of that attained by their *OMIrrR18* and *OLIrrR18* contemporaries (Table 1).

Ryegrass yield in *OMDryRO* and *OLDryRO* treatments was significantly lower than their *OIrrRO* contemporaries; chicory yield was lower in *OLDryRO* relative to *OLIrrRO* treatments (Table 1). Similarly both species yielded less in *HDryRO* compared to *OIrrRO* treatments, at the *M* and *L* durations (Table 1).

Dry matter yield of each species did not differ between *ODryRO* and *HDryRO* treatments at each stress duration (*S*, *M*, or *L*) (Table 1). The yield of both species when exposed to either treatment also did not significantly change between stress durations (Table 1).

Yield of each species did not significantly differ between *HlrrRO* and *OlrrRO* treatments at each stress duration (*S*, *M*, or *L*) (Table 1). Although not

significant the yield of ryegrass in *HMIrrRO* and *HLIrrRO* treatments was 36% and 26% less than their *OlrrRO* counterparts.

Table 1. Dry matter produced by ryegrass and chicory exposed to contrasting temperature regimes (*O* = Optimal, *H* = Heat wave) and moisture availability levels (*Irr* = optimal watering, *Dry* = no water) for different durations, with and without a recovery period (denoted, *RO* and *R18*). The back-transformed mean \pm one standard error is shown.

Species	Temperature x Moisture	Recovery	Stress Duration			
			Short (6 d)	Medium (12 d) Dry matter (g/pot)	Long (18 d)	
Perennial Ryegrass	<i>Olrr</i>	<i>RO</i>	5.87 \pm 0.62 Bba	10.95 \pm 0.85 Aba	12.38 \pm 0.89 Aba	
		<i>R18</i>	15.59 \pm 1.01 Baab	20.73 \pm 1.16 ABaa	24.85 \pm 1.27 Aaa	
	<i>ODry</i>	<i>RO</i>	5.17 \pm 0.58 Aba	5.00 \pm 0.57 Abbc	5.35 \pm 0.59 Abb	
		<i>R18</i>	13.58 \pm 0.94 Aaab	13.11 \pm 0.92 ABab	9.31 \pm 0.78 Bab	
	<i>Hlrr</i>	<i>RO</i>	5.10 \pm 0.57 Bba	7.04 \pm 0.68 ABbab	9.17 \pm 0.77 Aba	
		<i>R18</i>	17.47 \pm 1.06 Aaa	17.57 \pm 1.07 Aaab	22.36 \pm 1.20 Aaa	
	<i>HDry</i>	<i>RO</i>	4.03 \pm 0.51 Aba	3.29 \pm 0.46 Aac	3.16 \pm 0.45 Aab	
		<i>R18</i>	11.92 \pm 0.88 Aab	4.05 \pm 0.51 Bac	3.18 \pm 0.45 Bac	
	Chicory	<i>Olrr</i>	<i>RO</i>	4.17 \pm 0.52 Bba	6.47 \pm 0.65 ABba	9.91 \pm 0.80 Aba
			<i>R18</i>	11.54 \pm 0.87 Baab	12.67 \pm 0.91 Baa	18.12 \pm 1.09 Aaa
		<i>ODry</i>	<i>RO</i>	3.31 \pm 0.46 Aba	3.91 \pm 0.50 Abab	3.91 \pm 0.51 Abb
			<i>R18</i>	8.95 \pm 0.76 Aab	11.12 \pm 0.86 Aaab	9.65 \pm 0.80 Aab
<i>Hlrr</i>		<i>RO</i>	4.37 \pm 0.73 Bba	6.42 \pm 0.65 ABba	9.10 \pm 0.77 Aba	
		<i>R18</i>	15.62 \pm 1.15 Aaa	14.56 \pm 0.97 Aaa	16.13 \pm 1.03 Aaa	
<i>HDry</i>		<i>RO</i>	3.18 \pm 0.46 Aba	2.59 \pm 0.41 Abb	2.85 \pm 0.43 Abb	
		<i>R18</i>	8.46 \pm 0.75 Aab	7.24 \pm 0.69 Aab	4.15 \pm 0.52 Bac	

Values followed by the same letters do not differ ($P < 0.05$); upper-case letters compare species across stress durations within temperature by moisture by recovery period treatments; lower-case letters compare between recovery periods (*RO* vs. *R18*) within stress durations for each species by temperature by moisture combination; lower-case bolded and underlined letters compare between temperature by moisture levels (*Olrr* vs. *ODry* vs. *Hlrr* vs. *HDry*) within each stress duration for each species by recovery period combination.

DISCUSSION

Chicory had a superior ability compared to ryegrass to recover from combined heat stress and moisture deficit (*HDry*). After an 18 d recovery period (*R18*) from *HDry* chicory yield was 180% and 46% greater than at the end of *MRO* and *LRO* stress periods, respectively. Chicory yield at the end of *HMDryR18* and *HLDryR18* treatments was 57% and 23% of their *OlrrR18* contemporaries.

Ryegrass in contrast was unable to recover from either of these treatments, based on yield, indicating plants had senesced. Despite the low likelihood of comparable heat wave temperatures occurring for ≥ 12 d in SE Australia during the short-term (BOM, 2014), such conditions would be expected to have a greater impact on ryegrass survival in dryland systems already experiencing soil moisture deficits.

A possible explanation is provided by the high moisture content of the potting media at the commencement of treatments, meaning that moisture deficits developed progressively. It is hypothesised that the capacity of plants to mitigate heat stress via transpirational cooling would have declined with reductions in moisture content.

Chicory could enable dryland producers to mitigate the detrimental impact of these stresses on enterprise viability, through maintaining their competitive advantage of low-cost home-grown feed in a changing climate (Chapman *et.al.*, 2011).

This is particularly important, due to the regular occurrence of soil moisture deficits and increasing frequency of heat waves in SE Australia (Neal *et.al.*, 2009; Parker *et.al.*, 2014). However, widespread adoption of chicory depends on the development of grazing management practices to prolong the life of stands above 2-4 years (Volesky, 1996), which should form a future research objective.

In contrast to combined heat stress and moisture deficit (*HDry*), both species were able to recover from moisture deficit in isolation (*ODry*), regardless of duration. This demonstrated the greater severity of the additive stresses on ryegrass. Interestingly, if evaluations had been restricted to stress periods (*RO*) only, heat stress would have been concluded to have no additional impact on either species when subject to water deprivation, based on yield comparisons at the end of each stress period. This is because neither species continued to grow after the first 6 d of water deprivation treatments, regardless of temperature.

The finding that the yield of irrigated (*Irr*) pots was independent of examined temperature regimes contrasts with previous work, reporting reductions in ryegrass growth at temperatures above 29.4°C (Mitchell, 1956). However, it should be noted that ryegrass yield was lower in heat relative to optimal temperature regimes, but at a

non-significant level. Possible explanations for this discrepancy include the large pot volume used in the current study, which may have contained sufficient water to support evaporative cooling throughout the day. Research into the use of irrigation strategies to mitigate heat stress should also form a future research priority.

CONCLUSION

The key finding of this study was the ability of chicory to recover from combined heat stress and moisture deficit, when applied for *M* and *L* durations. These conditions caused ryegrass to senesce. Future research will confirm these findings under field conditions and elucidate the mechanisms underlying chicory's tolerance to combined heat stress and moisture deficit. Potential irrigation strategies for mitigating heat stress in existing ryegrass pastures will also be investigated.

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EFFECTS OF DIETARY FAT ON FERTILITY OF DAIRY CATTLE: A META-ANALYSIS AND META-REGRESSION

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ABSTRACT

There is increasing evidence of positive effects of feeding fats during transition on fertility and adaptation to lactation. This study utilized meta-analysis and meta-regression methods to explore the effects of including fats in the transition diet on the risk of pregnancy to service ('proportion pregnant'), calving to pregnancy interval and production outcomes. Only 17 studies containing 26 comparisons were suitable for inclusion in statistical evaluations. This relatively low number of high quality studies highlights the need for more work to improve understanding in this area. Production variables examined were milk yield, milk composition, and body weight. The sources of heterogeneity in these studies were also explored. A 27% overall increase in pregnancy to service was observed (RR = 1.27; 95% Confidence interval Knapp Hartung 1.09 to 1.45) and results were relatively consistent ($I^2 = 19.9\%$). A strong indication of a reduction in calving to pregnancy interval was also identified, which was consistent across studies ($I^2 = 0.0\%$), supporting a conclusion that overall, the inclusion of fats does improve fertility. Meta-regression of dietary factors contributing to proportion pregnant identified that increased fermentable neutral detergent fiber and soluble fiber intakes increased the proportion pregnant while increased milk yield of the treatment group decreased this measure. Unexpectedly, the estimated energy costs of urea production also had a positive association with proportion pregnant.

INTRODUCTION

Managing fertility of lactating dairy cattle is a challenge for dairy producers as poor fertility reduces productivity and profit. Studies are needed to identify which environmental factors, especially nutritional ones, may have a role in influencing the fertility of cattle. Good management during the transition period, in particular nutritional strategies, can reduce the effects of this metabolic stress and improve production and reproduction (De Veth *et al.*,

2009). DeGaris *et al.* (2010a, b) found that the risk of pregnancy increased by approximately 30% in cattle exposed to transition diets for 20 days compared to cattle not exposed. Recent understandings of the role of fats in metabolism open new opportunities for improving metabolism, health and reproduction in cattle. The strength of meta-analytic methods is the ability to integrate smaller studies using effect size metrics, enhance the statistical power over that of any single study and provide the potential to explore new hypotheses (Lean *et al.*, 2009).

Further, there is a challenge in nutrition studies that when a nutritional intervention is applied, something else in the diet necessarily changes (Lean *et al.*, 2012). Therefore, there is a need to consider the potential for confounding influences in interpreting studies of the effects of nutrition on reproduction. Meta-regression methods allow this type of investigation. This study was designed to utilize meta-analytic and meta-regression methods to explore the effects of including fats in the diet during the transition period on measures of pregnancy, calving to pregnancy interval, and milk yield, and components and the factors that may explain sources of variation in these responses.

METHODS

A systematic review, across three databases (PubMed, Web of Science CABI and Google Scholar) and references in papers, was used to identify studies exploring fat nutrition during transition and fertility that were published in English between 1970 and 2014 in a peer-reviewed journal or conference proceedings. Papers were deemed suitable for inclusion in the study if they were randomized controlled experiments using *Bos taurus* dairy cows in their first or later lactation and adequately evaluated the effect of feeding during the transition period (± 3 weeks of calving). Measures of fertility were reported as i) first service conception or pregnancy to a defined number of services ('proportion pregnant'); and/or ii) calving to pregnancy interval or days open. Milk production (kg/cow/d), milk fat percentage and yield (kg/cow/d) and milk protein percentage and yield (kg/cow/d) were also recorded.

Statistical Analysis

All statistical analyses were conducted using Stata (v 13 Intercooled Stata v.13, USA). Trials were grouped by type of fat intervention (oilseeds, calcium salts of fatty acids (CSFA), tallow, conjugated linoleic acids (CLA) or other) and

meta-analyses were conducted for each group and overall to examine the effects of fat intervention on 'proportion pregnant to service', days from calving to pregnancy, and milk yield and composition. Dicotomous data were analyzed by using relative risk (RR) and continuous data by standardized mean difference (SMD) which is also called effect size (ES) analysis. The RR estimates were pooled using methods for random effects models and evaluated using the Hartung-Knapp-Sidik-Jonkman (Knapp-Hartung) method (IntHout *et al.*, 2014). The use of this method for meta-analysis is more robust than alternative methods such as the DerSimonian and Laird (1986) method for discrete data, especially where there is heterogeneity (IntHout *et al.*, 2014). Publication bias was explored using funnel plots. The statistical methods for the meta-analytic procedures that were used in this paper have been based on those published by one of the authors of this study (Lean *et al.*, 2009). Meta-regression analyses were used to explore sources of heterogeneity of response arising from diet for proportion pregnant. Model fit during development of the final model was evaluated using I^2 , τ^2 and R^2 where I^2 describes the percentage of total variation across studies that is due to heterogeneity, τ^2 is the variance of the standard deviation of the distribution of true effects across studies and R^2 is the ratio of explained variance to total variance, or the proportion of variance explained by that covariate. Due to the low number of trials identified for calving to pregnancy interval, a multivariate analysis was not conducted.

RESULTS

Literature Review and Assessment

The detailed systematic review identified more than 5,000 papers. All papers were critically reviewed against the selection criteria. Where papers reported more than one comparison, they were assessed separately. After assessment, 17 studies containing 26 comparisons were found

suitable for inclusion in the meta-analysis. Comparisons were then classified by fat type; Oilseeds (n = 6), CSFA (n = 9), Tallow (n = 4), CLA (n = 4) and Other (n = 3). The Other group was comprised solely of comparisons of prilled fatty acids obtained from a single paper. Consequently, there is a limited ability to draw individual conclusions from this group but these data have been included in the overall pooled estimates.

Reproduction Outcomes

The pooled estimates show that increasing dietary fat during the transition period increased the risk of pregnancy (proportion pregnant to service) by 27% when predicted using the method described by Knapp and Hartung (2003) (95% CI 1.09 to 1.45) (Table 1, Figure 1). All groups tended to

show a positive effect, but none (excluding Other fats) showed an individually significant benefit.

Overall, there was a moderately high level of consistency among trials ($I^2 = 19.9\%$) (Figure 1), and the funnel plot is was symmetrical suggesting little publication bias. The proportion of cows pregnant increased with increasing intake of fermentable NDF and soluble fiber (kg/d) when assessed using a bivariate model accounting for fat group ($P = 0.035$ and 0.015 respectively). The estimated energetic cost of urea synthesis (MJ/d) was also positively associated with fertility ($P = 0.022$). Increased actual milk yield (kg/d) for the treatment group decreased the proportion pregnant ($P = 0.036$).

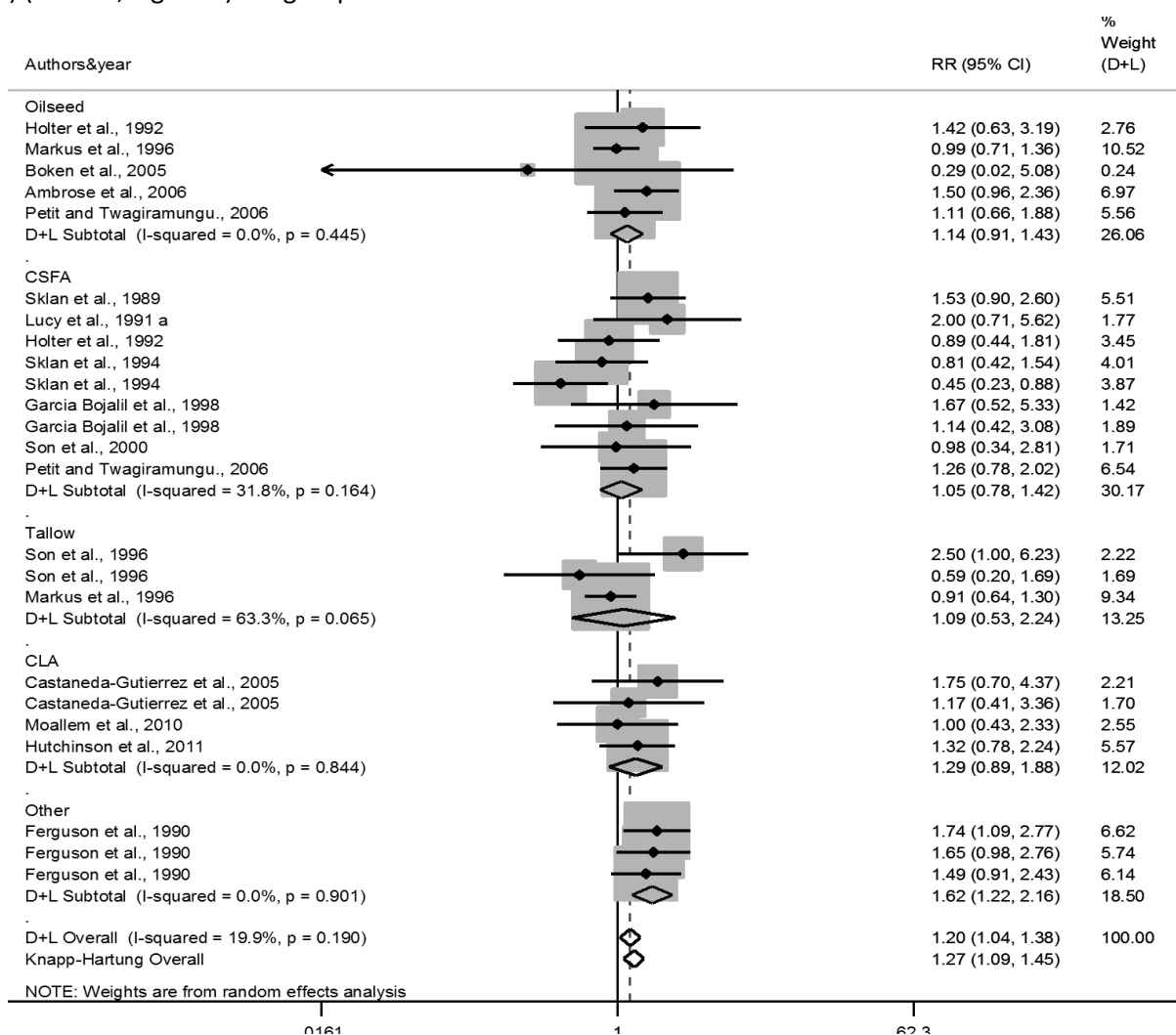


Figure 1: A Forest plot of the studies that examined the relative risk of pregnancy to service (95% confidence interval) for dietary fat interventions.

These relationships were all significant and had the same point direction in univariate models. No model that combined more than two covariables with the effect of fat group resulted in significant covariables, apart from fat group.

Most studies indicated that increasing dietary fat during the transition period numerically decreased calving to pregnancy interval, but none were individually significant. Only 10 comparisons provided adequate data on calving to pregnancy interval to be included in the meta-analysis. There was only one comparison for oilseeds which considerably reduced the inference range for this group.

Table 1. Effects of feeding fats on reproduction, milk yield and composition and body weight: meta-analysis outputs using DeSimonian and Laird random effects model unless specified.

	RR or SMD (95% CI)	I ²	P-value
Proportion pregnant to service *	1.20 (1.04 to 1.38) 1.27 (1.09 to 1.45) (Knapp-Hartung)	19.9	0.19
Calving to pregnancy interval	-0.16 (-0.33 to 0.00)	0.0	0.82
Milk yield	0.33(-0.1 to 0.67)	88.3	0.01
Protein %	-0.14 (-0.38 to 0.10)	74.3	0.01
Protein yield	0.34 (-0.07 to 0.75)	84.1	0.01
Fat yield	0.04 (-0.39 to 0.47)	87.4	0.01
Fat %	-0.03 (-0.32 to 0.26)	84.3	0.01

These are standardized units and do not correspond to normal metrics.

**RR (relative risk) is reported, while SMD (standardized mean difference) is reported for categories not signified with an asterisk.*

I² describes the percentage of total variation across studies that is due to heterogeneity.

Of the remaining groups, CLA had the greatest effect (SMD = -0.41), although this was not significant. Overall, there was a high level of consistency of response among trials (I² = 0.0%), but there appears to be some potential for publication bias in these data as the funnel plot was not symmetrical.

The asymmetry may, however, reflect the limited number of studies. Only oleic acid (C18:1cis) intake and availability at the duodenum was associated with reduced calving to pregnancy interval, with a P-value < 0.2. Therefore no dietary measures were significantly associated with the calving to pregnancy interval.

Production Outcomes

Production outcomes are detailed in Table 1. Overall, feeding fats during the transition period tended to increase milk yield and milk fat and protein yield while decreasing milk fat and protein concentration. Milk fat yield increased with Oilseed and CSFA feeding, but both milk fat yield and concentration both decreased when CLA were fed. Feeding CLA also reduced the percentage of protein in milk. For all milk yield and composition variables there was a high level of heterogeneity among studies (I² = > 80%) and funnel plots were asymmetrical suggesting a potential for publication bias.

DISCUSSION

Despite more than 5,000 papers being identified in a systematic literature search on this topic, only 17 of these, providing 26 comparisons, were suitable for inclusion. This limited number of studies highlights a need for more highly controlled studies to be conducted in this area, examining the effect of exposure variables (including diet) on reproductive outcomes. There was substantial variability in the fat content and type of control diets. Meta-analysis and meta-regression methods allow these sources of variation to be explored as a single data set and can be used evaluate differences in treatment

amounts of fat or differences in diet structure resulting from fat inclusion.

Fat feeding during transition has a variable impact on performance of lactating dairy cows with studies reporting mixed results on fertility (Grummer and Carroll, 1991). In the current study, the overall effects of fat feeding increased the proportion of cows pregnant to service and tended to reduce the interval from calving to pregnancy. When explored individually, the results show that each fat group tended to improve fertility, however, the limited number of studies available for analysis, and small size of many of these studies, prevented clear effects being identified.

For the studies suitable for inclusion in this meta-analysis, reproductive responses were consistent with I^2 of 19.9% and 0%, indicating low heterogeneity for the proportion pregnant to service and interval from calving to pregnancy, respectively. McNamara *et.al.* (2003) found that feeding fats increased first service pregnancy, but did not change overall percentage of cows pregnant. While no fat type individually increased fertility in this meta-analysis, studies exploring CLA feeding have previously shown positive results, although the number of high quality studies is limited (Thatcher *et.al.*, 2006). De Veth *et.al.* (2009) combined 5 studies and observed a marked improvement in median time to pregnancy (reduced from 151 to 117 days) in cows fed a ruminally protected CLA compared to unsupplemented cows.

Increased milk yield (kg/d) in the treatment groups decreased the proportion pregnant in both univariate and multivariate meta-regression models ($P = 0.02$ and $P = 0.04$ respectively). Milk production demands of the freshly lactating cow exceed the capacity of DMI to deliver key nutrients including amino acids and energy precursors, ensuring most cows are in a state of negative nutrient balance in early lactation. Including fat can increase energy density of the diet, without increased dependence on rapidly

fermentable carbohydrates which, when fed at high levels, can compromise rumen and metabolic health. Fats are important sources of essential fatty acids including linoleic (C18:2) and linolenic (C18:3) acids.

Unsaturated fatty acids may target reproductive tissues when supplied in a form absorbed in the lower gut (Thatcher *et.al.*, 2006). Fatty acids are essential precursors for reproductive hormones and Grummer and Carroll (1991) speculated that the presence of cholesterol-enriched lipoproteins could enhance progesterone production. This was supported by detection of increased levels of PGF2a after feeding prilled long chain fatty acids (Carroll *et.al.*, 1990). Lipogenic precursors are also required for efficient milk production, and the optimal requirement was estimated to be 15 to 25% of energy supplied as lipogenic precursors, or about 8% long chain fatty acids in the diet (Kronfeld, 1976). The tendency for pregnancy to be increased with higher milk fat percentages ($P = 0.055$) suggest that the ability of animals to spare fat for milk production is an indication of good metabolic status supporting reproduction. Inclusion of fats in the diet may also reduce liver triglyceride accumulation (Selberg *et.al.*, 2002) and concentrations of NEFA in blood (Doepel *et.al.*, 2002) immediately after calving and increase serum cholesterol concentrations (Rafalowski and Park, 1982, Carroll *et.al.*, 1990), a factor associated with better fertility (Westwood *et.al.*, 2000; Moss, 2001). In this meta-analysis, the potentially confounding effects of diet formulation to include fats in the diet were assessed by using meta-regression. Increasing dietary intake of slower fermenting carbohydrates (NDF and soluble fibre) favoured proportion pregnant, possibly because slower fermentation results in more stable rumen conditions and promotes microbial growth. Chalupa *et.al.* (1986) found that including high levels of fat in the diet affected microbial metabolism, as indicated by a decrease in the ratio of acetate to propionate concentrations in the rumen. The positive

association between the energetic cost of urea synthesis and pregnancy was unexpected, but may reflect a need for soluble protein intake to increase in high fat diets to maintain microbial protein synthesis and highlights the multivariable responses to nutritional intervention.

CONCLUSION

Feeding fats in transition may be an essential component of an integrated response to the challenges of controlling tissue mobilization in early lactation and limiting the amount of fermentable carbohydrate fed. However, meta-regression of the difference in diets between treatment and control groups did not identify the reasons for these improvements in regard to the fatty acid composition of the diet. The limited number of papers identified from the literature search and the positive results of this study, support the need for further work exploring the effects of including fat in the diet of the transition cow on fertility and the development of guidelines to assist study design in this area of research.

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INCREASING THE ACCURACY OF GENOMIC PREDICTIONS FOR RESIDUAL FEED INTAKE IN DAIRY CATTLE

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ABSTRACT

Residual feed intake (RFI) is the difference between actual feed intake and predicted feed intake for maintenance, growth and milk production. RFI is an important trait in beef and dairy cattle reflecting efficiency of animals in feed utilization, however it is expensive to measure and so difficult to select for. Genomic selection can be used to improve feed efficiency, but in cattle the reference population of animals that have RFI records is small and limits the accuracy of equations that predict RFI from DNA markers (i.e. Single Nucleotide Polymorphism or SNP) genotypes. The size of the reference population could be increased by combining dairy cattle with beef cattle data. Moreover, finding SNPs which are associated with RFI records can also increase the accuracy of RFI genomic estimated breeding values (GEBV). We used a population of beef cattle to find markers with larger than average effect on RFI by carrying out a genome wide association study (GWAS). The markers significantly ($P < 0.001$) associated with RFI were then used as an auxiliary source of information to calculate GEBVs for RFI in a multibreed population that consisted of 842 dairy heifers (Holstein) and 4,772 beef cattle with genomic best linear unbiased prediction (GBLUP) method. Using this strategy we increased the accuracy of GEBVs in a validation sample of Holsteins from 0.33 to 0.43. This shows that adding beef RFI data to a reference population of dairy data can increase the accuracy of genomic prediction for RFI in dairy cattle.

INTRODUCTION

Both producers and consumers play major roles in animal production systems. While consumers demand healthy food at affordable prices, breeders need to fulfil market demands at the same time as optimising their own profit. In order to maintain or increase their businesses, producers compete with each other to provide products of higher quality at lower prices (Polkinghorne and Thompson, 2010). While breeders mainly focus on increasing their returns,

they also need to reduce production costs in order to maximise their profit.

In dairy cattle production, the important traits in breeding programs are broad in accordance with the wide range of breeding objectives, but focus on milk yield and its components (i.e. protein and fat), fertility, longevity and mastitis resistance (Gonzalez-Recio *et al.*, 2014). However, another trait which is important in the profitability of beef and dairy production, whether based on grazing

or intensive systems, is the efficiency of converting feed to products. Feed costs represent 55 to 75% of beef production total costs which is on average 70% variable costs (Moore *et.al.* 2006) and 40 to 67% of dairy production total costs (Beever and Doyle, 2007). In dairy herds, 23 to 28% of dry matter is consumed by heifers and dry-cows (Connor, 2014). The replacement rates of dairy herds typically range between 20-30%, so a large proportion of stock on farm are replacements at any time and feeding them is an important and expensive part of farm businesses, as it is not until lactation begins that on investment in growing heifers is recouped. Therefore, improving feed efficiency in heifers is an important objective. Furthermore, efficient cattle also produce less methane and manure (Hegarty *et.al.*, 2007).

On top of this, feed costs have increased in recent decades, making feed efficiency more important (Connor, 2014) in addition to a greater reliance on total mixed rations and grain supplements for feeding high producing milking cows (Beever and Doyle, 2007).

The variation of RFI in cattle is partially due to genetic variation that makes it possible to select superior animals to improve feed efficiency in the next generations (Arthur *et.al.*, 2001). However, genetic evaluation for feed intake and efficiency requires the collection of individual feed intake data on many animals. Therefore, feed efficiency is hard to select for especially in milking cows (Williams *et.al.*, 2011).

Genomic selection, by using dense markers information from the reference population which contains animals with genotypes and phenotypes, makes selection for RFI feasible in animals that are genotyped but do not have phenotypic data at the farm level (Meuwissen *et.al.*, 2001). However, the small size of reference population with RFI records in dairy cattle limits the accuracy of equations that predict RFI from SNP genotypes. The size of the reference population could be

increased using data from beef breeds which have more RFI records comparatively.

The aim of our research was to increase the accuracy of GEBVs for RFI in dairy cattle (Holstein heifers) using information from beef cattle.

MATERIAL AND METHODS

There were 5,614 animals with RFI records that consisted of 842 Holstein heifers (Pryce *et.al.*, 2012), 2,009 Australian beef cattle (1,134 Angus, 217 Hereford, 79 Murray Grey and 579 Shorthorn) (Bolormaa *et.al.*, 2013) and 2,763 Canadian beef cattle (534 Angus, 384 Charolais and 1,845 mixed synthetic breed) (Abo-Ismael, 2011). The Holstein heifers and 820 Australian Angus cattle from Trangie Research Station, New South Wales, were fed an alfalfa pelleted diet and measured at about 9 months of age, while the other cattle were fed a finishing feedlot diet and measured at older ages (10 to 18 months of age). The phenotypic variance for RFI in the three datasets was adjusted to be 1 in our study.

The Holstein heifers were genotyped with the Illumina HD Bovine SNP chip (800K) and the beef cattle SNP data was either directly from the HD chip or imputed from lower density SNP chips to HD using BEAGLE software.

The common SNPs from the Australian beef, Australian dairy and Canadian beef datasets (606,096 SNPs) were used to generate the genomic relationship matrix (GRM) using the method of Yang *et.al.* (2010).

The SNP effects in a multi-breed population was estimated as the overall and the within breed SNP effects using the overall GRM in which genomic relationships between animals were included and within breed GRM in which all relationships between animals in different breeds are zero indicating that there is no relationship between them. However, the Murray Grey and non-Trangie Australian Angus were grouped together into a group called 'super-breed1', because of the genetic similarity of Murray Grey to Angus.

The Holsteins and the Angus cattle from the Trangie experiment were also grouped together into a group called 'super-breed2' because they were fed a similar diet (alfalfa cubes) and measured for RFI at an early age. So, the model for estimating GEBVs was:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Qg}_1 + \mathbf{Qg}_2 + \mathbf{Sa} + \mathbf{e} \quad (1)$$

where, \mathbf{y} is the vector of RFI records, \mathbf{X} , \mathbf{Q} and \mathbf{S} are the design matrices relating phenotypes to their corresponding fixed effects and random effects (polygenic effects and GEBVs), respectively; \mathbf{b} is the vector of fixed effects including dataset (study from which data was sourced), herd, feed management group prior to and on trial, contemporary group, sex and age.

The contemporary group in the Australian beef cattle dataset was defined as: animals of the same sex which were born within the same year and reared for a similar market (Japanese, Korean or Australian market); $\mathbf{g}_1 \sim N(0, \mathbf{Z}_1\mathbf{Z}_1'\sigma_{\text{SNP}}^2)$ and $\mathbf{g}_2 \sim N(0, \mathbf{Z}_2\mathbf{Z}_2'\sigma_{\text{SNP}*\text{breed}}^2)$ contain overall and within breed GEBVs ($\mathbf{Z}_1\mathbf{Z}_1'$ is the overall GRM in which genomic relationships between animals are included and $\mathbf{Z}_2\mathbf{Z}_2'$ is the GRM within breed, in which all relationships between animals in different (super)breeds are zero indicating that there is no relationship between them); \mathbf{a} is the vector of breeding values $\sim N(0, \mathbf{A}\sigma_g^2)$ when pedigree information was used to construct the relationship matrix (\mathbf{A}) and \mathbf{e} is the vector of random residual effects.

Moreover, in order to have a model equivalent to predicting GEBVs for each breed separately, the Holsteins and Trangie Angus cattle were not grouped as a super-breed and \mathbf{Qg}_1 was excluded from Model 1.

A GWAS was conducted using the beef cattle data to find the association of each SNP with RFI using a model where one SNP was included at a time in addition to the fixed effects and polygenic effects described in Model 1.

Then, the SNPs that were significantly ($p < 0.001$) associated with RFI in the beef cattle GWAS, were used to make an auxiliary GRM which was used to calculate GEBVs for Holstein.

The model used was:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Qg}_1^* + \mathbf{Qg}_3^* + \mathbf{Sa} + \mathbf{e} \quad (2)$$

where \mathbf{X} , \mathbf{Q} , \mathbf{S} , \mathbf{b} , \mathbf{a} and \mathbf{e} are similar to Model 1, but contain the Holstein information only, $\mathbf{g}_1^* \sim N(0, \mathbf{Z}_1\mathbf{Z}_1'\sigma_{\text{SNP}}^2)$ and $\mathbf{g}_3^* \sim N(0, \mathbf{Z}_2\mathbf{Z}_2'\sigma_{\text{Sig_SNPs}}^2)$. $\mathbf{Z}_1\mathbf{Z}_1'$ is the GRM for Holstein cattle constructed with all SNPs ($\text{GRM}_{\text{All_SNPs}}$) and $\mathbf{Z}_2\mathbf{Z}_2'$ is the GRM generated by significant SNPs according to beef cattle GWAS analysis ($\text{GRM}_{\text{Sig_SNPs}}$).

To maximize the benefits of using the beef cattle information in genetic evaluation of the dairy cattle, the significant SNPs ($p < 0.001$) from the beef cattle GWAS analysis were used to construct a GRM including both dairy and beef cattle. Then, the variance explained by $\text{GRM}_{\text{All_SNPs}}$ ($\sigma_{\text{All_SNPs}}^2$) and $\text{GRM}_{\text{Sig_SNPs}}$ ($\sigma_{\text{Sig_SNPs}}^2$), were used to aggregate the 2 GRMs to make a single GRM ($\text{GRM}_{\text{Aggregated}}$) and the GEBVs were calculated with:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Qg}_{\text{Aggregated}} + \mathbf{Sa} + \mathbf{e} \quad (3)$$

where \mathbf{X} , \mathbf{Q} , \mathbf{S} , \mathbf{b} , \mathbf{a} and \mathbf{e} are as described in Model 1 and $\mathbf{g}_{\text{Aggregated}} \sim N(0, \mathbf{Z}_1\mathbf{Z}_1'\sigma_{\text{All_SNPs}*\text{breed}}^2 + \mathbf{Z}_2\mathbf{Z}_2'\sigma_{\text{Sig_SNPs}*\text{breed}}^2)$.

The GEBV accuracies for Holsteins in Model 1, 2 and 3, were calculated using a 5 fold cross validation strategy. The dataset was divided into 5 subsets, 4 of the subsets were used as a reference population and the 5th subset was used as a validation sample. The animals in the 5 subsets were selected randomly except paternal half sibs were always placed in the same subset. Then, the GEBVs of validation animals, whose phenotypes were not included in the analysis, were estimated by GBLUP. Finally, the correlation between GEBVs and phenotypes adjusted for fixed effects in the

validation population divided by the square root of estimated heritability is defined as the accuracy of estimated breeding values in each validation population.

The overall correlation reported for each model was a weighted average, where the weight was the number of animals in each breed.

RESULTS

The heritability estimates of RFI in Holsteins and Australian and Canadian beef cattle were: 0.25, 0.40 and 0.20, respectively.

When the phenotypes combined together and \mathbf{g}_1 and \mathbf{g}_2 were excluded from Model 1, the overall heritability was 0.30 which was used to calculate the accuracy of GEBVs.

On average, the genomic relationships of animals within the same breed were greater than relationships of animals with different breeds. The relationship between the Murray Grey breed and Australian Angus breed is higher than other between breed relationships (0.0656). In Model 1, when the Holsteins and the Trangie Angus cattle were grouped together, 43% and 45% of genetic variance ($\sigma^2_a=0.3532$) was explained by the overall effects of SNPs (\mathbf{g}_1) and the effects of SNPs within (super)breed (\mathbf{g}_2). The polygenic effects which was about 12% of genetic variance were unexplained by the SNPs. Using a model equivalent to single breed prediction model, the effects of SNPs within breed and the polygenic effect explained 87% and 13% of genetic variance ($\sigma^2_a=0.3495$).

In Model 2, the auxiliary GRM calculated with 1,876 SNPs (0.31% of all SNPs) significantly associated with RFI ($P < 0.001$) according to the GWAS in the beef data, explained 25% of the genetic variance of Holstein heifers.

The average accuracies estimated by 5 cross-validations for Holsteins in a model equivalent to predicting GEBVs for each breed separately was 0.33. The accuracy of GEBVs within Holsteins increased to 0.35 when using a multi-breed

reference population. Using an auxiliary GRM calculated with SNPs significantly associated with RFI ($P < 0.001$) in beef data, increased the accuracy of predictions in Holsteins to 0.39 in single breed prediction model (Model 2) and 0.43 in multi-breed prediction model (Model3). The accuracies of cross-validations in different models are shown in Figure1.

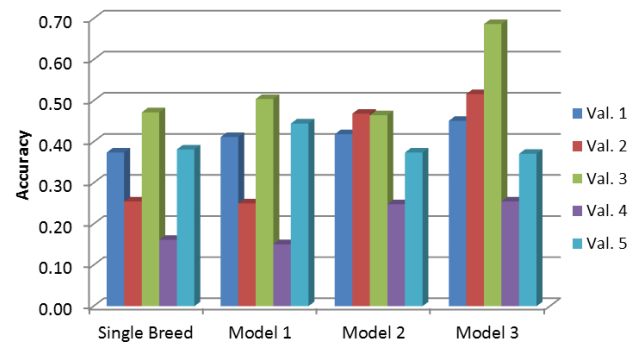


Figure 1. Accuracy of genomic predictions for RFI in Holsteins (5 validation sets) using different models

DISCUSSION

The accuracy of genomic prediction for RFI in Holstein increased from 0.33 to 0.35 using a multi-breed reference. There were several possible reasons why adding data from other breeds did not increase the accuracy of GEBVs by much when compared to within-breed genomic predictions. First, the SNP effects that are common to all breeds only explain 45% of the genetic variance and the SNP×breed interactions explain 43%. There are 2 reasons why SNP×breed interactions exist. They could reflect QTL×breed interactions arising from dominance or epistatic interactions, or because the trait measured in different breeds was different, for instance, in age of measurement or diet. Alternatively, SNP×breed interactions could be due to differences in linkage disequilibrium (LD) between SNP and QTL in the different breeds. LD phase is only likely to be conserved if QTL and SNP are closely linked. Even then, QTL that have arisen due to a mutation in one breed since it diverged from other breeds will

not be in consistent LD with SNPs across breeds. The second reason why adding data from other breeds only slightly improved accuracy is that all the relationships between animals from different breeds are similarly low. Adding data on beef cattle could only improve the accuracy of GEBVs in Holsteins if some Holsteins were more closely related to a particular beef animal than other Holsteins.

The model based on relationships described by the GRM is equivalent to a model based on SNP effects and so there is an equivalent explanation to that of the previous paragraph but based on SNP effects. When SNP effects are estimated within a breed it is the effect of large segments of chromosome that are estimated because animals within a breed share large segments (Goddard *et al.*, 2011). However, animals of different breeds share only small segments of chromosome and the effect of these small segments is much more difficult to estimate precisely. Consequently, information on RFI from animals in another breed is less useful than information from within a breed even if the true SNP effects are the same in both breeds (i.e. no SNP×breed interaction).

The GBLUP method of calculating GEBVs is optimal if the genetic architecture of the trait is nearly infinitesimal, so that all SNP effects are drawn from the same normal distribution. In reality it is likely that some SNPs have bigger effects than predicted under this infinitesimal model. Bayesian methods, which allow a distribution of SNP effects with some larger effects, generate GEBVs with higher accuracy than GBLUP for some traits (Bolormaa *et al.*, 2013). We have generated a GRM for Holsteins that gives additional weight to SNPs that are significant in a GWAS for RFI using the beef cattle data. Using this GRM within the Holstein data increased the accuracy of GEBVs from 0.33 to 0.39. This shows that at least some QTL for RFI exist in the same chromosomal regions in beef cattle and in Holsteins.

CONCLUSION

The accuracy of GEBVs for Holsteins can be increased by using a multi-breed analysis and by giving increased weight in the GRM to SNP that are significantly associated with RFI in beef breeds. However, the gain in accuracy from the multi-breed analysis over the analysis within each breed was small due to the existence of SNP×breed interactions and due to the low and small variation in relationships between animals of different breeds.

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SIMULATED AUTO-FETCHING OF DAIRY COWS OUT OF A NIGHT PASTURE ALLOCATION

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ABSTRACT

Fetching dairy cows from pasture to be milked is a time consuming and repetitive task that may be conducted by technologies such as unmanned ground vehicles, virtual fencing or automatic fence walkers in the future. The evaluation of fetching at night on cow behaviour and performance was investigated on a pasture based automatic milking system (AMS) managing up to 250 Holstein Friesian cows under a three way grazing system (3WG). This type of system requires fetching to be undertaken three times per day, one of which would ideally occur late at night to reduce the number of cows with extended milking intervals. Over a three week period, cows on an AMS farm were encouraged from a paddock (onto a laneway) at night (either 11:00 pm or 1:00 am) to investigate the potential impact of auto-fetching on cow performance and behaviour. Fetching at night was found to be associated with higher milking frequencies and trends towards increased milk yields were seen when cows were fetched at 11:00 pm. Cows fetched at night were also found to spend approximately 10 to 25 minutes less time in the pre-milking area (on concrete) than cows presenting for milking in the morning (at normal fetching time). During the study the cows responded positively to simulated auto-fetching by voluntarily trafficking from the paddock to the dairy, showing potential for long term performance improvements.

INTRODUCTION

Automatic milking systems (AMS) that are predominately pasture based use a variety of techniques to achieve voluntary cow traffic. As feed is the most reliable incentive to generate voluntary cow traffic, AMS farmers will often incorporate a three way grazing (3WG) management technique (Kerrisk, 2009). This involves three measured pasture allocations being made available to the cows at different times of the day with the knowledge that as each pasture allocation becomes depleted, a majority of the cows will voluntarily traffic from the paddock to

the dairy (Donohue, Kerrisk, Garcia, Dickeson, & Thomson, 2010). In the most part, 3WG is able to encourage sufficient voluntary movement of the cows around the AMS. Despite this, there are often still a minority of cows that will remain on depleted pasture for an extended period of time, requiring intervention from the farmer (de Koning, 2011). Fetching the remaining cows out of these areas is an important task for farmers to perform, not just to enable them to set the fences up for the next scheduled grazing in that area, but also to ensure that all cows are milked regularly.

Research suggests that cows which have exceeded a milking interval (MI) of 16 hours are at a greater risk of developing mastitis (Hammer, Morton, & Kerrisk, 2012) and of negative impacts on milk yield (Hogeveen, Ouweltjes, de Koning, & Stelwagen, 2001; Lyons, Kerrisk, Dhand, & Garcia, 2013) and mammary nutrient uptake (Delamaire & Guinard-Flament, 2006). However, due to the nature of 3WG, one of the times that farmers would ideally fetch their cows would occur late at night. As many farmers choose to install an AMS (at least in part) for the lifestyle benefits (de Koning, 2011), farmers are often reluctant to fetch during these undesirable hours and will instead conduct this fetching the following morning.

The future of dairy farming is consistently progressing towards further automation of repetitive and time consuming tasks such as fetching. Emerging technologies such as unmanned ground vehicles (UGV) (Underwood *et al.*, 2013), virtual fencing (Anderson, 2013) and automatic fence walkers (Lely, 2008) are showing promise for future use in this area. Should the task of fetching be automated 24 hours a day, further improvements to farmer lifestyle along with benefits to cow health and productivity may be possible. The most simple of the three known technologies is the automatic fence walker, or more simply put, a pasture based 'backing gate'. This would encourage cows out of a given pasture allocation and rely on the cows to traffic from the gateway of the paddock to the dairy unassisted. However, a concept such as this requires confidence that the cows will traffic to the dairy and not simply lie down in the laneway waiting to be manually fetched. The aim of this study was to investigate if cows would travel voluntarily along the laneway to the dairy if fetched out of the paddock at two different times of the night, and if fetching at these times can reduce the number of cows with extended milking intervals. It was hypothesised that fetching cows (early) at night would reduce the number of cows with extended

milking intervals. Furthermore, we hypothesised that cows fetched at the later time would be less likely to travel to the dairy voluntarily due to a stronger inclination to sleep at this time.

METHODOLOGY

The study was conducted over a 29 day period during October 2014, with a commercial herd of up to 226 lactating Holstein Friesian cows in the Gippsland region of Victoria, Australia. The herd ranged between 2 and 11 years of age and 5 and 530 days in milk (DIM) with most cows in early lactation and managed to calve in spring. The cows were milked by four Lely A4 automatic milking stalls and were managed on a milking area of approximately 91 ha implementing 3WG. The cows were fed up to 7 kg of concentrates per day in the milking stalls and from two automatic feeders in the post milking area. The three pasture allocations became available each day at 2:00 am (A), 10:00 am (B) and 6:00 pm (C). Each of these pasture allocations contained approximately 8-10 kg/cow of feed (dry matter). Normal farm practice was to fetch any remaining cows in the A, B and C allocations at approximately 5:00 pm, 8:00 am and 9:00 am respectively. This meant that the maximum occupancy time of cows in areas A and C was approximately 15 hours and area B was 22 hours. For this reason, the B pasture allocation was targeted for night fetching at 11:00 pm and 1:00 am so that the maximum time the cows could spend in the allocation could not exceed 15 hours.

A randomised complete block design with three groups of six days was generated ensuring that each fetching time (11:00 pm and 1:00 am) had nine replicates. Fetching was undertaken after the cows were conditioned to the presence of a night observer walking around them with a torch in all areas of the farm system over a seven day period. During the habituation and experimental periods data on cow visitation to the dairy, milk yield, health/treatment events and time spent in

different areas of the dairy facility were captured twice daily through computer generated reports.

Cows that were present on the laneway prior to the observer's arrival to the fetching paddock had their identification recorded with the time and distance from the dairy that they were found. The distance of the relevant paddock to the dairy and starting time of the night fetch were also recorded and where possible, the identification numbers of all the cows remaining in (and subsequently fetched from) the paddock were recorded. Cows were then calmly encouraged out of the paddock and left to travel voluntarily from the paddock entrance to the dairy with the gate closed behind them to prevent them returning to the paddock. The time the last cow exited the paddock was recorded and every ten minutes after this a scan sample of cows on the laneway was conducted to determine the proportion of cows walking, standing or lying until all cows had passed through the pre-selection gate at the dairy. The cows were observed for three hours or until the last cow volunteered through the pre-selection gate, whichever occurred first. If the cows had not all passed through the gate within three hours, they were encouraged to pass through the gate into the dairy. Any cows observed to be lame during a fetch were omitted from the data analysis.

Calculations and analysis

Microsoft Excel (Microsoft Office Corporation 2010) was used to manipulate and explore all data, with further analysis performed using Genstat® 16th Edition (VSN International Ltd). Significance was determined by a P-value of < 0.05.

Approximately 6,000 cow waiting times for pre and post milking areas were calculated and separated by the hour of the day that the cows entered each area. The mean, median, maximum and minimum length of time that the cows spent in each area was then calculated for individual cows at specific times of the day. As the distance of the paddocks to the dairy changed throughout

the study, an estimate of each cows travelling speed was used to compare behaviour on different fetching nights. Travel time for each cow was calculated as the time the first cow left the paddock (when the fetch began) until each individual cow passed through the automatic pre-selection gate at the dairy (time-stamped electronically). Speed was then calculated as distance of the paddock to the dairy divided by the time taken for the cow to travel that distance. Summary statistics were generated to identify the mean, median, maximum and minimum speed of cows fetched at the two different times. Prior to further analysis the data were checked for normality and were found to be positively skewed thereby requiring a \log_{10} transformation. A two sample t-test was used to identify statistical differences in the travelling speed of cows fetched at 11:00 pm and 1:00 am.

Linear mixed models (REML) were used to determine the impact of stage of lactation, parity and fetching time (11:00 pm, 1:00 am or not fetched) on milking interval (MI; time between two consecutive milkings), milking frequency (MF; number of milkings per day), milk yield (MY; litres/cow/day), milk yield per milking (MYM; litres/cow milking event) and milking time (MT; total milking stall occupancy time including teat preparation, milking and teat sanitation). The results for stage of lactation and parity are not presented in this conference paper. Milking time required a \log_{10} transformation prior to analysis due to slight positive skewing. In all models cow ID was fitted as a random term. Least significant differences (LSD's) were produced to calculate the location of any significant differences. Furthermore, a logistic regression model was fitted to data to evaluate the change in the number of cows which exceeded a 16 hour MI over the 29 day period.

RESULTS

During the data collection period 30 freshly calved cows were added to the milking herd (in three

separate groups) on different days. Data from these cows were excluded from the analysis. In addition, a blanket herd health vaccination program was implemented during the collection period causing interruptions to cow traffic and leading to two days of data being excluded from analysis. The final analysed data set comprised of 196 cows over a period of 27 days of which, 17 days involved a night fetched. No cows were present for fetching on two nights.

On average, 50% or more of the fetched cows passed through the pre-selection gate within 20 minutes from when the observer entered the paddock to fetch the cows. Similarly, within 40 minutes 80% or more of the fetched cows had passed through the pre-selection gate. A total of 4 cows (on three separate days) did not enter the dairy within three hours of being encouraged out of the paddock and were therefore fetched from the laneway into the dairy by the observer. On all three of these nights the fetching occurred at 1:00 am. Cows fetched at 11:00 pm voluntarily travelled from the paddock to the dairy significantly faster ($p = 0.001$) than cows fetched at 1:00 am (0.401 m/s and 0.294 m/s respectively). The values of the 95% confidence interval (back transformed) indicated that cows fetched at 11:00 pm travelled between 1.424 and 1.805 times faster than cows fetched at 1:00 am. There was no behavioural difference identified between the two fetching times i.e. proportion of cows standing, lying or walking after fetching.

Large variations in the pre and post milking waiting times were evident within each hour of the day, as a result, the median waiting times were observed for differences across the 24 hours of a day (Table 1).

The number of cows exceeding a 16 hour MI was significantly reduced ($p < 0.001$) on nights that the cows were fetched (mean 3.4 cows/day) compared to when a fetching did not occur (mean 9 cows/day).

Table 1. Median time (h:mm:ss) spent in the pre-milking and post-milking areas of the dairy at various times of the day.

	Pre-milking area	Post-milking area
11:00 pm ¹	0:16:35	0:13:43
1:00 am ¹	0:06:10	0:16:16
11:00 pm ²	0:12:36	0:11:12
1:00 am ²	0:08:35	0:16:46
6:00 am ³	0:26:36	0:09:50
7:00 am ³	0:30:04	0:09:50
8:00 am ³	0:30:35	0:09:51

- ¹ Cows fetched at the associated time of night during the data collection period
- ² Cows volunteering to the dairy at the associated times of night
- ³ Cows volunteering and/or fetched as part of normal farm practice at the associated times of the morning

Fetching at night had a significant impact on all five variables tested; MT, MI, MF, MYM and MY (Table 2).

Table 2. Predicted mean milking time (MT), milking interval (MI), milking frequency (MF), milk yield per milking (MYM) and milk yield (MY).

Response	11:00 pm	1:00 am	No fetch
MT (minutes/milking)	6.22 ^a	6.34 ^b	6.32 ^b
MI (hours between milkings)	10:30 ^a	10:53 ^b	10:32 ^a
MF (milkings/cow/day)	2.42 ^a	2.43 ^a	2.32 ^b
MYM (litres/cow/milking)	12.44 ^a	12.36 ^a	13.01 ^b
MY (litres/cow/day)	30.29 ^a	30.23 ^{ab}	30.10 ^b

^{a,b} Values containing the same superscripts are not significantly different ($p > 0.05$).

DISCUSSION

It is important to many AMS farmers that the voluntary visitation of their cows to the dairy is optimised in order to minimise labour inputs and improve profitability (Davis *et al.*, 2005). If 24 hour voluntary traffic can be achieved farmers would be able to reach greater numbers of milkings per day which can equate to greater MY

over time (Stockdale, 2006). Typically, pasture based AMS farms do not achieve the same voluntary visitation at the milking units as what is seen in indoor systems (Lyons, Kerrisk, & Garcia, 2013) indicating that potential system efficiency gains exist. In the present study, simulated auto-fetching of cows at night resulted in greater milking frequencies and yield over time.

Behaviourally, cows fetched at the two different times performed very similarly, albeit with cows fetched at 1:00 am slightly more reluctant to travel to and from the dairy. Observation of the travelling times of the cows identified that cows fetched at 1:00 am took longer to reach the dairy. It is generally suggested that cattle display polyphasic sleep (Ternman, Hänninen, Pastell, Agenäs, & Nielsen, 2012) where they may sleep for approximately 3 h per day over multiple bouts mostly occurring at night (Ruckebusch, 1972). It is possible that 1:00 am may have been closer to a pending sleeping bout causing the cows to be more reluctant to walk.

The longer median pre-milking waiting time of cows fetched at 11:00 pm to cows fetched at 1:00 am may have been caused by the higher voluntary visitation (therefore higher competition) of cows observed at the dairy at this time. Cows fetched at night were also generally seen to spend less time in the pre-milking area and more time in the post-milking area than cows presenting (fetched and/or voluntary) at the dairy in the morning. It was proposed that the shortened pre-milking time was caused by less competition for entry in the milking units at night. Research suggests that cows have a high motivation to seek pasture at night regardless of the distance required to travel (Charlton, Rutter, East, & Sinclair, 2013) so it is unclear why the cows spent longer in the post-milking area.

REML testing of performance criteria identified that all measured variables were influenced by night fetching. The MI of cows when a 1:00 am fetching took place was significantly higher than MI's on other days. Milking frequency was

significantly lower when a night fetching occurred and MY was higher when cows were fetched at 11:00 pm than when they were not fetched at night. In reflection of a lower MF, MYM was higher on non-fetching nights and 11:00 pm fetches were associated with a shorter MT than on other nights. In addition, an approximate four fold decrease in extended MIs (> 16 hours) shows promise for further improvements in MY and potentially udder health over time. When a night fetching did not occur, cows were 2.751 times more likely to have a milking interval that exceeded 16 hours.

CONCLUSION

Positive impacts on cow performance were found as a result of fetching at night with results suggesting that an earlier fetching time of 11:00 pm may be more beneficial in this situation. Over the three week fetching period the cows successfully volunteered at the dairy after being fetched out of the paddock. As a result, when auto-fetching technology becomes commercially available, it is apparent that its application for late night fetching of cows within a voluntary AMS could be viable.

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HERD SYNCHRONISATION IN A PASTURE-BASED AUTOMATIC MILKING SYSTEM

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ABSTRACT

The use of Automatic milking systems (AMS) in pasture-based farming represents a significant shift from the 'indoor' systems AMS was originally designed to operate in. Regardless, achieving a consistent level of robot utilisation across 24 h remains a key to maximising production in either pasture-based or indoor systems. A constant issue, faced by pasture based farmers, is a decrease in robot utilisation in the early morning hours, limiting the capacity and therefore total production from the system. The aim of this paper was to determine the herd dynamics found in a pasture-based AMS where milking was evenly distributed throughout 24 h. Milking data was collected over an eight week period between January and February 2013 from a farm in Tasmania milking 180 cows with three Lely A3 robotic milking units. The consistent robot utilisation was characterised by an interaction ($P < 0.001$) between three milking frequency (MF) groups and the proportion of milkings across time, with high MF cows coming in first, followed by the medium MF and low MF cows last into the allocation period. There was also a difference ($P < 0.001$) between the proportion of nights each group presented for milking, with the high, medium and low MF groups presenting for milking 77%, 57% and 50% of all days respectively.

INTRODUCTION

The development of automatic milking systems (AMS) signifies one of the most important advances in dairy farming in recent history. Initially conceived as a solution to labour shortages in the 1980s, AMS have removed the majority of human involvement in the milk harvesting process. Robotic milking systems have gained significant popularity over the last 20 years and are now in use on over 10,000 farms worldwide (de Koning, 2011). With the milk harvesting process accounting for 22-24% of a

farms labour costs, it is of little surprise that the technology is garnering interest from Australian farmers (Davis, Fulkerson, Garcia, Dickeson, & Barchia, 2008). Automatic milking systems were first installed on Australian farms in 2001 (Greenall *et al.*, 2004) and adoption has since expanded to 33 farms, and are present in all states of Australia, with the majority of Australian AMS farms using grazed pasture as the primary feed source (N. Lyons 2014, pers. comm.).

There are three main features present in pasture based AMS. Firstly, milking is performed automatically and essentially in total absence of human input. Secondly, cows present for milking

voluntarily, freely trafficking between paddock and dairy under the guidance of selection gates. Thirdly, milking is distributed across the entire 24 hour period. To facilitate an adequate milking frequency (MF) Australian farmers have chosen to use a system of three-way grazing (3WG), three pasture allocations per day which Lyons, Kerrisk, and Garcia (2013) has shown delivers increased MF and milk yield (MY) in comparison to conventional two-way grazing of two pasture allocations per day. The 3WG facilitates more cow movement, as pasture is depleted more rapidly in each allocation and cows then seek a new food source. Automatic milking systems rely on increased cow flow rates in order to achieve efficient levels of robot utilisation. However, in AMS a reduction in the number of milking events often occurs during the early morning period (Hogeveen, Ouweltjes, de Koning, & Stelwagen, 2001; Kerrisk, 2010; Speroni, Abeni, Capelletti, & Migliorati, 2011; Wagner-Storch & Palmer, 2003; Woolford *et.al.*, 2004). The reduction in milking presentation rate, is attributed to cows being crepuscular animals following diurnal grazing patterns and the reduction in presentations is thought to be more pronounced in pasture based AMS where only 10% of grazing occurs at night (Gregorini, 2012), compared to indoor AMS where feeding is more evenly distributed throughout 24 hours (Belle, Andre, & Pompe, 2012).

Whilst there is literature pertaining to 24 h robot utilisation in AMS, there is a paucity of information on how cows move within the system when factors such as MF, MY and stage of lactation (SOL) are considered. Almeida *et.al.* (2013) investigated herd behaviour under such groupings. In their study, MF significantly increased in conjunction with MY and all cows followed relatively similar milking patterns throughout each 24 h regardless of MY. In our study, we analysed the milking distribution patterns of cows, when categorised by milking frequency levels on a commercial AMS farm, using pasture as the main feed base. The objective was

to determine the herd dynamics in a pasture-based AMS where milking is evenly distributed throughout 24 h.

MATERIALS AND METHODS

An observational study of a commercial AMS farm was conducted over a period of eight weeks between January 7th and March 3rd 2013. The farm, located in Togari, Tasmania featured three Lely Astronaut A3 milking robots. The farm utilised 'three-way grazing' (3WG) on 79ha of perennial ryegrass/white clover pastures, with all concentrates fed in the robots and pasture silage supplemented in the paddocks. The milking herd consisted of 195 cows at the beginning of the observational period. Only cows >14 days in milk at the beginning of the observational period were included in the data analysis, resulting in 191 cows being analysed. The herd consisted of Friesian, Jersey and cross bred cows.

Pasture Management Data

Pasture allocation data for the entire experimental period was collected every Monday, Wednesday and Friday. Pre-grazing (prior to cows entering the allocated pasture) and post-grazing (after the last cow had exited the allocated pasture) compressed biomass was measured using a Rising Plate Meter (360mm diameter, 315g plate weight) fitted with an electronic counter (Farmworks, Palmerston North, New Zealand). Between 80 and 100 individual pasture height readings were taken across multiple transects (zig-zag pattern) in each paddock, avoiding areas of high cow traffic. The pre- and post-grazing compressed pasture heights were then converted to pasture biomass using the formula: Biomass (kg DM/ha) = height (cm) x 240 + 500 (Earle 1979). The area (ha) of each paddocks allocation for the next grazing event was recorded using a handheld global positioning system (GPS). From this, the pasture offered per cow in each individual allocation was determined and in conjunction with the post-grazing biomass the

average pasture consumed per cow was calculated.

To determine the quantity of silage offered, the number of silage bales fed in each allocation was recorded (at 304 kg/DM/bale) and added to the totals of pasture offered. To determine silage bale DM composition, eight random silage bales were weighed pre-feeding, to obtain an average mass per bale of 765kg. The average wet weight was then converted to kg.DM based on the average dry matter percentage of 39.7% obtained from all silage samples collected throughout the trial period.

Table 1. Three-way grazing parameters of the farm

Allocation	Gate Times	Feed Offered (kg ± SD)
A	0930-1730	6.7 ± 1.3
B	1730-0230	2.1 ± 0.6
C	0230-0930	5.3 ± 1.3

Gate Times = Period of the day cows are sent to the designated allocation.

Milking Data

To collect milking data, custom spreadsheets were created in the Lely milking management system ‘Time for Cows (T4C)’. The data collected for each individual cow included: daily milk yield, milking frequency, total concentrate fed, day of lactation and live weight. The time, date and milk yield of each individual cow’s milkings were recorded. The ‘proportion of nights milked’ was calculated from the number of days where a milking event occurred between 0000 and 0600 h.

Statistical Analysis

Cows were categorised by their mean daily MF over the duration of the study to form three evenly sized groups: low (<2.3 milkings/day), medium (2.31-2.7 milkings/day) and high (>2.71

milkings/day) MF. Time of milking to gate change was calculated as the time to the nearest gate change both before and after a milking event. The data was analysed using the REML function in Genostat 16th Edition. Significant effects are stated at p<0.05.

RESULTS

Table 2. Predicted Means for MF Group

	Low	Medium	High
MF (no./cow/day)	2.1 ^a	2.4 ^b	2.8 ^c
MY (L/cow/day)	23.9 ^a	24.9 ^b	26.1 ^c
SOL (days)	102	104	90
PN (%)	50 ^a	57 ^b	77 ^c
Total Milkings	115 ^a	137 ^b	160 ^c
n	65	58	68

MF = Daily Milking Frequency, MY = Daily Milk Yield, SOL = Stage of Lactation, PN = Proportion of Nights Milked, n = Number of Cows in Group. Significance indicated by letters at p<0.05

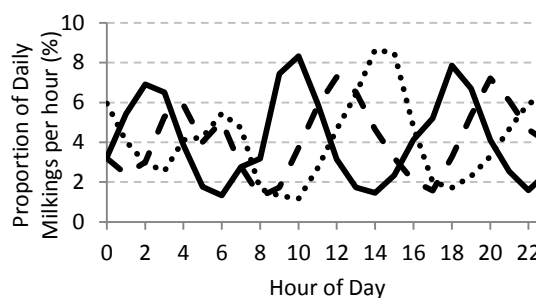


Figure 1. Interaction between proportion of daily milkings occurring per hour throughout 24 h for high (—), medium (---) and low (.....) MF groups, P<0.001

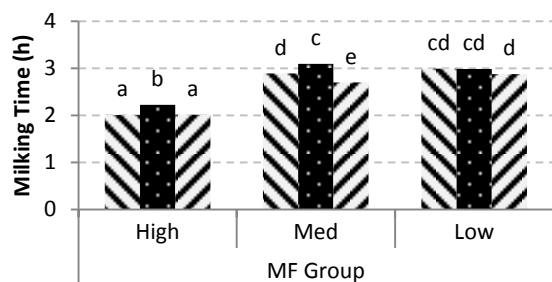





Figure 2. Interaction between MF group (high, medium and low) and gate change (A 0930h , B 1730h  and C 0230h ) for time of milking from a gate change, $p=0.048$

DISCUSSION

Achieving both high and consistent levels of robot utilisation is imperative to the efficiency of AMS. The farm in this study was able to achieve relatively consistent robot utilisation (Figure 1) with milking frequencies of 2.1, 2.4 and 2.8 for the low, medium and high MF groups, respectively. A 10% increase in MY was also observed between the low and high MF groups, which is consistent with such increases in MF (Stockdale, 2006). There could have been an effect of entry time to pasture on MY as the higher MF cows accessed pasture earlier (Figure 2), therefore ingesting higher quality pasture compared to cows that accessed the pasture later during the allocation period (Clark, 2013). Whether this is correct warrants future investigation, as it also highlights the potential for differential feeding depending upon which group individual cows are categorised. Interestingly, there was no significant increase in the SOL when moving from the high to low MF groups, where it could be expected that cows at increased SOL would tend to be the lowest MF cows within the herd (JG Jago, 2006).

Offering three allocations of fresh pasture throughout the day provides incentive for the cows to voluntarily traffic more frequently (Lyons *et al.*, 2013). This is the likely cause for each MF group having three distinct peak milking times (Figure 1) throughout the day as the cows synchronise their feeding to match the feeding

regime used (Livshin, Maltz, and Edan 1995). For each of the three MF groups having their own distinct MF patterns is contrary to most of the literature reporting on herd dynamics in AMS. A similar study of herd synchrony in an AMS where cows were grouped by MY found that all the cows followed the same milking pattern throughout 24 h (Almeida *et al.*, 2013). Likewise, where pasture has been offered in AMS, it has been reported that cows would follow a more synchronised behavioural pattern in terms of eating and resting (Ketelaar-de Lauwere, Devir, & Metz, 1996; Uetake, Hurnik, & Johnson, 1997), presenting for milking (J Jago, Jackson, & Woolford, 2003; Winter & Hillerton, 1995) and trafficking to and from the dairy (Ketelaar-de Lauwere *et al.*, 1999). It could be said that the herd in this study is still synchronised, not as one herd, but as three sub-herds based on each herds MF.

Social ranking is one possible explanation for the formation of the three sub-herds. During each allocation, the high MF cows voluntarily milked in the periods leading up to or at the beginning of each new pasture allocation, followed in succession by the medium and low MF groups. With the high MF cows gaining access to each allocation first, a natural hierarchy could be forming within the herd on this farm, with high MF cows exhibiting a higher social ranking than the medium and low MF cows. This type of social ranking has been suggested to occur on AMS farms by Ketelaar-de Lauwere *et al.* (1996). However, the high MF cows also had a higher proportion of night milkings when compared to the medium and low MF cows. This is contradictory to results from other studies, where lower ranking animals milked more frequently between 0000-0600 h compared to higher ranked animals. This result is likely to be due to less competition in accessing to the milking robots during this period of the day (J Jago *et al.*, 2003; Ketelaar-de Lauwere *et al.*, 1996). Furthermore, Livshin, Maltz, and Edan (1995) observed the attendance to a concentrate feeder followed a

defined order, rather than a random cycle of cows within both 4 and 6 hour feeding windows. Whether the cows in this study were motivated by the ability to access high nutritive value feed early in the pasture allocation period and if this behaviour is dominance driven, or if this behaviour is common to other pasture-based AMS farms, requires further inquiry.

CONCLUSION

The incorporation of AMS into pasture-based farming represents a large change from the 'housed' systems AMS was originally designed for. However, achieving a consistent level of robot utilisation throughout 24 h remains a crucial factor in the efficient running of a pasture-based AMS. Until now there have been no studies on herd dynamics in pasture-based AMS farming. This study shows the formation of three distinct groups of cows within the herd based on their MF levels, with each group having distinct peak milking times throughout the day. Furthermore, all three groups milked during the night, with the high MF group milking most often at night of the three groups. Assuming the high MF cows are higher in social rank due to their earlier access to pasture, these results contradict other published literature on the impact of social rank on robot attendance and warrants further investigation. Finally, the timing of entry to pasture varied between the three MF groups, raising the potential to increase milk production by better fulfilling individual cow nutritional requirements through differential feeding.

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DETERMINING PRESENTLY UNKNOWN CRITICAL PLANT TEST POTASSIUM VALUES FOR ANNUAL RYEGRASSES UNDER AUSTRALIAN CONDITIONS

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ABSTRACT

Fertiliser recommendations for potassium (K) fertiliser in dairy pastures are largely based on the higher K requirements for clover. Ryegrass biomass responses to fertiliser K are less common and smaller. South-western Australian dairy pastures are now dominated by high-yielding ryegrasses. Therefore, farmers may be applying an excess of K fertiliser to their ryegrass dominant pastures based on outdated recommendations. As a consequence, some dairy farmers have started to apply fertiliser K based on ryegrass plant test results rather than soil test results, but they have to rely on critical plant test values for perennial ryegrasses.

An experiment was conducted in south-western Australia to determine the critical plant test K concentrations for 'rain-fed' annual and Italian ryegrasses during 2013 and 2014. The study was conducted on a site that had been prepared over 7 years to deplete soil K to 31-43 mg/kg Colwell K. Potassium fertiliser was applied at amounts ranging from 0 to 320 kg/ha/year, split over 6 applications during the pasture seasons in 2013 and 2014. Ryegrass pasture was harvested mechanically when it reached the 3-leaf stage. Basal fertilisers' nitrogen, sulphur and phosphorus were applied so as to not limit production.

For these K-depleted soils, in both years, 95% of maximum pasture yield was achieved at 96 kg/ha/year of K fertiliser applied. At this level of K fertiliser use, the estimated K concentration in annual/Italian ryegrass pastures was 1.14% in DM in 2013 and 1.27% in 2014. So-called 'luxury uptake' of K started to happen above ~1.5% K in pasture DM. Increasing K fertiliser application also reduced pasture protein content. These results suggest that farmers may be able to reduce application of K fertiliser to annual and Italian ryegrass pastures without compromising DM production, and also demonstrate the effectiveness of plant tissue testing as an alternative to soil testing to determine potassium application rates.

INTRODUCTION

The Mediterranean climate in south-western Australia means that dairy production in the region is highly reliant on Annual ryegrass (*Lolium rigidum* Gaud.) and Italian ryegrass (*L. multiflorum* Lam.) and to a lesser extent subterranean clover ('subclover' *Trifolium subterraneum* L.). Annual

ryegrasses also play an important role from autumn to spring in the dairy regions of northern and south-western Victoria, and indeed a number of other dairy regions around the country.

Previous research by Boland, Cox & Codling (2002), showed that clover is very sensitive to potassium (K) deficiency. Traditionally clover

formed an important component of dairy swards in south-western Australia's dairy pastures; however the sandy soils in the region have a low capacity to retain K in the root zone of pasture plants, which is typically no deeper than 20cm (Bolland *et.al.* 2002). Therefore increasing intensification of dairy production in recent decades has led to clover levels diminishing in swards in the region, due to increased K deficiency (Bolland *et.al.* 2002, Bolland and Guthridge 2009). This has resulted in dairy pastures in the region which are dominated by high yielding annual ryegrasses. Despite this however, fertiliser recommendations for K are still largely based on the higher requirements for clover, due to its increased sensitivity to K deficiency. Consequently, farmers in the region could needlessly be applying too much fertiliser K based on outdated recommendations.

Some local farmers in south western Australia have started to apply fertiliser K based on ryegrass tissue test results, rather than soil test results, targeting levels of 2% K in leaf dry matter (DM) to avoid adverse impacts on cow health of excessive K levels in pasture. The objective of this study was to provide Australian dairy farmers with updated K fertiliser recommendations for modern intensively managed annual ryegrass dominant pastures based on plant tissue testing, by specifying the critical level of plant K concentration in annual and Italian ryegrasses that provides 95% of maximum pasture production under contemporary best grassland management practices.

MATERIAL AND METHODS

The experiment (May 2013 to November 2014) was a plot study located at the Vasse Research Centre near Busselton in south-western Australia. Mean annual rainfall in the area is 750 mm (range 500-1000), with 85% occurring between April and October, resulting in a typical pasture growing season from May to November. The soil type (1-2m sand to sandy loam over massive clay), flat

topography and winter rainfall pattern result in paddocks that are intermittently waterlogged from June to September.

The study site had been depleted of soil K from 2006 to 2012 by not applying K fertiliser, excluding livestock (urine patches), and removing pasture as silage/hay in October/November every year. Each experimental plot measured 4m x 4.5m. Mean soil K (0-10 cm) in individual plots had declined to 42 (range 22-69) mg/kg Colwell K at the start of the experiment in 2013. By comparison, target Colwell K values for dairy soils on commercial WA dairy farms in WA are in excess of 100 mg/kg.

The experiment was set up as a factorial design with 8 potassium fertiliser treatments and 2 pasture species as the main treatments, with 4 replicates in a randomised block design. The pasture species used were *Aristocrat* annual ryegrass and *Concord II* Italian ryegrass. Following season-opening rains, ryegrass seed was broadcast in both years on 7 May 2013 and 3 June 2014 respectively at a high rate of 200 kg/ha to mimic 'natural seed-set', as is common for annual pastures on WA dairy farms.

The eight K fertiliser treatments (with K in kg/ha/year) were K0, K0-low, K10, K20, K40, K80, K160 and K320, with K fertiliser applied as muriate of potash, split over 6 equal applications during the growing season in both years. Two control treatments were adopted for this experiment: K0 and K0-low. Treatment K0 was allocated to plots by stratified randomisation so that the mean initial soil K for treatment K0 was equal to that for treatments K10 to K320 (mean 43 mg/kg). Treatment K0-low was specifically allocated those plots with the lowest soil K (mean 31 mg/kg), to assess if there would be a difference in pasture production between treatments K0 and K0-low.

After each pasture harvest, nitrogen (N) and sulphur (S) fertiliser were applied as 'NS31', at a rate of 2 kg N per ha for each day since the last harvest (or the seeding date for the first harvest).

For example, as there were 40 days between pasture harvests 1 and 2 in 2013, an amount of 80 kg/ha of N was applied the day after pasture harvest 2. Phosphorus fertiliser (20 kg/ha as super phosphate) was applied at the start of the season in both years to ensure that soil P was not limiting pasture production. Lime was applied at the start of the 2013 growing season by means of topdressing into the soil at a rate of 6t/ha on all plots. The trace elements copper and boron were applied to all plots at rates of 2kg/ha and 1kg/ha respectively at the beginning of the 2014 growing season, while 100kg/ha of magnesium sulphate was also applied at this time.

Total pasture in each plot (from 5 cm above ground level) was harvested mechanically using a large ride-on lawn mower, whenever ryegrass reached the 3-leaf stage. As a result, six pasture harvests were made in each season over the course of both the 2013 and 2014 annual pasture seasons. The two ryegrass species reached the 3-leaf stage at similar times. Total pasture dry matter yield per plot was recorded after each harvest. Pasture was subsampled to determine mineral concentration at each harvest, and pasture feed quality at harvests 2 and 4 in both years. Pasture was dissolved in a nitric/perchloric acid mixture and the concentrations of elements in the digest were measured by inductively coupled plasma-atomic emission spectrometry (ICP-AES) (Zarcinas, Cartwright and Spouser, 1987).

Soil was sampled for each plot just prior to the start of the growing season and again after the last pasture harvest for each season. The sodium bicarbonate procedure as modified by Colwell (1963) was used to measure soil test potassium (Colwell and Esdaile 1968, Bolland *et al.*, 2002).

Data were analysed by two-way analysis of variance using GENSTAT. Total pasture harvest was plotted against K concentrations in plant and soil samples, to determine response relationships and to calculate the minimum plant test concentrations for annual ryegrass and Italian

ryegrass to achieve pasture production at 95% of the maximum achieved in this study (GENSTAT exponential curve fitting).

RESULTS

There was no significant difference in pasture DM yield between the two species of ryegrass ($P=0.14$), and the interaction between K fertiliser and pasture species was not significant ($P=0.58$) in either year. Results are therefore presented for K fertiliser treatment averaged across species in Figure 1 for 2013 and 2014. The effect of K fertiliser on pasture yield was highly significant ($P<0.001$) in both 2013 and 2014. There was a significant difference in total mean DM yield for each K treatment level between seasons ($P<0.005$), with all treatments having a higher total DM yield in 2013. There was no significant difference in pasture yield between plots receiving 160 and 320 kg/ha of K fertiliser in either season ($P>0.005$). In these K-depleted soils, 95% of maximum pasture yield (9.53 t DM/ha in 2013 and 7.38 t DM/ha in 2014) was achieved at 96kg/ha/year of K fertiliser in both seasons.

Figure 2 outlines the percentage of K detected in pasture DM at each level of K fertiliser application. The effect of K fertiliser on the K content of pasture DM was also highly significant ($P<0.005$), increasing linearly with increased K fertiliser application.

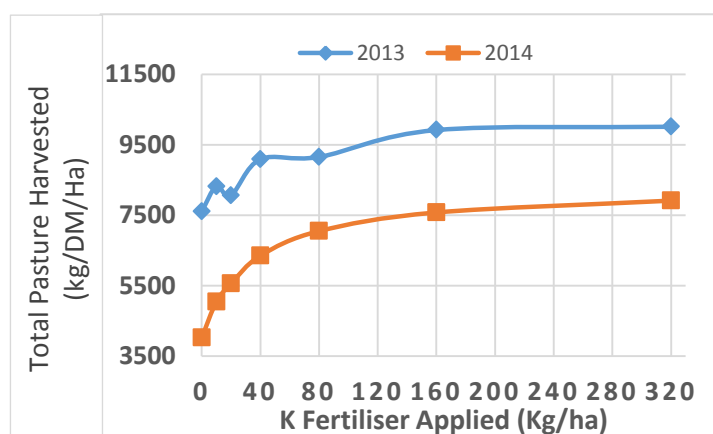


Figure 1. Effect of potassium fertiliser on total pasture yield

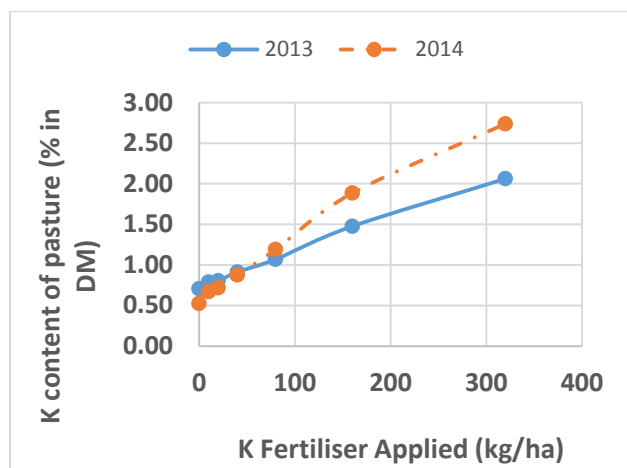


Figure 2. Potassium content of pasture vs K fertiliser applied

Mean pasture crude protein content declined linearly with increasing K fertiliser application in both years from 19.6 to 16.3 % in DM ($P=0.005$) in 2013 and 23.3 to 17.2 % in DM ($P=0.005$) in 2014. Mean pasture metabolisable energy (ME) content tended to be lower and neutral detergent fibre (NDF) content higher in the K0-low treatment (11.2 MJ/kg DM and 52% respectively) than in the other seven treatments (11.8 MJ/kg DM and 48% respectively; $P<0.10$) in 2013. A similar trend was observed for ME content of the pasture in the 2014 season, where the K0-low and K0 treatments had a mean of 10.8 MJ/kg DM, compared with 11.3 MJ/kg DM for the remaining six treatments. However the NDF content of pasture did not differ between treatments in the 2014 season ($P>0.10$).

Mean soil Colwell K concentration from 0-10cm declined in all treatments except K360 over the course of the 2013 growing season, however soil Colwell K concentrations did not differ for any treatments between the end of the 2013 and 2014 growing seasons, remaining at similar levels in both years. Plant tissue testing during the 2013 season showed that Cu, B and Mg levels in the plant tissue were marginal or deficient; therefore these minerals were applied to all plots at the beginning of the 2014 growing season at rates of 2kg/ha, 1kg/ha and 100kg/ha for Cu, B and magnesium sulphate respectively. Potassium fertiliser also affected other mineral

concentrations in pasture DM significantly, although many of these changes were biologically of little apparent significance and therefore these details are not reported here.

DISCUSSION

Limited information currently exists on the minimum K content required in annual and Italian ryegrass pasture. As stated above, some farmers in the south-western Australian region have targeted K levels of 2% of DM in pasture tissue samples, rather than the higher requirement of K for clover. When this strategy was adopted for dryland dairy pastures at DAFWA's Vasse Research Centre, it resulted in reduced potassium fertiliser use from 100 (2000-2005) to 35 kg/ha/yr. (2005-2010). As this did not appear to impact adversely on pasture production per ha per year, the result was that fertiliser use efficiency for potassium was increased nearly 3-fold (M. Staines pers. comm.). However, to the best of our knowledge, the only study to assess minimum plant test concentrations for potassium in annual ryegrass was the pot study of Brennan and Bolland (2006). These authors reported that clover species required approx. 55% more applied K to produce 75% of the maximum shoot yield in a glasshouse experiment than annual ryegrass, and estimated a concentration of 1.5% K in DM to achieve 90% of maximum yield for annual ryegrass. Similarly there is also very limited information for Italian Ryegrass, based on pot studies from the US and UK (e.g. Nowakowski, Bolton and Byers, 1974; Barraclough and Leigh 1993). However none of these studies employed pasture grown under field conditions relevant to contemporary pasture-based dairy farming in Australia. Exponential curve fitting of the data presented here using GENSTAT indicated that at 96 Kg/ha of K fertiliser (the amount required to achieve 95% of maximum DM yield in both seasons), the mean estimated critical K concentration in pasture was 1.14% and 1.27% for the 2013 and 2014 growing seasons respectively.

Both of these values are significantly lower than the target of 2% K in DM currently used by farmers in the region. This means that there is potential for significant cost savings by farmers with annual and Italian ryegrass dominant pastures when applying K fertiliser, by virtue of reduced use of K fertiliser.

There were a number of other observations of note from the study, including the reduction in crude protein levels with increased K fertiliser application. This was most likely due to a 'dilution effect' with the increased pasture biomass produced at increasing K fertiliser rates. The 'dilution effect' theory is further supported by the fact that the total pasture yield across all treatments in 2014 was lower than in 2013 ($P < 0.005$), while mean CP content of all treatments was higher in 2014.

The difference in total DM production between seasons was probably due to seasonal factors, although interestingly the lower soil Colwell K content at the beginning of the 2014 growing season in all treatments except the K360 treatment indicates significant 'mining' of soil K occurred under the experimental conditions.

It is important to remember however, that the soil conditions in the current experiment are not a reflection of reality on commercial dairy farms, as there was no replenishment of K to the soil in the current experiment through urine or faeces.

Approximately 90% of the total K consumed by dairy cows is returned to the soil in excreta (Dairy Australia 2015), however paddocks repeatedly cut for hay or silage may be prone to low K levels due to the same reasons described above.

CONCLUSION

Our results indicate that there is an opportunity for significant cost savings to be made in the use of K fertiliser on dairy pastures that are composed predominantly of Annual or Italian ryegrasses. A target level of ~1.2-1.3% K in DM of plant tissue will ensure 95% of maximum potential pasture

yield can be achieved under grazing management best practices. Plant tissue testing is more precise in these situations than soil testing, and is usually easier and quicker for farmers to carry out. Thus plant tissue testing is a useful decision tool to decide how much K fertiliser to apply to ryegrass pasture. However, the target levels of K we recommend based on this study this will not provide enough fertiliser K for clovers, so where clover is an important part of the sward soil testing should continue to be used to estimate K fertiliser requirements. In that case, one can expect to spend substantially more \$/ha on K fertiliser.

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