**Supplementary material**

**Analysis of pre-weaning feeding policies and other risk factors influencing growth rates of calves on eleven commercial dairy farms**

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**Supplementary Table S1** *Milk powder and typical whole milk composition (dry), fed to calves in the study*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Milks fed  |  | Protein(%) | Oil(%) | Ash(%) | Fibre(%) | Lactose(%) | Total Solids(%) |
| Milk Powders1  | A | 20.6 | 17.5 | 7.7 | 0.5 | 53.6 | Mixing rates of 10 -15% used |
| B | 23.2 | 17.9 | 7.4 | 0 | 51.6 |
| C | 24 | 18.8 | 7.3 | 0 | 50 |
| D | 27.1 | 16.7 | 7.3 | 0 | 49 |
| Typical Holstein milk1  |  | 24.1 | 28.3 | 6.3 | 0 | 41.3 | 12.7 |
| Typical Holstein colostrum2  |  | 54 | 24.2 | 0.2 | 0 | 21.6 | 27.6 |

1Milk powders: A, Shine Once a day (Bonanza Calf Nutrition Ltd, Dundalk IE); B, Mole Valley Multistart (Mole Valley Farmers Ltd, South Molton, UK). C and D, Blossom and Heiferlac (Volac Ltd, Royston, UK). Gross analysis was provided in the product technical materials. The lactose% for milk powder was estimated by subtracting other components from 100% of dry matter.

2Mature milk data were taken from the USDA (2016) annual survey data.

3Holstein colostrum data was taken from a survey by Kehoe et al. (2007). Transition milk will have a composition intermediate between milk and colostrum.

**References**

Kehoe SI, Jayarao BM and Heinrichs AJ 2007. A survey of bovine colostrum composition and colostrum management practices on Pennsylvania dairy farms 1. Journal of Dairy Science 90, 4108–4116.

USDA. Summary of 2016 DHI herd averages DHI Report K-3. Retrieved on 1 March 2017 from https://www.uscdcb.com/publish/dhi/current/hax.html

**Supplementary Table S2** Summary of potential explanatory variables tested in the models for growth rates and size for 492 dairy heifer calves on 11 farms recruited to the study in their first week of life

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Variable1 | Description | Incidence (n, %)2 | Mean ± SD or range and median2 | Final variable tested for inclusion in model |
| Farm |  |  | 11 farms  |  | Random factor, included in all models |
| Dam and calving related | Dam perinatal disease | Milk fever, mastitis, metritis, retained fetal membranes  | 34 (6.9%) cows |  | Binary Y/N |
|  | Dystocia | Unassisted, manual assistance, traction, uterine torsion | 68 (13.8%) assisted calvings  |  | Binary Y/N |
|  | Supplementary colostrum feeding | Calves given supplementary colostrum by bottle or tube | 173 (35.2%) calves supplemented |  | Binary Y/N |
|  | Calf breed | Holstein, Friesian, Jersey Ayrshire, Crossbred | H 351 (71.3%); F 37 (7.5 %); J 24 (4.9%); A 9 (1.8 %);C 71, (14.4%) calves |  | Categorical and Binary Holstein/Other |
| Calf husbandry | Calving pattern3 | Autumn block or all-year-round | AB 153 (31.1%), AYR 339 (68.9%) calves |  | Categorical  |
|  | Calving intensity3 | No. of calves born on that farm in the week of recruitment  |  | Range 1 - 21, median 6 | Log transformation of continuous data |
|  | Environmental temperature3 | Mean temperature in the month of birth oC |  | Range 4.4 -16.6, median 9.5  | Log transformation of continuous data |
|  | Movement | Pre-weaning movement of calves to another farm | 288 (58.5%) calves did not move |  | Binary Y/N |
|  | Group size | Single pens, small group (<7 calves), medium group (7-12 calves), large group (> 12 calves) | S 62 (12.6%); SG 131 (26.6%); MG 135 (27.4 %); LG 164 (33.3 %) calves |  | Categorical  |
|  | Group mixing | Pre-weaned calves moved between groups | 155/492 (31.5 %) calves were mixed  |  | Binary Y/N |
|  | Age at disbudding | <3 weeks, 3-6 weeks, >6 weeks | <3 14 (2.8%); 3-6 237 (48.2%0; >6 241 (49.0%) calves |  | Categorical |
| Calf feeding | Feeding Frequency | 3 feeds/day on automated feeders, bucket twice daily, bucket once daily (from 3 weeks), continuous supply of waste milk | x3 206 (41.9%); x2 200 (40.7%); x1 86 (17.4%); cont 96 (19.5%) calves |  | Categorical |
|  | Age at weaning | Days |  | 64.3 ± 9.4 | Continuous |
|  | Milk solids fed days 1-35 | Kg4 |  | 20.5 ± 5.0  | Continuous |
|  | Milk solids fed days 1-63 | Kg4 |  | 34.5 ± 10.8  | Continuous |
| Calf size and growth | Weight at recruitment | Kg |  | 39.6 ± 8.8  | Continuous |
|  | Height at recruitment | Cm |  | 76.4 ± 4.1  | Continuous |
|  | Length at recruitment | Cm |  | 61.9 ± 4.6  | Continuous |
|  | Ponderal index at recruitment | Kg/m3 |  | 14.8 ± 2.4  | Continuous |
|  | Age at recruitment | Days |  | 4.5 ± 2.9 | Continuous |
|  | ADG days 1-635 | Kg/day |  | 0.62 ± 0.174 | Continuous |
|  | Height increase days 1-635 | Cm/day  |  | 0.21 ± 0.081 | Continuous |
|  | Estimated weight at 63 days5 | Kg |  | 74.6 ± 10.9 | Continuous |
|  | Estimated height at 63 days5 | Cm |  | 88.9 ± 5.0 | Continuous |
| Calf blood measurements | Serum total protein at recruitment | mg/ml |  | 56.7 ± 10.3 | Continuous |
|  | Serum IgG at recruitment | mg/ml  |  | 19.0 ± 9.9  | Continuous |
|  | Plasma IGF-1 at recruitment | ng/ml |  | Range <1.8 – 177, median 47.0 | Log transformation of continuous variable |
|  | Plasma IGF-1 week 5 | ng/ml  |  | Range <1.8 – 560, median 52.4 | Log transformation of continuous variable |
|  | Plasma IGF-1 week 95 | ng/ml  |  | Range <1.8 – 303.6, median 57.6 | Log transformation of continuous variable |
| Calf health weeks 1-9 | BRD | Any BRD | 226/492 (45.9%) calves |  | Binary Y/N |
|  | BRD | Total score above the threshold for diagnosis |  | Range 0-15, median 0 | Raw data6 |
|  | BRD | No. weeks with disease |  | Range 1-6, median 0 | Raw data6 |
|  | Diarrhoea | Any diarrhoea | 237/492 (48.2%) calves |  | Binary Y/N |
|  | Diarrhoea | Total score above the threshold for diagnosis |  | Range 0-6, median 0 | Raw data6  |
|  | Diarrhoea | No. weeks with disease |  | Range 0-6, median 0 | Raw data6  |
|  | Umbilical disease | Any umbilical disease | 141/492 (28.7%) calves |  | Binary Y/N |
|  | Umbilical disease | Total score above the threshold for diagnosis |  | Range 0-11, median 0 | Raw data6 |
|  | Umbilical disease | No. weeks with disease |  | Range 0-8, median 0 | Raw data6 |

1Variables which were remained in at least one of the final models tested are shaded.

2For categorical data the count and percentage of calves in each group are shown. Normally distributed data are presented as mean ± SD. Other continuous data are given as the range and median.

3The high degree of correlation between the environmental temperature, calving pattern and the heifer calving intensity meant that only one of these variables could be included in any model without convergence errors. Therefore only the variable which most improved the model was included in the final model.

4Calculated as described in Materials and methods

5These variables were only tested for inclusion in size and growth models from 63-229 days.

6Treating the data as an ordered factor was tested but using the raw data significantly improved the model in all cases.

**Supplementary Table S3** *Calf size by breed from recruitment in week 1 to 7.5 months of age1*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Breed2 | n3 | Recruitment | 63 days | 229 days |
| Weight (kg) |
| H | 351 | 41.2 ± 7.7a | 77.4 ± 10.5a | 220 ± 24.5 |
| A | 9 | 41.8 ± 8.7a | 78.6 ± 21.7a | 191.3 ± 29.5 |
| F | 37 | 40.8 ± 6.6 a | 72.4 ± 7.3ab | 206.5 ± 19.6 |
| J | 24 | 22 ± 7.1c | 63.6 ± 7.6b | 169 ± 17.7 |
| SRX | 43 | 39.5 ± 5.8a | 74.7 ± 12.3ab | 209.7 ± 33.2 |
| FXO | 4 | 36 ± 7.4ab | 74.8 ± 8.1ab | 195 ± 35.4 |
| JXO | 11 | 34.1 ± 7.7ab | 77.1 ± 7.8a | 206.6 ± 14.7 |
| FXJ | 13 | 29.1 ± 8.9bc | 69 ± 8.4ab | 172.5 ± 23.2 |
| Height (cm) |
| H | 351 | 77.2 ± 3.8a | 90.6 ± 5.2a | 116.2 ± 5.3a |
| A | 9 | 76.1 ± 3.4abc | 87.1 ± 2.7bc | 109.1 ± 4.4ab |
| F | 37 | 74.3 ± 3.4bc | 86.5 ± 3.1bc | 111.5 ± 4.8ab |
| J | 24 | 70.7 ± 3.8c | 82.3 ± 3.5c | 108.8 ± 5.7b |
| SRX | 43 | 76.6 ± 3.3ab | 88 ± 4bc | 116.7 ± 5.6ab |
| FXO | 4 | 76.3 ± 3.6abc | 88.8 ± 2.8abc | 113.8 ± 4.3ab |
| JXO | 11 | 74.1 ± 3.9bc | 89 ± 5ab | 113 ± 4.4ab |
| FXJ | 13 | 72.7 ± 3.2c | 83 ± 4.1bc | 110.2 ± 2.6ab |

1All results are presented as mean ± SD. Within columns a>b>c, P<0.05 by ANOVA with Tukey post-hoc testing.

2A, Ayrshire; F, Friesian; FXJ, Friesian cross Jersey; FXO, Friesian cross other breed; H, Holstein; J, Jersey; JXO, Jersey cross other; SRX, Scandinavian red cross black and white breed.

3 Number of animals recruited at birth. As there were deaths in the study the number of animals surviving at 63 days and 229 days was lower than the total recruited.

 **Supplementary Figure S1** Box and whisker plots of (a) height, (b) length and (c) weight of all 492 calves in the study, corrected based on individual growth rates to give the estimated values at each of the four time points.