**USDA Milk Study: Calf Growth Preliminary Analysis**

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**Study Design & Research Goals:**

One of the goals of your research is to determine the impact of cow and calf performance measures on milk production level (milk AUC). You are interested in the association of milkAUC and these cow and calf performance measures including cow body weight, cow body condition, as well as calf weights. This report summarizes the results of the calf growth data.

**Data:**

You collected data on 60 pairs of cows and separated cows and calves in 2020 and 2021. You collected data on these cow/calf pairs in March 2020, May 2020, March 2021, as well as May 2021, with a total of 118 cow/calf pairs. You also computed the estimated milk production level by calculating the Area Under the Curve (AUC). You recorded the cow body weight and body condition score for the cow at pre-calving, pre-breeding, breeding, as well as at the weaning state. You also calculated the change in body weight at pre-breeding, breeding, and wean stage. Calf weights were also recorded every time they are milked at birth, 30, 60, 90, and 120 days after birth, and then again at weaning.

I created a variable that measures the number of days of calving within each year and season. I created this by taking calve date and subtracting the first calving date from the calving date. This created a variable known as “cdate” in the data set. I also created a variable called “seasonyear” which basically concatenates the season and the year together in a single column. I did this to fit the model properly. I also created variable that modifies the cow age variable and called this “cowagen”. I did this because only 7-year-old cows appeared in May 2020, so the 6 and 7 year old cows were grouped into the six year old age group.

**Statistical Model:**

To analyze the association between milkAUC and the cow/calf performance measures, I ran 17 Linear Mixed Models (LMM). Each model has a different response variable. I ran models with cow body weight as the response at each breeding stage. I also ran models with the body condition score as the response at each breeding stage. Models with the calf weights as the response were run for the six time points the calves were weight. I am running these models under the assumption of normality for these response variables.

In the model, I included a fixed effect of gender, a fixed effect for the day in calving season, as well as cow age in the model to better estimate the association of milk production and the cow/calf performance measure. I ran the models with gender and cow age as classification variables, with cdate and milk AUC as quantitative variables. I also included a random effect for the season/year. This accounts for the variability associated with the change in season. This random effect also accounts for the fact that you sometimes had the same cows in both years. This will also help us get a better estimate of the milk AUC. I first ran these models with a quadratic effect for the days in calving season (cdate), but dropped this term from the model where this term was insignificant according to the Type I Test of Fixed Effects table.

**Results:**

The SAS output for these models is shown in the attached file “Results\_cows\_final.pdf”. I won’t walk through the interpretations of every model, but to summarize, after accounting for the effects of cow age, calve age, gender, as well as the random effect of season/year, I found the milkAUC term to be significant with weanBCS as the response, as well as with the calf body weights as the response at 30, 60, 90, and 120 days after birth, as well as at weaning. None of cow body weights had a significant association with the milkAUC. I’ll only report the results for the calf weight at 30 days as the interpretation is similar for the other days. I’ll also report the results for the body condition score at weaning. Below is a scatter plot looking at the association of milkAUC and the calf weight 30 days after birth:

Chart, scatter chart

Description automatically generated

We can see that there appears to be a slight positive association between milkAUC and the calf weight at 30 days. The model I ran does confirm this association. I will now walk through the SAS output for this model:

| **Type I Tests of Fixed Effects** | | | | |
| --- | --- | --- | --- | --- |
| **Effect** | **Num DF** | **Den DF** | **F Value** | **Pr > F** |
| **calfsex** | 1 | 108 | 0.10 | 0.7568 |
| **cdate** | 1 | 108 | 31.61 | <.0001 |
| **cdate\*cdate** | 1 | 108 | 4.04 | 0.0469 |
| **cowagen** | 2 | 108 | 2.66 | 0.0747 |
| **milkAUC** | 1 | 108 | 15.27 | 0.0002 |

I first examine the Type I Test of Fixed Effects table. Notice that the linear effect of calve age (cdate) is significant along with the quadratic effect of cdate. Most importantly, this table says that the effect of milkAUC is significant overall for calf weights at 30 days. To determine the direction and significance of the association, I then look at the solution for fixed effects table below:

| **Solutions for Fixed Effects** | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Effect** | **calfsex** | **cowagen** | **Estimate** | **Standard Error** | **DF** | **t Value** | **Pr > |t|** |
| **Intercept** |  |  | 63.3489 | 9.4109 | 3 | 6.73 | 0.0067 |
| **calfsex** | heifer |  | -2.8964 | 1.5605 | 108 | -1.86 | 0.0662 |
| **calfsex** | steer |  | 0 | . | . | . | . |
| **cdate** |  |  | -0.02561 | 0.3505 | 108 | -0.07 | 0.9419 |
| **cdate\*cdate** |  |  | -0.01875 | 0.01208 | 108 | -1.55 | 0.1235 |
| **cowagen** |  | 4 | -5.1836 | 2.1175 | 108 | -2.45 | 0.0160 |
| **cowagen** |  | 5 | -0.3367 | 1.8909 | 108 | -0.18 | 0.8590 |
| **cowagen** |  | 6 | 0 | . | . | . | . |
| **milkAUC** |  |  | 0.01808 | 0.004626 | 108 | 3.91 | 0.0002 |

We see that the positive association of milkAUC and calf weight at 30 days is slightly positive while also being statistically significant. The estimate of 0.01808 means that for every one unit increase in milkAUC, there is a 0.01808 kg increase in calf weight on average.

I will now summarize the model where milkAUC was significant for weanBCS. Below is a scatter plot looking at the association of weaning body condition score and milkAUC:

Chart, scatter chart

Description automatically generated

The fitted regression line shows that there may be a slight negative association between milkAUC and weaning body condition score. The model does confirm this negative association. Below is the relevant SAS output:

| **Type I Tests of Fixed Effects** | | | | |
| --- | --- | --- | --- | --- |
| **Effect** | **Num DF** | **Den DF** | **F Value** | **Pr > F** |
| **calfsex** | 1 | 109 | 0.01 | 0.9353 |
| **cdate** | 1 | 109 | 0.40 | 0.5304 |
| **cowagen** | 2 | 109 | 3.18 | 0.0456 |
| **milkAUC** | 1 | 109 | 5.64 | 0.0193 |

Looking at the Type I test of Fixed Effects Tables, we see that the linear effect of milkAUC is significant overall, along with cow age. Note that I dropped the quadratic term for cdate since that was insignificant.

| **Solutions for Fixed Effects** | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Effect** | **calfsex** | **cowagen** | **Estimate** | **Standard Error** | **DF** | **t Value** | **Pr > |t|** |
| **Intercept** |  |  | 5.9680 | 0.3071 | 3 | 19.44 | 0.0003 |
| **calfsex** | heifer |  | -0.03151 | 0.08067 | 109 | -0.39 | 0.6969 |
| **calfsex** | steer |  | 0 | . | . | . | . |
| **cdate** |  |  | -0.00435 | 0.006204 | 109 | -0.70 | 0.4848 |
| **cowagen** |  | 4 | -0.2169 | 0.1084 | 109 | -2.00 | 0.0479 |
| **cowagen** |  | 5 | -0.02892 | 0.09756 | 109 | -0.30 | 0.7675 |
| **cowagen** |  | 6 | 0 | . | . | . | . |
| **milkAUC** |  |  | -0.00055 | 0.000233 | 109 | -2.37 | 0.0193 |

According to the solutions for fixed effects table, we see that the direction for the association between milkAUC and weaning body condition score is negative and statistically significant. The meaning of the estimate of -0.00055 is that for every one unit increase in milkAUC, there is a 0.00055 point decrease in body condition score on average.

**Attachments:**

* See attached *sas-output.pdf* for cow body weight, body condition, and calf weight analyses.
* See attached “milk\_onetime.csv” for updated data set.