PROJECT C100001368

LARGE HERDS: CREATING VALUE FROM DATA

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The impact of milking order on milk yield and composition for large herds.

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1. INTRODUCTION

The depletion of a pasture sward by cattle typically occurs in successive layers from the tip of the youngest leaf (Wade & Carvalho, 2000) progressively down the sward until reaching the residual biomass level. The chemical composition of a perennial ryegrass sward varies between these successive layers, with the higher end of the fraction typically containing more crude protein and less neutral detergent fibre than lower fractions (Delagarde et al., 2000). As there is a consistent milking order for cows both within and between days (Botheras, 2006), the last cows being milked may be accessing pasture of differing nutritive value compared to those consistently arriving to a paddock first after milking. Our work (Scott et al 2014) showed that the quantity and nutritive value of kikuyu pasture accessed by dairy cows varies substantially. Pasture was depleted 36% to ground level (70% relative to the post grazing mass) during the duration between the first and last cow entering the paddock. The average CP across the paddock also decreased from 19 to 15% over the duration of cow entry, whilst the ADF content increased from 26 to 30%. The implications of these findings for milk yield and composition, and for alternative herd sizes, remained unknown and were the topics for the current research.

The overall objective of this project was to evaluate milk yield and milk composition as milking order progresses for large herds and how this relates to diet composition (pasture quality, pasture mass and levels of concentrate). Based on this information, strategies such as changing farm layout, feed allocation and developing new methods for differential feeding could be applied to improve overall farm performance and sustainability for no additional input. The three preliminary experimental phases as steps towards this overarching objective were:

Phase 1. To determine the association between herd size and milking time from an existing Dairy Australia dataset (CowTime, 2009). Our hypothesis was that farmers with large herds spend more time milking their cows than smaller herds, with a subsequent greater impact on the spread in pasture nutritive value accessed by individual cows in a herd. <u>Note: This phase was in addition to required milestones.</u>

Phase 2. To collect existing data from multiple large herds to determine the association between milking order and milk yield. <u>Note: This phase acquired new data in addition to required milestones from Tasmanian herds as data from University of Melbourne was not made available.</u>

Phase 3. Based on results from second phase, the third phase collected milk and pasture samples from focus farms to determine the association between milk yield, milk composition and pasture composition for the first and last cows in the milking order. Note: Samples from 3 strategically selected farms were acquired based on type of farm system and proximity to Elliot research station. This was to ensure best practice milk and feed sample storage and preparation.

2. MATERIAL AND METHOD

2.1 Phase 1

291 farms in Australia (Watson, 2009) varying in herd size from 30 to 1,000 were analysed to determine the association between herd size and milking time. Farms were grouped according to herd size (Table 1) and the dependent variables analysed were total milking time and time to collect cows.

Table 1 Group number, range of herd size and number of farms in each group.

Group	Number of cows	Number of farms
1	1 - 100	47
2	101 - 200	93
3	201 - 300	59
4	301 - 400	41
5	> 400	51

2.2 Phase 2

Milk yield, bodyweight and grain-based concentrate data on a per milking basis was taken from January 2015 to August 2015 (32 backup files) for six farms with ALPRO (Delaval, Sweden) systems in Tasmania. Three farms were located in the North (farms 1, 2 and 5) and 3 in the South of Tasmania (farms 3, 4 and 6) (see Table 2).

Table 2 The number of cows, days in milk (DIM), milk yield (L/cow/day), body weight (kg/cow) and grain-based concentrate offered (kg/cow/day) of six farms in Tasmania.

Farm	**Number cows**		**DIM[1]**		**Milk Yield[2] (L/cow/day)**		**Body Weight (kg/cow)[2]**		**Grain-based concentrate[2] (kg/cow/day)**	
	Average	SD[3]	Average	SD	Average	SD	Average	SD	Average	SD
1	451	40	192	97	27.1	8	555	88	9.8	3
2	519	50	227	119	21.2	6	-	-	5.2	1
3	704	33	178	127	24.6	8	-	-	6.9	2
4	770	41	187	121	26.4	8	-	-	6.6	2
5	497	5	253	35	13.0	3	-	-	1.5	1
6	774	36	278	186	15.5	5	475	77	3.6	3

[1]Days in Milk; [2]7 days average; [3]Standard deviation

2.3 Phase 3

The farms enrolled for phase 3 were farms 2 and 5 from phase 2 and additional farm 7. All three farms had large herds (see table 3) and only one farm split the herd (Farm 2). All farms consisted of a 50 to 60 bail rotary milking parlor with only one farm using MISTRO computer system (Farm 7) instead of ALPRO system. Cows were Holstein breed in most of farms, except Farms 5 which were Holstein cross Jersey breed, and were milked around 5am and 3pm daily. According to the morning milking order, milk samples of the first and last 50 cows (morning and afternoon) were collected for three consecutive days in each farm for fat and protein composition, with the first and last 5 cows having samples taken for fatty acid analysis. In Farm 2, the cows from first herd were selected to collect the milk samples. Two samples per cow were collected, one aliquot (50mL) was stored at 4ºC with preservative (bronopol table) until analysed for fat, protein by infrared analysis (Fourier Transform Spectrometer - FTS) and somatic cells by fluorescence cytometry analysis (Flow Cytometer - FCM) at TasHerd laboratory (Tasmania). A second aliquot (15mL) without preservative was stored at -8ºC until analysed for further fatty acid analyses at University of Sydney (Camden). Milk yield and cow information (days in milk, cow number, number of lactation, grains and milking order) was automatically recorded by farm system and in the last day of experiment the data from three days was downloaded.

Table 3 The number of cows, milk yield (L/cow/day), days in milk (DIM) and grain-based concentrate offered (kg/cow/day) of three farms from Tasmania.

Farm	**Number of cows**	**Milk Yield (L/cow/day)**		**Days in Milk**		**Grain-Based Concentrate (kg/cow/day)**	
		Average	SD[1]	Average	SD[1]	Average	SD[1]
2	805	28.7	12.9	128	127	4.3	0.6
5	708	23.7	12.4	311	172	1.9	1.1
7	724	22.9	9.8	137	117	4.3	0.7

[1] Standard deviation

The height of paddocks (extended tiller) was evaluated with a ruler pre-grazing, post-grazing and every 15 min from the first cow entering the paddock until the last cow. To evaluate the pre- and post-grazing herbage mass, nine quadrats (30 x 30 cm) were randomly placed in the paddocks pre- and post-grazing. The tillers within the quadrat were cut to ground level with a cordless grass shearer (RYOBI-RGS182Li15), the fresh weight was recorded and each quadrat was frozen separately. For pre-grazing pasture collection, the tillers were removed to maintain the vertical structure of the sward, labelled and taken for chemical composition analysis. A representative sample of each pre-grazing quadrat was used to determine the dry matter content, botanical composition and chemical composition. With the dry matter content in each quadrat the herbage mass were calculated in pre- and post-grazing (average of all quadrats). According to paddock size and number of cows per paddock, the pre-grazing herbage mass was used to calculate the pasture allowance (kg DM/ha). The difference between pre- and post-grazing herbage mass, multiplied by the size paddock and divided by the number of cows were used to measure the pasture intake. For botanical composition the pasture was separated in ryegrass, clover and other species. For chemical composition the pasture samples were cut into 2 cm (0-2 cm= stratum 1, 2-4 cm= stratum 2, etc.) from ground to top level and the strata were weighed (fresh weight), dried at 60˚C for 48 hours, grounded (1 mm) and then analysed for crude protein (CP, FP628 Food/Protein Analyzer, LECO, Michigan, USA) and acid detergent fibre (ADF) (ANKOM[200] Fibre Analyzer, ANKOM, New York, USA). Digestible organic matter (DMO) and metabolisable energy (ME) were estimated according to Ketellars and Tolkamp (1992).

Statistical analysis

Descriptive statistics and linear regression of data were obtained using Sigmaplot 10.0 (Systat, 2006). For the second phase, the animals were classified in milking order groups of 50 animals for a.m. and p.m. milking (e.g. group number 1: 1^{st} to 50^{th} cow; group number 2: 50^{th} to 100^{th}, etc.). The daily milking order considered for statistical analyses was the average of a.m. and p.m. milking order. Animals without recordings were considered missing values. Animals with peak yield lower than milk yield were excluded from the data analysis. The average of Holstein cows in all farms, recorded by system, was 99.2% and the other breeds were included in data analysis. Plus and minus two standard deviation of the mean (about 95% of the data) was the criteria used to exclude DIM and milk yield outliers. Factors in the model were grouped accordingly: Period (week of the year), parity, milking order (groups 1-50, 51-100 and so on) and concentrate intake (groups 0-3.0, 3.1-6.0 and so on). Cows were included as a random effect and DIM as a covariate, using the statistical program SAS, MIXED procedure. Individual cows were considered as an experimental unit and period as a repeated measurement. To determine the effects of milking order (MO) (11 to 24 groups), period (P) (31 groups), parity (PA), DIM (D) and concentrate intake (C) (4 groups) on milk yield (MY) (Model 1) and the differences in days to milk peak (DP) and milk peak yield (PY) among farms (F) and parities (PA) (Model 2), a mixed linear model was fitted to the data as follows:

Model 1: $MY_{ijklm} = \mu + MO_{\mathrm{i}} + P_{\mathrm{j}} + PA_{\mathrm{k}} + C_{\mathrm{m}} + b1(D)_{\mathrm{ijklm}} + \varepsilon_{\mathrm{ijklm}}$

Model 2: DP_{ijk} *or* $PY_{ijk} = \mu + F_{\mathrm{i}} + P_{\mathrm{j}} + PA_{\mathrm{k}} + \varepsilon_{\mathrm{ijk}}$

where MY, DP or PY are the dependent variables, μ is the overall mean, $b1(D)ijklm$ is days in milk as a covariate and $\varepsilon ijklm$ is the random experimental error.

For the third phase, milk and pasture results of first and last 50 cows were analysed using the statistical program SAS, MIXED procedure. Cows were included as a random effect, individual cows were considered as an experimental unit and day as a repeated measurement. DIM, number of lactations and grain were excluded in the model as they were not significant (P>0.05). To determine the effects of milking order (MO) (First and Last cows) on milk yield (MY) or milk composition (M), a mixed linear model was fitted to the data as follows:

MY_i *or* $MY_i = \mu + MO_{\mathrm{i}} + \varepsilon_{\mathrm{i}}$

where M is the dependent variable, μ is the overall mean and $\varepsilon ijklm$ is the random experimental error.

3. RESULTS

3.1 Phase 1

On average, the herd took 3.5 hours to be milked and 1 hour per day to bring to the dairy. There was, however, substantial variability around these means for milking time (range of 0.8 to 9.8h) and collection time (range of 5min to 1.5h).

There was a strong association (R^2 = 89%; P<0.01) (Figure 1) between morning and afternoon milking times across herd sizes, with the afternoon milking time taking 90% of the morning milking time duration.

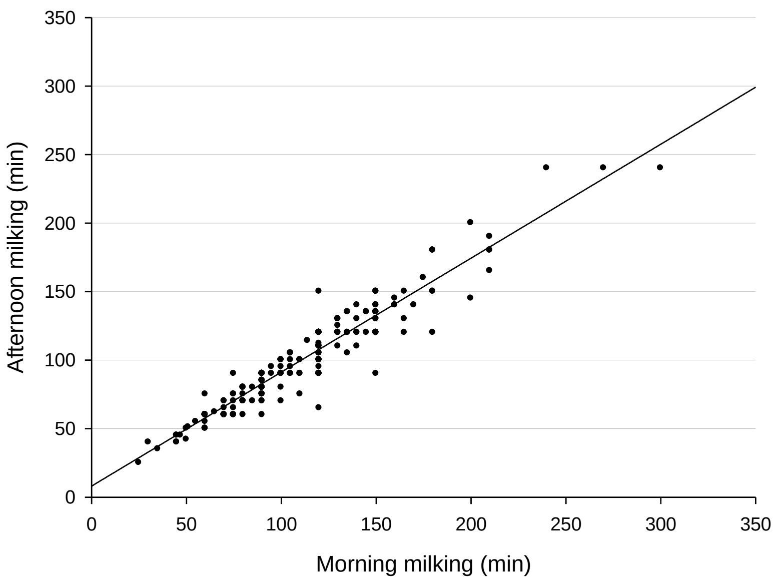


Figure 1 Association between duration of morning and afternoon milking (minutes) in 291 dairy herds; y= 8.1 + 0.83x, R^2= 0.89, P<0.0001.

The data showed high variability between milking time and number of cows or time to collect cows within herd size groupings (Figure 2 and 3), but there was a general trend for the duration of milking to be extended as herd size increased from less than 100 cows to about 1,000 cow herds. The variation is illustrated by identifying that the milking time and time to collect cows in two farms at 600 cows was 2.5h and 8.5h per day, and 30 and 90 min per day, respectively. Large herds (>400cows) took longer to milk and collect cows than all other herd size groupings, especially small farms (Group 1; Figure 3). Comparing group 2, 3 and 4 with group 1, herd milking time increased 1h, 1h20min and 1h30min, respectively. In contrast, average time to collect cows was only 10 min longer in group 4 than group 1 and was similar among groups 2, 3 and 4.

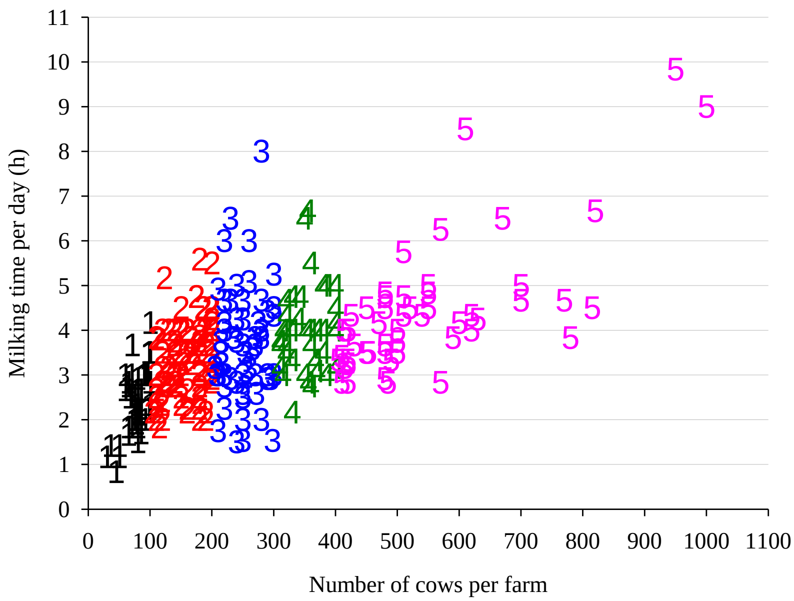


Figure 2 Distribution of total milking time (hours) per farm in each group of farms.

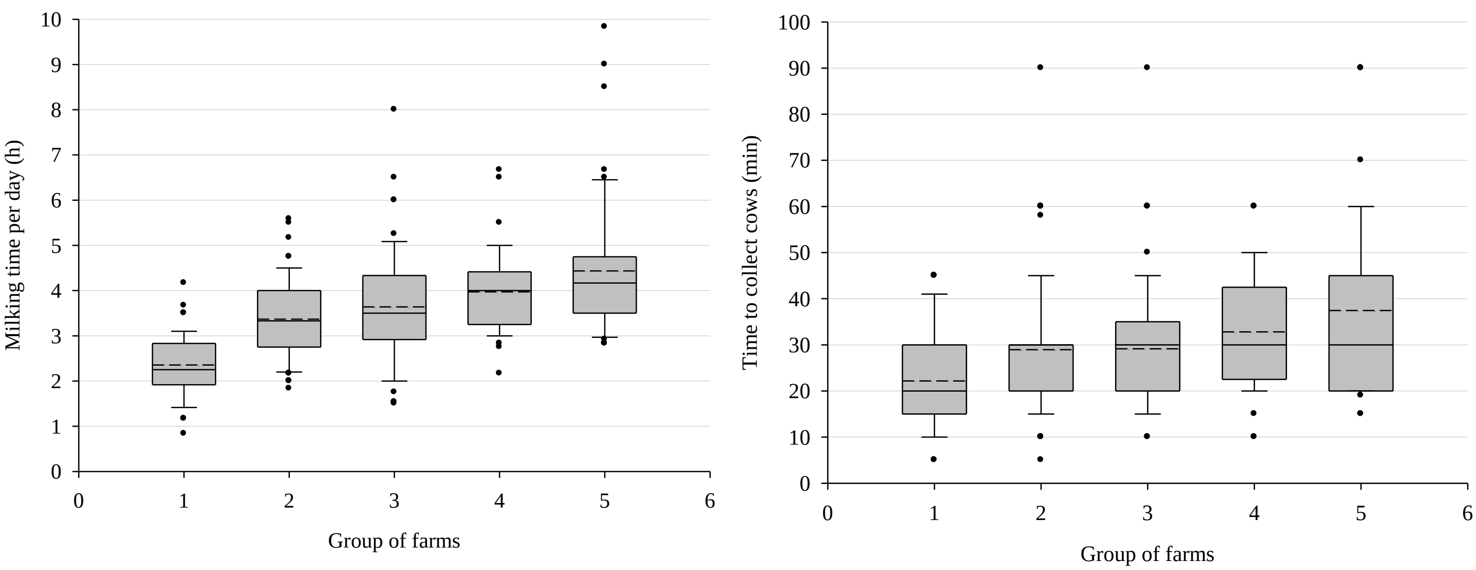


Figure 3 Box plot of group of farms and total milking time per day (min) and total time to collect cows (min). Solid line is first quartile and dashed line is the median.

3.2 Phase 2

The strong association between morning and afternoon milking order (R^2=0.87) is shown in Figure 4.

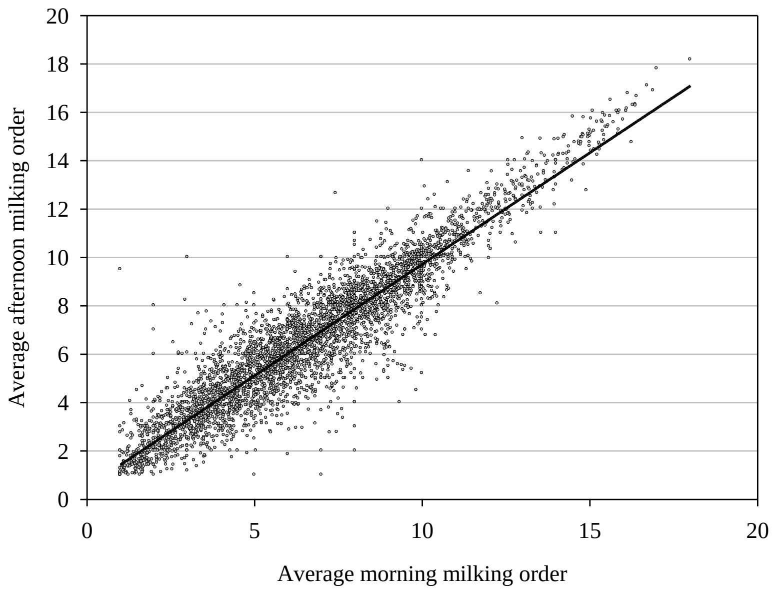


Figure 4 The association between morning (a.m.) and afternoon (p.m.) cow milking order for individual cows in six large herd farms in Tasmania. y= 0.51 + 0.92x; R^2= 0.87, P<0.0001.

There were differences for days to milk yield peak and milk production at peak among farms (Table 4). Average days to peak and milk yield at lactation peak were 53 days and 34.1L/cow/day, respectively.

Table 4 Milk peak yield and days to peak of 6 Tasmanian Farms.

	Days to Peak			**Peak Yield**		
Farm	Average	SE[1]		Average	SE	
1	60.0	0.96	B	39.1	0.15	B
2	65.1	0.98	A	34.1	0.15	D
3	57.7	0.92	C	34.4	0.15	C
4	46.6	0.93	D	39.9	0.15	A
5	43.4	1.31	E	28.6	0.21	E
6	45.9	1.00	D	28.4	0.16	E

[1]: Standard Error; Different capital letters show statistical difference between farms (P<0.05).

There were differences in days to peak yield and milk yield at peak between partities (Figure 5). Days to milk yield peak and peak milk yield were inversely related. Days to milk peak decreased from parity 1-4 and tended to increase past parity 5 and peak milk yield increased to parity 4 and then decreased from parity 6 onwards.

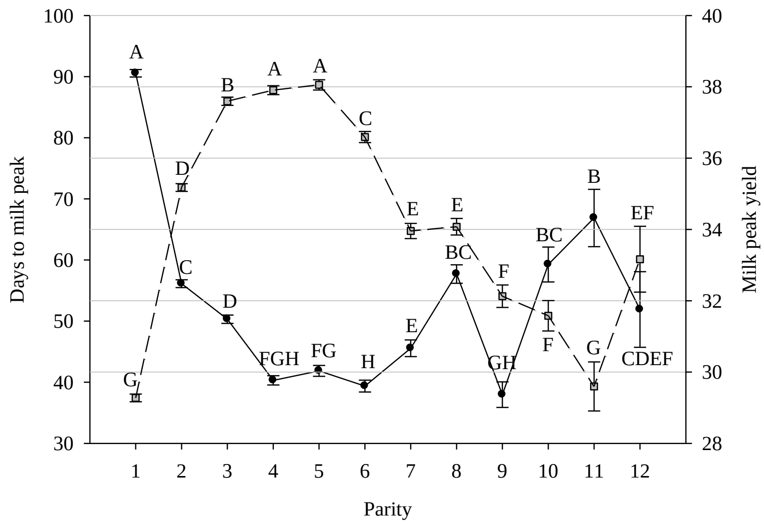
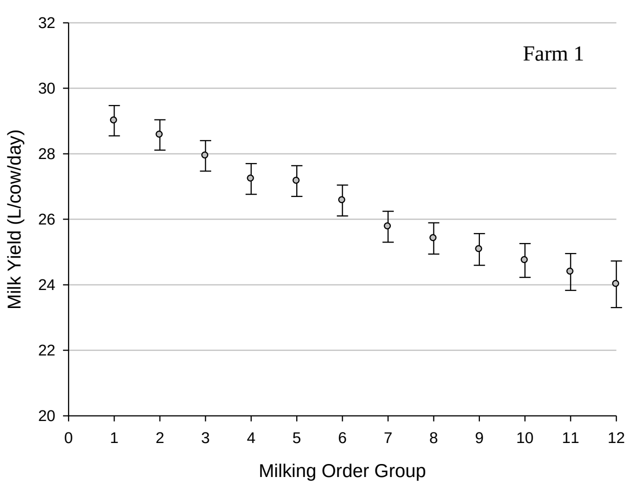
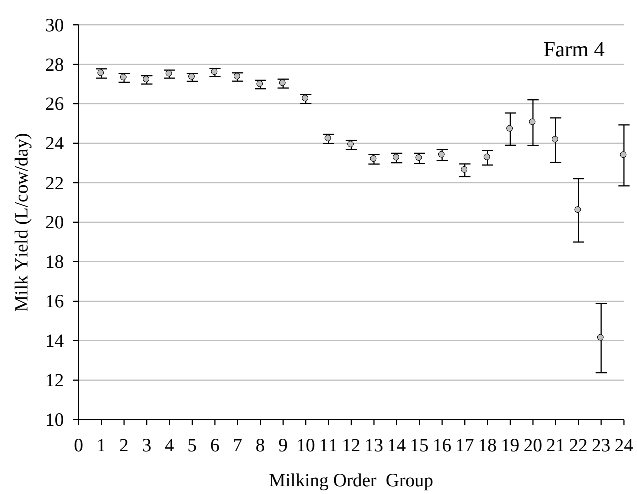
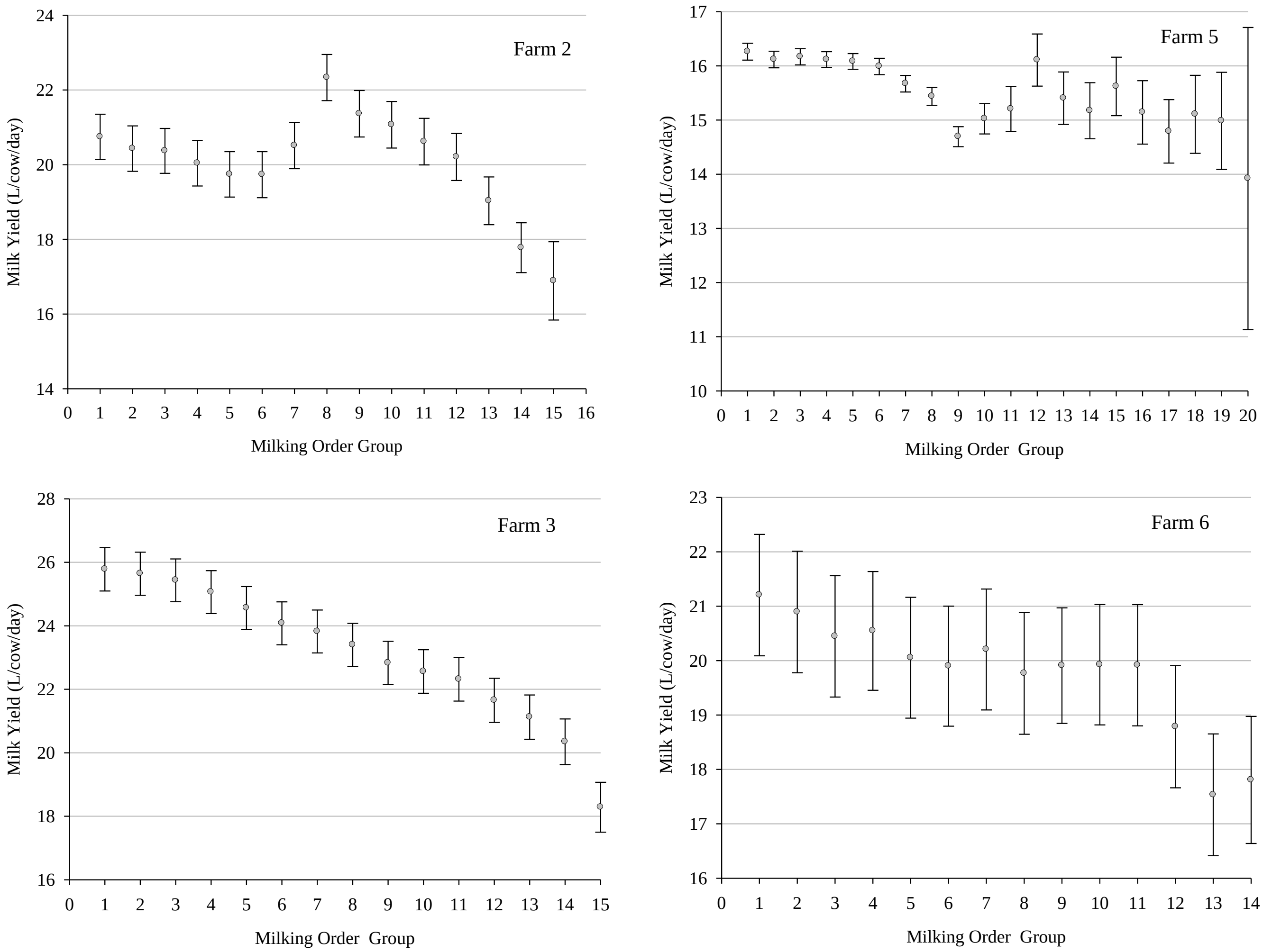


Figure 5 Milk peak (open square) and days to milk peak (circle) of 6 Tasmanian Farms and according to parity. Bars denote standard error of the mean and different capital letters show statistical difference between farms (P<0.05).

Milking order had a significant impact on milk yield (P<0.01) for all farms (Figures 5).







Figures 6 The association between milk yield and milking order for farms 1 – 6. Bars denote standard error of the mean.

The average milk yield difference between the between first and last 50 cows (milking order groups 1 and 11) was 4.5 L/cow/day (20% less milk) for all farms (Table 4). Farms 4, 6 and 3 had the highest difference in milk yield (L/day) and also highest milking duration (>3h). There was no relationship between milk yield difference and milk duration or supplement fed.

Table 5 Milk yield difference (MYdif) between first 50 and last 50 cows and milking information for each farm.

Farm	MYdif (%)	MYdif (L/cow/day)	Milked Cows		Cows/hour		Milking duration[2] (h/day)	
			Average	SD[1]	Average	SD	Average	SD
1	17.2	-5	476	115	210	38	2.3	0.9

2	18.6	-3.9	568	172	212	40	2.7	0.9
3	29.1	-7.5	700	111	231	42	3.2	0.9
4	15.1	-4.1	776	118	178	29	4.5	0.9
5	14.4	-2.3	618	82	272	47	2.3	0.6
6	16.0	-3.4	763	210	232	55	3.4	1.2

[1]SD: Standard deviation; [2]: total time of morning and afternoon milking.

3.3 Phase 3

There was a strong association between am and pm milking order across all three farms during three consecutive days (R^2=0.82; Figure 7A). However, the association was weaker, yet still highly significant (R^2=0.56; Figure 7B), between the first and last 50 cows.

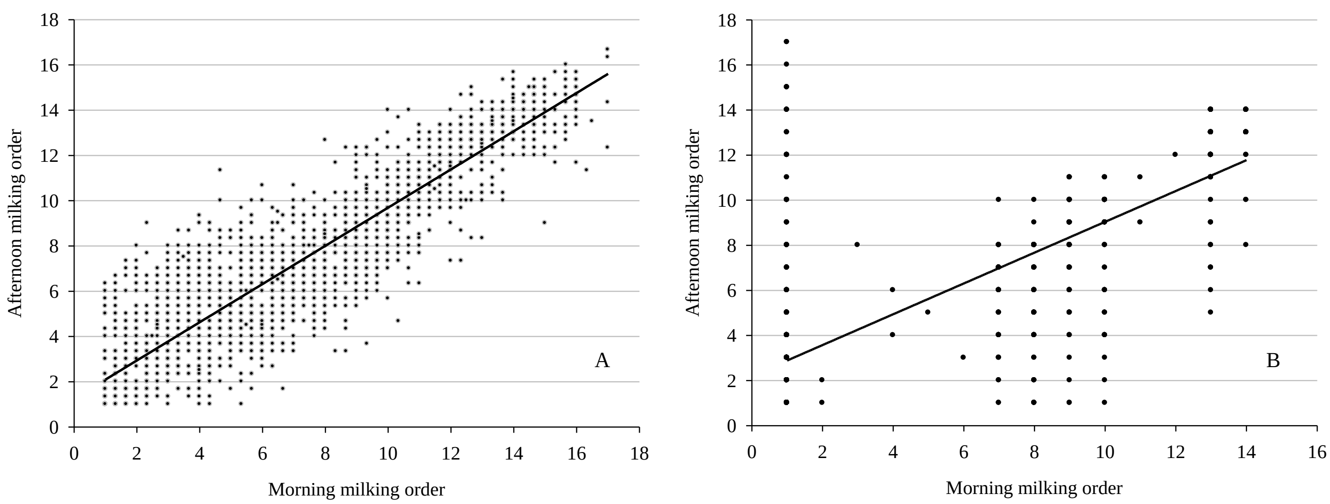


Figure 7 The association between morning (a.m.) and afternoon (p.m.) cow milking order from individual cows in the whole herd (A) and average of first and last 50 cows (B) of three farms in Tasmania. A: y= 1.25 + 0.84x; R^2= 0.82; P<0.01 B: 2.21 + 0.68x; R^2= 0.56; P<0.01

The paddocks from all the farms were 1 to 1.5 km from milking parlour and mainly comprised perennial ryegrass (Table 6). Pasture intakes for each farm varied markedly from 4.3 to 13.8 kgDM/cow/day. Farms 2 and 3 offered double the amount of grain per cow as compared with farm 1. Farm 3 offered grain with the greatest crude protein content.

Table 6 Characteristics of herd and pasture from three farms in Tasmania.

	Farm 5		Farm 2		Farm 7		SE[1]	*P* value
Ryegrass (%)	89.6	A	85.5	A	71.7	B	1.1	*
Clover (%)	5.8	B	10.1	AB	16.1	A	1.1	*
Other species (%)	4.6	B	4.3	B	12.3	A	1.1	*
Distance from milking parlor	1.0		1.5		1.2		0.2	NS
Number of cows	495	B	386	C	717	A	0	*
Size paddock (ha)	4.2	A	1.1	B	5.1	A	0.3	*
Cows allocated per area (ha)	123.5	B	402.1	A	140.7	B	43.9	*
DIF access time[2] (h)	2.2	B	1.5	C	3.0	A	0.09	*
Pre-grazing height (cm)	20.9		22.7		26.9		1.4	NS
Post-grazing height (cm)	11.5		10.5		12.2		2.0	NS
Pre-grazing cover (kg DM/ha)	3,648	B	4,136	B	5,641	A	389	*
Post-grazing cover (kg DM/ha)	2,800	B	3,072	AB	3,660	A	408	*
Pasture allowance (kg DM/cow)	28.5	A	11.9	B	39.9	A	3.8	*
Pasture intake (kg DM/cow)	10.1	AB	4.7	B	13.8	A	1.8	*
Grain (kg/cow)	1.9	B	4.2	A	4.3	A	0.03	*
Grain crude protein (%)	5.9		8.4		11.1			

[1]: Standard Error; [1]: Difference in access time between first and last 50 cows; *: $P<0.05$; †: $P<0.10$; NS: No significant ($P>0.10$); Different capital letters show statistical difference between farms ($P<0.05$).

Numbers of lactations and DIM for the first and last cows were similar within each farm (Table 8). There were differences in milk yield and milk composition between first and last cows, especially in farms 2 and 5 (Table 7). The first cows in Farm 5 produced more milk (8%), protein (12%), SNF (4.5%), lactose yields (8.3%, tendency) and less lactose (1.9%) and fat content (4.5%, tendency). In Farm 2, the first cows produced more milk (11.3%), SNF (7.4%), lactose (7.1%), fat yield (10%, tendency) and less protein (1.9%), SNF (3%) and lactose content (tendency). However, in Farm 7 the only difference was greater fat (5.7%) and protein content (2.7%) in the milk of the first cows.

Milk from last cows had greater C4:0 (+8.9%), C16:1 (+10.3%), C17:0 (+16.3%), C17:1 (+38.6%), C18:0 (+15.5%), C20:2n6c (+19.9%), C20:0 (+15%) and PUFA (+13.3%) content than the first cows while milk from first cows had greater C8:0 (+5.7%), C10:0 (+11.2%), C12:0 (+12.8%) and C18:1n9t (+81.2%) contents than the last cows (see Table 7).

Table 7. Milk fatty acid profiles for the first and last cows from farms 2, 5 and 7.

	First	Last	SE	P Value	P Value	Farm 5		Farm 2		Farm 7		SE	P Value	P Value
C4:0	6.22	6.77	0.186	0.0465	*	6.84		6.14		6.50		6.493	0.1082	NS
C6:0	3.84	3.83	0.064	0.6966	NS	3.83	a	3.21	b	3.05	b	0.235	<0,0001	*
C8:0	1.92	1.82	0.040	0.0829	†	2.14	a	1.84	b	1.63	c	0.049	<0,0001	*
C10:0	4.64	4.17	0.123	0.0137	*	4.93	a	4.47	b	3.81	c	0.151	0.0001	*
C11:0	0.17	0.13	0.015	0.2635	NS	0.11	b	0.20	a	0.14	b	0.019	0.0085	*
C12:0	5.29	4.69	0.163	0.0168	*	5.39	a	5.19	a	4.38	b	0.200	0.0043	*
C13:0	0.21	0.19	0.015	0.3037	NS	0.16	b	0.26	a	0.20	b	0.018	0.0024	*
C14:0	14.17	13.56	0.293	0.1575	NS	14.21	a	14.39	a	14.99	b	0.359	0.0244	*
C14:1	1.06	1.04	0.057	0.8509	NS	0.86	b	1.23	a	1.07	a	0.070	0.0045	*
C15:0	1.79	1.75	0.084	0.7831	NS	1.44	c	2.10	a	1.77	b	0.102	0.0006	*
C15:1	0.001	0.001	0.0008	0.7637	NS	0.001		0.002		0.000		0.0009	0.5377	NS
C16:0	32.52	32.21	0.728	0.7634	NS	33.64		32.10		31.37		0.892	0.2075	NS
C16:1	1.94	2.14	0.076	0.0784	†	1.88		2.14		2.09		0.094	0.1365	NS
C17:0	1.05	1.22	0.044	0.0120	*	0.99	b	1.20	a	1.22	a	0.054	0.0107	*
C17:1	0.23	0.31	0.021	0.0085	*	0.23		0.29		0.29		0.026	0.1388	NS
C18:0	10.26	11.85	0.455	0.0218	*	12.74	a	9.36	c	11.07	b	0.557	0.0011	*
C18:1n9t	0.58	0.32	0.096	0.0700	†	0.38		0.58		0.38		0.118	0.3794	NS
C18:1n9c	9.96	9.44	1.374	0.7915	NS	5.80	b	10.81	a	12.50	a	1.683	0.0267	*
C18:2n6t	0.15	0.15	0.011	0.7218	NS	0.16		0.14		0.15		0.055	0.6672	NS
C20:2n6c	1.76	2.12	0.070	0.0017	*	1.43	c	1.90	b	2.49	a	0.085	<0,0001	*
C20:0	0.12	0.14	0.004	0.0045	*	0.15	a	0.11	c	0.12	b	0.005	<0,0001	*
C18:3n6	0.01	0.00	0.003	0.1308	NS	0.01		0.01		0.00		0.003	0.1790	NS
C20:1	0.06	0.08	0.011	0.2017	NS	0.04	b	0.08	ab	0.10	a	0.014	0.0207	*
C18:3n3	0.94	1.05	0.054	0.1815	NS	0.94		0.95		1.11		0.067	0.1505	NS
C21:0	1.02	0.88	0.078	0.2145	NS	1.00	ab	0.74	b	1.11	a	0.096	0.0346	*

C20:2	0.04	0.02	0.006	0.1652	NS	0.02	b	0.04	a	0.02	b	0.008	0.0709	†
C22:0	0.10	1.00	0.007	0.6297	NS	0.09		0.09		0.11		0.008	0.27	NS
C20:3n6	0.09	0.09	0.007	0.7832	NS	0.07	b	0.10	a	0.10	a	0.008	0.0077	*
C22:1n9	0.00	0.12	0.062	0.1706	NS	0.00		0.00		0.19		0.075	0.1638	NS
C20:3n3	0.00	0.00	0.002	0.3072	NS	0.01		0.00		0.00		0.002	0.1432	NS
C23:0	0.11	0.11	0.008	0.5617	NS	0.13	a	0.11	ab	0.08	b	0.010	0.0062	*
C20:4n6	0.01	0.00	0.001	0.3263	NS	0.01	a	0.00	b	0.00	b	0.002	<0,0001	*
C22:2	0.09	0.09	0.008	0.8335	NS	0.15	a	0.09	b	0.03	c	0.009	<0,0001	*
C24:0	0.02	0.02	0.003	0.3382	NS	0.03	a	0.02	a	0.00	b	0.003	<0,0001	*
C20:5n3	0.13	0.13	0.012	0.9434	NS	0.18	a	0.13	b	0.06	c	0.015	<0,0001	*
De novo (4:0 - 15:0)	38.83	37.34	0.690	0.1396	NS	39.88	a	39.02	a	35.36	b	0.845	0.0026	*
Mixed Origin (16:0+16:1)	34.47	34.35	0.766	0.9133	NS	35.52		34.24		33.46		0.939	0.3121	NS
Preformed (>17:0)	26.70	28.43	1.203	0.3222	NS	24.73	b	26.74	b	31.22	a	1.473	0.0163	*
SFA	82.96	82.89	1.260	0.9709	NS	87.84	a	81.52	b	79.43	b	1.543	0.0024	*
MUFA	13.83	13.45	1.315	0.8398	NS	9.18	b	15.13	a	16.60	a	1.610	0.0085	*
PUFA	3.21	3.64	0.125	0.0238	*	2.96	b	3.36	b	3.97	a	0.153	0.0005	*
Saturated:unsaturated ratio	6.93	6.59	0.561	0.6708	NS	9.80	a	5.66	b	4.82	b	0.687	<0,0001	*
n-6:n-3 ratio	1.92	2.06	0.077	0.2080	NS	1.49	c	2.02	b	2.45	a	0.094	<0,0001	*
14:1/14:0	0.07	0.07	0.003	0.7440	NS	0.06	b	0.08	a	0.75	a	0.003	0.0006	*
16:1/16:0	0.06	0.06	0.002	0.0628	†	0.05	b	0.06	a	0.06	a	0.002	0.0163	*
18:1/18:0	0.40	0.34	0.043	0.3523	NS	0.22	b	0.44	a	0.45	a	0.052	0.0061	*
Atherogenicity Index	7.83	7.25	0.633	0.5220	NS	10.73	a	6.61	b	5.28	b	0.775	0.0002	*

Table 8 Cows characteristics, milk yield and composition between first and last cows from three farms in Tasmania. Note: No DIM and lactation data available for Farm 1 due to lack of farmer records.

	Farm 5						**Farm 2**						**Farm 7**					
	First		**Last**		**SE**[1]	***P* value**	**First**		**Last**		**SE**	***P* value**	**First**		**Last**		**SE**	***P* value**
DIM (d)							106		107		8.43	NS	218		218		5.17	NS
Number of lactations							2.1		2.3		1.38	NS	3.0		2.5		1.84	NS
MY (L/d)	24.6	A	22.8	B	0.54	*	30.4	A	27.3	B	0.65	*	23.1		23.2		0.68	NS
Fat (%)	4.2		4.4		0.08	NS	3.7		3.8		0.07	NS	3.7	A	3.5	B	0.06	*
Protein (%)	3.7		3.7		0.04	NS	3.8	B	3.9	A	0.04	*	3.7	A	3.6	B	0.03	*
SCC (x1000)	54.7		70.5		12.42	NS	82.0		100.6		22.88	NS	69.2		70.6		16.48	NS
SNF (%)	9.4		9.5		0.04	NS	9.5	B	9.8	A	0.05	*	9.6		9.5		0.03	NS
Lactose (%)	5.1	B	5.2	A	0.02	*	5.0		5.0		0.02		5.1		5.1		0.02	NS
Fat Yield (kg/d)	1.0		1.0		0.02	NS	1.1		1.0		0.02		0.9		0.8		0.03	NS
Protein Yield (kg/d)	0.9	A	0.8	B	0.02	*	1.1		1.1		0.02	NS	0.8		0.8		0.02	NS
SNF Yield (kg/d)	2.3	A	2.2	B	0.05	*	2.9	A	2.7	B	0.06	*	2.2		2.2		0.06	NS
Lactose Yield (kg/d)	1.3		1.2		0.03	NS	1.5	A	1.4	B	0.03	*	1.2		1.2		8.43	NS

[1]: Standard Error; *: P<0.05; †: P<0.10; NS: No significant (P>0.10); Different capital letters show statistical difference between first and last cows within each farm (P<0.05).

Overall, there were differences in pasture composition offered for the first and last cows, except for Farm 5 (Table 9). The height of the pasture and protein content was greater for first cows in Farm 2 (45 and 22%, respectively) and 7 (32% and 17%, respectively).

Table 9 Pasture height and composition between first and last cows for three farms in Tasmania.

	Farm 5				Farm 2						Farm 7					
	First	**Last**	**SE**[1]	***P* value**	**First**		**Last**		**SE**	***P* value**	**First**		**Last**		**SE**	***P* value**
Pasture Height (cm)	20.9	18.4	1.6	NS	22.7	A	15.7	B	1.6	*	26.9	A	20.4	B	1.6	*
Pasture Stratum	11.0	10.0	0.8	NS	12.0	A	8.0	B	0.8	*	14.0	A	11.0	B	0.8	*
Pasture Crude Protein (%)	23.4	21.9	0.9	NS	28.7	A	23.5	B	0.9	*	21.2	A	18.1	B	0.9	*
ADF (%)[1]	25.4	27.6	1.2	NS	23.6	B	29.4	A	1.2	*	23.6		25.8		1.2	NS
DOM (%)[2]	68.9	68.3	0.3	NS	69.4	A	67.8	B	0.3	*	69.4		68.8		0.3	NS
ME (MJ/kg DM)[3]	10.3	10.2	0.0	NS	10.4	A	10.2	B	0.0	*	10.5		10.4		0.0	NS

[1]: Standard Error; *: $P<0.05$; NS: Not significant ($P>0.10$); Different capital letters show statistical difference between first and last cows within each farm ($P<0.05$); [1]: Acid detergent fiber; [2]: Digestible organic matter; [3]: Metabolisable energy.

4. DISCUSSION

4.1 Phase 1

Despite an overall increase in milking time with increasing herd size, our data showed high variability between farms in milking time across all herd sizes. Our previous work (Scott et al. 2014) with an intermediate herd size (350 cows) milked over 1.7 h showed the kikuyu protein and acid detergent fibre content offered to the first and last cows in the milking order to decrease by 21% and 15%, respectively. Thus, the first and last cows in larger herds, and/or any sized herd with a greater milking duration, could therefore be hypothesised to have individual cows accessing a greater disparity in pasture nutritive value than we have published. This phase also raised the question: What is the impact of milking order on milk yield and milk composition as a consequence of changes in nutritive value accessed across a milking session for alternative pasture species such as ryegrass?

4.2 Phase 2

Retrospective data acquired from 6 Tasmanian large herds showed earlier days to peak yield for multiparous cows (40-60 days in milk) which is within the range of 45-90 days to peak yield reported in the US literature. The reduced time to peak yield is likely due to a combination of genetics and feeding as higher yielding cows (ie housed cows in the USA) typically reach peak yield later than lower yielding cows (ie Australian pasture-based cows).

A substantial difference in milk yield of 4.5 L/cow/day, or 20% less milk, between the first and last 50 cows from all farm was observed. The difference in milk yield between the first and last cows in the majority of herds was quite similar and ranged from 15-18%. On average, milk yield decreased as milking order increased, however, there were deviations from this rule of thumb. Farm 2 was the notable exception with a decrease in milk yield with milking order to mid-way through the total number of cows with a jump in milk yield and a subsequent decrease to the end of the milking session. Upon discussion of these findings with the farmer in question, this herd was split to minimise the impact of milking order on the amount and nutritive value of pasture accessed by individual cows. These findings highlight the requirement for detailed studies to elucidate opportunities to improve the efficiency of milk production from pasture. Foremost of these opportunities was to determine the nutritive value of pasture accessed by the herds to answer the question raised in phase 1.

4.3 Phase 3

The impact of milking order on milk yield and the nutritive value of pasture accessed between farms was variable. However there were some consistent changes, although not significant in all cases. For example CP was less, ADF was higher and ME was lower for late cows in all three herds. These results highlight the differences in management practices that we know exist in the dairy industry. In this regard, the findings from each farm will be discussed in turn.

Farm 2: The first cows produced 10% more milk yield, solids non-fat and lactose yield than those milked last. Differences in milk yield and composition were reflected in changes in pasture height, CP, ADF and DOM. The main point of contrast for this farm, as compared with the others, was the more restricted area offered per cow and greater pasture CP% offered.

Farm 5: The first cows produced 7% more milk yield and 11% more protein yield than those milked last. Differences in milk yield and composition were not reflected in overall changes in pasture composition. Despite this, there was a reduction (trend) in pasture height and protein, and an increase in ADF, from the first to the last cows. These findings suggest that further work should increase sample number for sward height in line with paddock area (cows were offered in excess of $80m^2$ each in the morning paddock; 5ha for 495 cows) to pick up smaller changes in height and pasture nutritive value.

Farm 7: There were no differences in milk yield or components between the first and last cows. This was despite differences in pasture height and CP% between these cow groupings. Despite pasture height decreasing, the pre-graze height levels were by far the greatest across all farms. In this regard, pasture height when the last cow arrived to farm 7 was a similar height to the pre-graze height in other farms. Thus, the similarity in yield and milk composition between the first and last cows may be due a greater pasture allowance for farm 7, enabling greater production for the last cows. However, this management practice may be also associated with reduced pasture utilisation. These findings provide justification for further research on the influence of pasture allowance on the productivity of the first and last cows on dairy farms.

Across all farms we found an impact of milking order on milk FA composition between the first and last cows milked. The last cows to be milked had greater MUFA and PUFA content suggesting that even though the cows that are milked last produce less milk volume, the value of this milk to the consumer may exceed that of the first cows. There were also differences in milk FA composition between farms and milk from Farm 5 showed better FA composition than other farms (+MUFA, +PUFA, -SFA, -atherogenicity index), most likely due to the greater herbage allowance offered (HA; 39.9 kg/cow/day). Optimisation of pasture allowance both for the herd and the individual cow to maximum the value of milk produced from a herd is thus a key area for further research. Also, further detailed analyses should determine milk CLA cis-9, trans-11, CLA trans-10, cis-12, C18:1 trans-11 and OBCFA content.

5. SUMMARY/CONCLUSIONS

These pilot studies together provide ample evidence that there is an impact of milking order on the amount and nutritive value of pasture offered and associated milk yield and composition with milk yield decreasing by about 15-18% between first and last groups of cows. The impact of milking order on milk yield is likely to be due to the reduced CP, greater ADF increasing and reduced ME on offer to late cows due to current methods of pasture allocation. The changes in pasture nutritive value are likely to be associated with changed in milk fatty acid profile with PUFA/MUFA being greater for later milked cows.

These studies reveal an immense opportunity to increase feed use efficiency on Australian dairy farms through simple changes in farm management. Further work is required to control variables caused by differences in management and animal health to determine the true value of milking order data for Australia’s pasture-based dairy farmers.

6. FURTHER WORK

Further work is required to:

1) Provide the impact of milking order on the nutritive value of pasture accessed by cows in a controlled study when the same grazing management is implemented.
2) Provide, or account for, the impact of reduced health (lameness etc) on milking order and its association with milk yield.
3) Provide management strategies to increase nutrient use efficiency to increase farm profitability/productivity and to reduce environmental impact.
    - Changes in pasture allocation
    - Changes in supplement allocation

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