

Predicting dairy pen DMI with Machine Learning

P. M. Lucey, H. A. Rossow.

UC Davis Veterinary Medicine Teaching and Research Center



Precision Dairy Nutrition

Challenges:

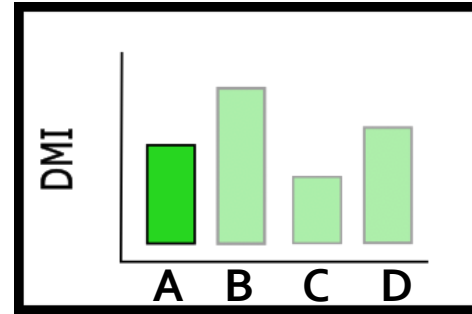
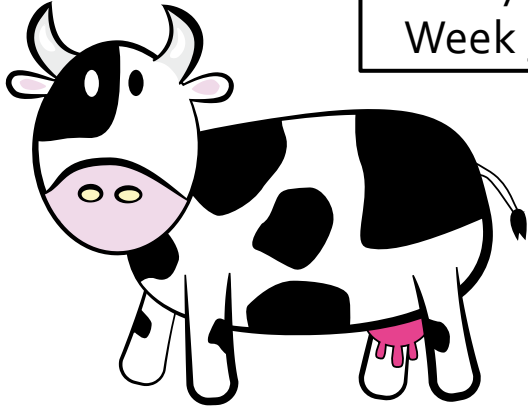
- Cows are fed by pen
- Assumes every cows eats the same DMI
- Diet formulated to this DMI

Solution:

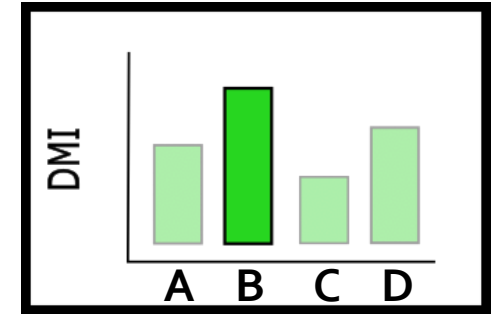
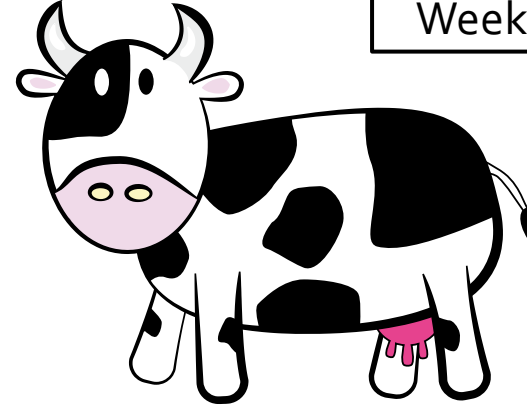
- Explain the distribution of DMI
- Predict this from milk data
- Formulate a different diet

Modeling Process -> Frame problem – Data – Model – Solution

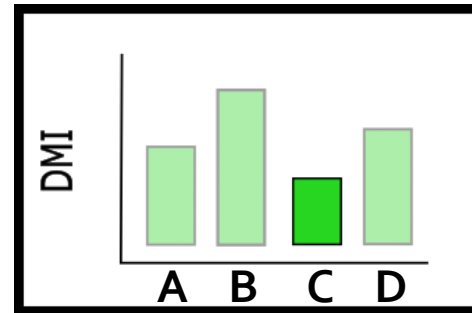
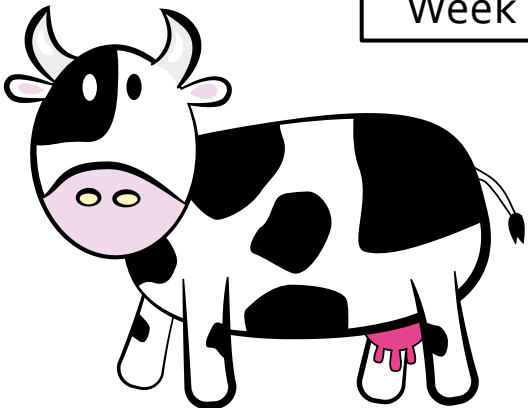
Cow: A
Parity 2
Week 5 of lactation



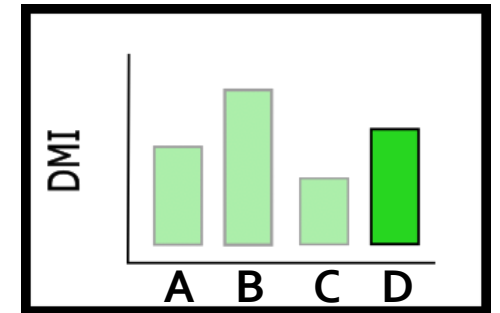
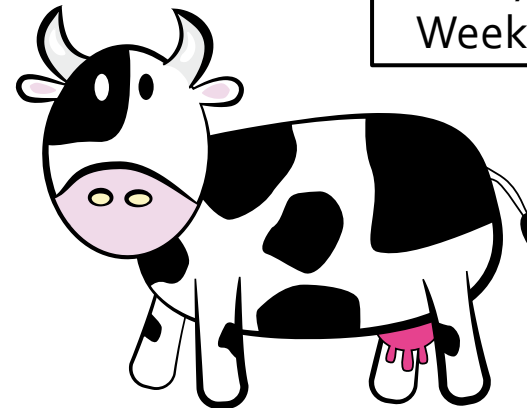
Cow: B
Parity 2
Week 8 of lactation



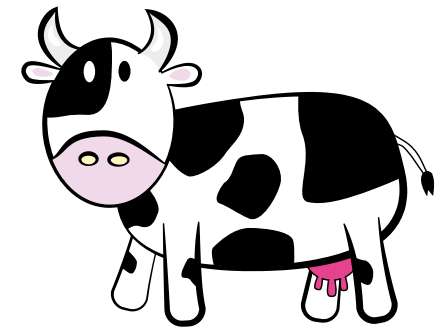
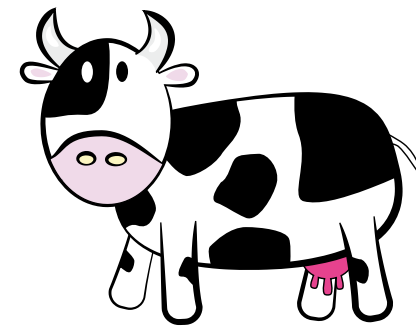
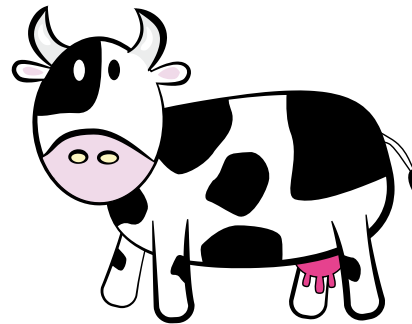
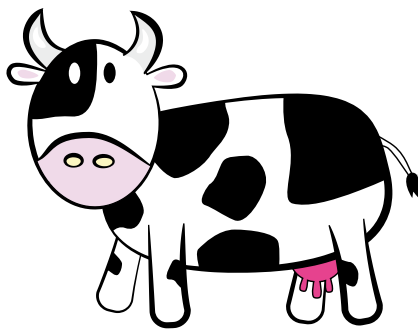
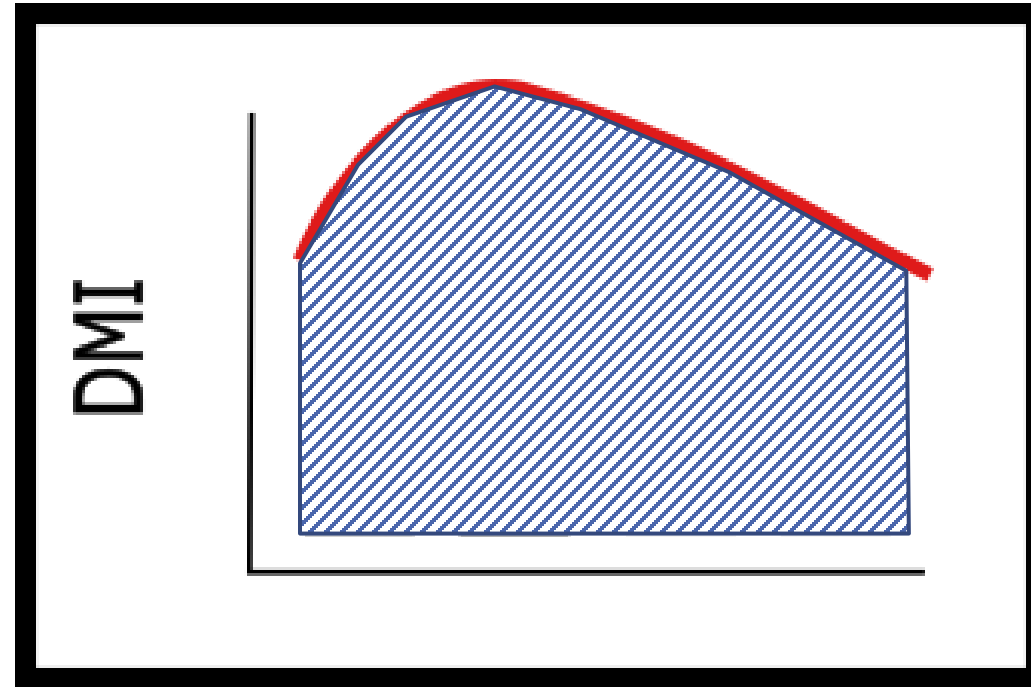
Cow: C
Parity 1
Week 10 of lactation



Cow: D
Parity 1
Week 7 of lactation



Modeling Process -> Frame problem – Data – Model – Solution



Objective

Predict the DMI of a pen from
its distribution shape with
machine learning

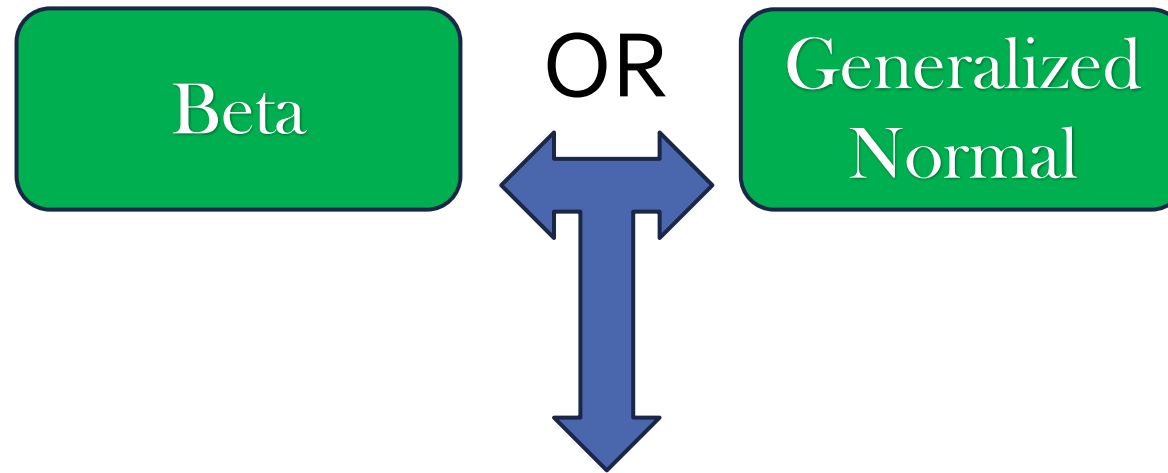
Methods: Dataset description

	N of Cows	N of lact 1	N of lact > 1	Lactation wk range	Breed	Initial bodyweight (kg)	Region of study
1	55	15	40	1 – 44	Holstein	631	CA, USA
2	74	29	45	1 – 36	Holstein	550	WI, USA
3	36	12	24	3 – 43	Holstein & Jersey	533	OH, USA
4	57	0	57	1 – 9	Holstein	724	PA, USA
5	40	0	40	1 – 21	Not stated	597	PA, USA
6	45	0	45	3 – 18	Not stated	578	CA, USA
7	51	51	0	1 – 14	Holstein	597	UK
8	37	0	37	3 - 43	Holstein	691	IN, USA
9	31	0	31	1 – 10	Holstein	698	WA, USA
Total	426	107	319				

Lactating cow pens

N of cows	Lactation range	Mean milk (kg)	Milk Distribution type	DMI Distribution type	Shape	Scale
200	1 - 3	32	Beta	Beta	2.3	2.1
150	4 - 21	45	Gen Normal	Beta	3.3	3.6
200	4 - 12	43	Beta	Gen Normal	3.2	2.8
50	1 - 3	34	Beta			

1. Classification – Random Forest



2. Multioutput Regression - XGBoost



Modeling Process -> Frame problem – Data – Model – Fine-tune – **Solution**

DMI distribution Classification model

Beta

Gen Normal

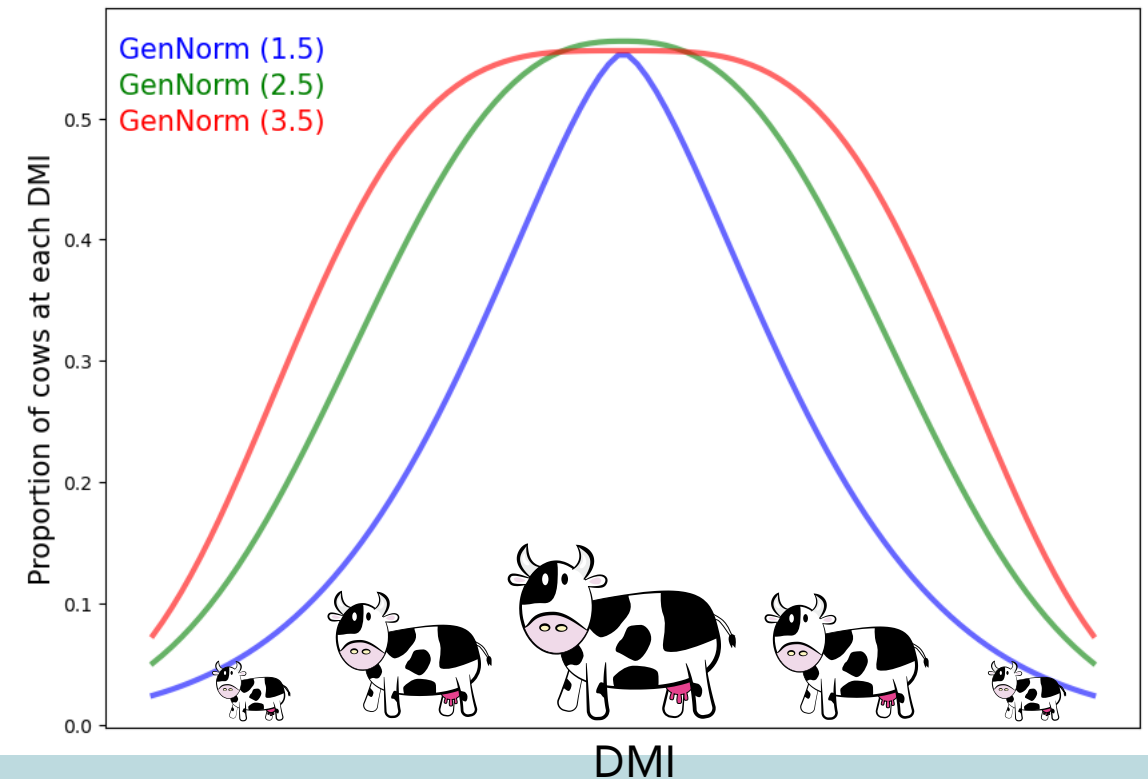
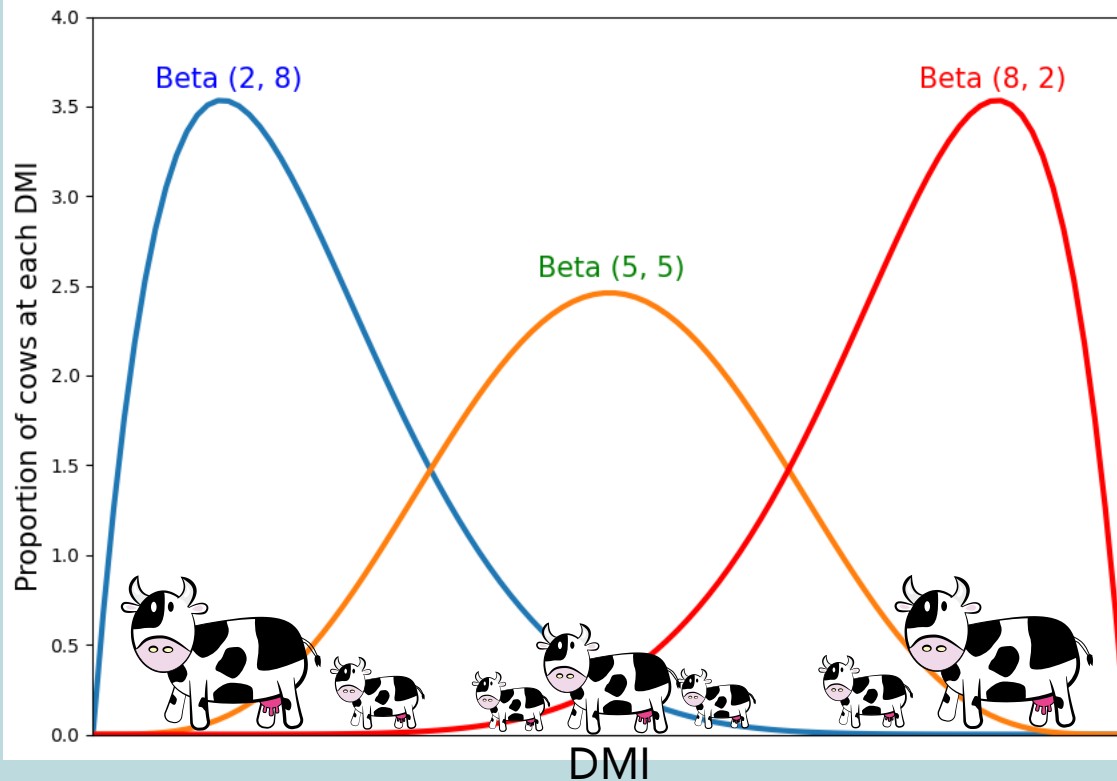
Regression model:
 α , β , location, scale

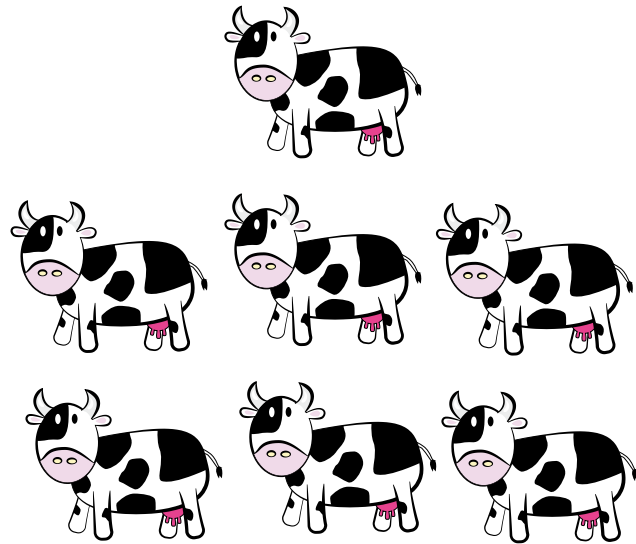
Validation data

Regression model:
 α , β , location

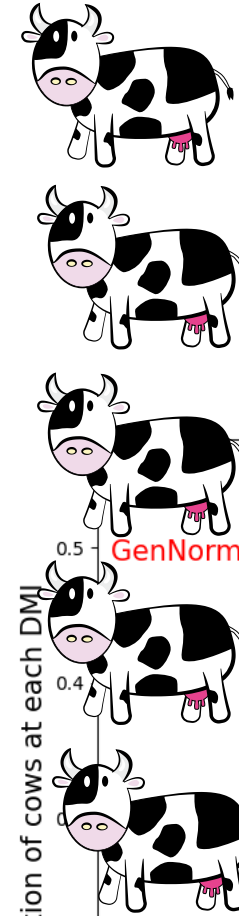
Plot distribution and
calculate pen DMI

Plot distribution and
calculate pen DMI





DMI



Proportion of cows at each DMI

0.5 GenNorm (3.5)

0.4



Pen DMI

Top features:

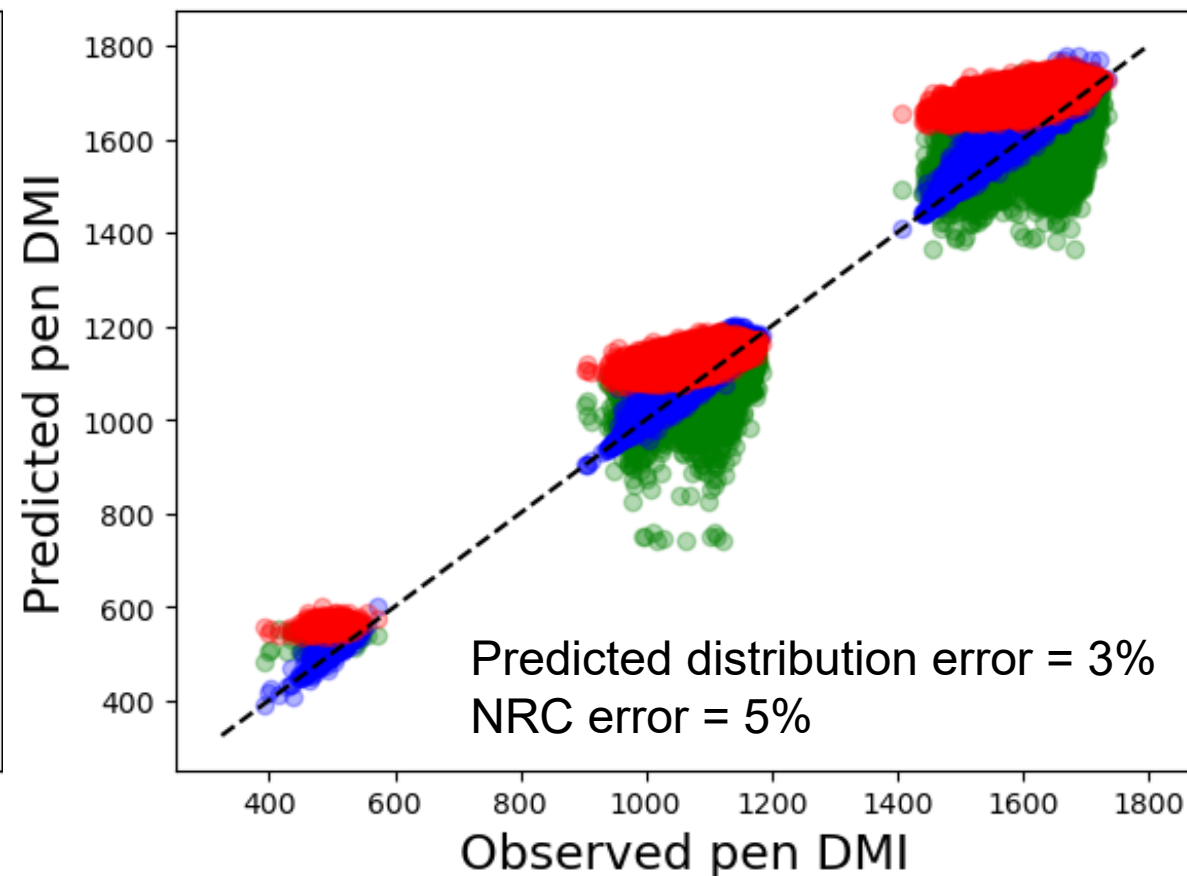
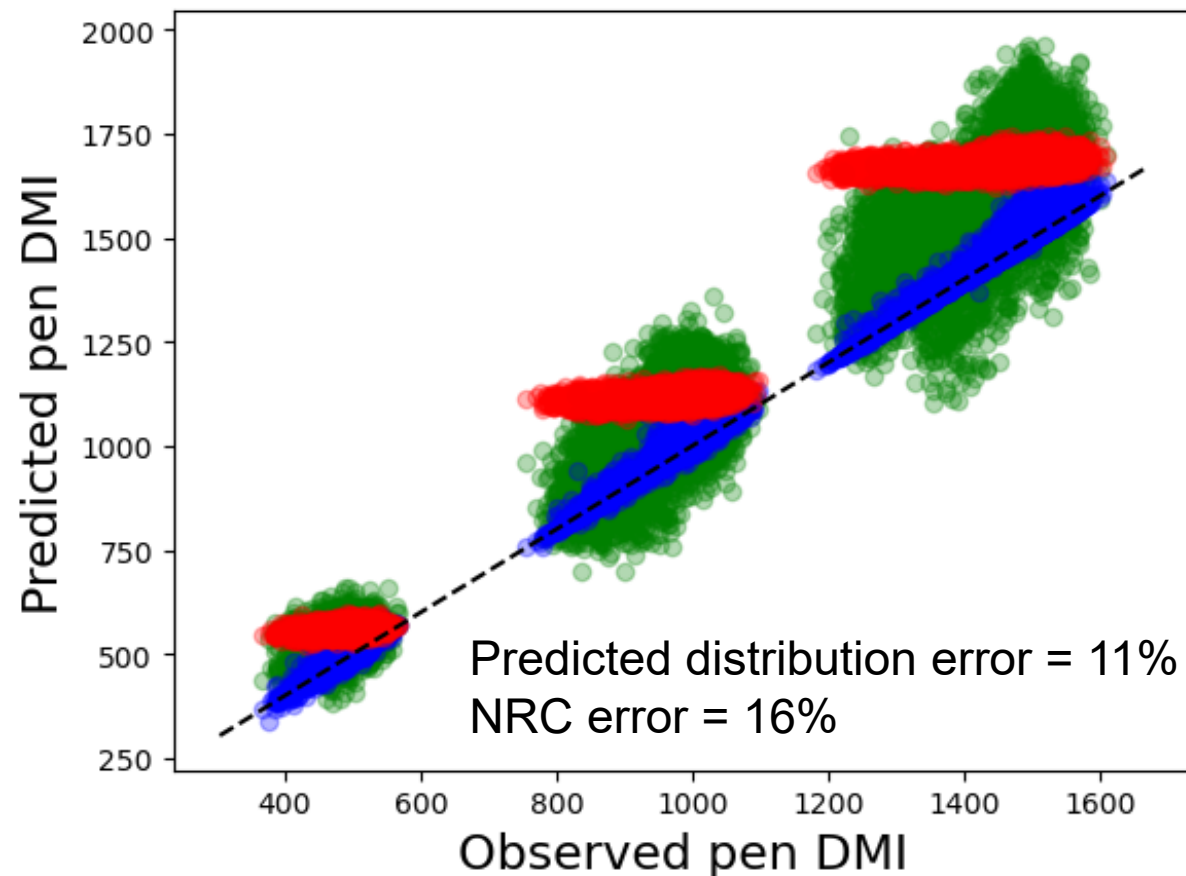
- Pen size
- Variance of milk yield
- Earliest and latest week in milk
- Parity of pen

Compare predicted DMI to NRC

Beta

- Known distribution
- Predicted distribution
- NRC prediction

GenNorm



Conclusions

- Model can reduce pen DMI error for diet formulation
- A different diet will be formulated if DMI is a binding constraint

Limitations:

- Validation data only small pens

Next steps:

- Formulate diets to the predicted pen DMI
- Compare diet solution to an NRC ration

Thank you for listening

Dataset donations welcome!

Contact:

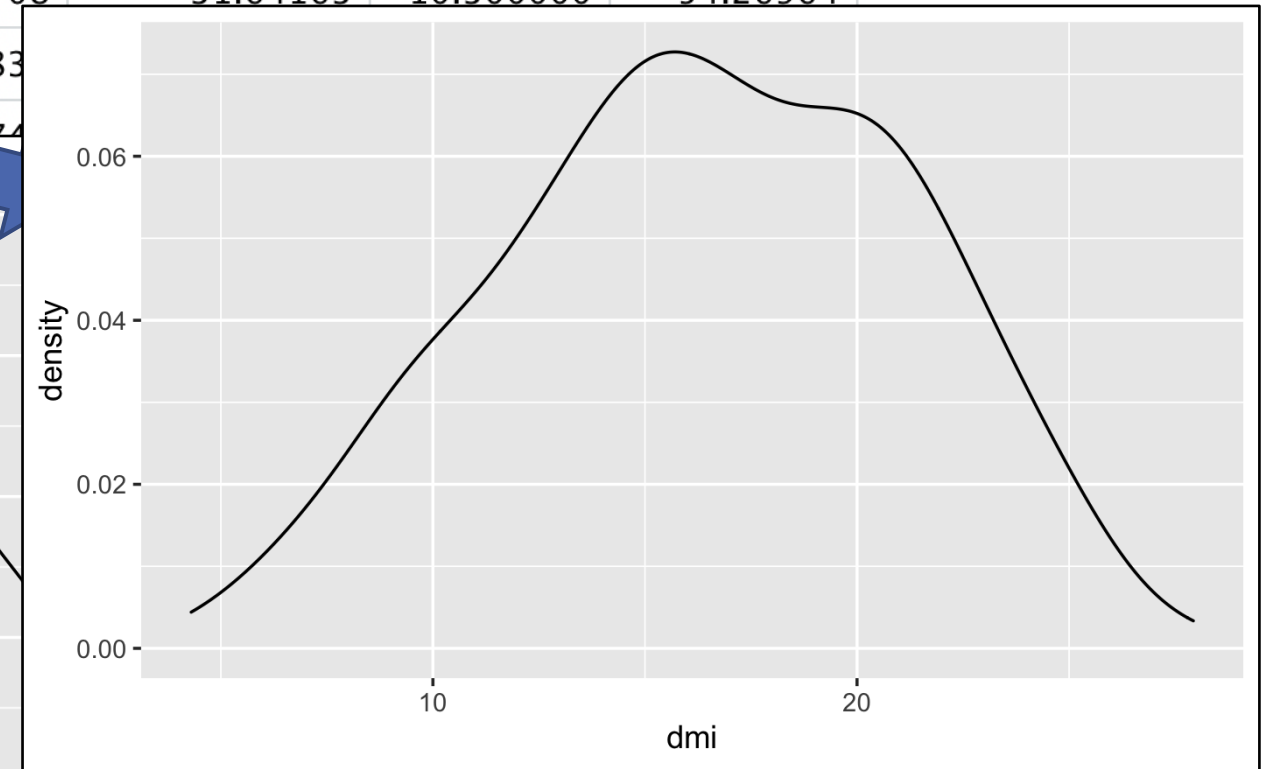
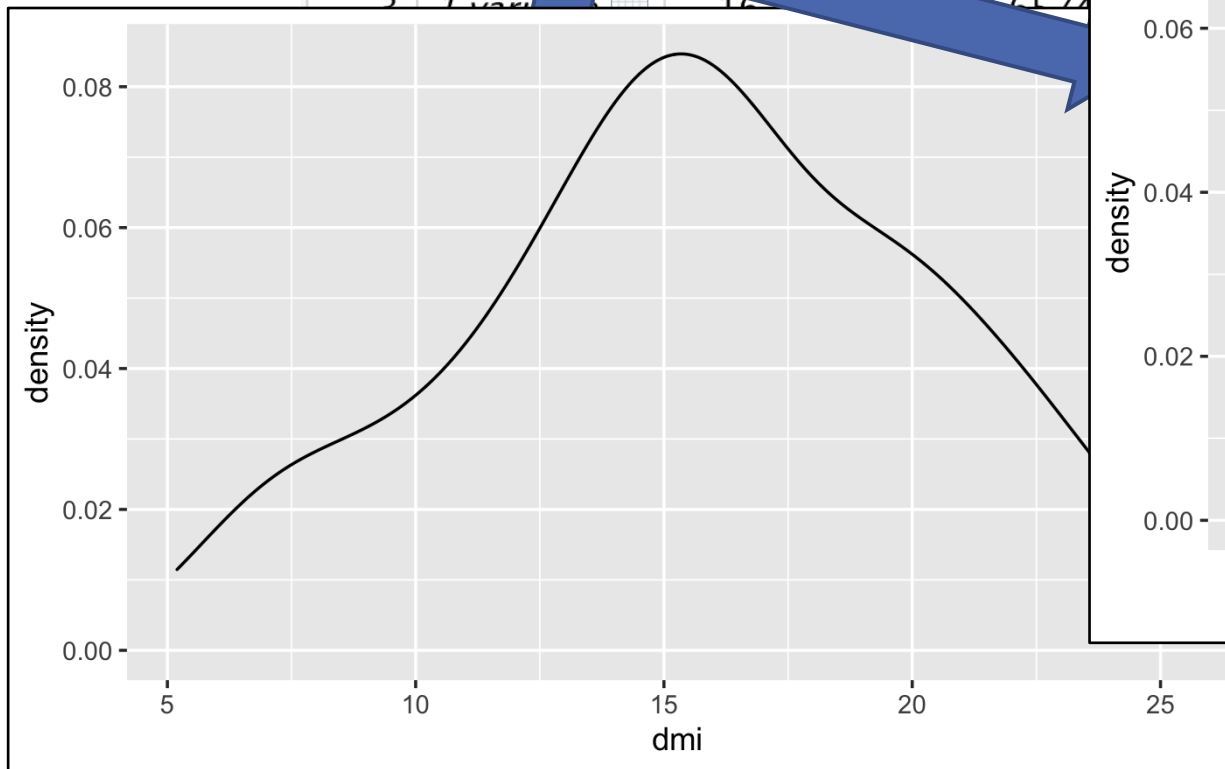
padraig.lucey@elancoah.com

[LinkedIn.com/padraiglucey](https://www.linkedin.com/company/padraiglucey)

DairyDataScience.com

Methods: Simulate pens

i	data	avgDMI	avgMilk	medianMilk	minMilk	maxMilk
1	1 variable	15.71571	32.40708	31.64163	10.300000	54.26964
2	1 varia	16.73664	33.9183			
3	1 vari	17.6574	35.4296			



Pen DMI distribution

DMI Distribution Proportions of best distribution of DMI
 description for all replicates (%)

Pen type, n cows	Lactation range, wk	Pen replicates, n	Mean DMI, cow (kg)	Skew	Kurtosis	Normal	Beta	Weibull	Logistic
Fresh, 20	1 - 3	100	17.06	0.07	2.76	8	85	1	6
Fresh, 60	1 - 3	100	16.97	-0.03	2.49	8	87	0	5
High, 50	4 - 18	100	22.71	-0.2	2.99	8	77	0	15
High, 200	4 - 18	100	22.97	-0.2	3.12	28	60	0	12
Low, 50	19 - 44	100	20.90	-0.2	3.22	10	62	4	24
Low, 150	19 - 44	100	20.86	-0.2	3.43	29	36	1	34

Best Classification Model

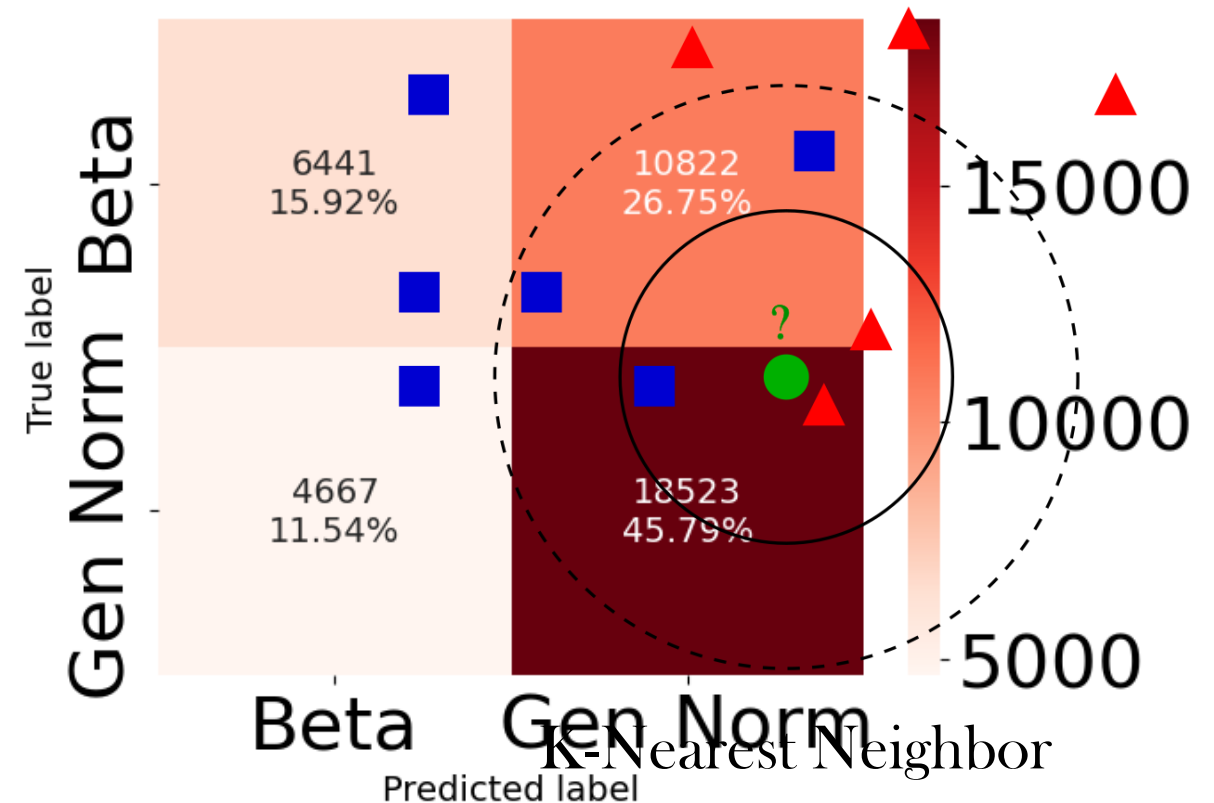
	Precision	Recall	F1-score
Beta	0.58	0.37	0.45
Gen Norm	0.63	0.80	0.71
Accuracy			0.62

Accuracy = $\frac{TP + TN}{TP + TN + FP + FN}$

Precision = $\frac{TP}{TP + FP}$

Recall = $\frac{TP}{TP + FN}$

F1-score = Harmonic mean of precision and recall



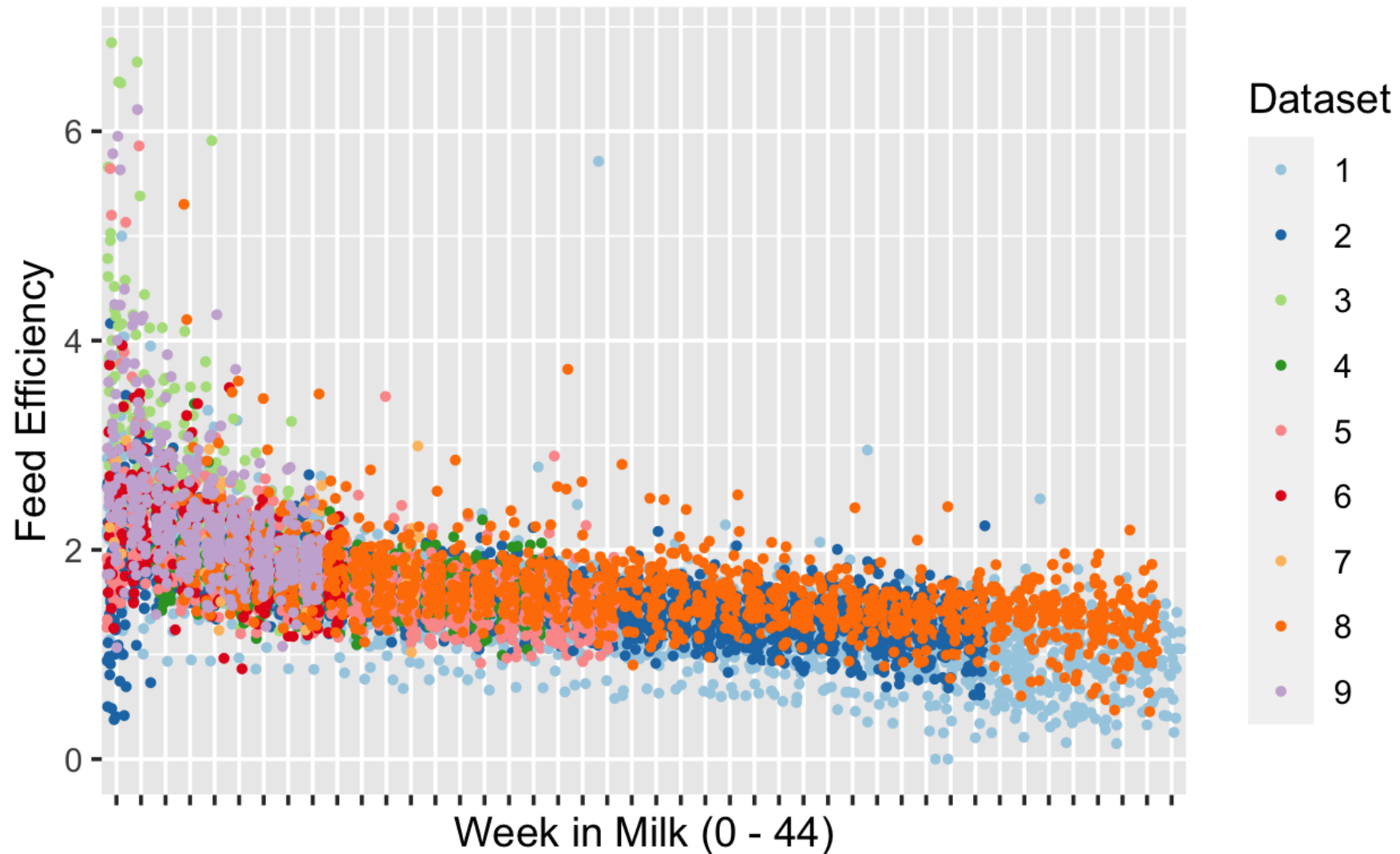
TP = True Positive
TN = True Negative
FP = False Positive
FN = False Negative

Methods: Dataset description

	N of Cows	N of lact 1	N of lact > 1	Lactation wk range*	Breed	Initial bodyweight (kg)	Region of study
1	55	15	40	1 – 44	Holstein	631	CA, USA
2	74	29	45	1 – 36	Holstein	550	WI, USA
3	36	12	24	3 – 43	Holstein & Jersey	533	OH, USA
4	57	0	57	PreP 4 – 0 PostP 1 – 9	Holstein	724	PA, USA
5	40	0	40	1 – 21	Not stated	597	PA, USA
6	45	0	45	3 – 18	Not stated	578	CA, USA
7	51	51	0	1 – 14	Holstein	597	UK
8	37	0	37		Holstein	691	IN, USA
9	31	0	31	PreP 6 – 0 PostP 1 – 10	Holstein	698	WA, USA
Total	426	107	319				

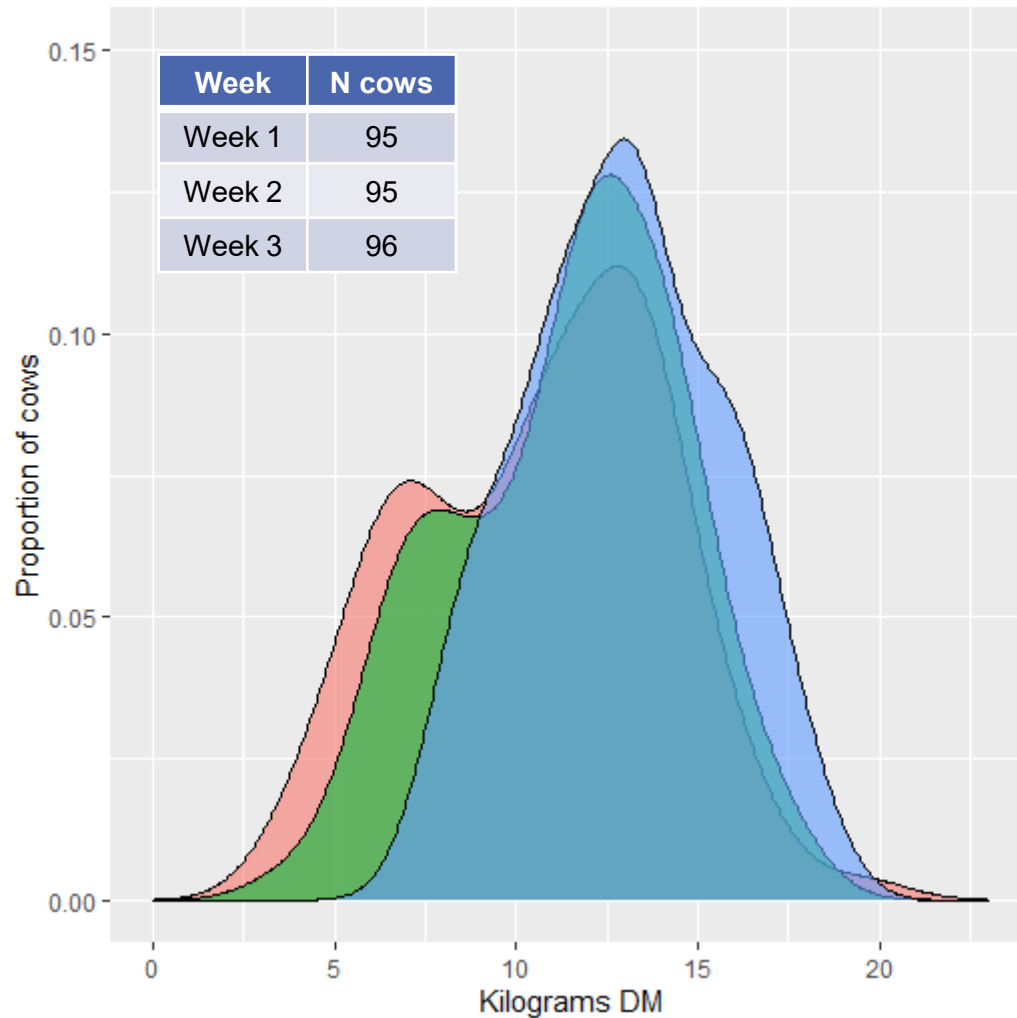
*PreP = prepartum, PostP= postpartum

Methods: Feed efficiency by dataset

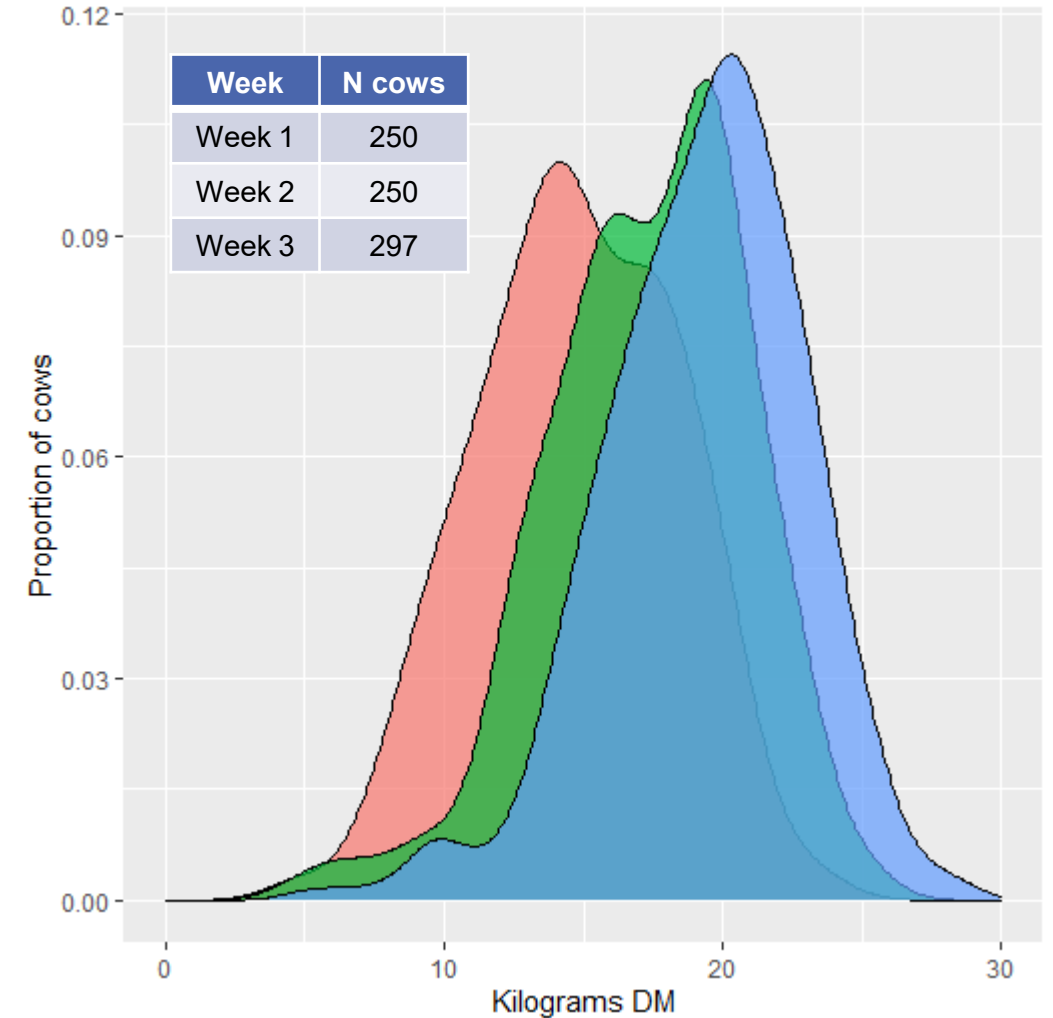


Methods: Distribution of DMI by week

Density of DMI for lact 1 by week

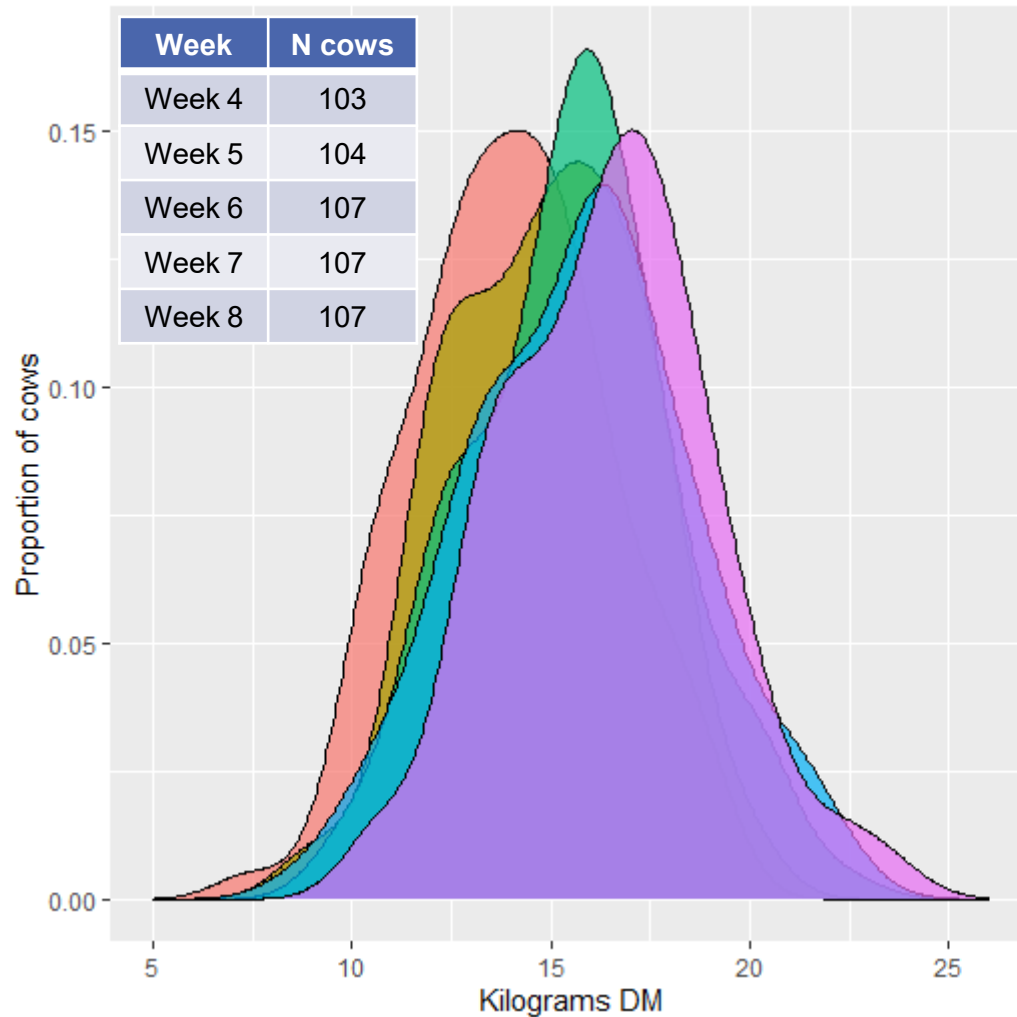


Density of DMI for lact > 1 by week

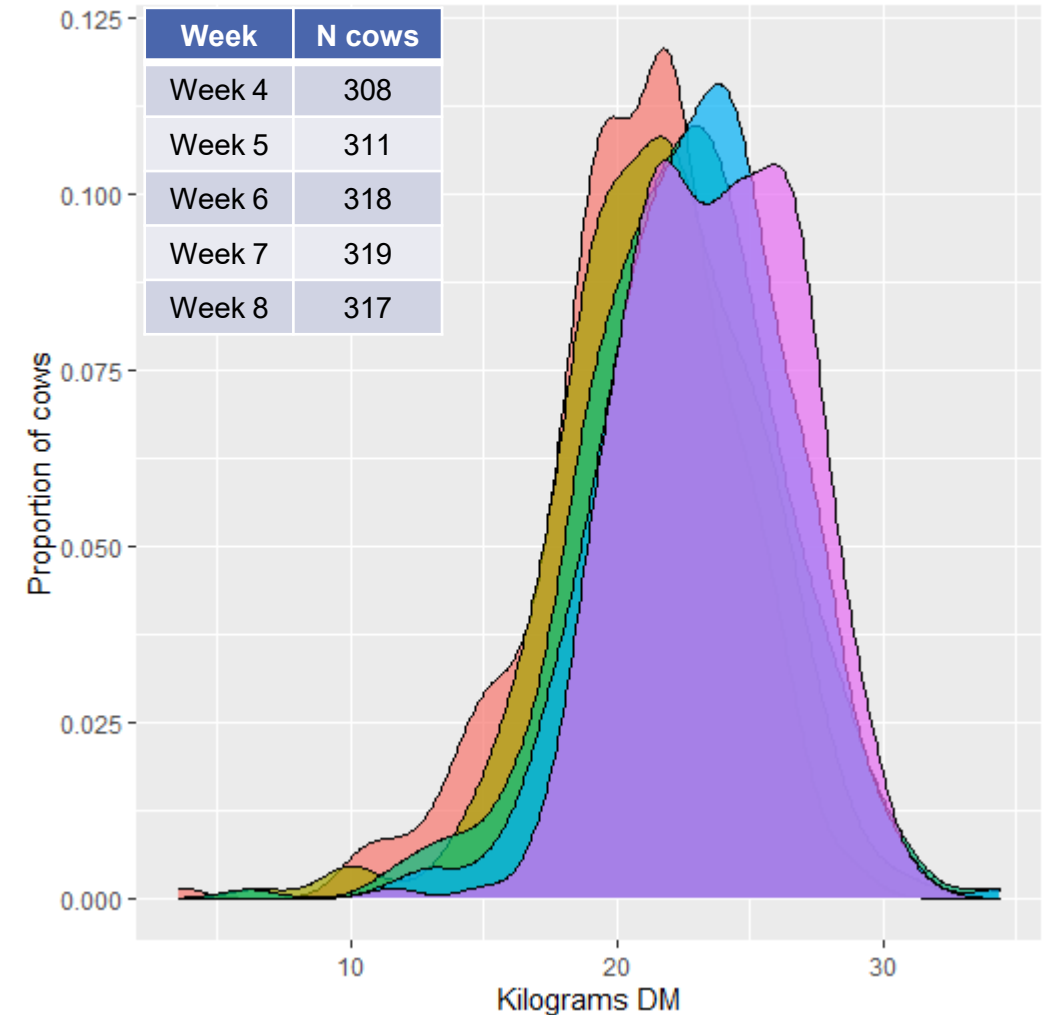


Methods: Distribution of DMI by week

Density of DMI for lactation 1 by wk

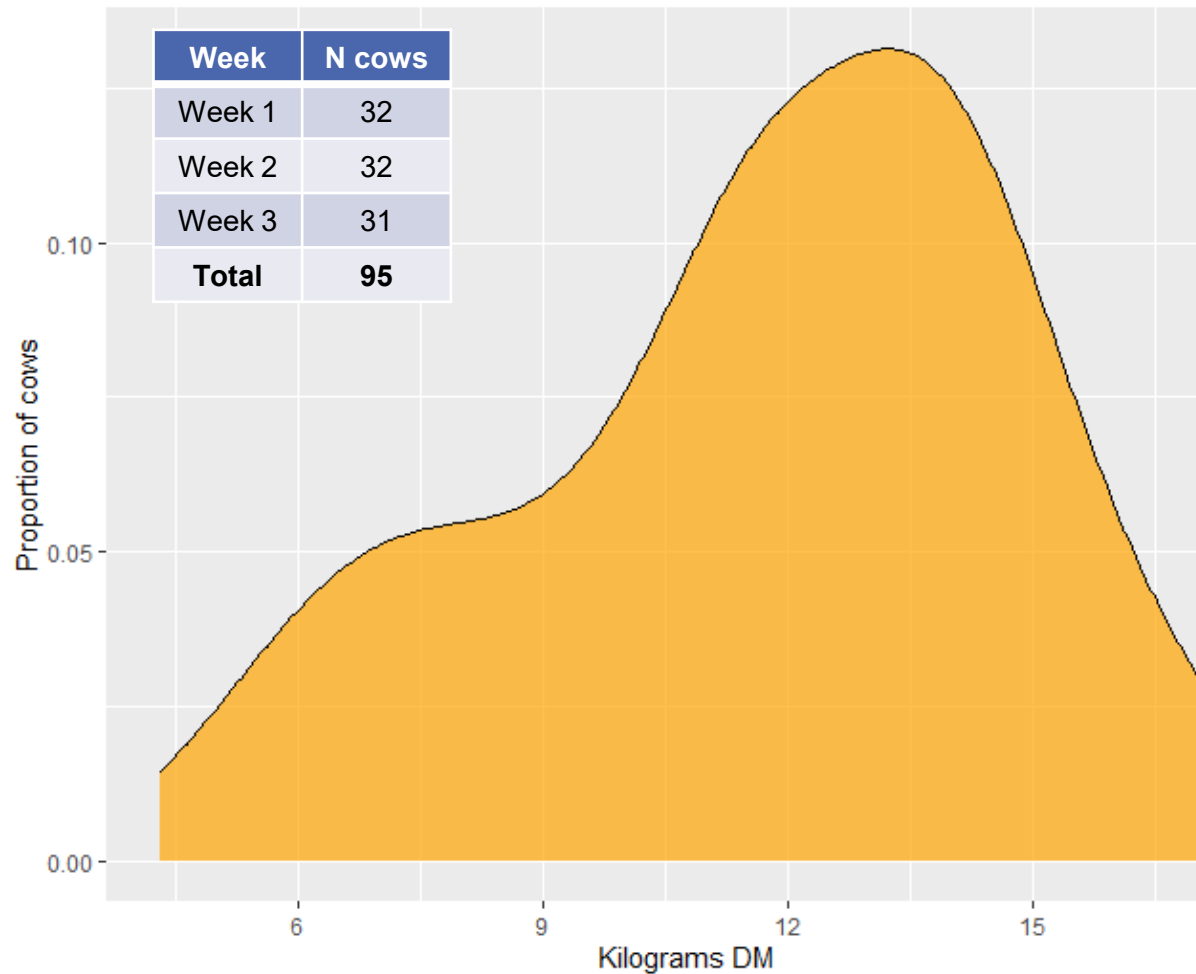


Density of DMI for lactation > 1 by wk

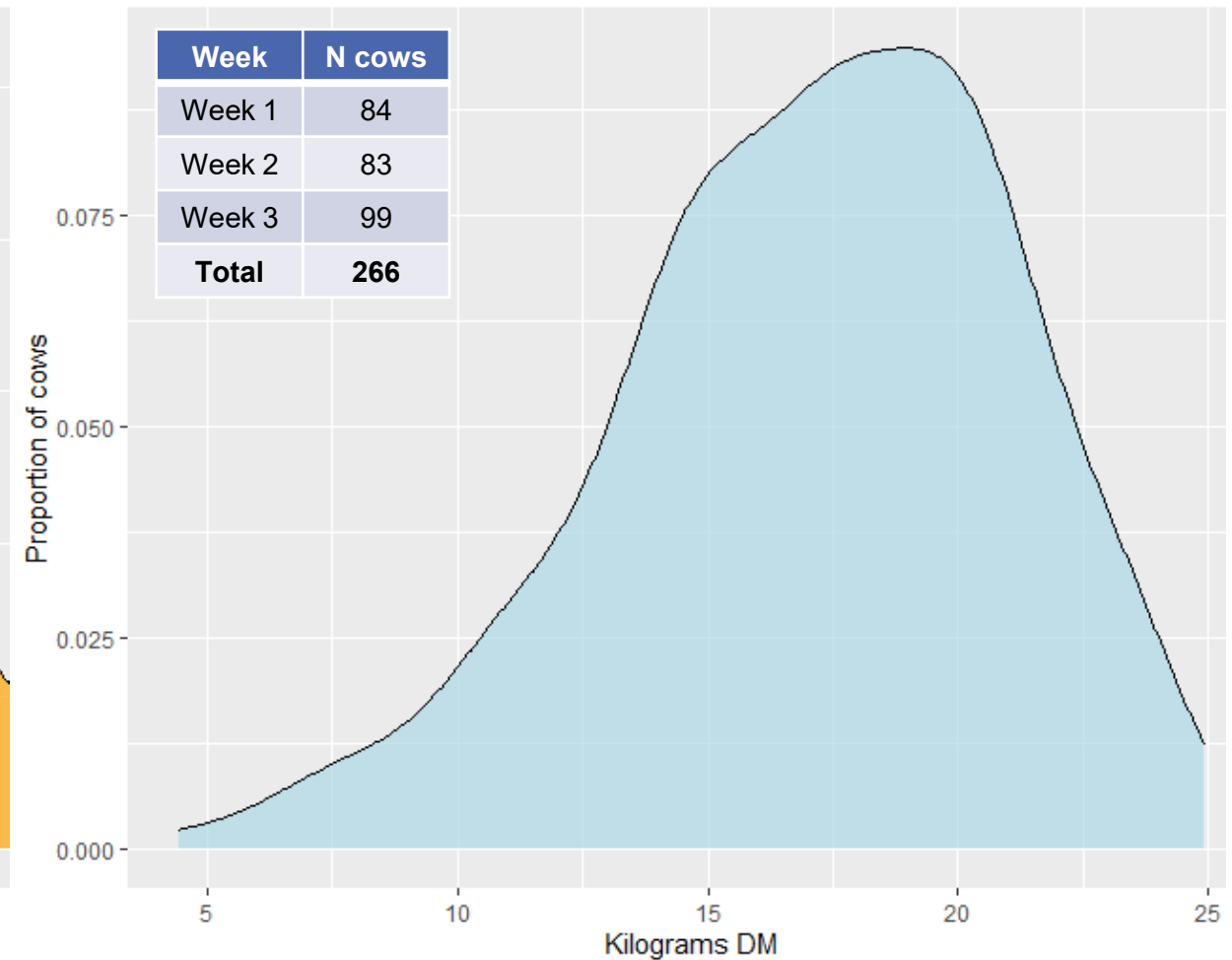


Methods: Fresh pen of cows week 1 - 3

Density of DMI for lactation 1 pen wk 1 - 3

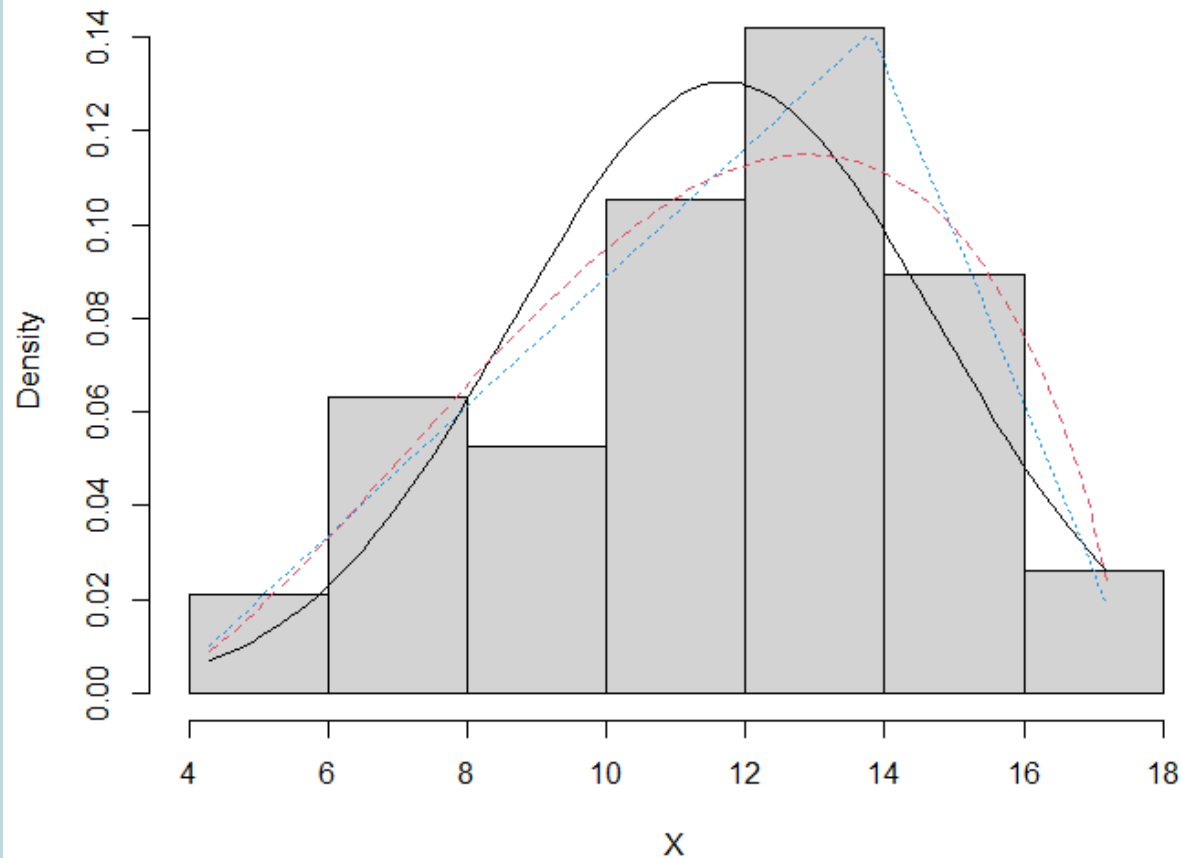


Density of DMI for lactation > 1 pen wk 1 - 3

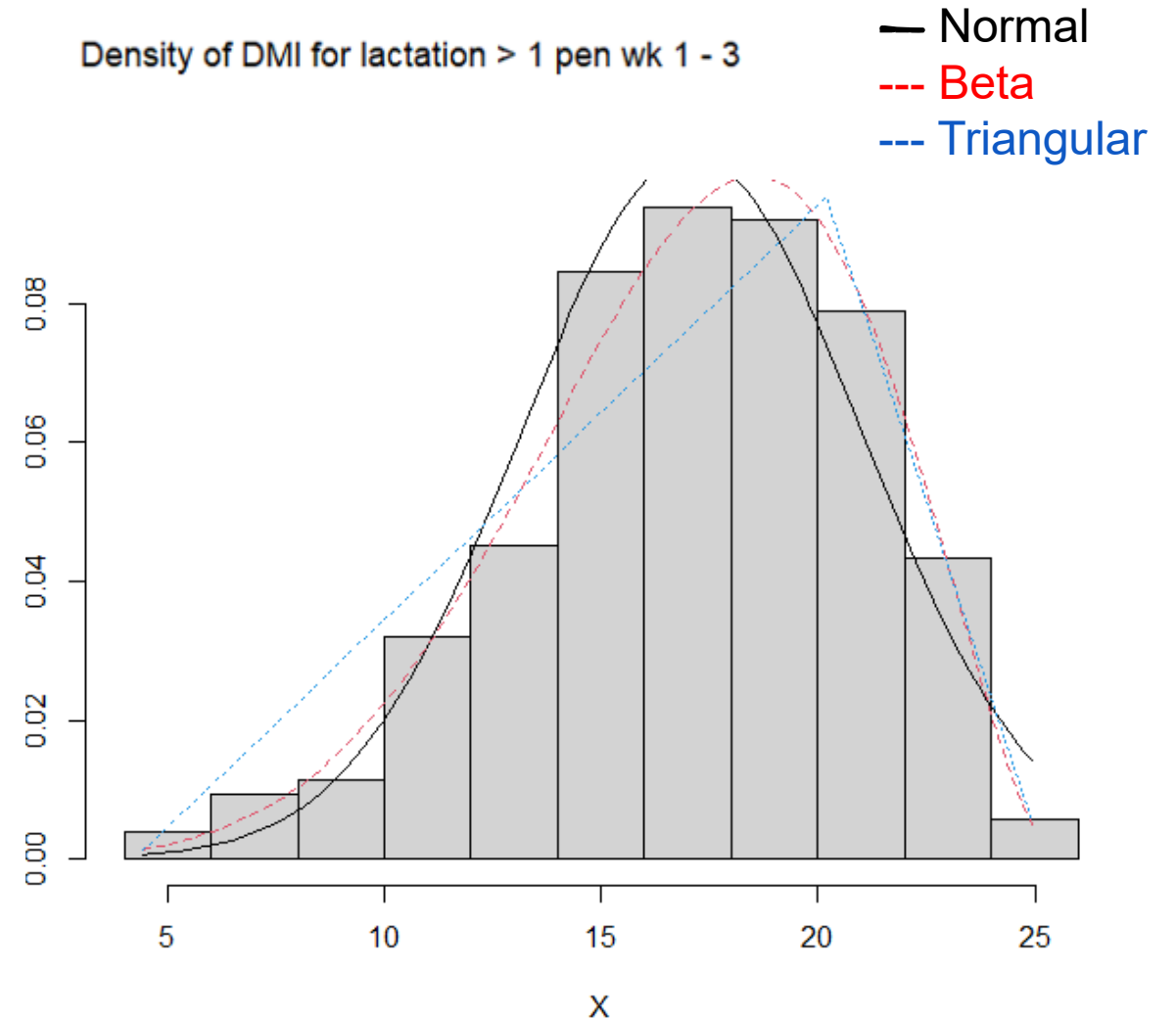


Methods: Best distribution fit - Beta

Density of DMI for lactation 1 pen wk 1 - 3

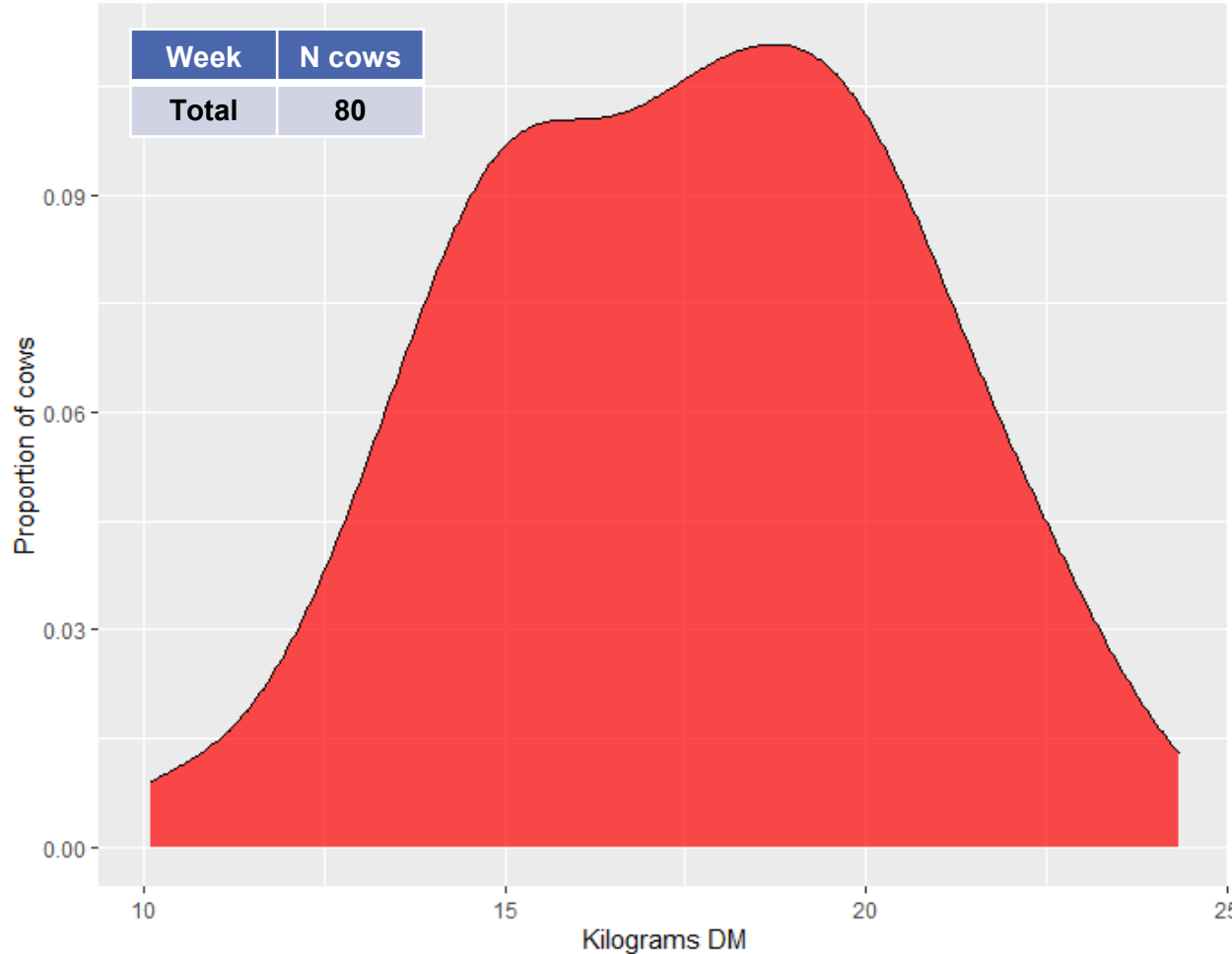


Density of DMI for lactation > 1 pen wk 1 - 3

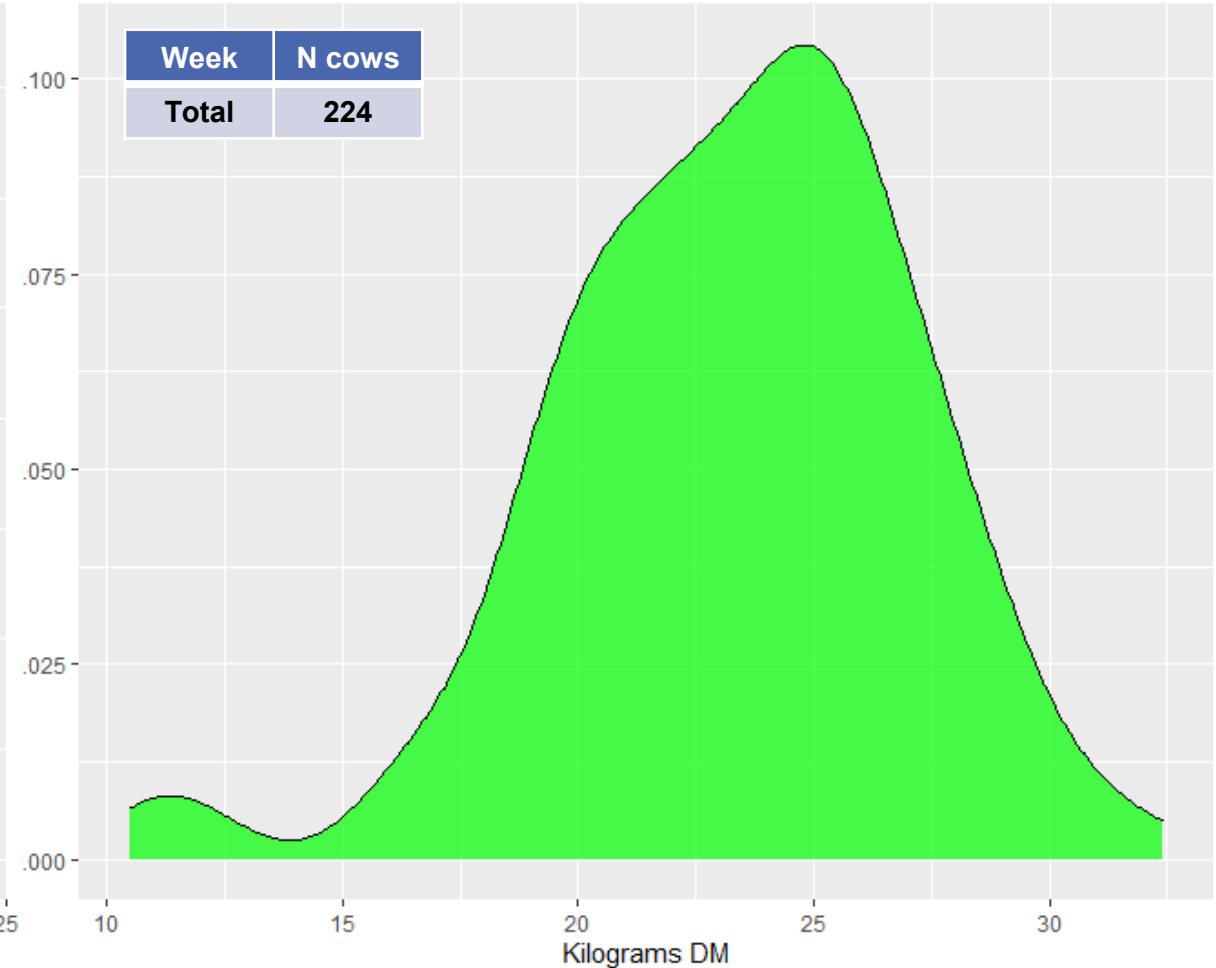


Methods: Pen of cows week 4 - 21

Density of DMI for lactation 1 pen wk 4 - 21

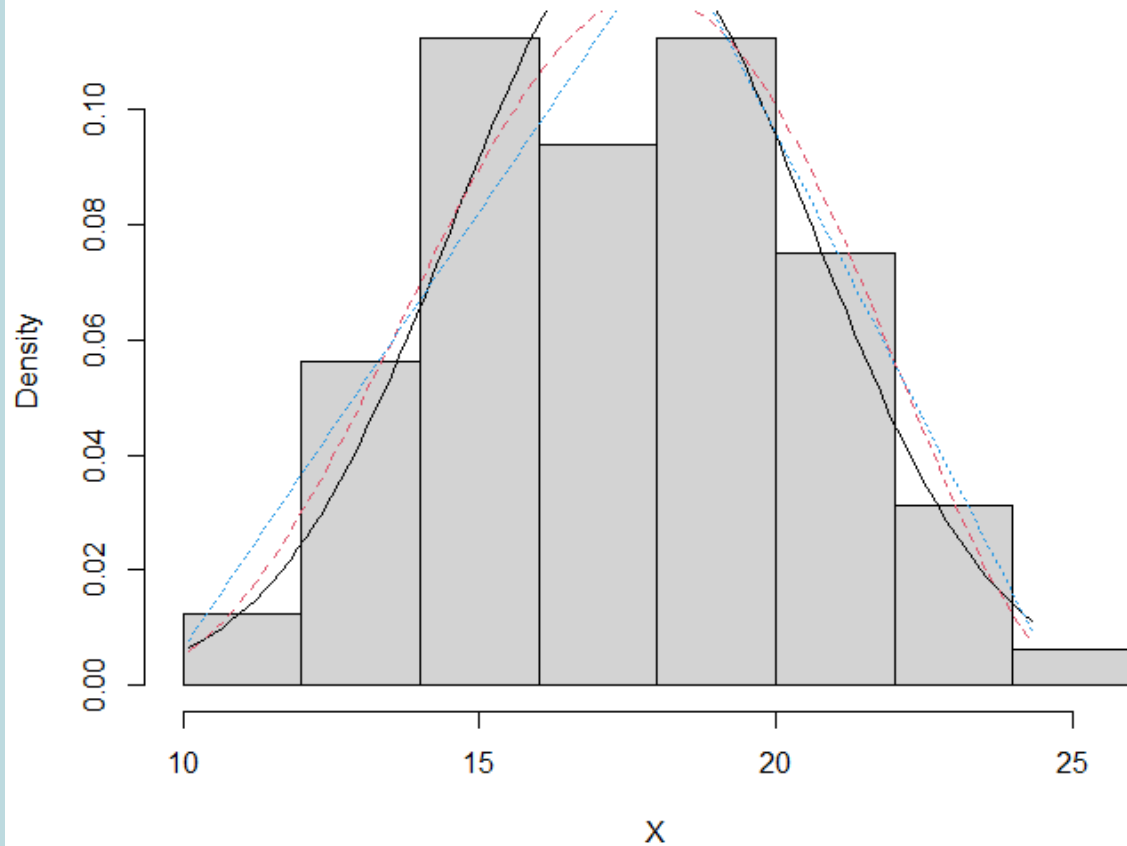


Density of DMI for lactation > 1 pen wk 4 - 21

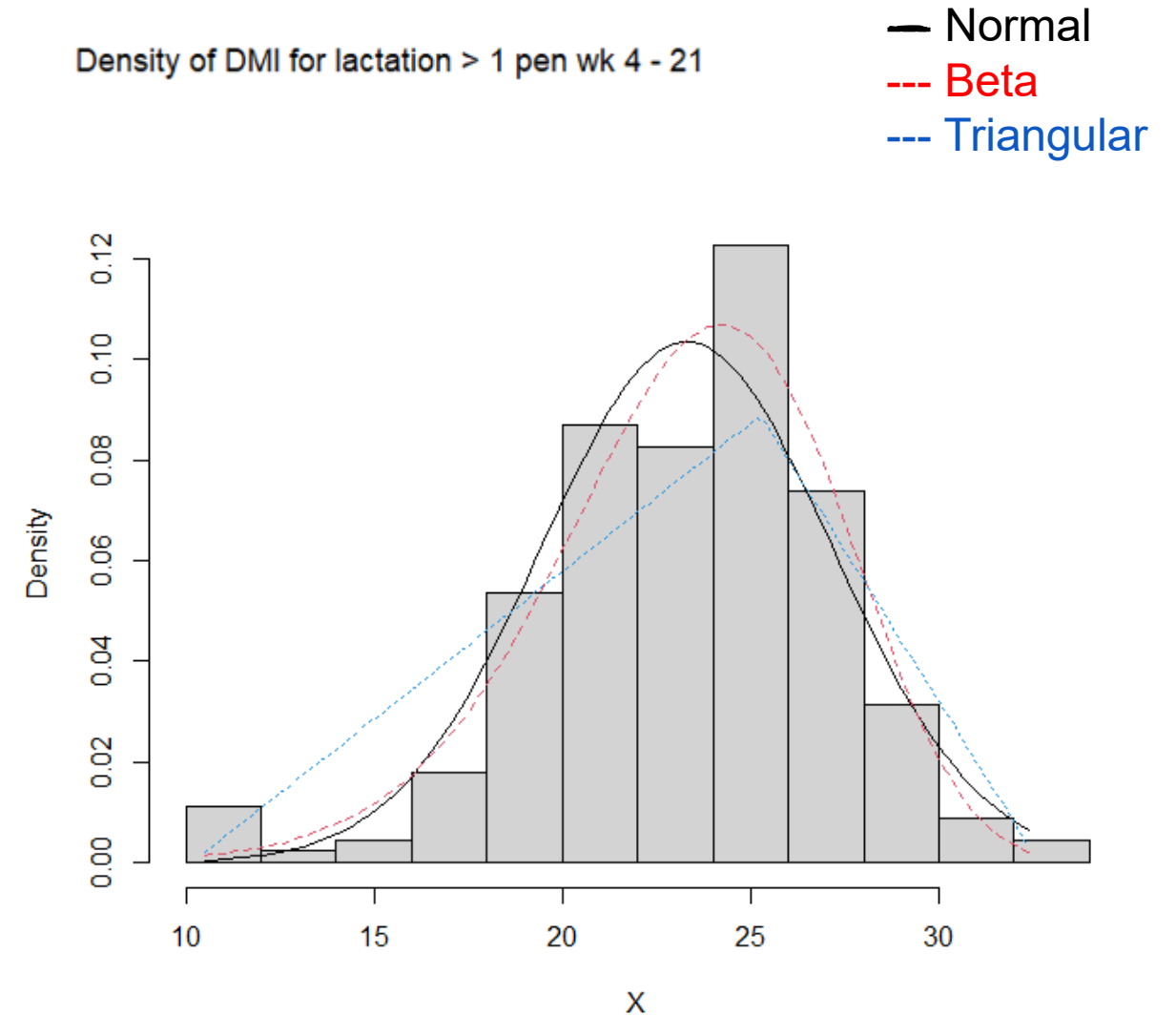


Methods: Best distribution fit - Beta

Density of DMI for lactation 1 pen wk 4 - 21



Density of DMI for lactation > 1 pen wk 4 - 21



Conclusion

- DMI is well described by Beta distribution
- Can predict the distribution parameters from pen level statistics
- AUC calculates total feed for pen for formulation

Next steps:

- Train model
- Evaluate with testing dataset
- Compare diet formulate to conventional technique