EVALUATION OF PROTEIN VALUE OF DAIRY COW DIETS

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Why to worry about protein/N feeding of the cow?

- Maximize/optimize production efficiency
  - Complex effects on nutrient utilization
- Minimize production cost
- Environment
- Public image

Importance of protein evaluation

- None of the goals (production efficiency, economy, environment can not be reached unless feed/diet protein values are accurately and precisely estimated

Prediction error of milk protein yield (284 diets, 43 studies)

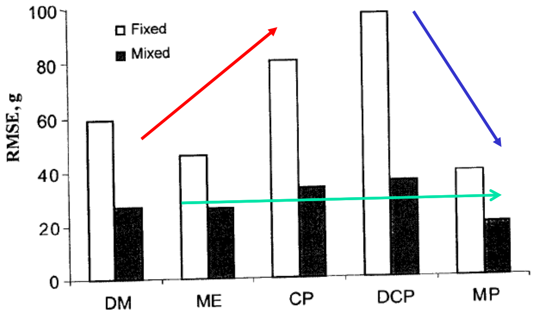


Figure 3. Prediction error in milk protein yield when estimated from intakes of dry matter (DM), metabolisable energy (ME), crude protein (CP), digestible CP (DCP) or metabolisable protein

Huhtanen (2005)

Metabolizable protein (MP)

- Metabolisable protein = Absorbed amino acids
- Two major sources
  - Microbial (Bacterial) Protein
  - Rumen Undegraded Protein (RUP)
- Endogenous MP
  - Minor contribution to total MP

Microbial (Bacterial) MP (BactMP)

- Contributes a major proportion of total MP in most dairy cow diets
- Good AA composition: high Lys and Met
  - Relatively poor in His
  - His seems to be the first limiting AA with grass based diets (high proportion of BactMP of total MP)

Estimation of BactMP

- BactMP is related to the supply of fermentable energy (ATP) for rumen microbes
- In feed protein evaluation systems BactMP is calculated for intake of digestible organic matter (DOM) or corresponding parameter
- In NRC (2001) BactCP (g) = 130 (g/kg) × TDN (kg); TDN discounted
- BactMP = 0.8 × 0.8 × BactCP = 0.64 × BactCP

Proportion of amino N Digestibility

How correct is TDN or DOM?

- Only substrates fermented in the rumen provide energy for microbial growth
- Substrates included in DOM/TDN not fermented in the rumen
  - RUP
  - Long-chain fatty acids
  - Escape starch
  - NDF fermented in the hind-gut
- Substrates that provide less energy per unit
  - Rumen degradable protein
  - Silage fermentation acids (Lactic acid, VFA)

Estimation of BactMP (1)

- Meta-analysis of 988 diets, 204 studies
- BactMP estimated using different substrates
- The total mean BactMP and FeedMP similar for all systems

	Intercept	SE[1]	Slope	SE[1]	RMSE	AIC[2]
DCHO + RDP	117	16.7	407	10.1	19.5	9811.2
DCHO	93	18.3	421	11.3	20.6	9897.4
DOM	141	16.0	393	9.5	**19.3**	9791.7
ME_m	143	15.9	392	9.4	**19.2**	9777.5
ME_p	116	17.0	408	10.0	19.7	9826.0
TDN_m	146	16.1	390	9.5	**19.4**	9797.1
TDN_p	85	17.2	426	10.3	20.3	9854.3

Estimation of BactMP (2)

- Silage fermentation acids provide no (VFA) or little energy (lactic acid) for rumen microbes
- However, discounting DOM intake for total acids (TA) did not improve predictions of milk protein yield (n = 397 diets)

TA discount	A	SE	B	SE	RMSE	AIC
0.00	92	19.4	0.437	0.0114	**16.2**	3917.6
0.25	110	19.1	0.433	0.0114	**16.4**	3924.9
0.50	134	19.0	0.424	0.0115	17.0	3946.0
0.75	161	19.1	0.413	0.0117	17.9	3976.9
1.00	192	19.2	0.400	0.0119	**19.0**	4013.6

Rinne et al. 2008

Estimation of BactMP – conclusions

- Although theoretically more correct, more complicated equations do not improve predictions of MPY because,

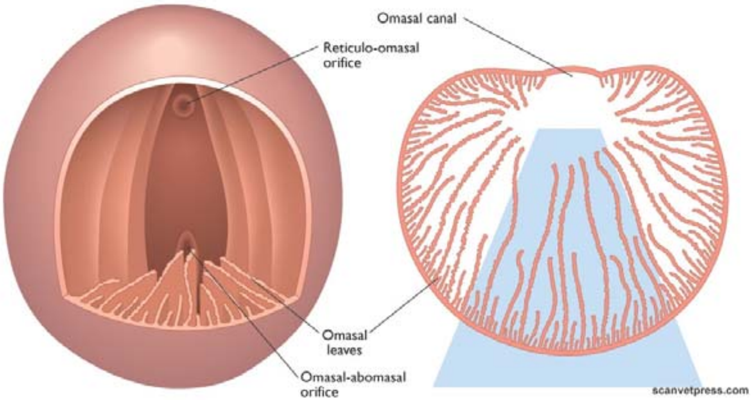
1. Variation in these components is small
2. Estimation of these components inaccurate
3. "Compensatory" effects
    1. Intestinal starch digestion increase glucose
    2. Lactic acid increase propionate → glucose
    3. Fatty acids inhibit protozoa, efficiency of microbial N synthesis may increase

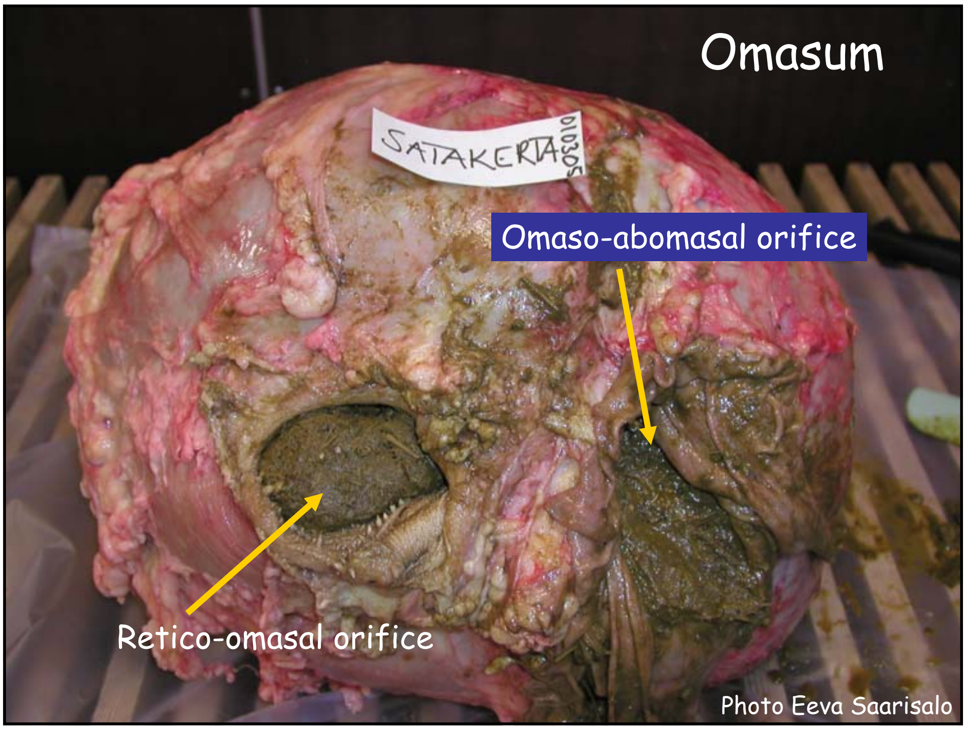
Determination of microbial N synthesis

- Needs cannulated animals, usually rumen and duodenal cannulae
- Needs flow markers and microbial markers
- Technically demanding
- Usually large random errors
- **Omasal sampling technique**
    - Less invasive, only rumen cannulae needed
    - Less endogenous N; more reliable estimation of RUP flow
    - Triple-marker technique allows more accurate and precise flow estimation

Omasal sampling

Sampling site



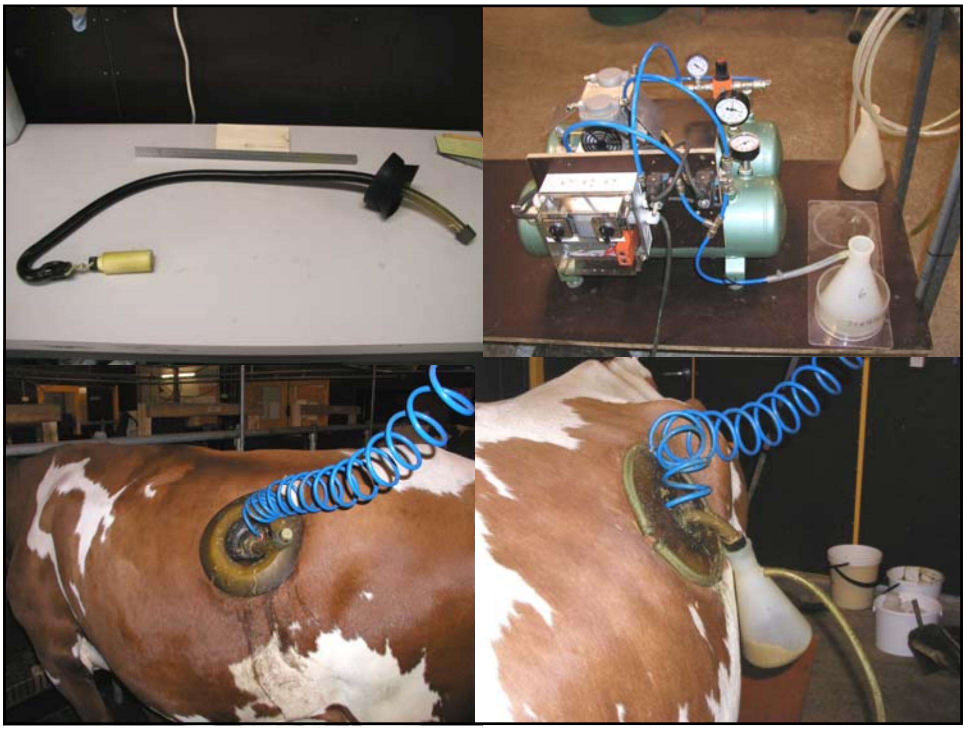


Omasum

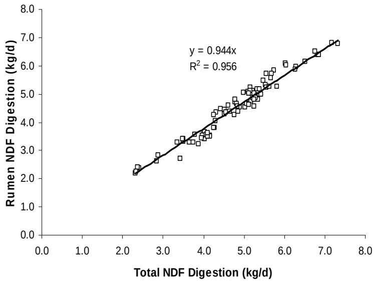
Omaso-abomasal orifice

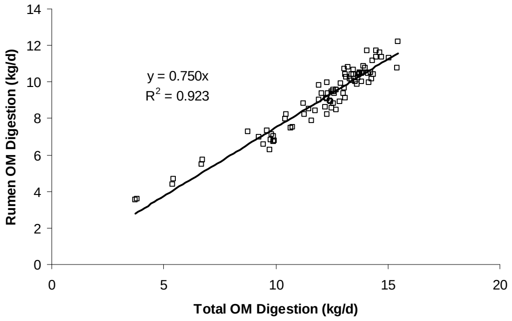
Retico-omasal orifice

Photo Eeva Saarisalo



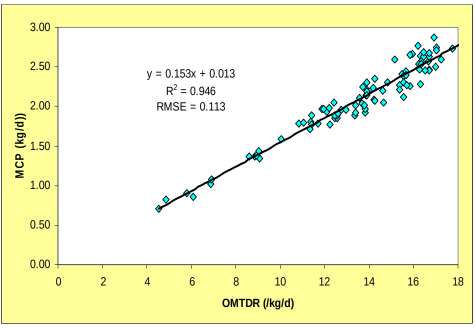
Total and rumen NDF and OM digestion determined by omasal sampling technique





Consistent relationships between total and rumen digestion

Microbial CP measured by omasal sampling technique



- Observed MCP greater than NRC predicted (2.08 vs. 1.82 kg/d)
- Efficiency increase slightly with DMI
- The contribution of BactMP to total MP is greater than predicted by NRC
  - The effects of CP concentration or degradability on the efficiency was not significant
- Microbial CP flow may be 5-10% greater than measured
  - Protozoa (lower marker:N ratio)

Analysis of dietary intake variables important in predicting milk protein yield

			RMSE	RMSE	AIC	AIC	NA	NE
CP			56.3	29.8	8692	10639	10	10
CP	Degr		55.5	29.5	8667	10612	8	8
RDP	RUP		55.3	30.7	8667	10619	8	9
MP			52.6	27.3	8621	10438	7	7
MP	MP×MP		49.5	26.8	8550	10400	6	6
MPBact			50.9	27.4	8542	10371	4	4
DM			51.2	28.0	8566	10393	5	5
TDN			47.6	26.6	8479	10289	3	3
TDN	CP		47.5	23.5	8465	10091	2	2
TDN	CP	Degr	46.9	23.2	8447	10059	1	1

RMSE = Residual mean square error
AIC = Akaike´s information criterion

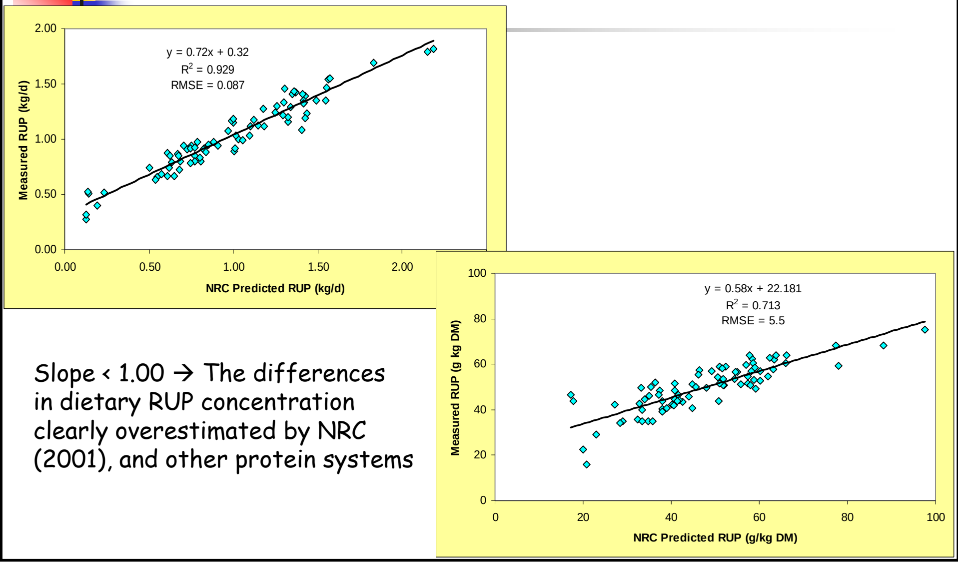
Huhtanen & Hristov 2008

Selected models predicting MPY responses from NA (n=723) and NE (n=998) datasets (Huhtanen & Hristov)

X_1	X_2	Data	Intecept	$Slope_1$	Slope2	RMSE
MP		NA	491	209		49.6
MP		NE	256	329		27.0
MP	MP * MP	NA	114	546	-74	48.9
MP	MP * MP	NE	-129	793	-139	26.4
BactMP		NA	266	589		48.4
BactMP		NE	-89	897		27.2
BactMP	FeedMP	NA	289	491	96	45.9
BactMP	FeedMP	NE	-28	750	142	24.7

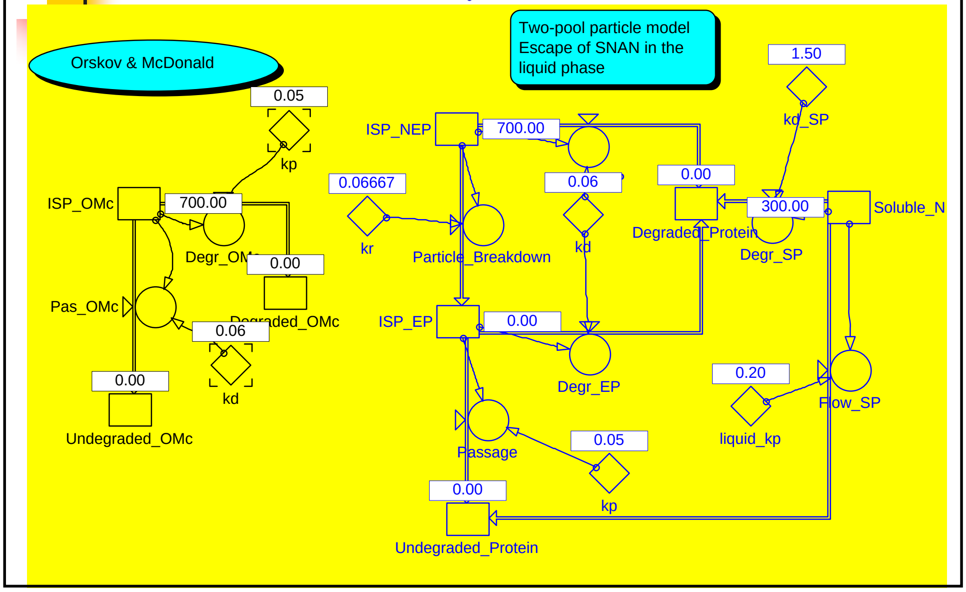
- BactMP predicted milk protein yield at least as well as total MP
- The coefficients of BactMP were about 5-fold compared with FeedMP in both datasets
- Is FeedMP (RUP) overvalued?

Relationship between NRC (2001) predicted and measured omasal flow of RUP



Slope < 1.00 → The differences in dietary RUP concentration clearly overestimated by NRC (2001), and other protein systems

Rumen protein degradation models



Model simulation results

	ISP	SP	kd ISP	kd SP	kl SP	Particle MRT
	(g/kg CP)	(g/kg CP)	(1/h)	(1/h)	(1/h)	h
Forage A	700	300	0.06	15	0.2	0+20
Forage B	500	500	0.06	15	0.2	0+20
Forage A	700	300	0.06	1.5	0.2	15+20
Forage B	500	500	0.06	1.5	0.2	15+20

		Undegraded protein				
	EPD	**ISP**	**SP**	**ADIN**	**dRUP**	**A-B**
	(g/kg)	(g/kg N)	(g/kg N)	(g/kg N)	(g/kg N)	(g/kg N)
Forage A	0.680	316	4	50	270	
Forage B	0.768	226	6	50	182	**88**
Forage A	0.797	167	35	50	153	
Forage B	0.822	119	58	50	128	**25**

Silage soluble NAN did not influence milk protein yield, when constant degradability and RUP digestibility were used to calculate silage MP

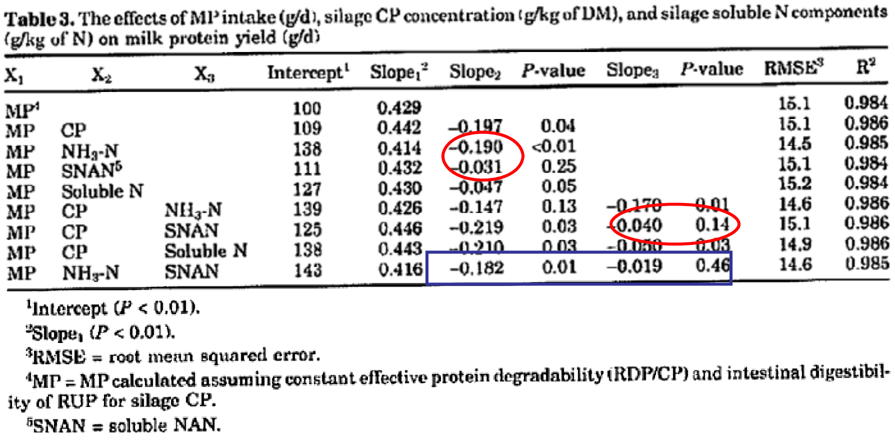


Table 3. The effects of MP intake (g/d), silage CP concentration (g/kg of DM), and silage soluble N components (g/kg of N) on milk protein yield (g/d)

X_1	X_2	X_3	Intercept[1]	$Slope_1$[2]	$Slope_2$	*P*-value	$Slope_3$	*P*-value	RMSE[3]	R^2
MP[4]			100	0.429					15.1	0.984
MP	CP		109	0.442	−0.197	0.04			15.1	0.986
MP	NH_3-N		138	0.414	−0.190	<0.01			14.5	0.985
MP	SNAN[5]		111	0.432	−0.031	0.25			15.1	0.984
MP	Soluble N		127	0.430	−0.047	0.05			15.2	0.984
MP	CP	NH_3-N	139	0.426	−0.147	0.13	−0.170	0.01	14.6	0.986
MP	CP	SNAN	125	0.446	−0.219	0.03	−0.040	0.14	15.1	0.986
MP	CP	Soluble N	138	0.443	−0.210	0.03	−0.050	0.03	14.9	0.986
MP	NH_3-N	SNAN	143	0.416	−0.182	0.01	−0.019	0.46	14.6	0.985

[1] Intercept ($P < 0.01$).

[2] $Slope_1$ ($P < 0.01$).

[3] RMSE = root mean squared error.

[4] MP = MP calculated assuming constant effective protein degradability (RDP/CP) and intestinal digestibility of RUP for silage CP.

[5] SNAN = soluble NAN.

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Effect of RUP sources on non-microbial NAN (NMNAN = RUP + endogenous) flow (Ipharraguerre & Clark, 2005)

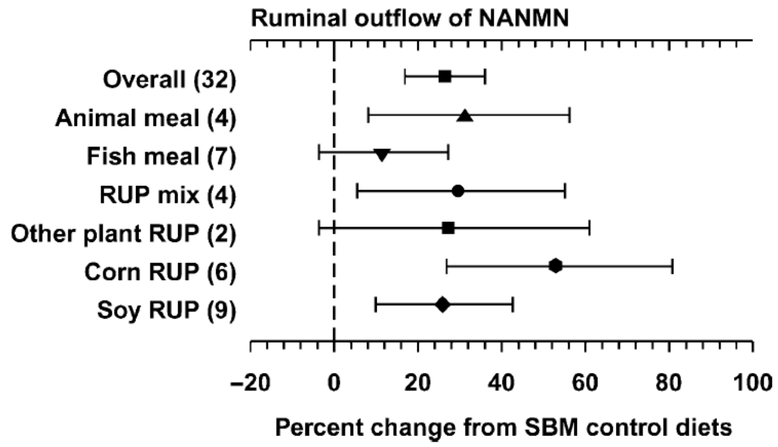
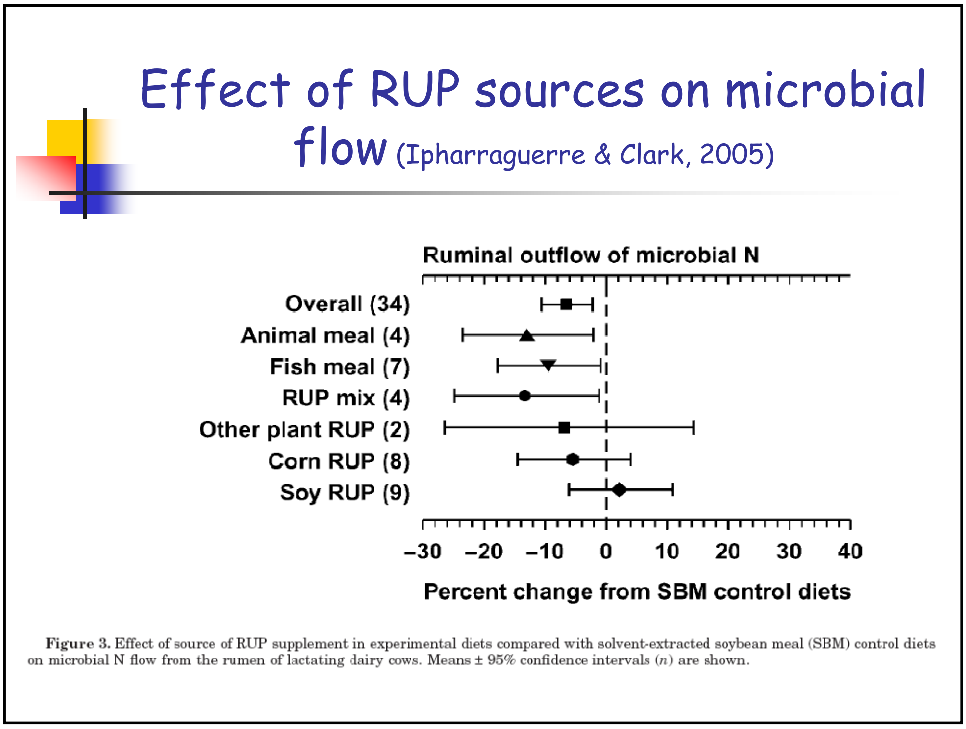
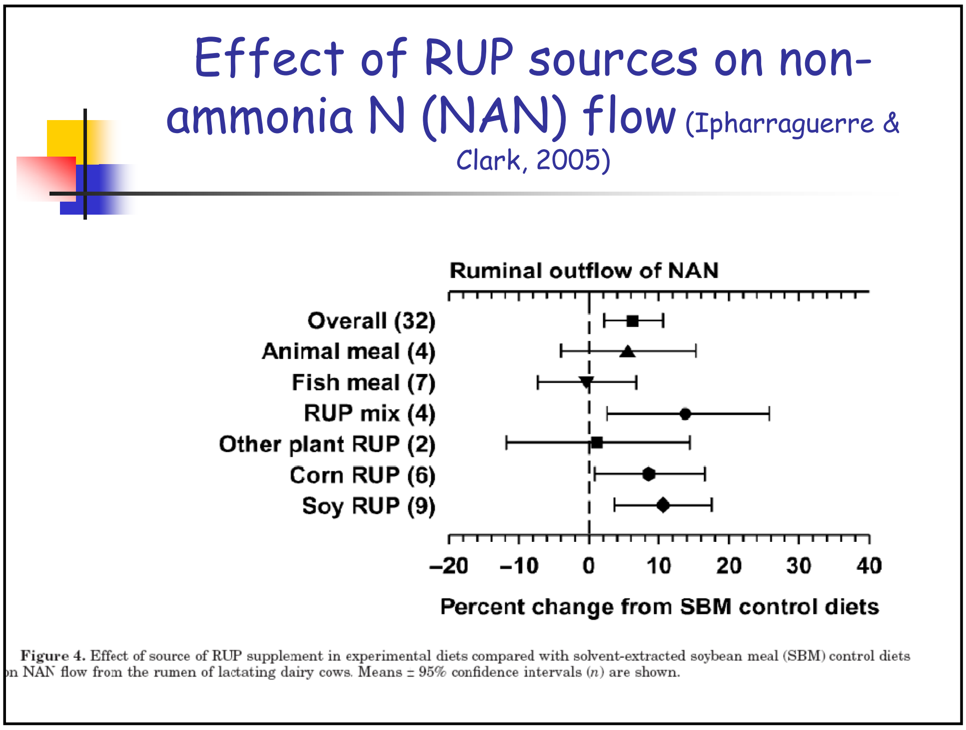


Figure 2. Effect of source of RUP supplement in experimental diets compared with solvent-extracted soybean meal (SBM) control diets on nonammonia, nonmicrobial N (NANMN) flow from the rumen of lactating dairy cows. Means ± 95% confidence intervals (*n*) are shown.



Effect of RUP sources on microbial flow (Ipharraguerre & Clark, 2005)

Figure 3. Effect of source of RUP supplement in experimental diets compared with solvent-extracted soybean meal (SBM) control diets on microbial N flow from the rumen of lactating dairy cows. Means ± 95% confidence intervals (*n*) are shown.



Effect of RUP sources on non-ammonia N (NAN) flow (Ipharraguerre & Clark, 2005)

Figure 4. Effect of source of RUP supplement in experimental diets compared with solvent-extracted soybean meal (SBM) control diets n NAN flow from the rumen of lactating dairy cows. Means ± 95% confidence intervals (*n*) are shown.

Effect of RUP sources on milk yield (Ipharraguerre & Clark, 2005)

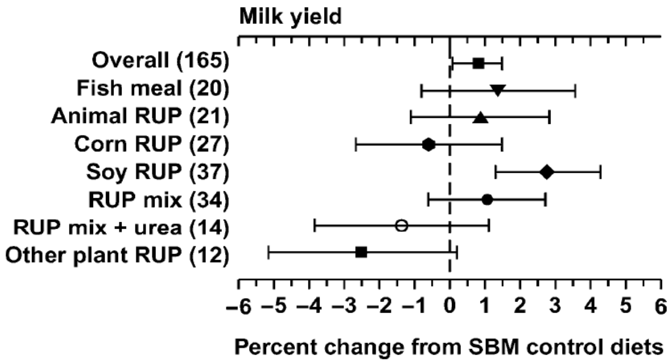


Figure 11. Effect of source of RUP supplement in experimental diets compared with solvent-extracted soybean meal (SBM) control diets on milk production of dairy cows. Means ± 95% confidence intervals (*n*) are shown.

Conclusions

- Contribution of microbial CP to total MP supply is greater than the current models predict
- Simple models to predict BactMP (DOM, TDN)
- The contribution of RUP is overvalued
  - The methods overestimate differences in ruminal CP degradability
  - Treatments may reduce intestinal digestibility of RUP
  - Treatments may reduce availability of AA (especially Lys)