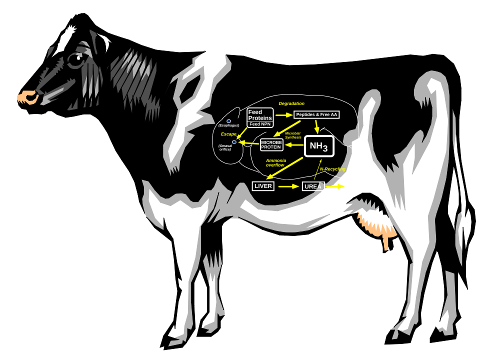
# Formulating Protein in Dairy Diets to Meet Economic and Environmental Challenges

**Intermountain Nutrition Conference**
**January 23, 2007**

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**Web site: http://ars.usda.gov/mwa/madison/dfrc**

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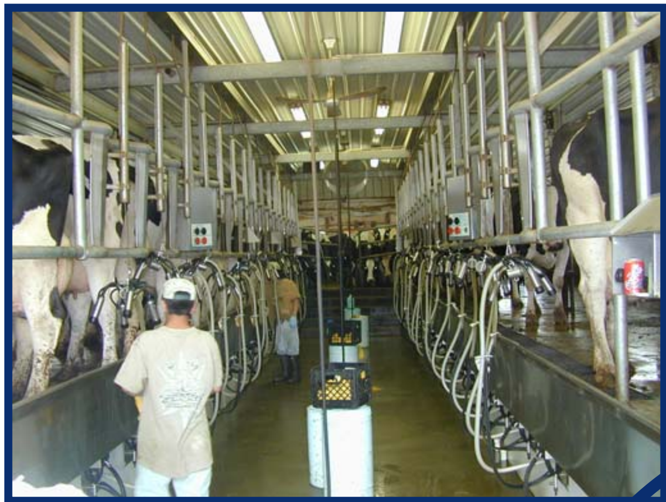
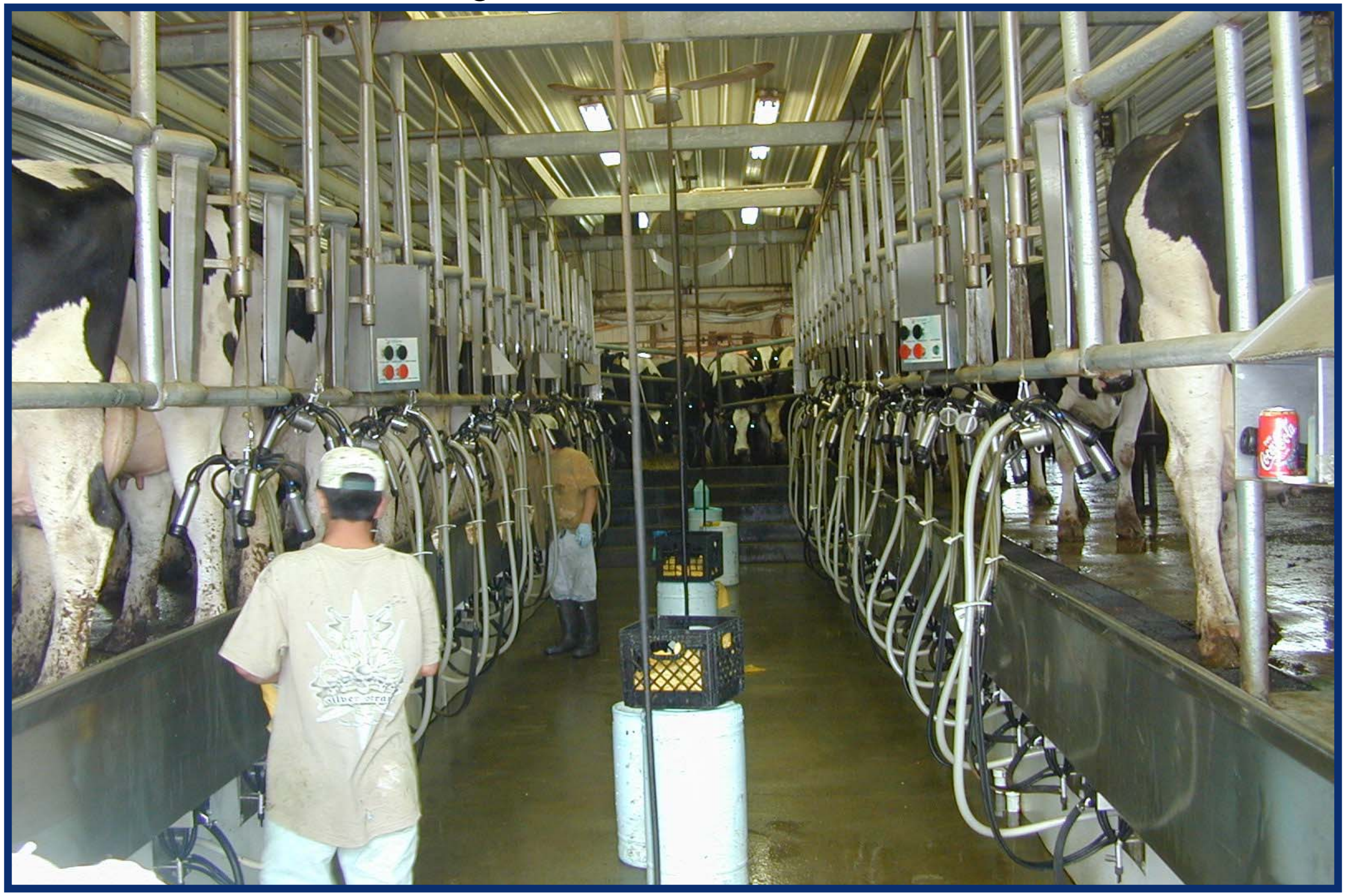
# Dairy Cows are Relatively Efficient Users of Dietary Crude Protein,
# *but . . . .*



Feed N utilization

Manure N utilization

# How can Diets be Formulated for <u>Optimal</u> Economic & Environmental Efficiency of Protein Use?



# Improving Protein Efficiency . . .

**An overview:**

1. Optimize Production of Microbial Protein
   a. Optimize CHO Fermentation
   b. Match RDP Supply with the Requirement
2. Don't Over-Feed Crude Protein
   a. Accurately Track Dietary CP
   b. Formulate to Meet RDP & RUP Requirements
3. Feed "Complementary" Rumen-Undegraded Protein & Rumen-Protected AA

# Improving Protein Efficiency . . .

## Point by point:

1. **Optimize Production of Microbial Protein**
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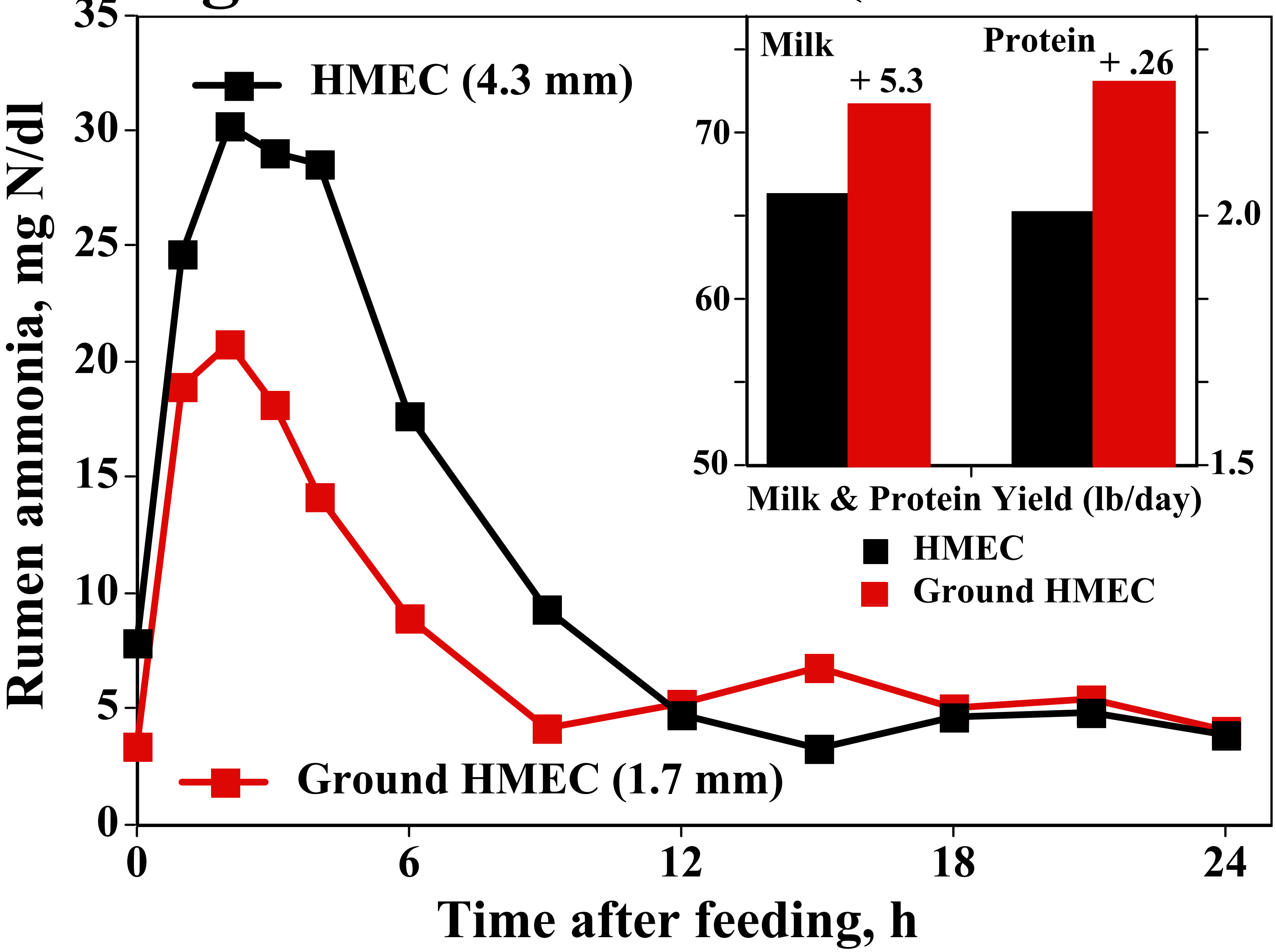
# Effect of Processing on Digestibility of Corn & Barley Starch (Owens et al., 1986)

| Starch Source | Proportion of Starch Digestion, % | | | |
|---|---|---|---|---|
| | Rumen | Small Intestine | Large Intestine | Total tract |
| Cracked Corn | 69 | 13 | 8 | 89 |
| Ground Corn | 78 | 14 | 4 | 94 |
| Steam-Flaked Corn | 83 | 16 | 1 | 98 |
| High Moisture Corn | 86 | 6 | 1 | 95 |
| Ground Barley | 94 | . . . | . . . | . . . |

# Rumen $NH_3$ & Production of Cows fed Alfalfa Silage & High Moisture Corn (Ekinci & Broderick, 1997)

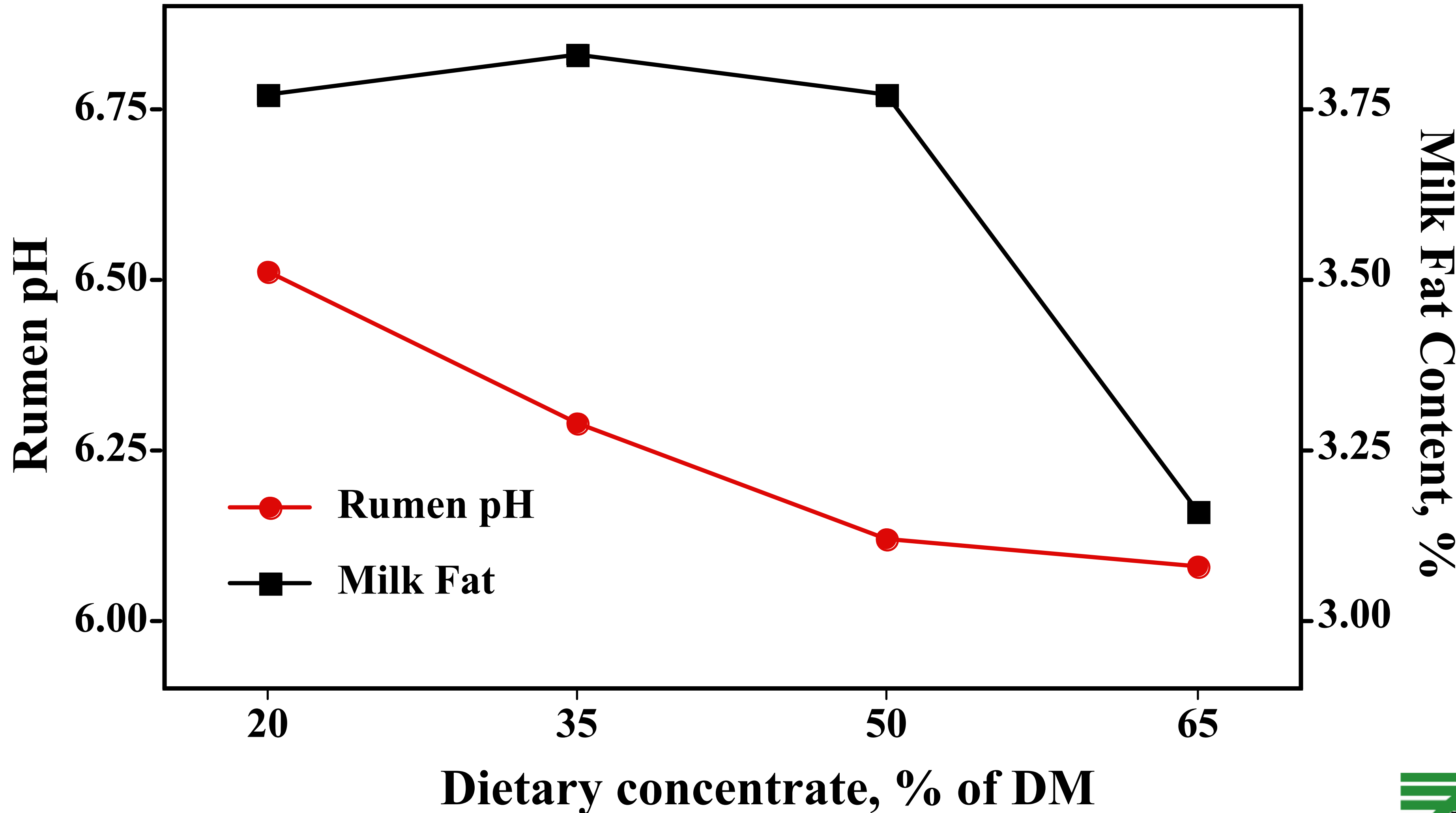


# CHO Source--Production
## (Charbonneau et al., 2006)

| Item | Diet | | | | *Prob.* |
|---|---|---|---|---|---|
| | Cracked corn | Ground corn | GC + Starch | GC + Whey | |
| DMI, lb/d | 50.0[c] | 53.6[b] | 53.8[b] | 56.7[a] | < 0.01 |
| Milk, lb/d | 75.0[c] | 82.5[ab] | 82.9[a] | 78.9[b] | < 0.01 |
| Fat, lb/d | 2.82 | 2.89 | 2.82 | 3.02 | 0.45 |
| Protein, lb/d | 2.38[c] | 2.71[a] | 2.73[a] | 2.60[b] | < 0.01 |
| MUN, mg/dl | 13.4[a] | 10.7[b] | 9.9[b] | 9.8[b] | < 0.01 |
| Milk N/N-Intake, % | 25[b] | 28[a] | 28[a] | 25[b] | < 0.01 |
| Rumen $NH_3$, mg N/dl | 14.1[a] | 12.2[ab] | 6.9[b] | 7.6[b] | 0.07 |

(Diets averaged 18% CP & 27% NDF)

# Forage Helps Maintain Rumen pH & Milk Fat (Valadares et al., 2000)



# Improving Protein Efficiency

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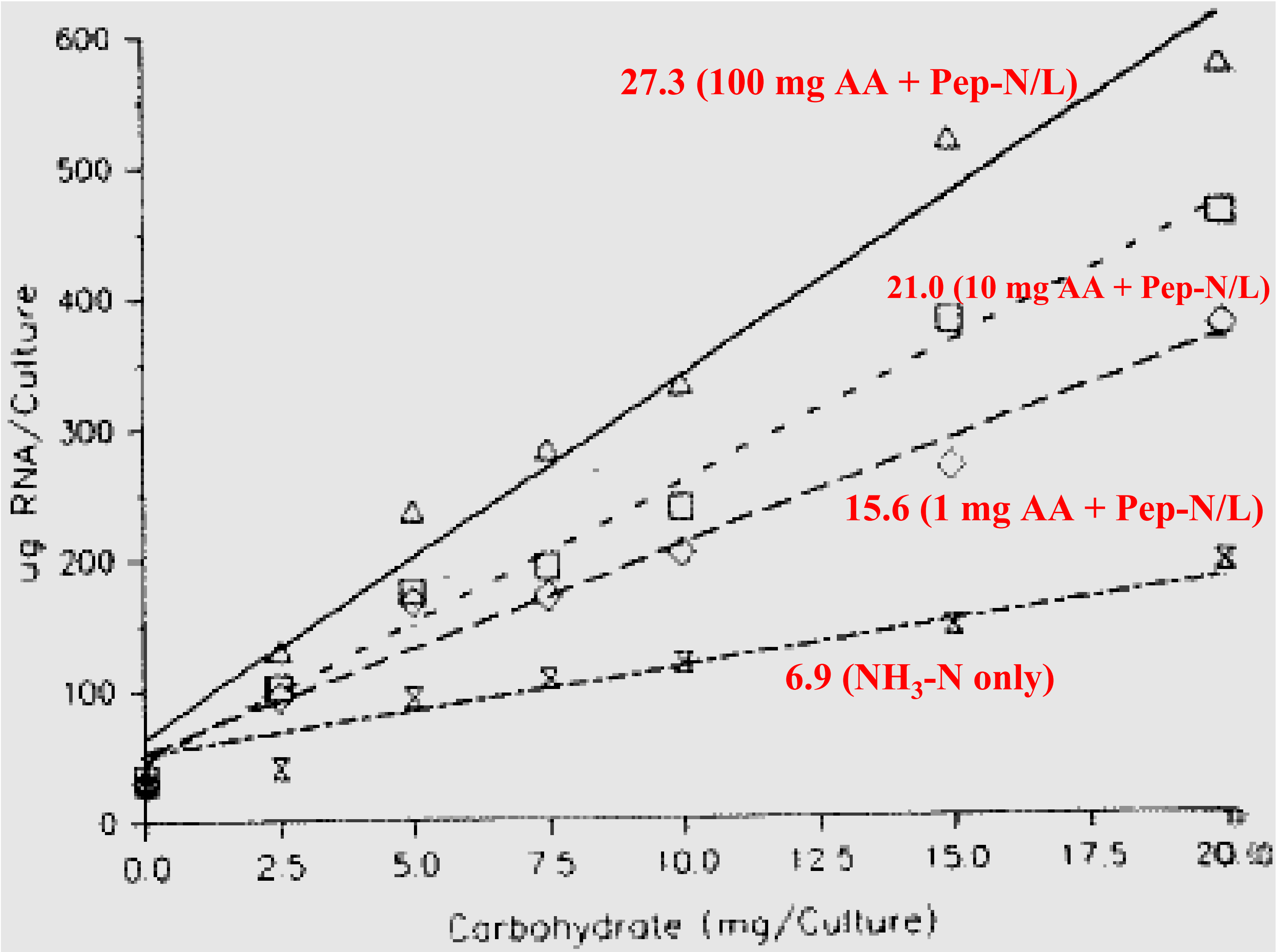
# Microbial Protein Yield Increases with RDP from True Protein (Argyle & Baldwin, 1989)

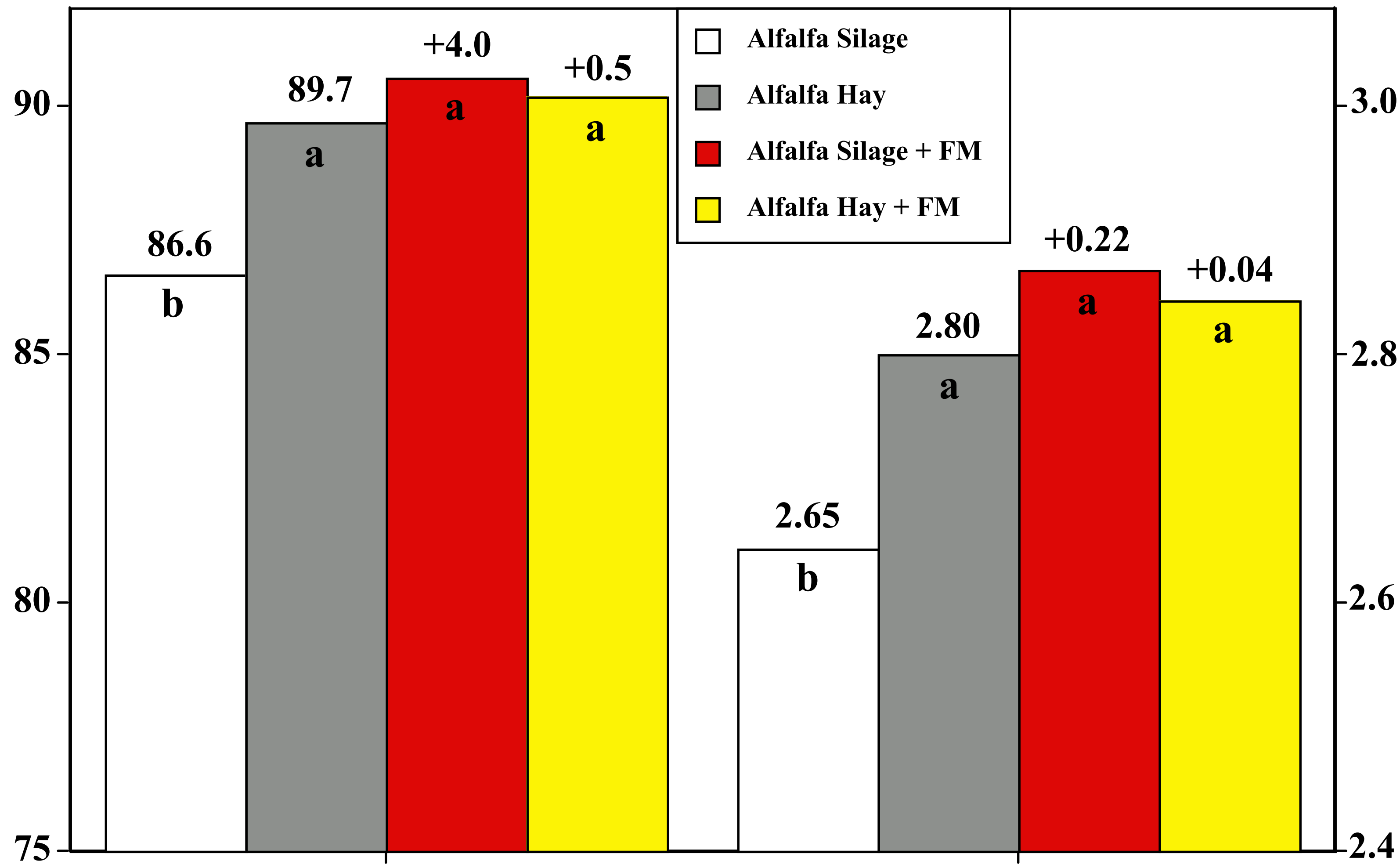


# Mean Composition of Alfalfa Silage & Hay

| Item | Silage | Hay | Change, % |
|---|---|---|---|
| DM, % | 41 | 86 | - - - |
| CP, % DM | 20.6 | 18.1 | -12 |
| NPN, % CP | 52 | 8 | -85 |
| IV-RDP, % CP | 71 | 73 | NS |
| NDF, % DM | 38 | 38 | NS |

# Cows Fed Alfalfa Silage Respond More to Fish Meal (FM) than Cows Fed Alfalfa Hay

(Vagnoni & Broderick, 1997)



# In Vitro Protein Degradation & Synthesis Determined with $^{15}NH_3$ (Peltekova & Broderick, 1996)

| Protein | Est. RDP | Microbial Protein |
|---|---|---|
| | (%) | (mg/100 ml) |
| Casein | 93[a] | 5.9[b] |
| Alfalfa Forages | | |
| Silage | 71[b] | 5.4[b] |
| Hay | 73[b] | 7.2[a] |

[a,b]($P < 0.05$)

# CP Supplement & Protein Supply from the Rumen (Brito & Broderick, 2007)

| Item | Protein Supplement | | | | |
|---|---|---|---|---|---|
| | Urea | Soybean meal | Cottonseed meal | Canola meal | *P* > F |
| Total RDP | 3148[a] | 3062[ab] | 2845[b] | 3192[a] | 0.05 |
| "Protein" RDP, g/d | 1905 | 3062 | 2845 | 3192 | |
| Microbial protein, g/d | 2344[b] | 2706[a] | 2706[a] | 2775[a] | 0.04 |
| Microbial efficiency, g N/kg of OMTDR | 26.3[b] | 29.0[a] | 29.7[a] | 29.5[a] | < 0.01 |

Diets Formulated from AS, CS & HMSC with 16.5% CP; [a-c]($P < 0.05$)

**This table shows the omasal flow of N fractions.**

- Omasal flow of NAN was 27% lower on the urea diet compared to the average of SSBM, CSM, and CM diets that did not differ significantly.
- RDP supply was 10% lower on the CSM diet than the average of urea, SSBM, and CM diets that were similar.
- On the other hand, RUP flow was significantly lower on diet A compared to the true protein supplements.
- Among the true protein diets, cows fed CSM had the highest RUP flow, those fed CM were intermediate, and cows fed SSBM were the lowest.
- Omasal flow of both NDIN and ADIN did not differ between urea and SSBM diets but were higher on CSM and CM diets, reflecting the NDIN and ADIN contents of the diets.
- Microbial efficiency did not differ among the true protein sources but was 11% lower on the urea diet.
- The reason for the lowest RDP supply and the highest RUP flow on CSM was related to the escape of the protein supplements.

# Urea Supplementation & Production

## (Corn Silage & Grain; Gressley, 2005)

| Item | Low RDP | High RDP | Prob. |
|---|---|---|---|
| Dietary CP, % | 13.5 | 16.1 | . . . |
| Dietary urea, % | 0 | 1.0 | . . . |
| Response | | | |
| Milk, kg/d | 30.5 | 29.9 | 0.25 |
| Protein, kg/d | 0.98 | 0.96 | 0.25 |
| Fat, kg/d | 1.09 | 1.07 | 0.29 |
| Rumen $NH_3$, mg N/dl | 3.2 | 7.9 | 0.001 |
| In situ NDF, % | 25.0 | 27.5 | 0.02 |

# Improving Protein Efficiency

1. Optimize Production of Microbial Protein
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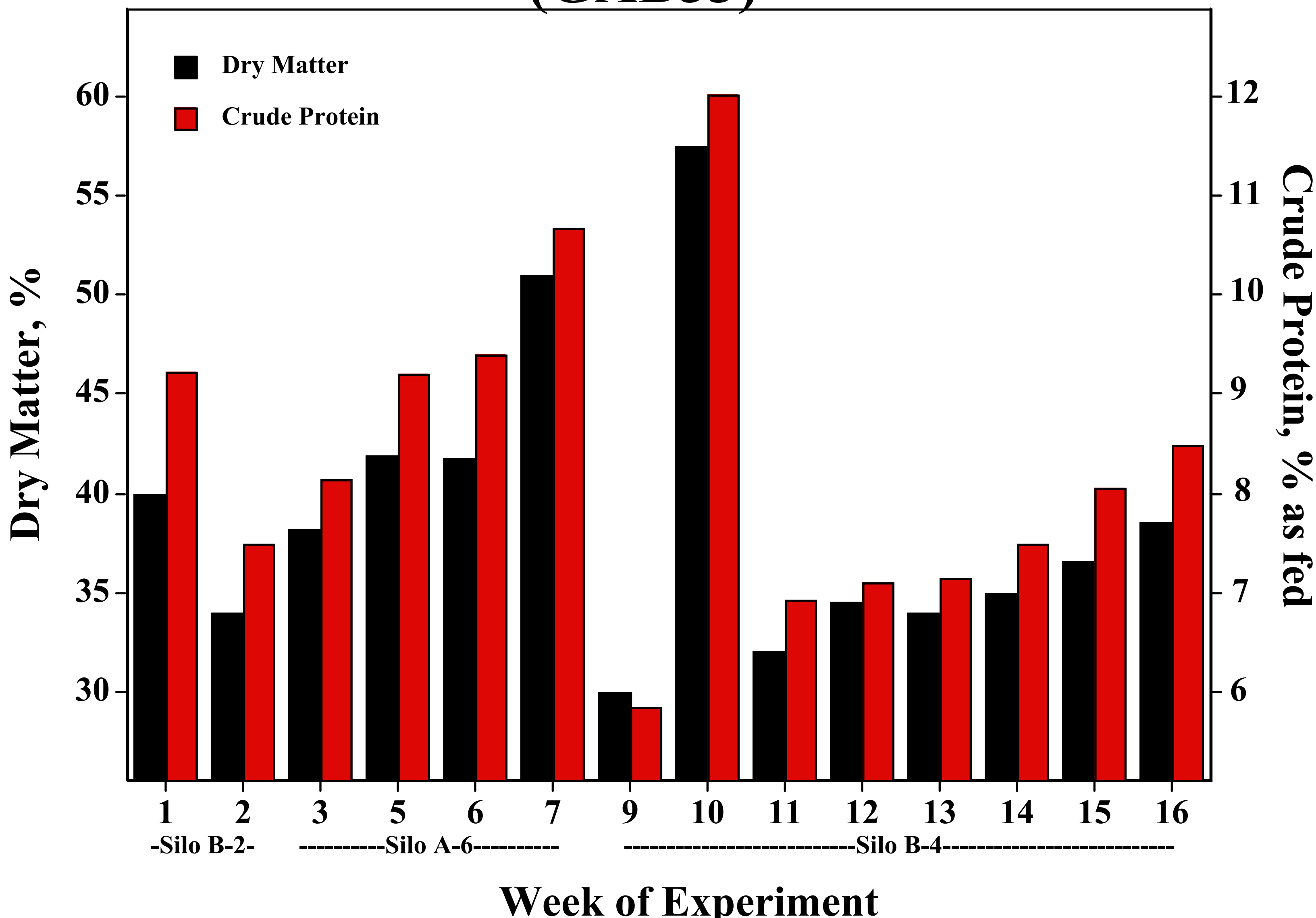
# Sampling Forage is Very Important

# Variation of DM & CP in Alfalfa Silage

## (GAB53)



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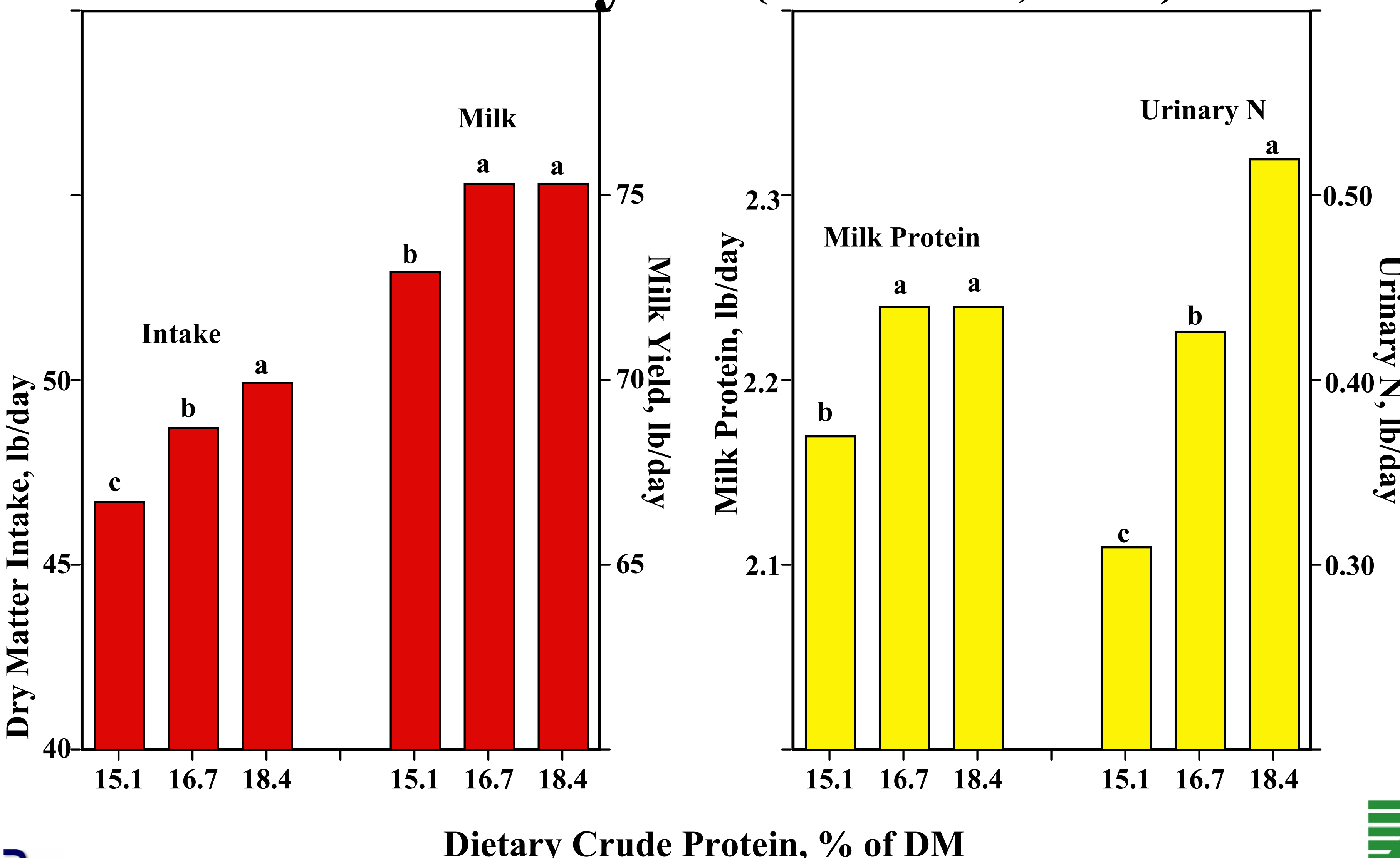
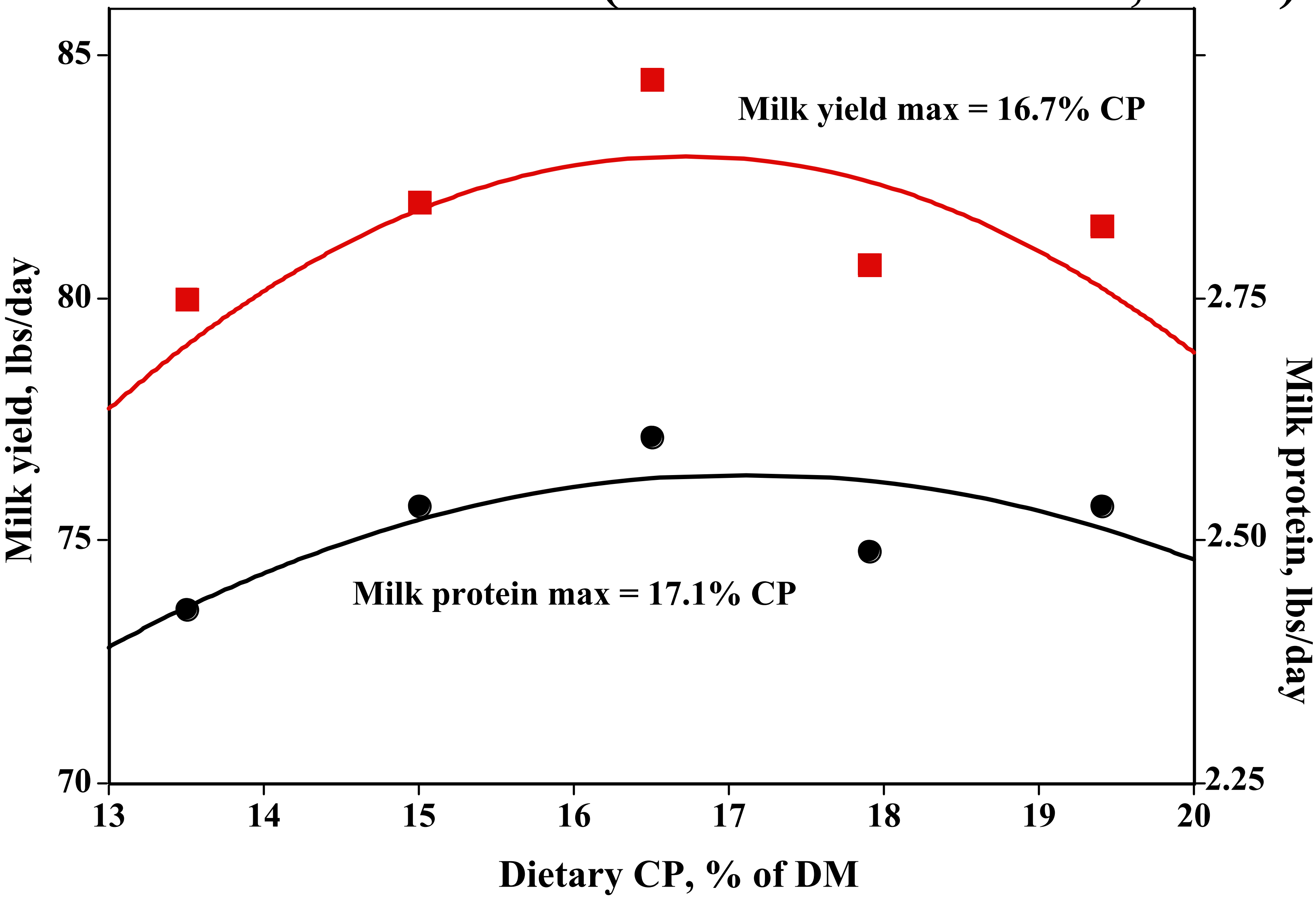
# Production & Feeding--Top Wisconsin Herds

| Date | RHA | Fat | Protein | Dietary CP |
|---|---|---|---|---|
| | --------(lbs/lactation)-------- | | | |
| 12/31/97 | 31,300 | 1109 | 933 | 19.4% |
| (7 top herds) | (119 cows) | (3.55%) | (3.2%) | (18.5-21.5%) |
| | | | | (28% NDF) |
| 2/1/04 | 30,900 | 1144 | 915 | 17.7% |
| (6 top free-stall herds) | (396 cows) | (3.75%) | (3.0%) (true protein) | (16.7-18.4%) (29% NDF) |

# Effect of Dietary CP on Intake, Yield & Urinary N (Broderick, 2003)

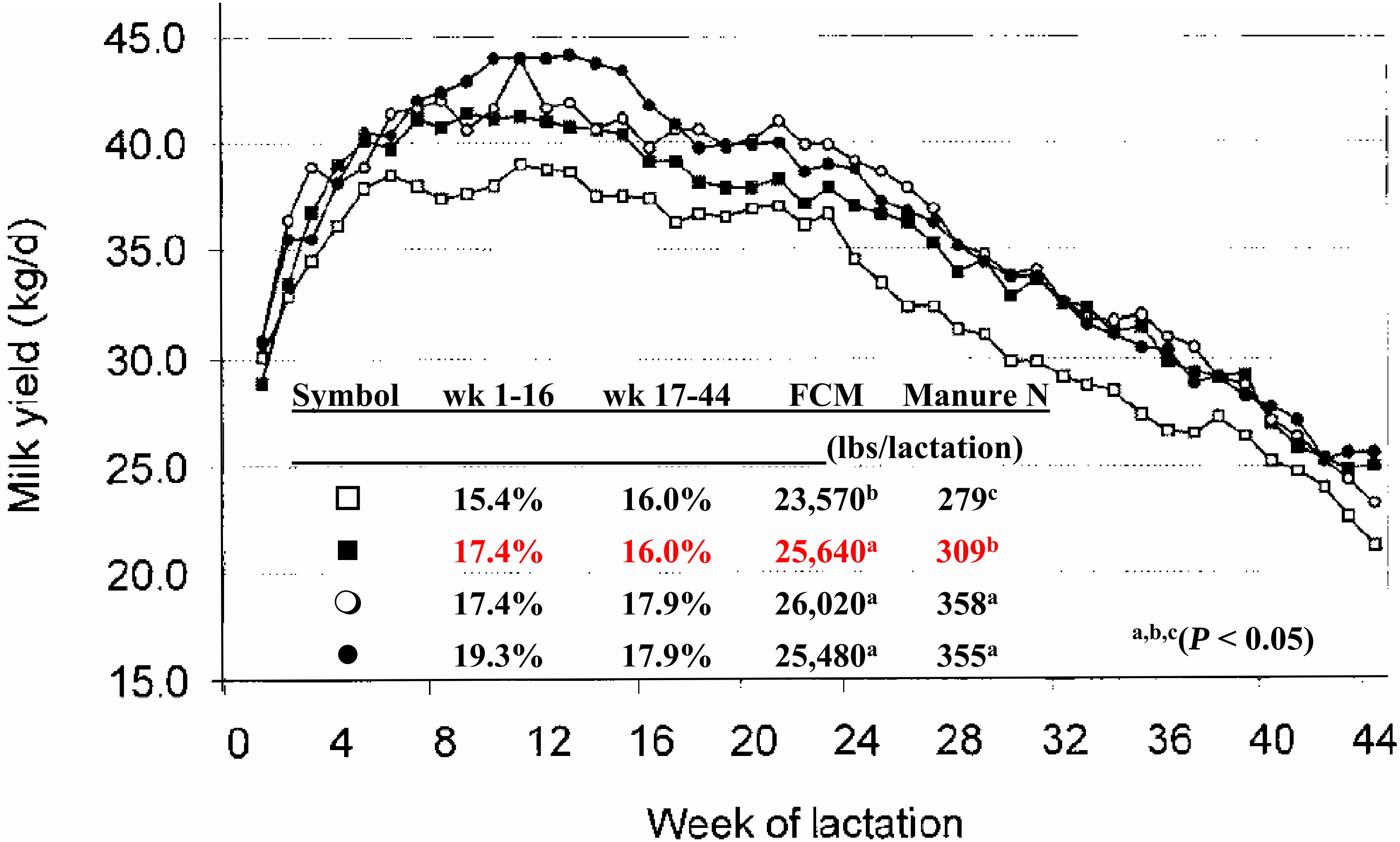


# Effect of CP (Solvent SBM) on Milk & Protein Yield (Olmos & Broderick, 2006)



# Effect of Dietary CP on the Lactation Curve

## (Wu & Satter, 2000)




| Symbol | wk 1-16 | wk 17-44 | FCM (lbs/lactation) | Manure N (lbs/lactation) |
|---|---|---|---|---|
| □ | 15.4% | 16.0% | 23,570[b] | 279[c] |
| ■ | 17.4% | 16.0% | 25,640[a] | 309[b] |
| ○ | 17.4% | 17.9% | 26,020[a] | 358[a] |
| ● | 19.3% | 17.9% | 25,480[a] | 355[a] |

[a,b,c]($P < 0.05$)

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# CP Supplements & Production

(Brito & Broderick, 2007)

| Item | a. Urea | b. Soybean meal | c. Cottonseed meal | d. Canola meal | *P* > F |
|---|---|---|---|---|---|
| | Protein Supplement | | | | |
| | --------------------(lbs/d)-------------------- | | | | |
| DM intake | 49[c] | 53[b] | 55[ab] | 55[a] | < 0.01 |
| Milk yield | 73[b] | 88[a] | 89[a] | 91[a] | < 0.01 |
| Protein yield | 2.0[c] | 2.7[ab] | 2.6[b] | 2.8[a] | < 0.01 |
| Fat yield | 2.2[c] | 2.7[ab] | 2.6[b] | 2.8[a] | < 0.01 |
| Total protein, g/d | 2882[c] | 3693[b] | 4054[a] | 3925[ab] | < 0.01 |
| MUN, mg/dl | 16.9[a] | 12.0[b] | 10.0[c] | 11.6[b] | < 0.01 |

**Diets Formulated from AS, CS & HMSC & had 16.5% CP; [a-c]($P < 0.05$)**

- Cows fed diet A had lower DMI than cows supplemented with the true protein sources.
- Among diets B, C, and D, cows fed CM had the highest intake; CSM intermediate; and SSBM lowest.
- Milk yield paralleled DMI and was on average 19% lower on diet A compared to diets B, C, and D.
- No significant difference was observed among diets supplemented with true protein sources.
- Milk protein content was significantly lower on diets A and C compared to diets B and D.
- Milk protein yield also was significantly lower on diet A compared to the true protein sources.
- Among diets B, C, and D, cows fed CM had the highest milk protein yield; SSBM intermediate; and CSM lowest.
- No significant difference was observed for milk fat content and averaged 3.11% among diets. However, milk fat yield was significantly lower on diet A than on the remaining diets.
- When cows were supplemented with the true protein sources, diet D resulted in the highest yield of milk fat; diet B intermediate; and diet C lowest.

# Essential Amino Acid (EAA) Compositions

| Item | Cow's Milk | Bacterial Protein | Solvent SBM | Cottonseed meal | Canola meal |
|---|---|---|---|---|---|
| | ------------------------(% of EAA)------------------------ | | | | |
| LYS | 15.0 | 16.7 | 13.9 | 9.7 | 13.2 |
| MET | 5.4 | 5.4 | 3.2 | 3.7 | 4.4 |
| Lys:Met | 2.8 | 3.1 | 4.3 | 2.6 | 3.0 |

# Studies on Rumen-Protected Methionine


1. Rumen-Protected Methionine (RP-Met) from Mepron.
2. Assumed to Supply 0.6 g absorbed Met/g Mepron).
3. 2 “Reversal” & 1 “Continuous” Feeding Trials (1st & ≥2nd Lact; 100-125 DIM; 92-100/d).

# Composition of Diets (28% NDF)

| Ingredient | Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|
| | | (% of DM) | |
| Crude Protein | 14.8-18.6 | 15.7 or 17.0 | 16.6 |
| RUP Supplement | --- | 0 or 2.4 | --- |
| Alfalfa Silage | 21 | 21 | 40 |
| Corn Silage | 28 | 34 | 25 |
| High Moisture Corn | 28-36 | 25-33 | 24 |
| Solvent Soybean Meal | 4-12 | 3-13 | 3.5 |
| Expeller Soybean Meal | --- | 0 or 5.0 | 0 |
| Mepron (g/d) | 0-25 | 0 or 15 | 0 or 15 |
| Roasted Soybeans | 4.5 | 0 | 4.0 |
| Soy Hulls | 5.8 | 4.0 | 0 |
| Bicarb/Dical/Salt/TM/Vit | 1.1 | 1.2 | 1.0 |

# Replacing SBM-CP with RP-Met: Intake & Milk Yield--Trial 1

| Item | CP, % | 18.6 | 17.3 | 16.1 | 14.8 | |
|---|---|---|---|---|---|---|
| | Mepron, g/d | 0 | 8 | 17 | 25 | P > F |
| Milk, lb/d | | 87.6[ab] | 91.7[a] | 91.9[a] | 87.4[b] | 0.06 |
| Milk/DMI | | 1.72[ab] | 1.80[a] | 1.77[ab] | 1.69[b] | 0.06 |
| Fat Yield, lb/d | | 3.01[ab] | 3.28[a] | 3.15[ab] | 2.90[b] | 0.08 |
| MUN, mg/dl | | 14.5[a] | 11.8[b] | 9.4[c] | 7.9[d] | < 0.01 |
| Milk-N/NI, % | | 26[c] | 30[b] | 32[b] | 34[a] | < 0.01 |
| Urinary-N, g/d | | 260[a] | 207[b] | 188[c] | 150[d] | < 0.01 |

DMI = 52 lbs/d; [a-d](P < 0.05)

# Effect of Adding RP-Met--Trial 2

| | Mepron Level, g/d | | |
|---|---|---|---|
| **Item** | **0** | **15** | **P > F** |
| DM intake, lb/d | 54.2 | 55.6 | 0.04 |
| Milk, lb/d | 89.2 | 90.8 | 0.26 |
| Milk/DMI | 1.65 | 1.64 | 0.60 |
| 3.5% FCM, lb/d | 99.5 | 103.5 | 0.04 |
| Fat, lb/d | 3.17 | 3.34 | 0.02 |
| Protein, lb/d | 2.83 | 2.91 | 0.05 |
| SNF, lb/d | 7.91 | 8.09 | 0.17 |
| MUN, mg/dl | 10.6 | 10.8 | 0.36 |

(Over all CP & RUP Levels)

# Can We Reduce CP with RP-Met?

## (Trial 2)

| CP/Mepron | DMI | Milk | FCM | Fat | Protein |
|---|---|---|---|---|---|
| | --------------------- | ----------(lbs/day) | ---------- | ----- | --------------------- |
| 17.0%/0 | 56 | 92 | 102 | 3.3 | 2.9 |
| 17.0%/15 g/d | 57 | 92 | 105 | 3.4 | 3.0 |
| 15.7%/0 | 53 | 87 | 96 | 3.0 | 2.8 |
| 15.7%/15 g/d | 55 | 90 | 101 | 3.3 | 2.9 |

# Effect of RP-Met Supplementation without Diet Reversal (Trial 3)

| Variable | Supplement: Control | Supplement: RP-Met | Prob. |
|---|---|---|---|
| DMI, lb/d | 49.0 | 48.2 | 0.41 |
| Milk, lb/d | 80.5 | 82.5 | 0.25 |
| Milk/DMI | 1.66 | 1.72 | 0.08 |
| Fat, lb/d | 2.91 | 2.95 | 0.72 |
| Protein, lb/d | 2.31 | 2.40 | 0.09 |
| MUN, mg/dl | 11.0 | 11.1 | 0.83 |

(12-Week Trial; 18 Cows/Diet)

# RP-Met Supplementation & Supply of MP & MAA (Trial 3)

| Component | Control | RP-Met |
|---|---|---|
| CP, % of DM | 16.6 | 16.6 |
| RDP, % of DM | 11.8 | 11.8 |
| RUP, % of DM | 4.8 | 4.8 |
| MP, g/d | 2450 | 2460 |
| Met, g/d | 46 | 55 |
| Lys, g/d | 161 | 161 |
| Lys/Met | 3.50 | 2.93 |

(NRC Model; Assuming 60% Absorbable Met in Mepron)

# Pay-Back on Feeding RP-Met

| Increased Milk Yield | |
|---|---|
| 3 lb Milk/day @ $14/cwt = | $0.42 |
| 15 g Mepron/day @ $0.01/g = | $0.15 |
| Net return/cow/day | $0.27 |

| Reduced Soybean Meal Cost | |
|---|---|
| 0.72 lb less CP/day (55*0.013) = 1.5 lb SBM (0.72/0.48) | |
| 1.5 lb less SBM/day @ $210/ton = | $0.16 |
| 15 g Mepron/day @ $0.01/g = | $0.15 |
| Net return/cow/day | $0.01 |

# Summary & Conclusions

1. **Optimize Carbohydrate Digestion in Rumen (Grain Processing & Level).**
2. **RDP from True Protein Stimulates Microbial Protein Formation.**
3. **Dietary CP Can be Reduced if Accurately Tracked (16.5% of DM; 17.4 / 16.0% over lactation).**
4. **Feed "Complementary" RUP (Good AA Pattern).**
5. **RP-Methionine Improved Production & Allowed ≥1% Less Dietary CP.**