Assessment of factors which influence feed efficiency and rumen development of dairy calves, in relation to biological and physical growth and development, with consequences on first calving age and production efficiency through rearing

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Background to heifer rearing

- Dairy heifers are vital for replacing cull cows, and for breed improvement of the lactating herd
- Average cost of heifer rearing from birth to calving £1819 (Boulton et al. 2017)
- Target calving age is set at 22-24 months
- UK average calving age is 28 months, £2.87/day, for each day beyond 24 months (AHDB, 2015)
- Heifers calving later than target calving age have reduced odds of surviving first lactation (Bach 2011)

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The significance of calf rearing

- Traditional restricted milk feeding at 8-10% of birth weight can result in under achievement of growth potential (Appleby et al. 2001)
- Evidence suggesting epigenetic programming during pre-weaning period (Soberon et al. 2012)
- Milk feeding potentially having long term affects on first lactation performance (Moallem et al. 2010)
- Increased milk feeding associated with suppressed concentrate intake and poor rumen development (Terré et al. 2007)

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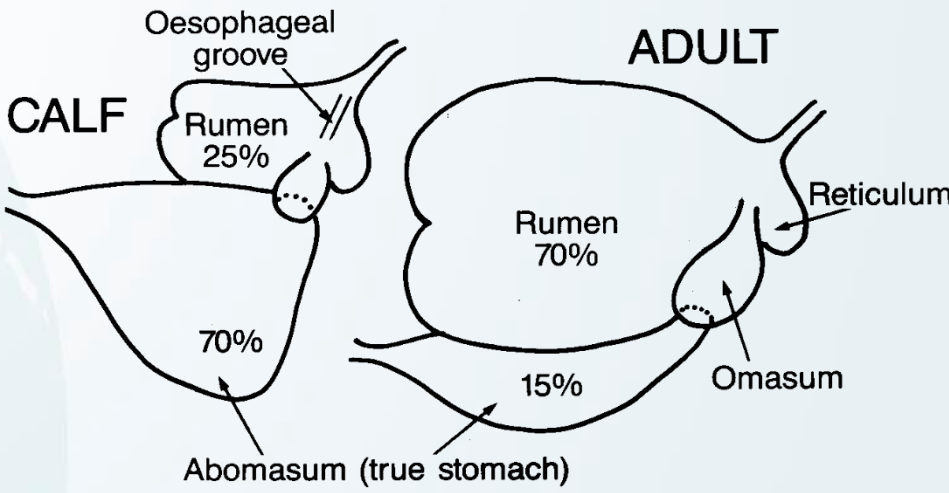
Transition from milk to a solid feed diet

- Fermentation end-products, especially butyrate from concentrate intake, promote rumen epithelial proliferation (Flatt et al. 1958)



Source: lifestyleblock.co.nz

- Forage supplementation can encourage concentrate intake in restricted milk fed calves (Khan et al. 2011)
- Little information on the use of forage, or age at introduction, for calves fed elevated milk quantities

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Project aims

This project aims to evaluate the long term effects of pre-weaned milk feeding level, and forage provision on:

- Growth and performance from birth to calving age
- Energy metabolism and nutrient utilisation pre and post-weaning
- Feed efficiency and calving age

Studies conducted

1. Calf rearing study
2. Pre-weaned chamber and balance study
3. Post-weaned chamber and balance study (8 mo of age)
4. Examination of maintenance energy requirements at 16 months of age

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Calf rearing study

Aims

- Build a foundation for post-weaned energy metabolism, and nutrient utilisation studies
- To understand if pre-weaned milk feeding level and forage provision affect program nutrient utilisation and energy metabolism after weaning
- Investigate effects of various forage sources, and age at introduction, on concentrate uptake

Pre-weaned dietary treatments

Forage treatment*	CS14 CS56 GS56 NF					
Milk feeding regimen	**Accelerated**				**Conventional**	
MR feeding (days)	**5-42**	**43-56**	**57-67**	**68 - 70**	**5-67**	**68-70**
MR powder (g/day)	1350	900	450	300	600	300
MR quantity (L/day)**	9	6	3	2	4	2
Frequency (meals/day)	3	2	1		2	1

***CS = chopped straw, GS = grass silage, NF = no forage provision, number = age at introduction **MR powder 150g/L**

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Overview of calf rearing study results

	Live weight (LW)									
	Milk replacer				Forage					
	Accel	Conv	SED	P	CS14	CS56	GS56	NF	SED	P
Growth 0 - 70 d of age										
LW (kg)	64.83	57.87	1.51	***<0.001***	63.20	61.04	60.38	60.79	2.13	*0.581*
ADG (kg/d)	0.72	0.60	0.02	***<0.001***	0.68	0.63	0.66	0.68	0.03	*0.450*

- No milk replacer x forage interactions on live weight or ADG

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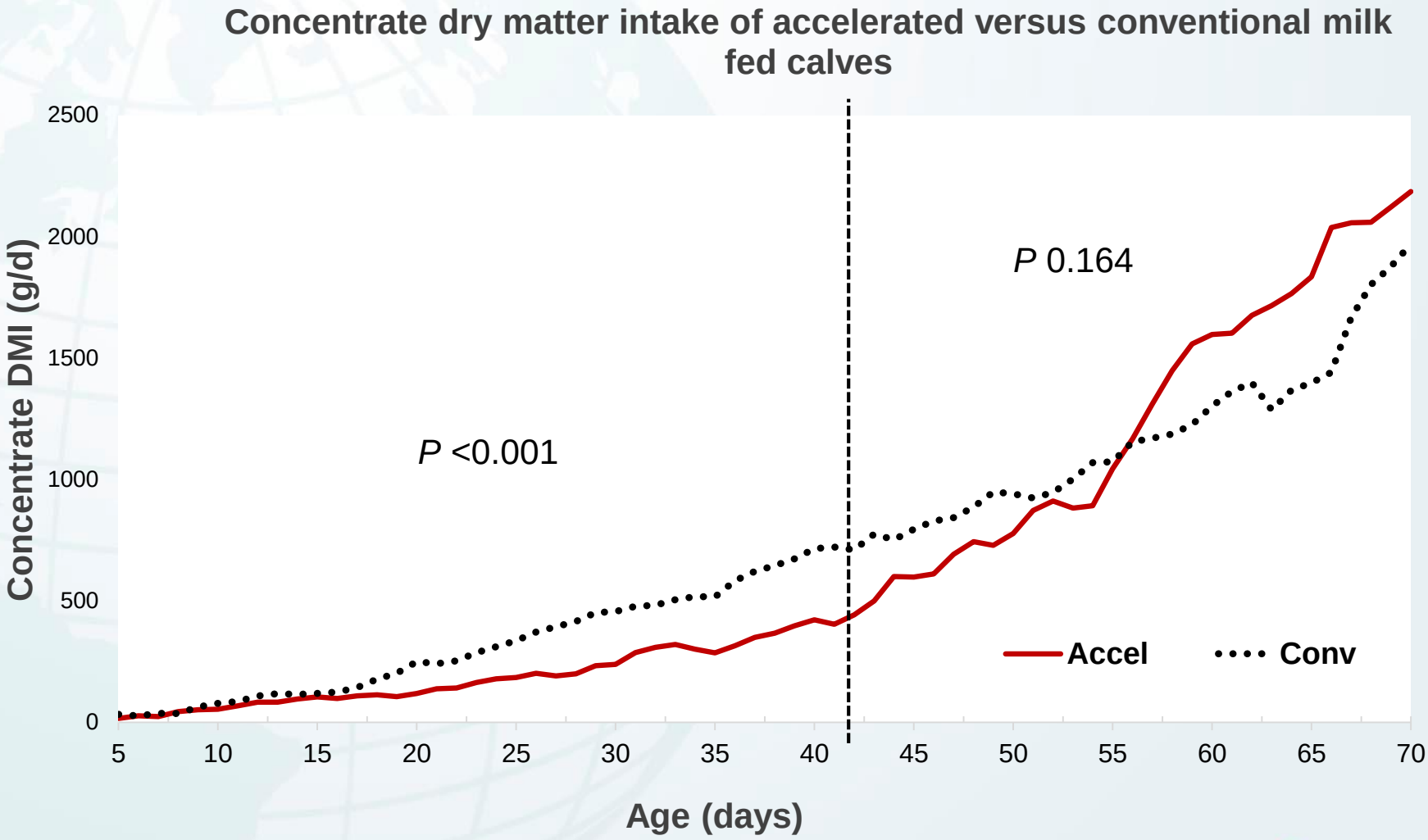
Results continued



Results continued

	Milk replacer X forage interactions									
	Accel. CS14	Accel. CS56	Accel. GS56	Accel. NF	Conv. CS14	Conv. CS56	Conv. GS56	Conv. NF	SED	P
5 - 70 d of age										
Conc. DMI (kg/d)	0.62^{ab}	0.67^{abc}	0.70^{bcd}	0.64^{abc}	0.78^{d}	0.58^{a}	0.68^{bc}	0.73^{cd}	0.05	***<0.001***
42- 70 d of age										
Conc. DMI (kg/d)	1.18^{b}	1.28^{bc}	1.38^{c}	1.22^{bc}	1.35^{bc}	0.99^{a}	1.18^{b}	1.20^{bc}	0.09	***<0.001***

- No benefit of forage on concentrate DMI to accelerated milk fed calves
- Chopped straw at 56 d of age, suppressed concentrate DMI of conventional milk calves

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Pre-weaned chamber and digestibility study

To understand the effects of pre-weaned milk feeding level and forage provision on:

- Nitrogen utilisation efficiency and energy metabolism of pre-weaned calves
- Dry matter and nutrient digestibility
- Methane (CH_4) emissions and heat production (HP)

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Study Design

- 30 dairy heifer calves aged 82.5 ± 2.7 (mean ± SD) days were used for the present study
- Heifer calves selected randomly from calf rearing study
- Both accelerated and conventional milk fed calves and MR allowance reduced to 2L MR per day
- Forage treatments remained the same
- Total collection of faeces and urine for 4 d
- Recording of gaseous exchange for 72 h

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Results

	Dietary Intake									
	Milk replacer				Forage					
	Accel	Conv	SED	*P*	CS14	CS56	GS56	NF	SED	*P*
LW (kg)	102.70	92.73	3.47	***0.009***	98.33	94.00	98.10	94.25	4.79	*0.680*
Feed intake										
Conc.DMI (kg/d)	2.54	2.46	0.14	*0.547*	2.62^{b}	2.65^{b}	2.58^{b}	2.14^{a}	0.20	***0.042***
Forage DMI (kg/d)	0.12	0.09	0.04	*0.395*	0.07	0.08	0.17	-	0.05	*0.087*
MR DMI (kg/d)	0.29	0.29	0.07	*0.215*	0.29	0.29	0.29	0.29	0.10	*0.867*
Total DMI (kg/d)	2.92	2.83	0.14	*0.416*	2.98^{b}	3.03^{b}	3.04^{b}	2.43^{a}	0.19	***0.008***
Water intake (L/d)	5.70	5.72	0.37	*0.928*	5.95^{b}	6.29^{b}	5.96^{b}	4.66^{a}	5.23	***0.015***

- Calves with no forage also had lower GEI, MEI, and DEI
- No milk feeding by forage interactions

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Results

	Nutrient Digestibility									
	Milk replacer				Forage					
	Accel	Conv	SED	*P*	CS14	CS56	GS56	NF	SED	*P*
Nutrient apparent digestibility (%)										
DM	79.97	80.96	0.97	*0.250*	79.47	80.60	79.95	81.84	1.37	*0.354*
OM	81.13	82.14	0.94	*0.229*	80.67	81.72	81.13	83.03	1.33	*0.334*
NDF	61.72	63.62	2.26	*0.289*	61.28	63.18	60.66	65.56	3.19	*0.423*
ADF	50.75	53.79	2.56	*0.205*	50.23	53.71	52.08	53.06	3.62	*0.810*
Nitrogen	51.48	50.86	2.88	*0.999*	48.47	56.67	49.3	50.24	4.06	*0.180*

- Digestibilities unaffected by dietary treatment
- No milk feeding by forage interactions

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Results

Nitrogen (N) Utilization

	Milk Replacer Level				Forage					
	Accel	**Conv**	**SED**	***P***	**CS14**	**CS56**	**GS56**	**NF**	**SED**	***P***
Daily Nitrogen Intake and Output (g)										
N intake	89.31	87.24	4.26	0.532	91.03^{b}	92.78^{b}	92.95^{b}	76.35^{a}	6.02	***0.021***
Faecal N	24.02	22.84	1.52	0.310	24.87^{b}	23.06^{ab}	26.16^{b}	19.63^{a}	2.15	***0.023***
Urine N	19.22	20.55	2.60	0.758	22.51	17.24	21.13	18.67	3.68	0.482
Retained N	46.06	43.86	2.89	0.510	43.66^{a}	52.48^{b}	45.66^{ab}	38.06^{a}	4.08	***0.011***
Nitrogen Utilization (g)										
Manure N/NI	0.49	0.49	0.03	0.999	0.52	0.43	0.51	0.50	0.04	0.180
Retained N/NI	0.51	0.51	0.03	0.999	0.48	0.57	0.49	0.50	0.04	0.180

- Milk feeding level did not influence on N intake, output, and utilisation
- Lower N intake and output between forage treatments a reflection of concentrate intake

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Results

Energy intake and output

	Milk replacer				Forage					
	Accel	Conv	SED	*P*	CS14	CS56	GS56	NF	SED	*P*
GEI (MJ)	53.67	51.52	2.67	0.353	54.83^{b}	55.71^{b}	55.06^{b}	44.78^{a}	3.77	0.010
Faecal E (MJ)	11.31	10.44	0.77	0.185	11.84^{b}	11.24^{b}	11.85^{b}	8.56^{a}	1.09	0.013
Urinal E (MJ)	1.17	1.11	0.08	0.508	1.23	1.12	1.18	1.03	0.12	0.378
CH4-E (MJ)	0.96	0.95	0.08	0.605	0.98^{b}	0.97^{b}	1.14^{b}	0.73^{a}	0.12	0.004
HP (MJ)	19.64	17.39	1.67	0.178	19.48	19.09	19.32	16.15	2.36	0.272
HP/LW$^{0.75}$ (MJ/kg)	0.62	0.60	0.06	0.707	0.63	0.63	0.62	0.53	0.08	0.395
ER (MJ)	20.59	22.14	1.91	0.492	21.29	23.29	22.59	18.31	2.70	0.252
ER (MJ/ kg LW $^{0.75}$)	0.64	0.75	0.06	0.091	0.68	0.77	0.73	0.60	0.08	0.155

- Tendency for ER/ kg LW $^{0.75}$ in accelerated calves to be lower
- Reduced energy intake and output of NF calves a reflection of reduced concentrate intake

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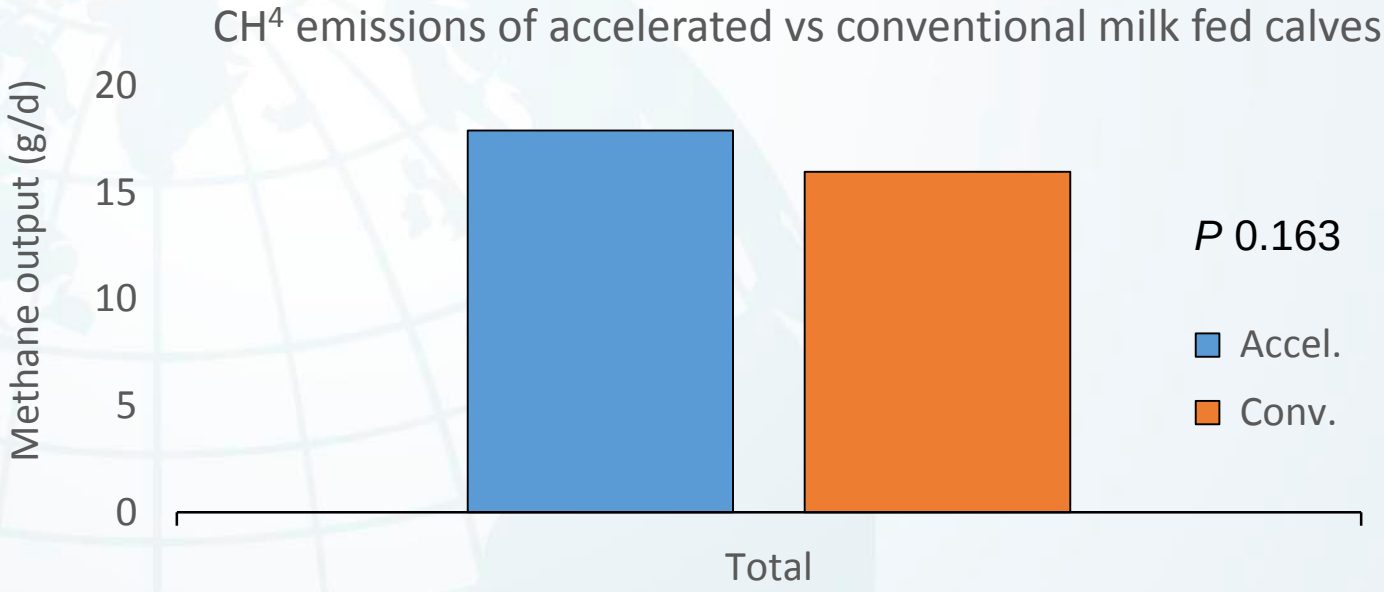
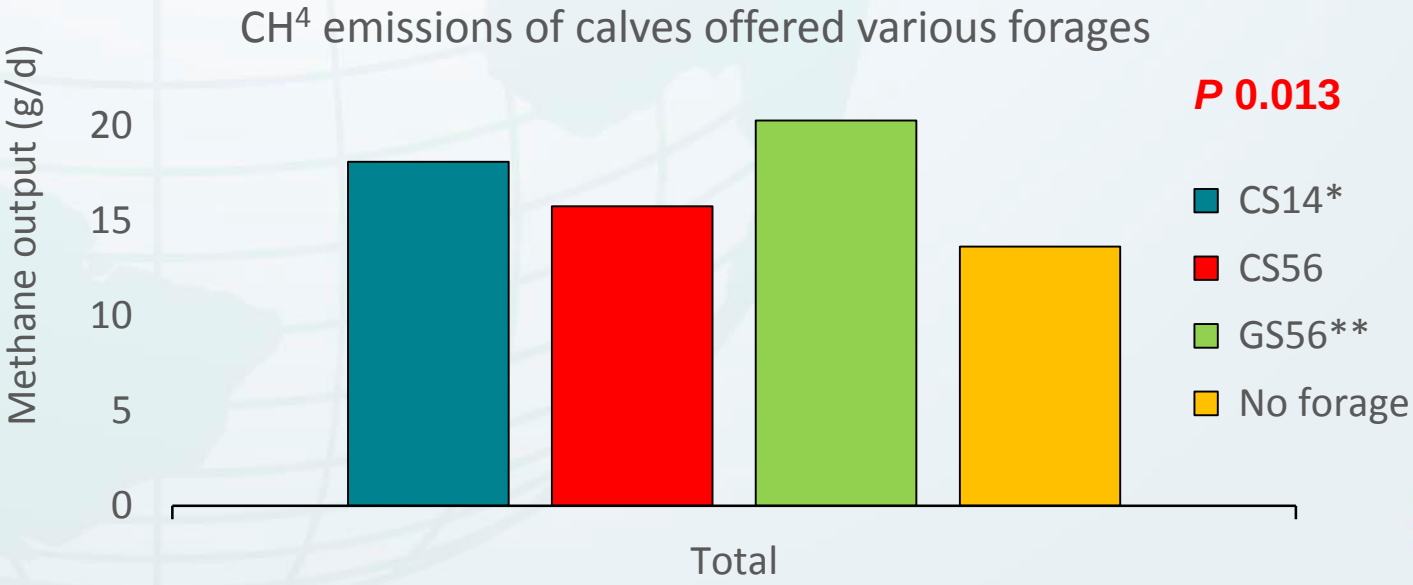
Results





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Insight into post-weaned performance

	Post-weaning growth									
	Milk replacer				Forage					
	Accel	Conv	SED	P	CS14	CS56	GS56	NF	SED	P
Growth 84 - 233 d of age										
LW (kg)	166.00	150.20	4.57	***0.010***	166.20^{b}	158.90^{a}	153.80^{a}	153.50^{a}	6.47	***0.034***
ADG (kg/d)	1.09	0.99	0.03	***0.009***	1.10	1.09	0.96	1.02	0.05	***0.051***

- Accelerated milk fed heifers maintained superior growth and live weight to conventional milk fed calves
- Heifers from CS14 pre-weaned forage treatment, were significantly heavier post-weaning

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Insight into post-weaned nutrient digestibility

	Dietary Intake and Nutrient Digestibility									
	Milk replacer				Forage					
	Accel	Conv	SED	P	CS14	CS56	GS56	NF	SED	P
Forage DMI (kg/d)	5.82	4.89	0.26	***0.001***	5.42	5.60	5.24	5.18	0.36	*0.736*
GEI (MJ/d)	110.50	92.20	5.19	***0.001***	101.60	105.00	101.60	97.30	7.33	*0.791*
NI (g/d)	167.00	139.90	8.04	***0.002***	154.70	157.20	154.40	147.60	11.37	*0.834*
Nutrient apparent digestibility										
DM (%)	75.41	77.87	0.85	***0.012***	74.53^{a}	77.31^{ab}	76.34^{b}	78.37^{b}	1.19	***0.034***
Nitrogen (%)	64.39	67.46	1.47	***0.085***	62.29	66.75	66.51	68.15	2.07	***0.071***

- Accelerated milk fed heifers showed lower digestibility of dry matter and tended to have lower nitrogen digestibility, than conventional milk fed calves
- Heifers from CS14 pre-weaned treatment group had lower DM digestibility, and tended to have lower nitrogen digestibility

Conclusions

- Accelerated milk feeding supports greater growth both pre-weaning, without weight loss at weaning
- Forage provision encourages concentrate intake, particularly as calves reach weaning age, leading to greater N and GE intake
- Milk feeding level does not appear to influence methane emissions immediately pre-weaning
- Introducing chopped straw at 14 d of age helps post-weaned live weight performance
- Greater post-weaning feed intakes of accelerated milk fed heifers led to lower digestibility of dry matter, and a tendency for lower nitrogen digestibility

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Other studies

- Data analysis ongoing examining the maintenance energy requirements of heifers reared on accelerated vs conventional milk feeding levels
- Maintenance energy study based on recent findings at AFBI by Jiao et al. 2015, which reported higher maintenance requirement of heifers than recommended by energy feeding systems
- Data collected for residual feed intake, and feeding behaviour throughout studies using biocontrol feed monitoring system
- Blood samples taken at regular intervals from birth to 8 months of age and tested for NEFA, BHB and UREA

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