Protein Nutrition of Transition Cows and Amino Acid Balancing in Early Lactation

José Eduardo P. Santos

University of Florida
Gainesville, USA

UF ANIMAL SCIENCES

UF UNIVERSITY of FLORIDA
Department of Animal Sciences

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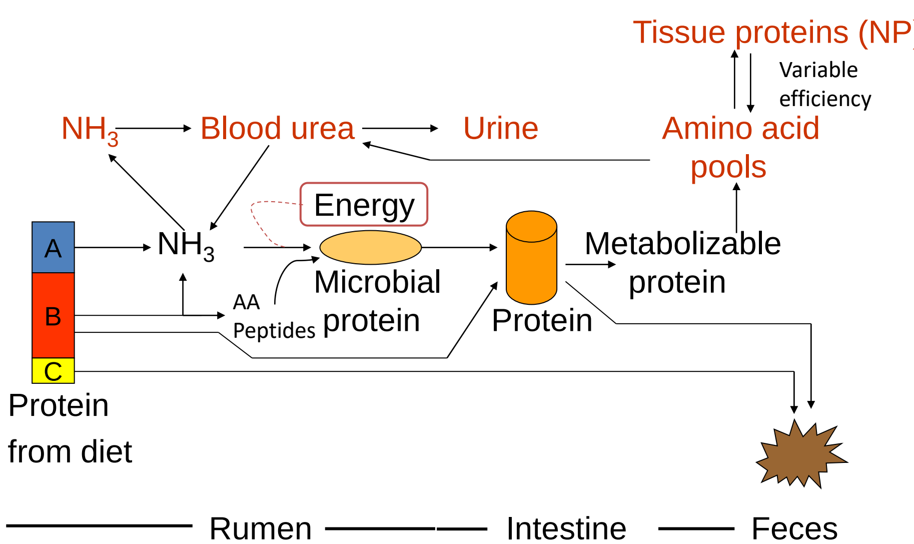
Metabolizable and Net Protein Models



NP = net protein

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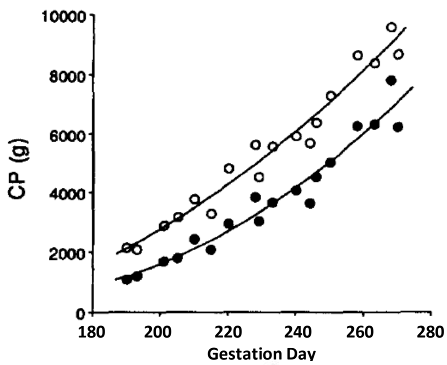
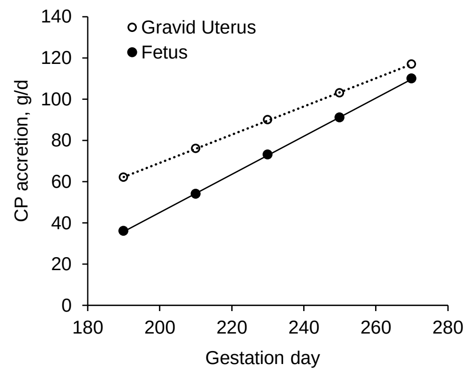
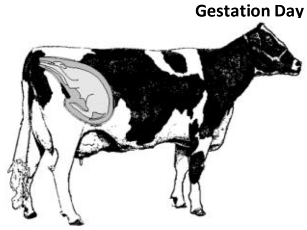
Accretion of CP in Gravid Uterus of Pregnant Cows







Bell et al. (1995) J. Dairy Sci. 78:1954-1961

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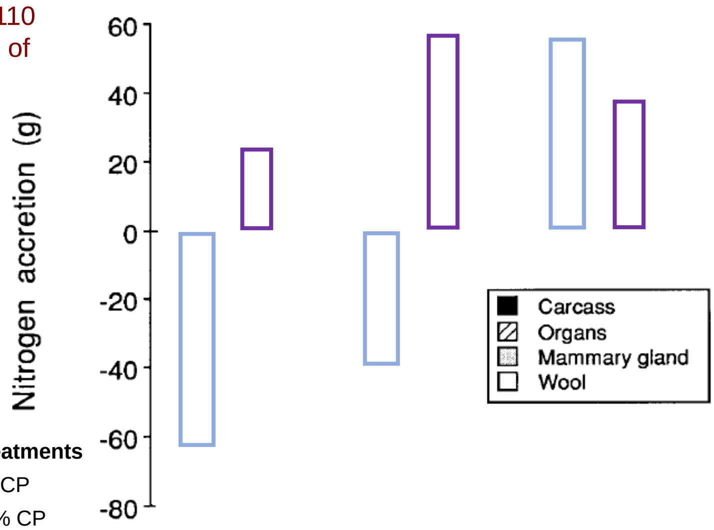
Tissue N Accretion in Late pregnancy

Incorporation into mammary tissue

Between 110 and 140 d of gestation



Dietary treatments

LP = 7.9% CP

MP = 11.7% CP

HP = 15.9% CP

McNeil et al. (1997) J. Anim. Sci. 75:809-816

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NASEM 2021

- ✓ 700 kg dry cow requires approximately 480-500 g/d of metabolizable protein for maintenance
  - ✓ Scurf loss
  - ✓ Endogenous urinary loss
  - ✓ Metabolic fecal loss
  - ✓ Frame growth → it is assumed that 86% of the live BW is empty BW, and 11% of the empty body weight is net protein
- ✓ MP for scurf (g/d) = [(0.20 x $BW^{0.60}$) x 0.85]/ 0.69
  - ✓ Where 0.85 is the ratio of true protein to CP in scurf and 0.69 is the efficiency of MP use for NP in tissues
- ✓ MP for endogenous urinary
  - ✓ MP (g/d) = 53 x 6.25 x BW x 0.001 (same as NP as efficiency is 1)
- ✓ MP for endogenous fecal
  - ✓ MP (g/d) = ([11.62 + (0.134 x NDF % DM)] x DMI x 0.73)/0.69
  - ✓ Where 11.62 is the intercept of the equation, 0.134 is the g of MFP per unit of NDF in each kg of DMI, and 0.73 is because 73% of MFP is considered to be true protein, and 0.69 is the efficiency of conversion of MP to NP
- ✓ MP for growth = (live BW gain x 0.85 x 0.11 x 0.86)/0.40
  - ✓ 0.85 is the empty BW relative to live BW; 0.11 represent 11% true protein in empty BW, 0.86 is the ratio of true protein to CP in tissues, and 0.40 is the efficiency of MP use into NP for growth
- ✓ If change in BW is not frame growth, but reserves, then the protein content of reserves is assumed to be 8%, and not 11%

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NASEM 2021

- ✓ Metabolizable protein needed for gravid uterus accretion
  - ✓ 125 g of net protein per kg of gravid uterus gain
  - ✓ 230 d of gestation = 190 g/d
  - ✓ 250 d of gestation = 260 g/d
  - ✓ 270 d of gestation = 360 g/d
- ✓ Efficiency of incorporation of MP into net protein (NP) in the gravid uterus is 33%
- ✓ At 250 days of gestation, the cow would need
  - ✓ 480 g of MP for maintenance
  - ✓ 260 g of MP for pregnancy
  - ✓ Total = 740 g/d of MP (410 g/d of NP)
  - ✓ Plus any additional MP for frame growth replenishment of body reserves
- ✓ At 270 days of gestation, the cow would need
  - ✓ 480 g of MP for maintenance
  - ✓ 381 g of MP for pregnancy
  - ✓ Total = 864 g/d of MP (535 g/d of NP)
  - ✓ Plus any additional MP for frame growth replenishment of body reserves

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NASEM 2021

- ✓ Estimated requirements for metabolizable protein as cows approach calving
  - ✓ 870 g/d to meet maintenance and gravid uterus accretion
- ✓ Estimated additional 120 g/d of metabolizable protein for mammary accretion in nulliparous cows (Capuco et al. JDS 1997; McNeil et al. JAS 1997)
  - ✓ Nulliparous are still growing and have requirements for lean tissue accretion
  - ✓ Late pregnant nulliparous cows might need 1,000 to 1,100 g/d of MP

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Factorial Protein Needs of a Prepartum Cow

Cow: 50-mo old Holstein, 270 d of gestation, 720 kg BW, 0.1 kg/d frame growth, eating 12.5 kg of DM with 44% NDF

Heifer: 22-mo old Holstein, 270 d of gestation, 620 kg BW, 0.8 kg/d frame growth, eating 11.0 kg of DM with 44% NDF

	Net protein		Metabolizable protein	
Item	Heifer	Cow	Heifer	Cow
Scurf, g/d	8	9	12	13
Endogenous urinary, g/d	205	240	205	240
Metabolic fecal, g/d	138	158	200	230
Frame growth, g/d	77	8	112	12
Body reserves	0	0	0	0
Pregnancy	119	126	360	381
Total	**547**	**541**	**890**	**876**

Very likely there are needs for mammary tissue accretion, particularly in nulliparous
Estimated at 120 g of MP or 89 g of NP/d (Capuco et al. JDS 1997; McNeil et al. JAS 1997)

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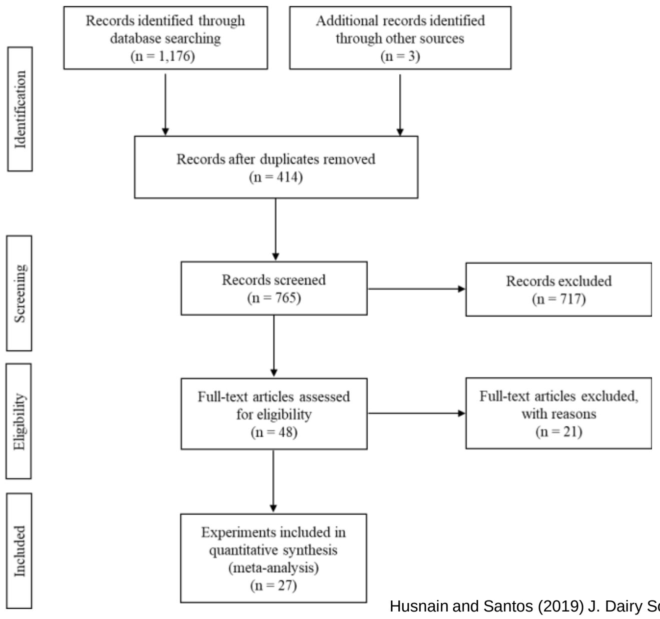
Prisma Diagram



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Meta-Analysis of Published Literature

✓27 randomized experiments

- 125 treatment means and 1,801 cows
- 8 experiments with 27 treatment means reported responses for 510 nulliparous cows

✓Diets entered into the NRC (20021) software using the ingredient composition and nutrient content, and observed prepartum intake for the specific cows

- ✓Net energy for lactation (Mcal/kg)
- ✓Metabolizable protein (g/d)
- ✓Metabolizable amino acids (g/d)
  - ✓ Essential AA
  - ✓ Methionine
  - ✓ Lysine

Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Descriptive Statistics of Protein Inputs

Item	TRT Means, n	Mean	SD	Median	Min	Max
NE_L, Mcal/kg	114	1.59	0.10	1.62	1.25	1.73
CP, %	114	14.3	2.1	14.4	9.0	20.9
RDP, % DM	114	9.6	1.2	9.5	5.5	12.2
RUP, % DM	114	4.7	1.4	4.6	2.7	9.0
CP intake, g/d	114	1,681	407	1,648	745	2,482
Metabolizable, g/d						
Total MP	114	1,100	290	1,091	463	1,733
Microbial CP	114	603	119	601	257	876
RUP	114	446	190	425	159	937
Met	114	22	6	21	9	40
Lys	114	76	18	75	31	120
Total EAA	114	505	125	505	211	766

Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Descriptive statistics of production responses according to parity group

	Nulliparous		Parous	
Item	TRT Means, n	Mean ± SD	TRT Means, n	Mean ± SD
Prepartum				
DMI, kg/d	12	10.1 ± 0.8	76	12.4 ± 2.2
BW, kg	12	606 ± 25	66	700 ± 50
Postpartum				
DMI, kg/d	6	17.0 ± 1.6	70	20.7 ± 2.7
Yield, kg/d				
Milk	25	31.6 ± 3.2	89	38.5 ± 4.6
FCM	25	32.0 ± 3.5	89	40.5 ± 4.6
Milk fat				
%	25	3.65 ± 0.23	89	3.88 ± 0.38
kg/d	25	1.14 ± 0.12	89	1.48 ± 0.18
Milk protein				
%	25	3.21 ± 0.11	87	3.07 ± 0.17
kg/d	25	1.01 ± 0.11	87	1.18 ± 0.12
BW, kg	8	542 ± 26	82	622 ± 31

Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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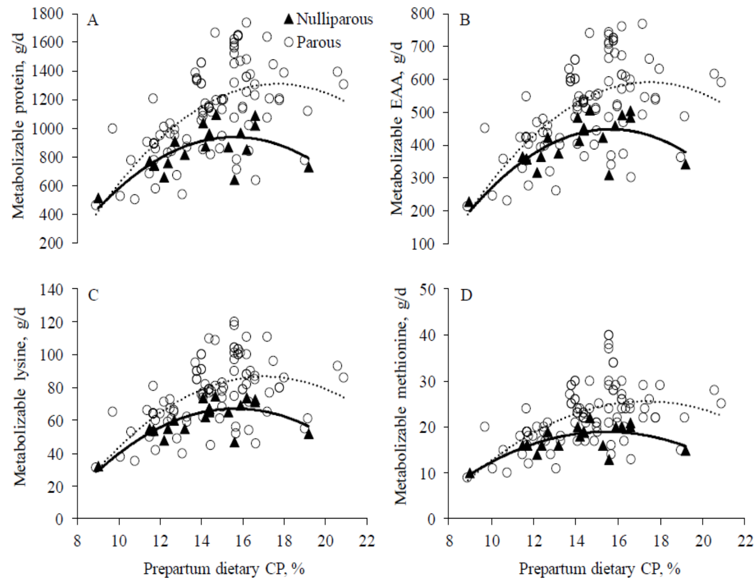
Predicted Supply of Metabolizable Amino Acids According to Prepartum Dietary CP



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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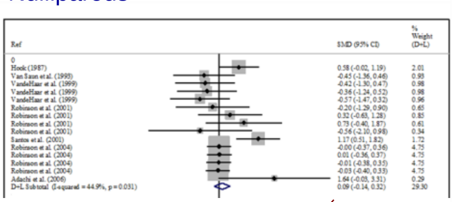
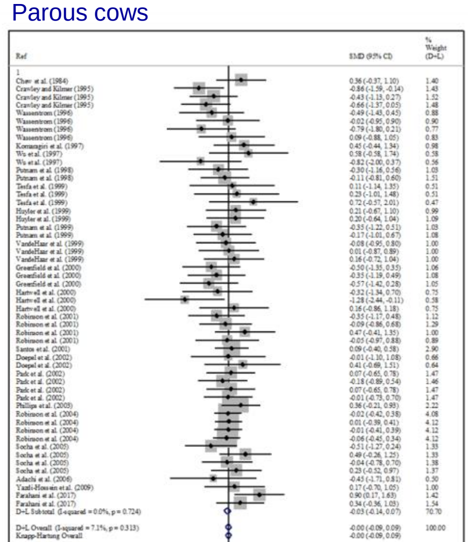
Milk Yield Responses to Increasing Metabolizable Protein Prepartum

Nulliparous



0.09 SD
P = 0.03

Parous cows



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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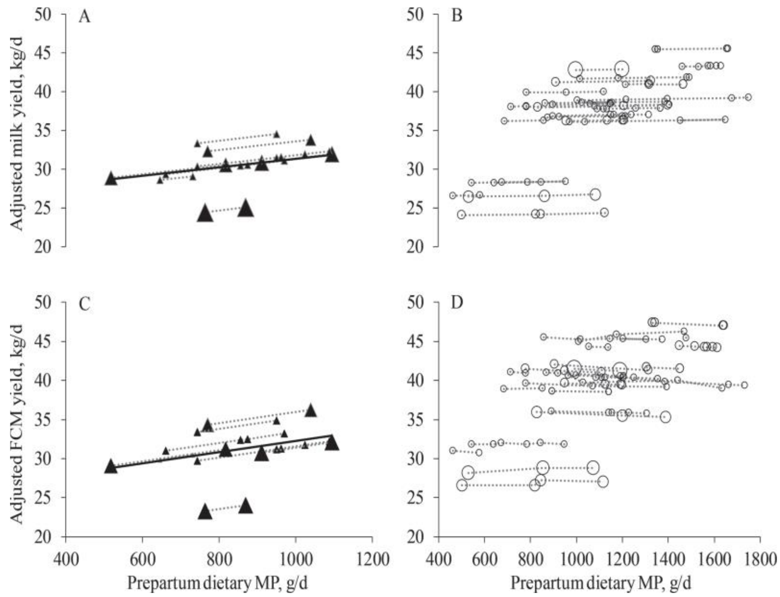
Yields of Milk and FCM



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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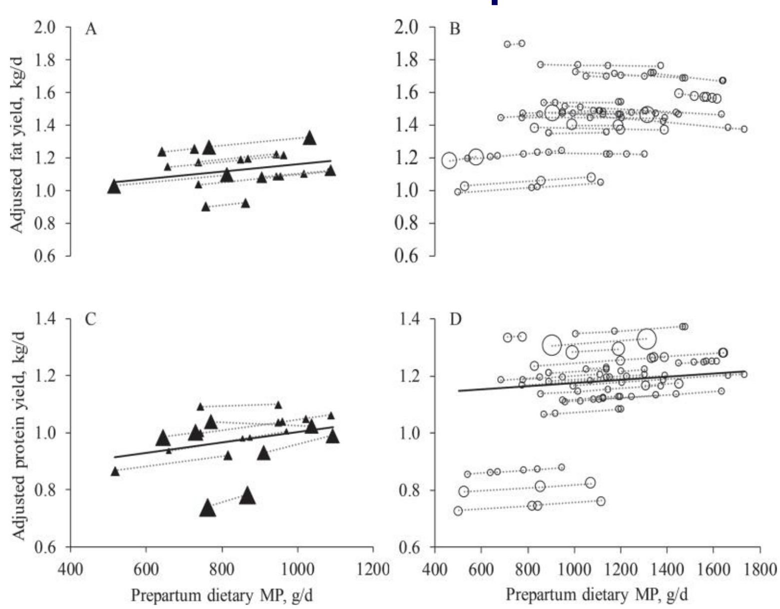
Yields of Milk Components



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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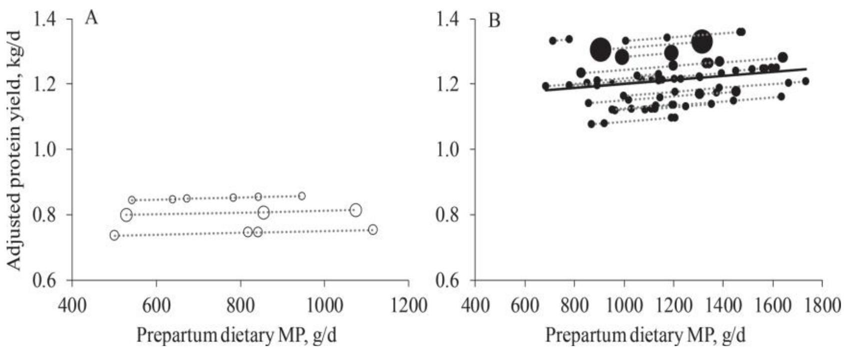
Yields of Milk Components



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Conclusion and Implications

- ✓Formulate diets based on supply of metabolizable protein
  - ✓Parous cows: 800 to 900 g/d seems sufficient to meet the needs and to support postpartum performance (12 to 13% CP is sufficient is adequate intake of DM is achieved)
  - ✓Nulliparous require more than parous cows. At this point, approximately 1,100 g/day (14 to 15% CP is needed, with added undegraded protein source)
- ✓If housed together, feed for the nulliparous cows
- ✓Limited to no data today in the literature to support health effects of manipulating prepartum dietary protein content

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Issues Start Before or Around Calving

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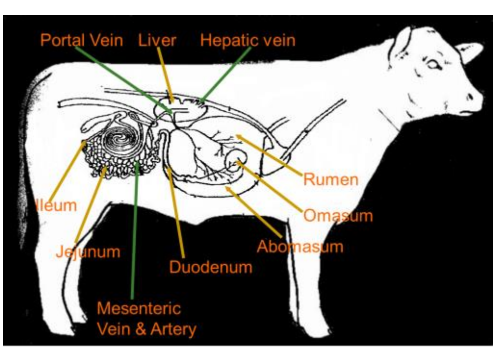
Inflammatory Disease and Nutrient Flux

- ✓ Control
  - ✓ Steers received saline (no inflammation)
- ✓ Challenge
  - ✓ Intra-tracheal challenge with 10 mL containing 1 x 10^9 CFU of *Mannheimia haemolytica* at hour 0



Burciaga-Robles et al. (2009)

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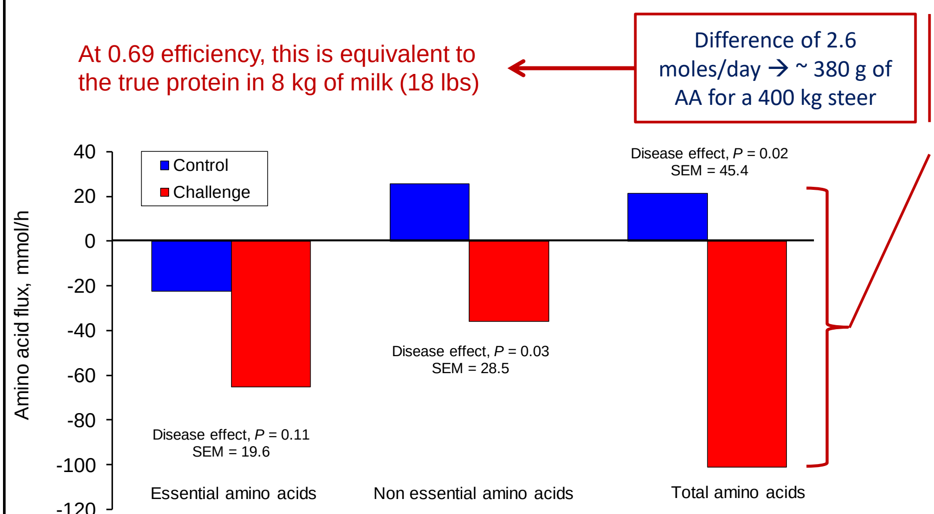
Amino Acid Hepatic Flux in Steers Without (Control) or with (Challenge) an Intratracheal Challenge with *M. haemolytica*



Burciaga-Robles PhD Dissertation (2009)

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Protein in Early Lactation

	Treatment		
Ingredients	Control	High MP	High MP + AA
Corn silage	40.0	40.0	40.0
Alfalfa silage + alfalfa hay	17.0	17.0	17.0
Whole cottonseed	9.0	9.0	9.0
Ground corn	15.7	14.0	15.7
Soybean hulls	4.4	1.9	4.4
Soybean meal (48%)	9.0	7.1	8.7
Heat-treated SBM (AminoPlus)	2.0	7.0	---
Corn gluten meal (60%)	---	1.6	---
Blood meal + AA	---	---	2.3
Fat + Minerals and Vitamins	3.0	2.8	2.8
Nutrients			
Crude protein, %	16.3	18.4	17.4
Rumen degradable protein, %	10.7	11.3	10.2
Methionine, % MP	1.85	1.83	2.60
Lysine, % MP	6.68	6.33	7.20
Histidine, % MP	2.25	2.21	2.90

N = 56 cows

Calder and Weiss (2017) J. Dairy Sci. 100:4528–4538

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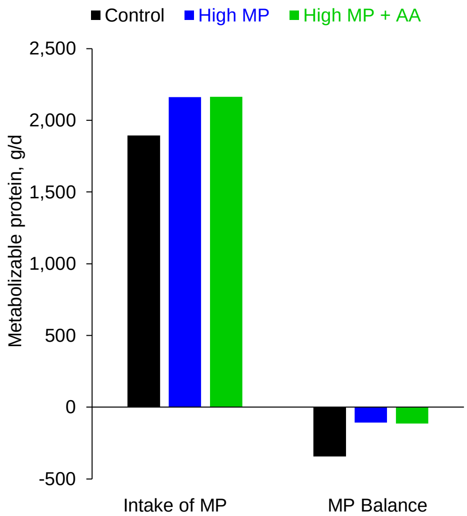
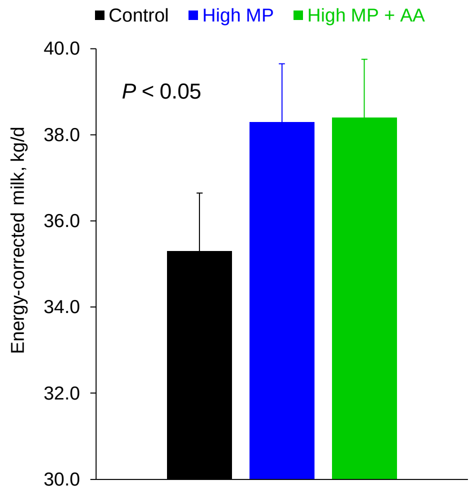
Responses in the First 3 Weeks of Lactation





Calder and Weiss (2017) J. Dairy Sci. 100:4528–4538

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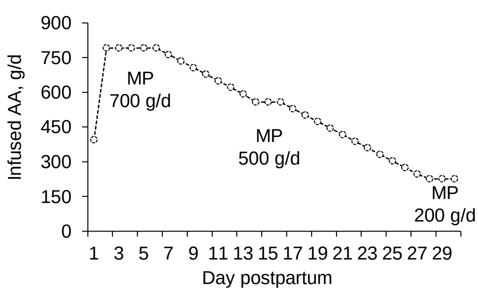
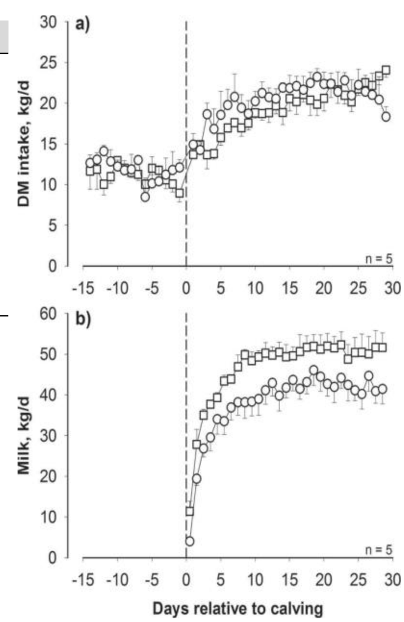
Protein in Early Lactation

Item	Prepartum	Postpartum
NE_L, Mcal/d	17.5	34.0
Crude protein, % DM	14.2	16.4
NDF, % DM	39.5	36.1
ADF, % DM	27.0	23.2
Metabolizable protein, g/d	1153	2365
Microbes	585	1157
Undegraded	511	1108
Endogenous	57	100

Treatment: ± infusion of free AA with similar profile to that of casein (88% metabolizable)





Larsen et al. (2015) J. Dairy Sci. 98:7944–7961

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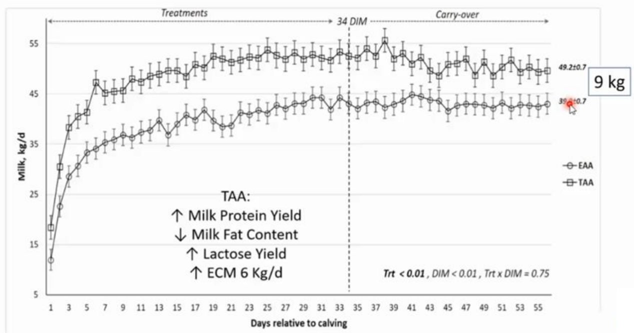
Effect of Abomasal Infusion of EAA or TAA on Production in Early Lactation Cows

Bahloul et al., 2021

- 9 Holstein Cows, Calving to 50 DIM
- 2 Trts: TAA or EAA, Casein AA Profile
- Abomasal infusions



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Synthesis of Milk and Milk Protein are Energy-Driven Processes

Table 1. Least squares means for DMI, milk yield, and milk protein concentration and yield.

Variable	Water	CB	Water+I	CB+I	SEM	P^2 INS
DMI,[3] kg/d	26.2	27.6	25.1	25.2	1.2	0.09
Milk yield, kg/d	26.5^b	27.5^b	28.3^{ab}	29.8^a	2.4	0.02
Milk protein						
%	3.29^b	3.31^b	3.52^a	3.66^a	0.185	0.001
kg/d	0.867^c	0.895^c	0.995^b	1.080^a	0.073	0.001

Treatment[1] spans Water, CB, Water+I, CB+I.

[a,b,c]Least squares means within rows with different superscripts differ ($P < 0.05$).

Treatments (abomasal infusions)

Water = water

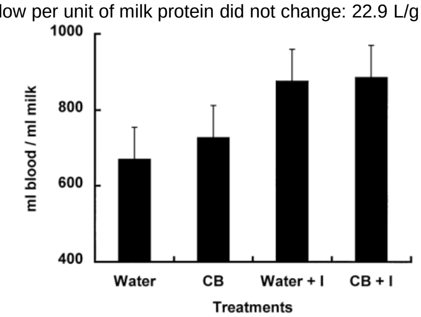
CB = casein and branched chain AA

Water + hyperinsulinemic/euglycemic clamp

CB+I = CB + hyperinsulinemic/euglycemic clamp

Insulin affected absolute MBF: 5.8 vs. 8.2 L/min

Blood flow per unit of milk protein did not change: 22.9 L/g



Mackle et al. (2000) J. Dairy Sci. 83:93–105

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Table 19.3. Relative net fluxes of amino acids across the mesenteric-drained viscera (MDV), the portal-drained viscera (PDV) and small intestinal disappearance (SID) in sheep and dairy cows.

Amino acid	Sheep[a]		Dairy cow[b]	
	MDV:SID	PDV:MDV	MDV:SID	PDV:MDV
Histidine	–	–	1.27	0.75
Isoleucine	1.11	0.55	1.02	0.61
Leucine	1.02	0.64	0.92	0.68
Lysine	1.03	0.56	0.76	0.72
Methionine	–	–	1.01	0.66
Phenylalanine	1.12	0.68	1.00	0.76
Threonine	0.85	0.69	1.15	0.38
Valine	0.76	0.57	1.11	0.46

[a]From MacRae *et al.* (1997b).
[b]From Berthiaume *et al.* (2001).

Bequette et al. (2003) https://doi.org/10.1079/9780851996547.0347

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Hepatic Removal of Amino Acids in Dairy Cows

Table 19.4. Proportion of net portal absorption of amino acids removed by the liver in non-lactating and lactating dairy cows.

Amino acid	Non-lactating cows[a]	Lactating cow[b]
Histidine	0.57	0.28
Isoleucine	0.41	n.r.[c]
Leucine	0.01	n.r.[c]
Lysine	0.16	0.06[d]
Methionine	0.70	0.43
Phenylalanine	0.67	0.50
Threonine	0.72	0.11
Valine	0.12	n.r.[c]

[a]From Wray-Cahen *et al.* (1997), basal periods.
[b]From Blouin *et al.* (2002) and Berthiaume (2000).
[c]Net removal by the liver zero.
[d]Data only from Blouin *et al.* (2002).

Bequette et al. (2003) Mammary uptake and metabolism of amino acids by lactating ruminants

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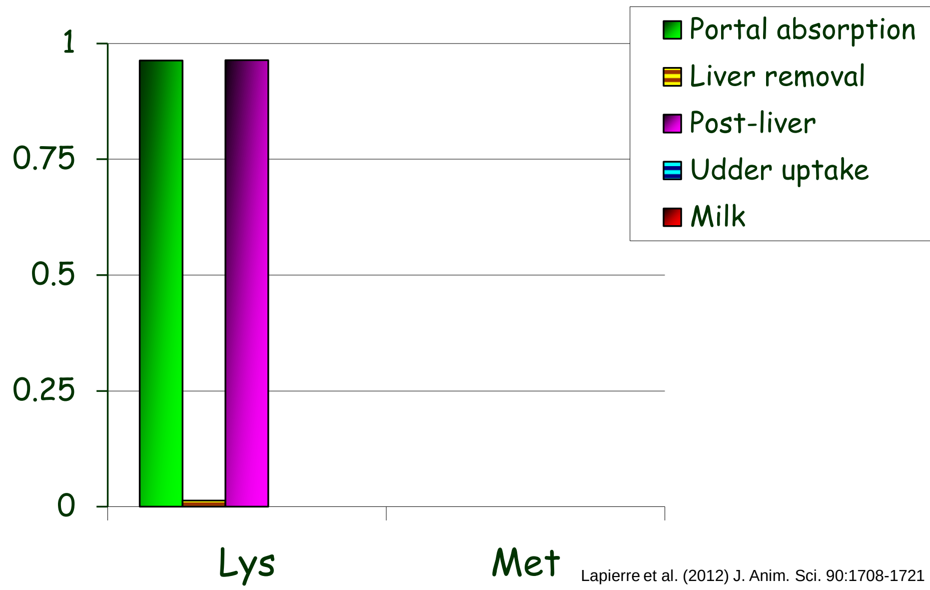
Partition of Digestible AA



Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

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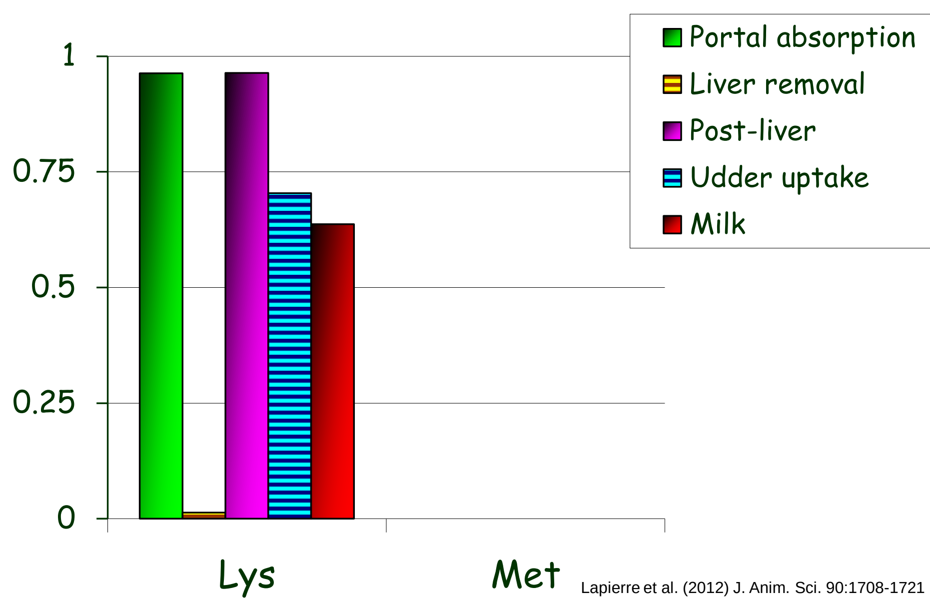
Partition of Digestible AA



Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

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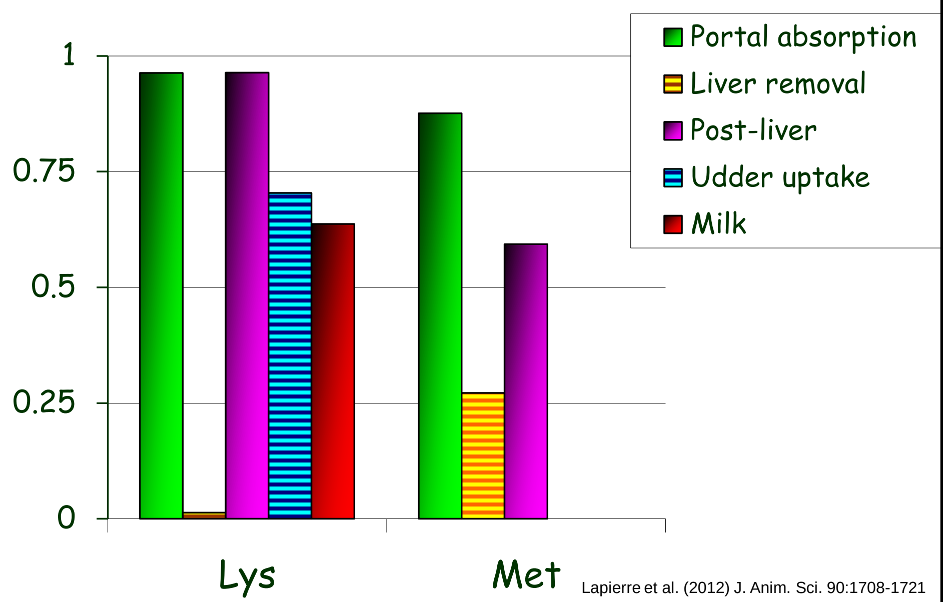
Partition of Digestible AA



Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

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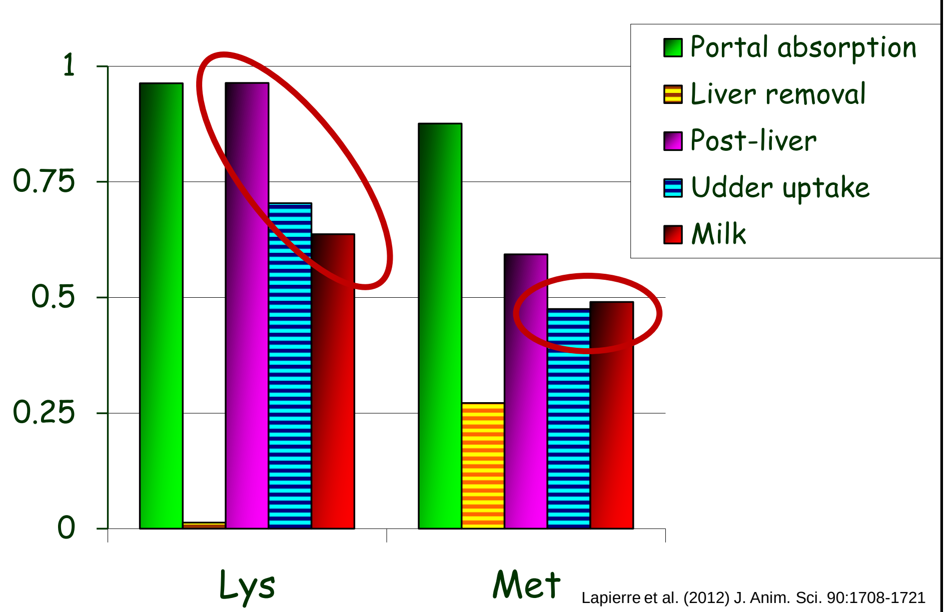
Partition of Digestible AA



Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

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Efficiency of Incorporation of Mammary Extracted AA into Milk AA

	Amino acid group (Mepham, 1982)		
	1	2	3
	Histidine	Isoleucine	Alanine
	Phenylalanine	Leucine	Asparagine
	Methionine	Valine	Cysteine
	Tyrosine	Lysine	Glutamine
	Tryptophan	Arginine*	Glycine
		Threonine*	Proline
			Serine
Efficiency (AA-N uptake/ AA-N secreted in milk)	1	> 1.15	< 1.0

* Suggested group according to Lapierre et al. (2012)

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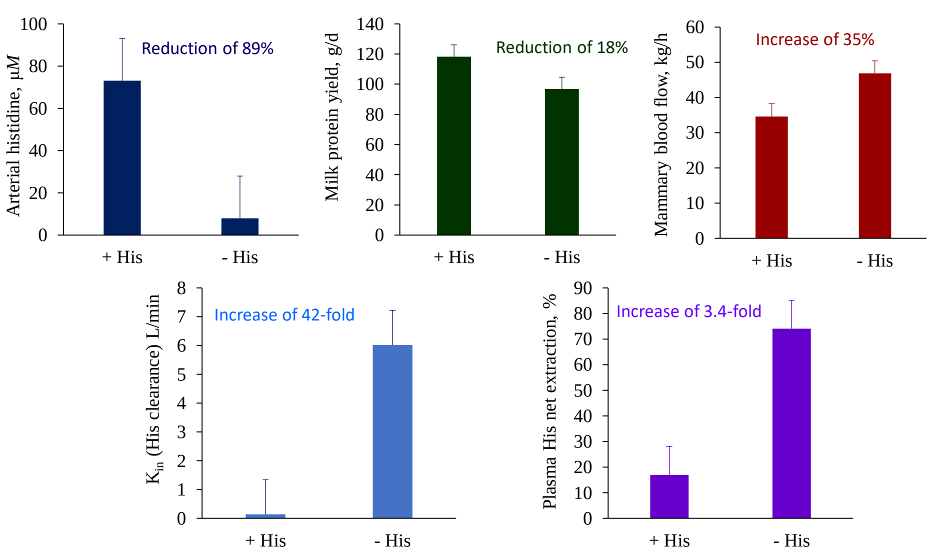
Mammary Gland is Metabolically Flexible



Lactating goats fed a low protein diet (77% of MP needed) and infused abomasally with a mixture of AA (67 g/d) with (+His) or without (-His) 4.4 g/d of histidine

Bequette et al. (2000) J Dairy Sci 83:765–775

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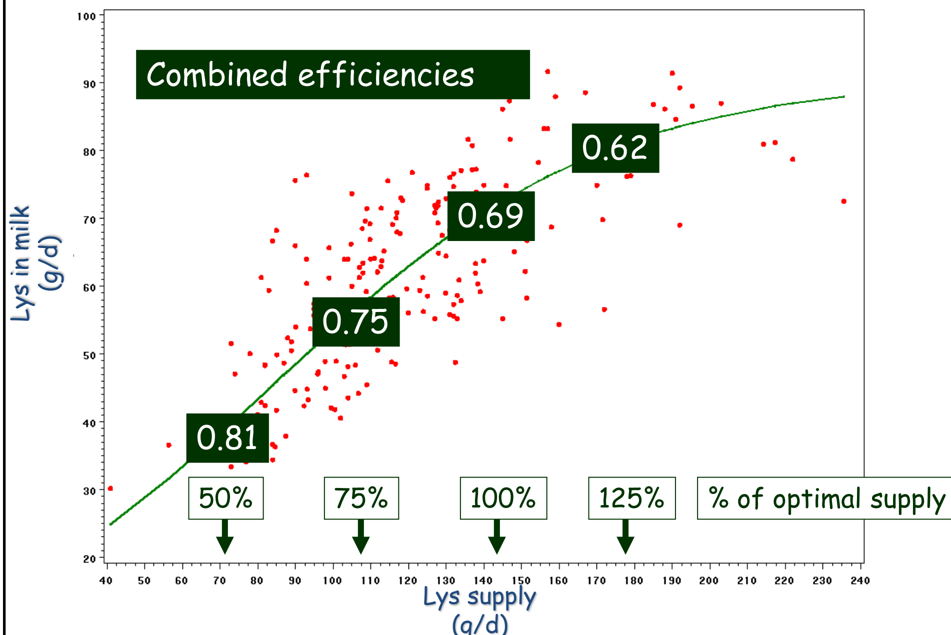

Lapierre et al. (2007) Proc. Cornell Nutr. Conf. Pages 39-59

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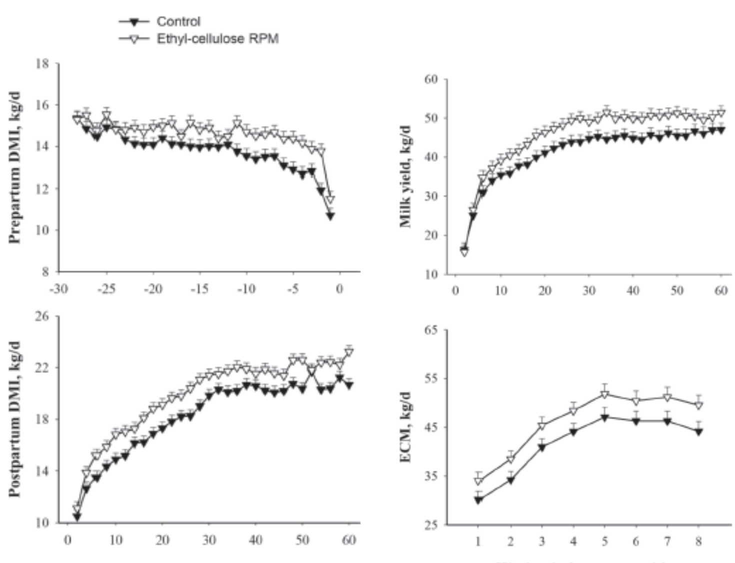
Effect of RP-Met supplementation during the prepartum and early lactation period on Intake and milk yield



Batistel et al. (2017) J. Dairy Sci. 100:7455-7487

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Colostrum Yield

	Treatment					P-value		
	CON		RPA					
Item	Null	Parous	Null	Parous	SEM	TRT	Parity	TRT x parity
Yield, kg	5.38	5.16	8.52	7.19	1.23	0.02	0.51	0.69
Fat, kg	0.405	0.256	0.677	0.401	0.07	< 0.001	0.001	0.26
True protein, kg	1.01	1.03	1.33	1.25	0.16	0.03	0.82	0.67
Lactose, kg	0.200	0.184	0.238	0.244	0.03	0.05	0.86	0.68
Total solids, kg	1.71	1.58	2.39	2.02	0.26	0.01	0.29	0.58

[a,b,c] Distinct superscripts in the same row denote differences among LSM ($P < 0.05$)

Simões et al. (2023) J. Dairy Sci. 106 (Abstr.)

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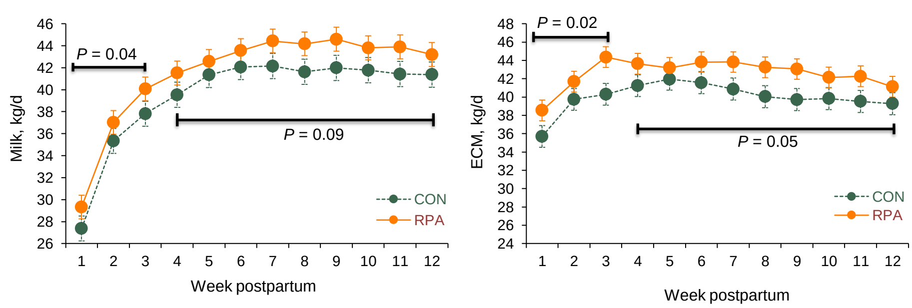
Yields of Milk and Energy-Corrected Milk



Simões et al. (2023) J. Dairy Sci. 106 (Abstr.)

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Protein in Early Lactation

- ✓ Early lactation
  - ✓ Feed diets with 17 to 18% CP to result in ~11.5 to 12% MP
  - ✓ 11% of the diet DM should be degraded protein
  - ✓ 6 to 7% of the diet DM should be undegraded protein
- ✓ Prioritize high quality rumen undegraded protein sources that complement microbial protein
  - ✓ Blood meal of high intestinal digestibility
  - ✓ Heat-treated soybean meal or canola meal
- ✓ RP Methionine and Lysine should be incorporated into early lactation diets
  - ✓ 2.50% of MP (1.14-1.19 g/Mcal of ME) as methionine and 7.50% of MP (3.03 g/Mcal of ME) as lysine
  - ✓ ~5.5% of EAA as methionine and ~15.0% of EAA as lysine
- ✓ Remember, improving protein supply will stimulate milk synthesis, which will likely increase body fat mobilization in the first 2 to 4 weeks of lactation

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