Getting More from Forages

Targeted plant modifications:

Redesigning forages

Improving protein utilization by ruminants with protein-binding polyphenols

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An Overview of Research on Protein-Binding Polyphenols in Dairy-Forage Systems

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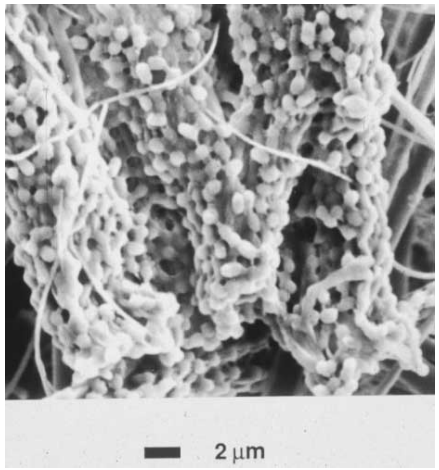
Why incorporate forages with protein-binding polyphenols into dairy-forage systems?

Alfalfa proteins undergo excessive degradation (~80%) during ensiling and rumen fermentation

- Residual membrane proteins are of inferior nutritional value

Although proteolytic products are converted to rumen microbial proteins of high nutritional value, up to one-third of alfalfa protein is ultimately excreted as urea by dairy cattle

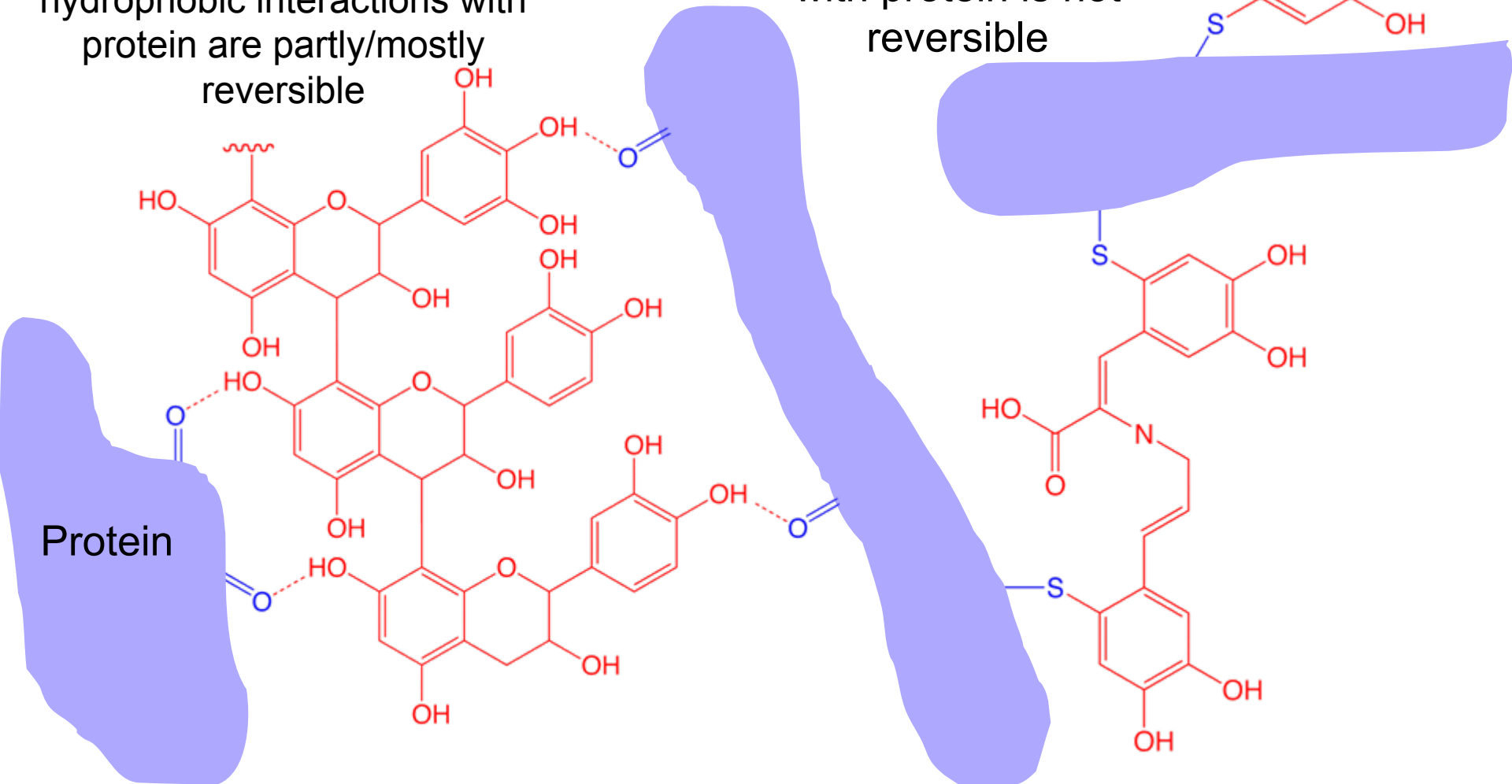
- Urea excretion–metabolic cost
- Ammonia from urea readily lost to the atmosphere
- Farmers often substitute alfalfa with protein sources derived from row crops or feed protein supplements at extra cost

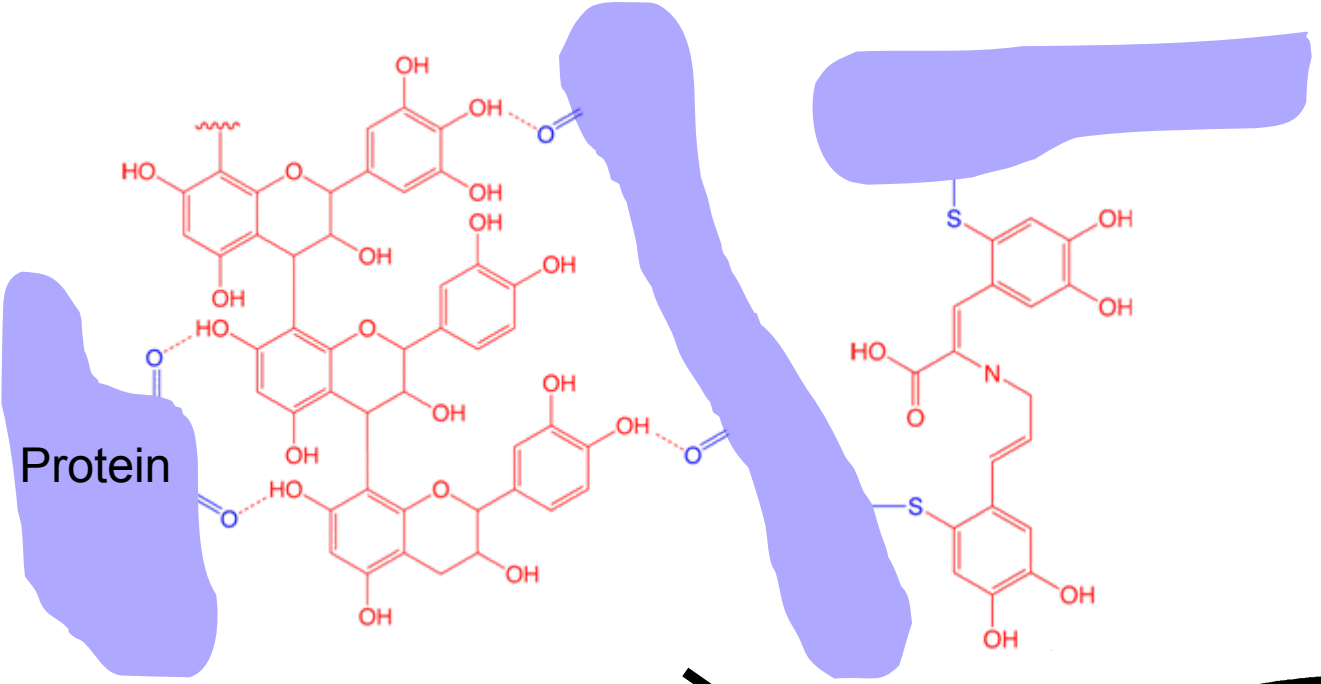


Binding of polyphenols to protein restricts proteolysis in some forages

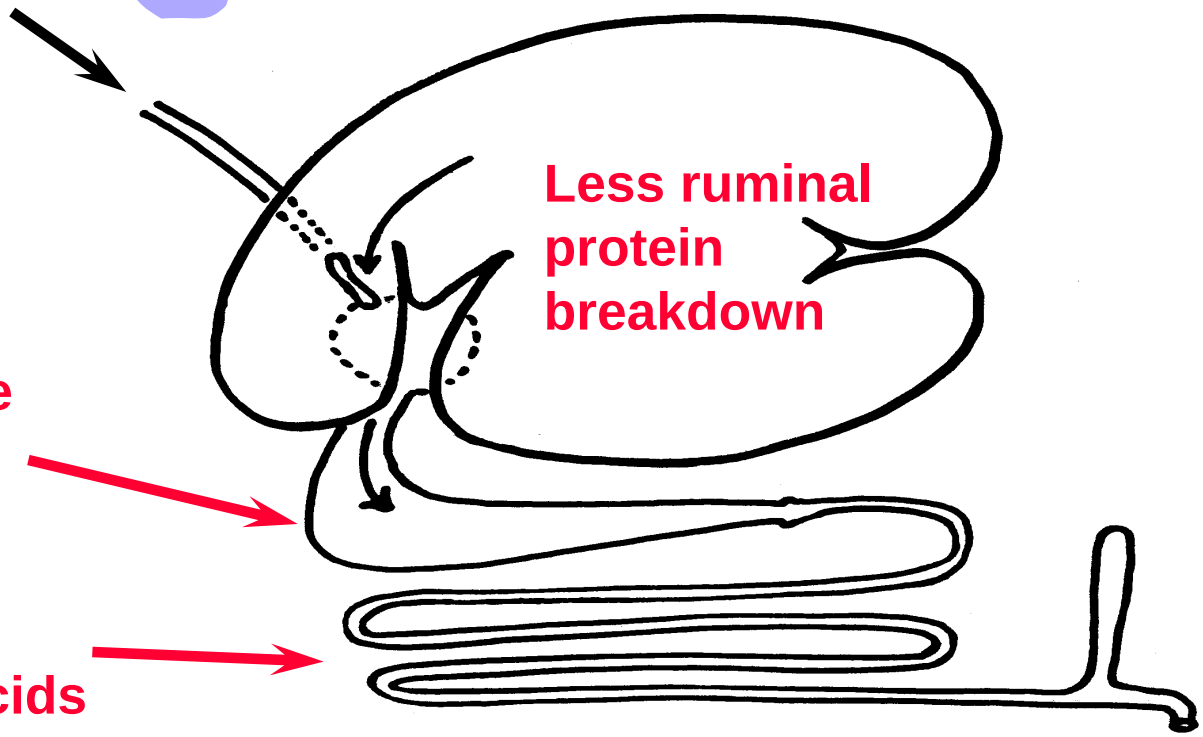
Condensed tannins: hydrogen bonding and hydrophobic interactions with protein are partly/mostly reversible

o-Quinones: covalent bonding with protein is not reversible





Condensed tannins and *o*-quinones can enhance forage protein utilization

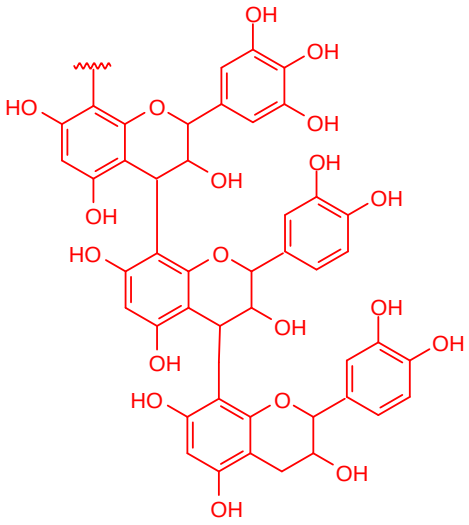


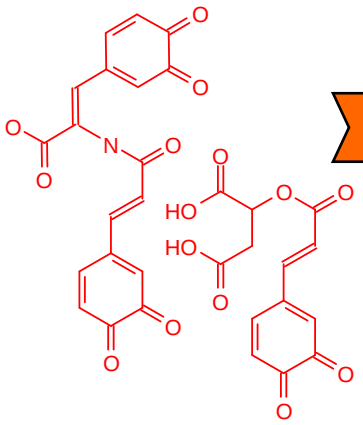
Less ruminal protein breakdown

More plant protein flowing to the gastrointestinal tract

Increased intestinal absorption of amino acids

Expression of condensed tannins or *o*-quinones in alfalfa should enhance protein utilization and profitability and lessen environmental impacts





Comprehensive research on forage polyphenols

- Improve methods for measuring polyphenols and protein degradability
- Assess plant maturity, growth environmental, and conservation method impacts on polyphenols and protein degradability
- Identify optimal concentrations and types of polyphenols for protecting protein while permitting extensive intestinal amino acids absorption
- Evaluate forage polyphenol impacts on milk production by dairy cattle
- Characterize excretion and loss of nitrogen in manure derived from polyphenol-containing diets
- Examine crop use of nitrogen from manure and forage residues containing polyphenols
- Model whole-farm impacts of growing and feeding polyphenol containing forages
- Develop alfalfa with protein-protecting polyphenols (Ron Hatfield's talk!)

Primary goal: Identify optimal characteristics & production systems for polyphenol-containing alfalfa

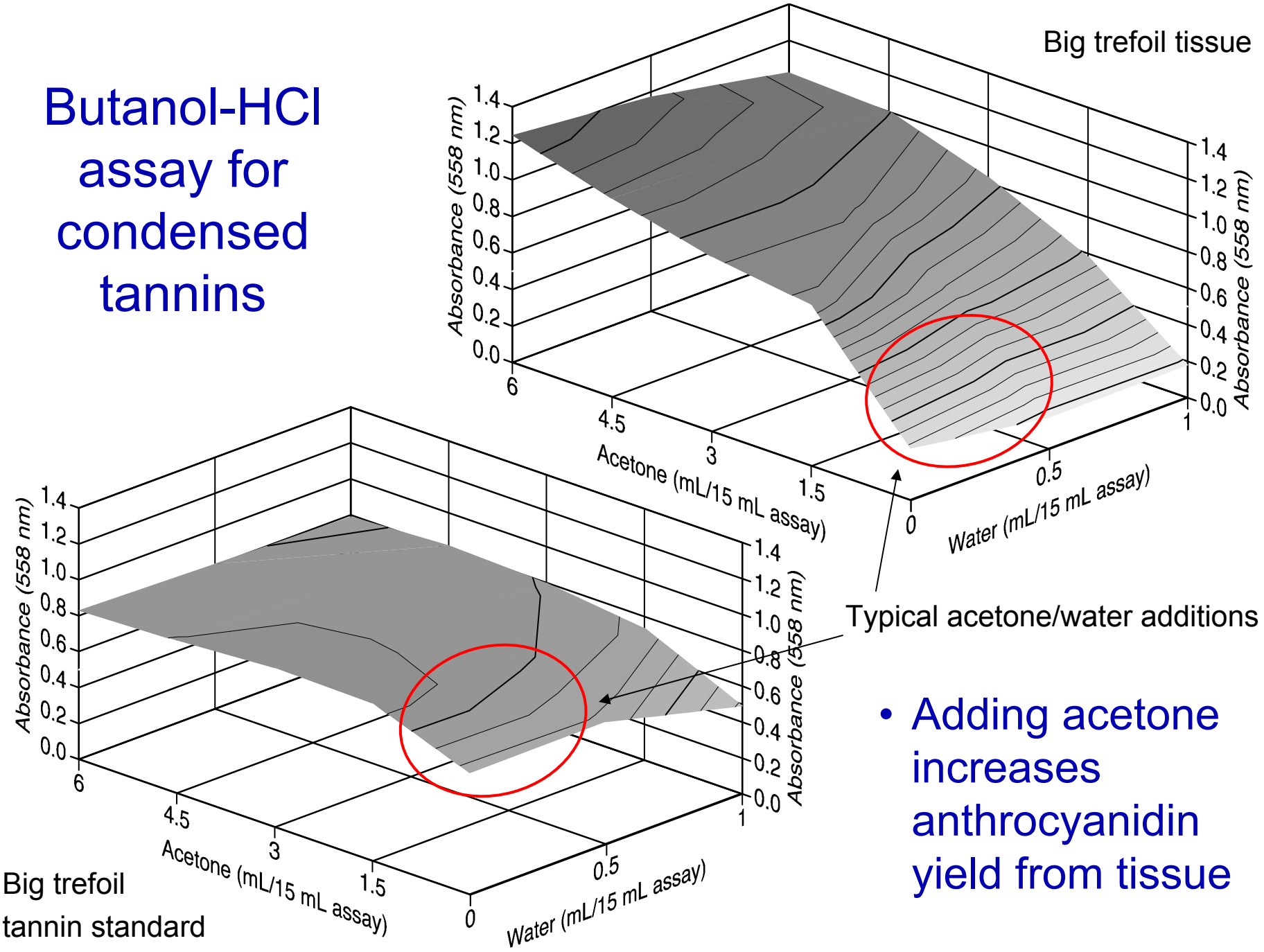
Forages used in polyphenol studies

- Conventional alfalfa essentially free of protein-binding polyphenols
- Birdsfoot trefoil with 0.5 to 40 g/kg total condensed tannins
- Red clover with and without polyphenol oxidase and *o*-diphenol derivatives of caffeic acid
- Condensed-tannin containing big trefoil, sainfoin, crownvetch
- Polyphenol-containing alfalfa (when sufficient quantities available)

Examples of forage polyphenol research

Polyphenol assays

Butanol-HCl assay for condensed tannins



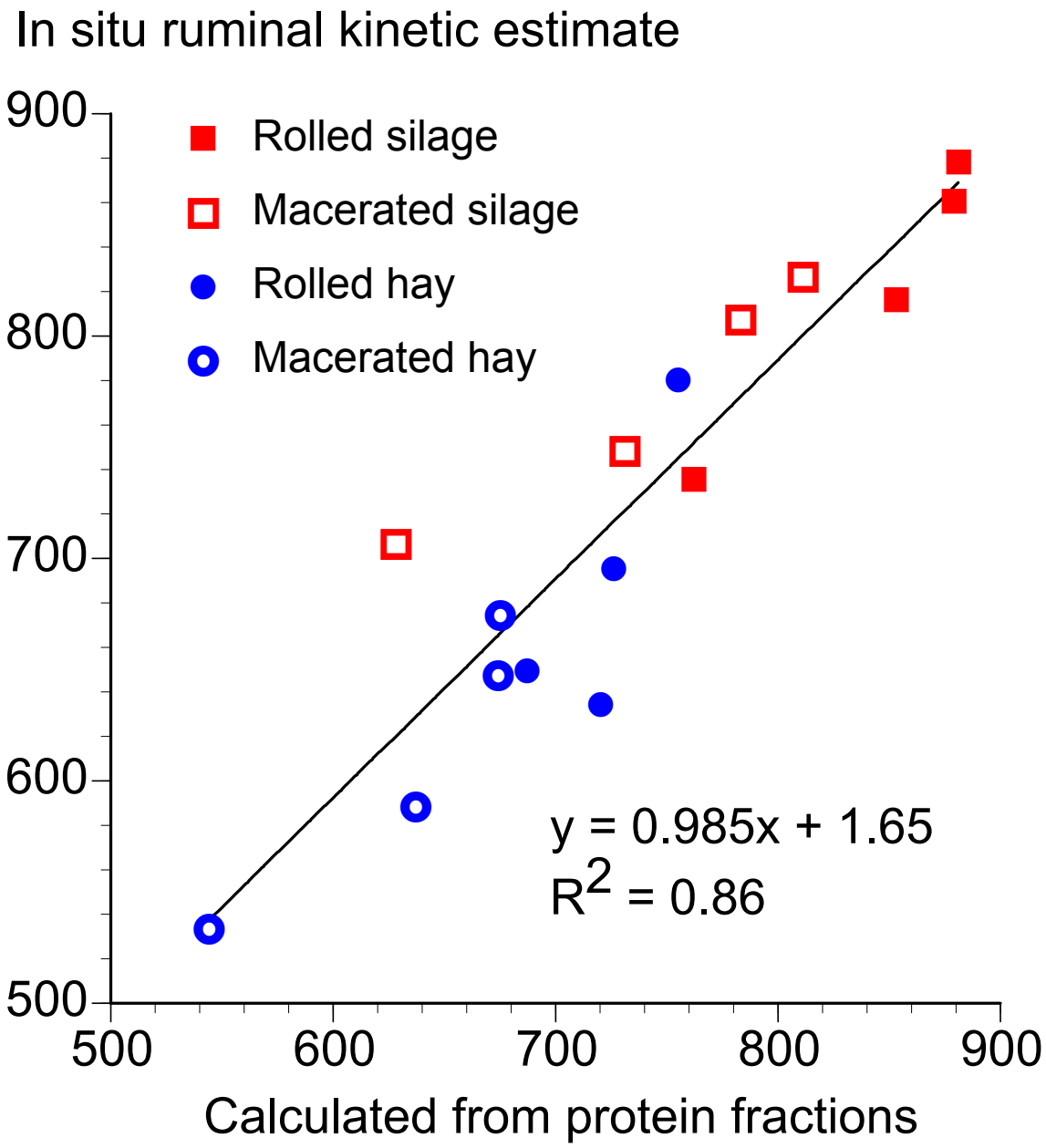
- Adding acetone increases anthrocyanidin yield from tissue

Ruminal protein degradability

Rumen degradable protein:

In situ kinetic vs. calculated (g/kg crude protein)

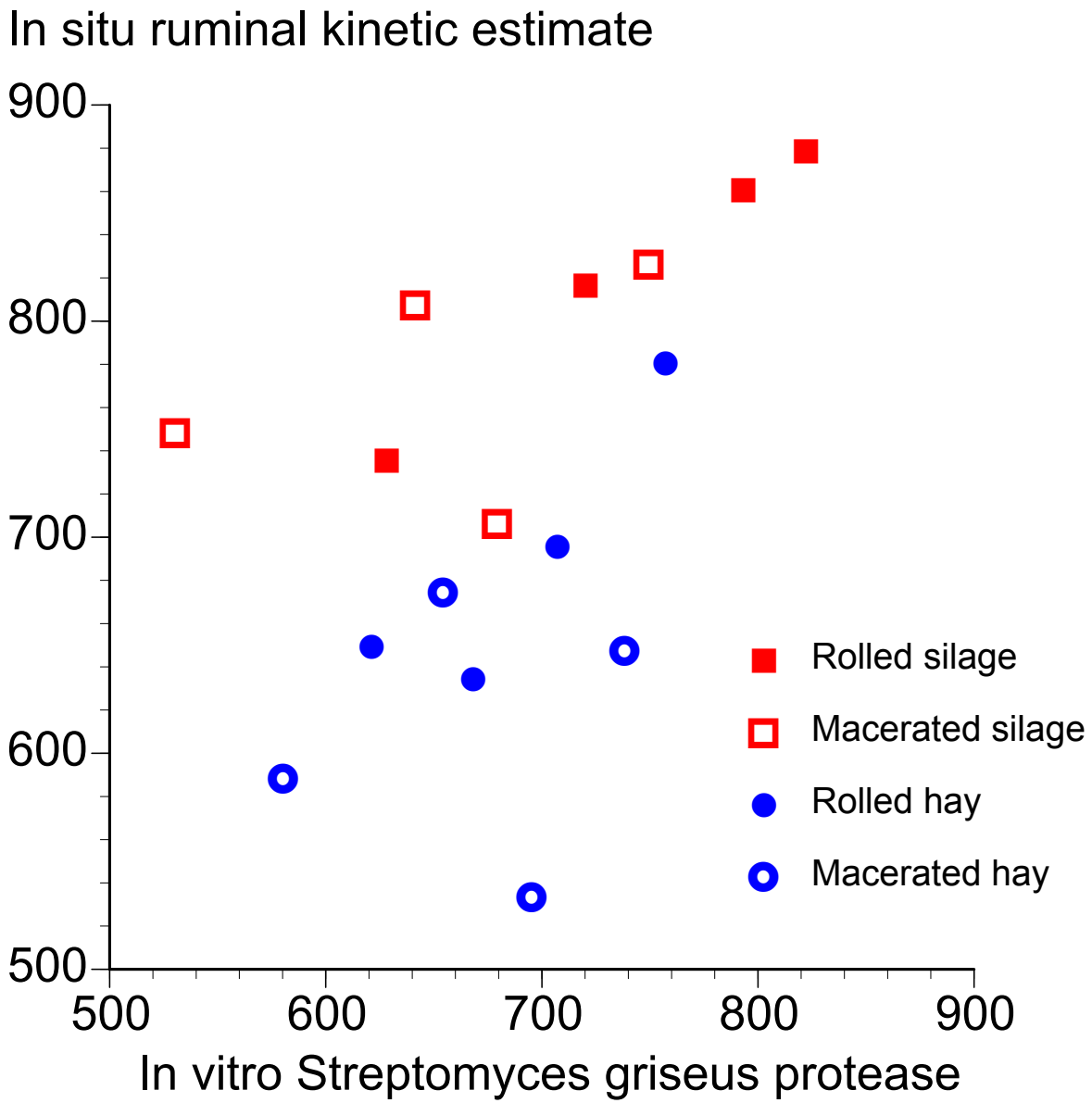
- Good overall relationship with no bias, but…
- Relationship differs between each type of conserved forage
- Adjust degradation rates for B2 and B3 proteins?



Rumen degradable protein:

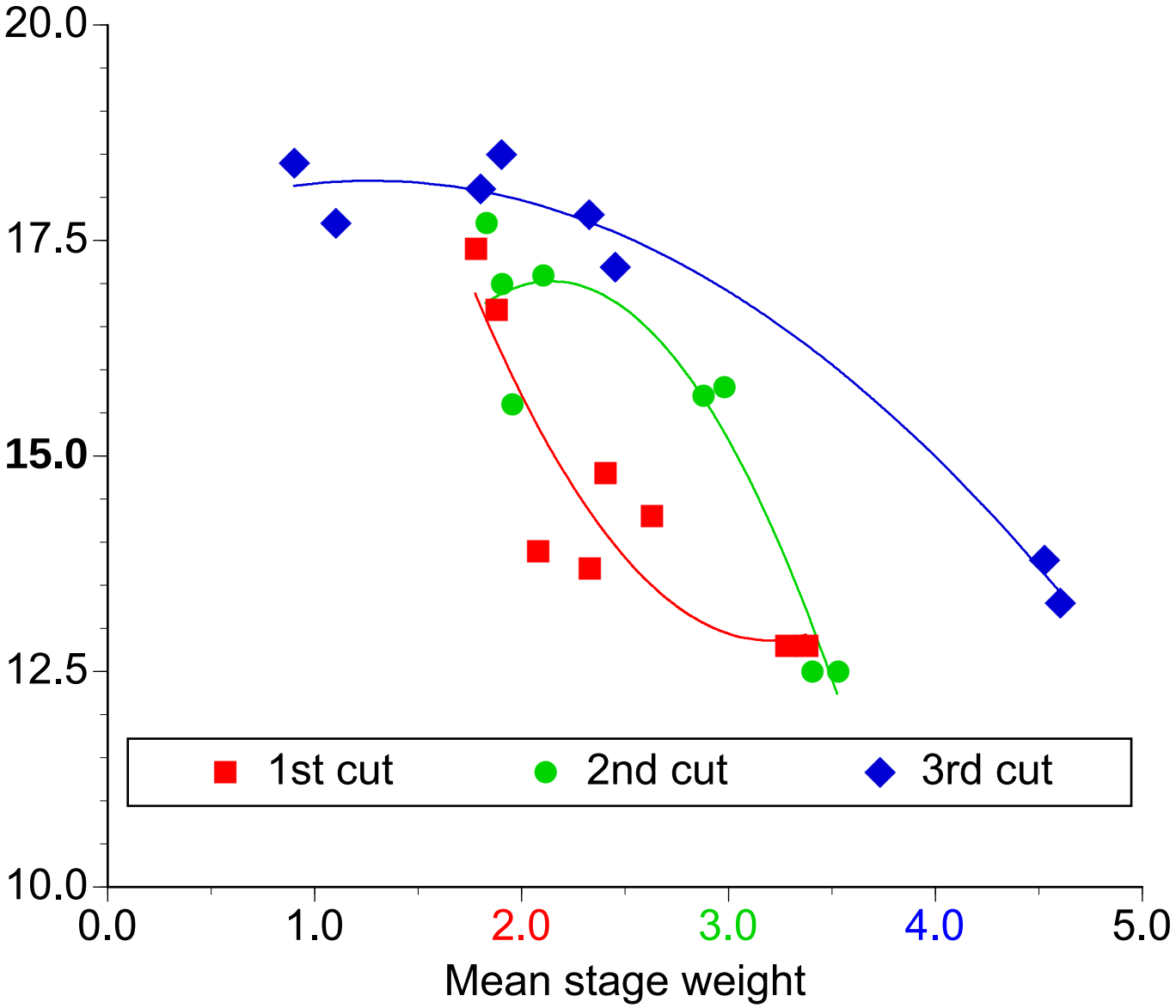
In situ kinetic vs. protease (g/kg crude protein)

- Poor overall relationship, especially for macerated forages



Plant maturity and environmental influences

Rumen degradable protein in red clover (% dry matter)



Cut 1 Vegetative

Cut 2 Early bud

Cut 3 Late bud

Forage conditioning and conservation effects

In situ rumen degradable protein

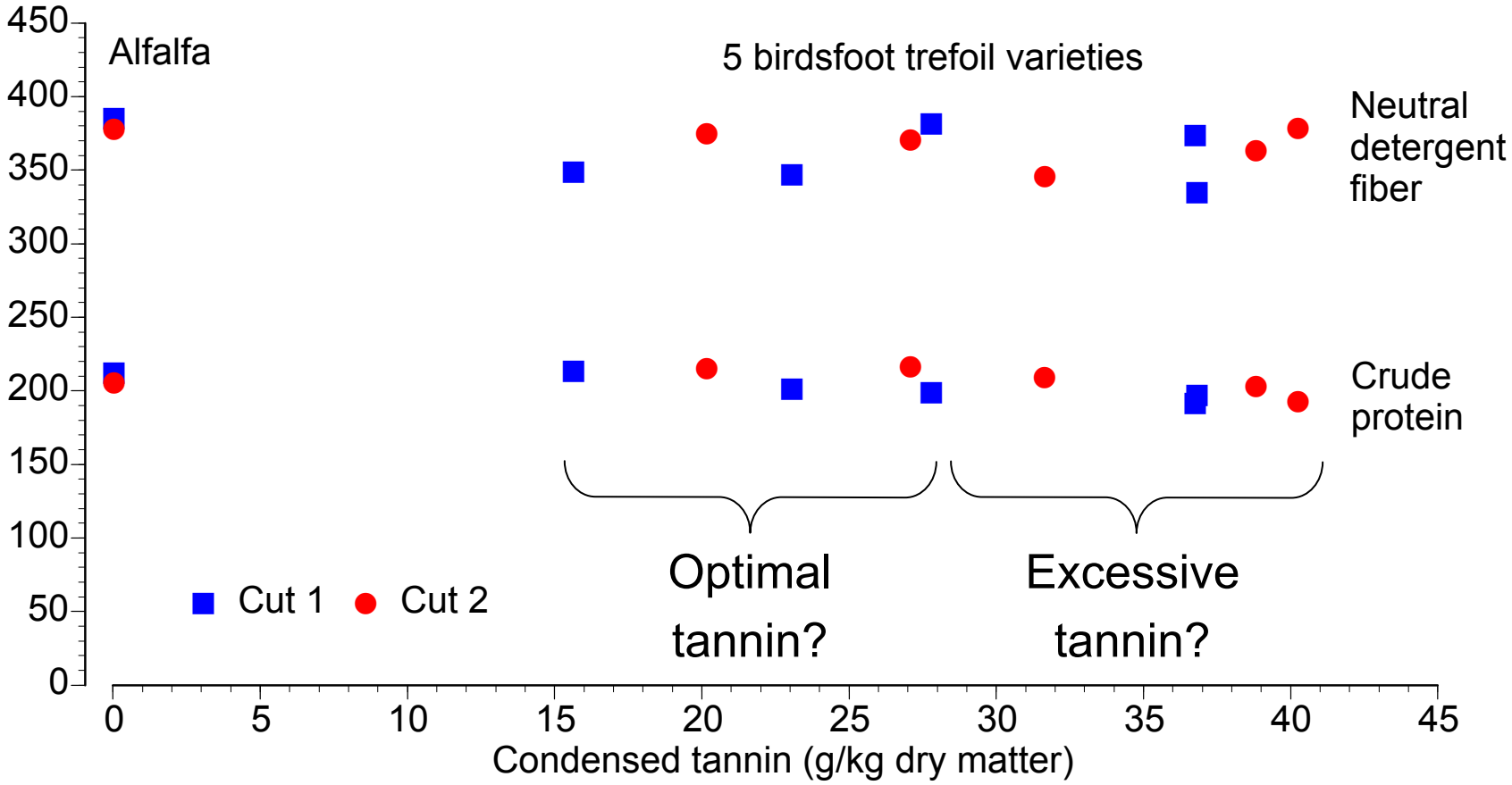
(0.06 per h passage rate)

	Alfalfa	Low tannin trefoil	High tannin trefoil	Red clover
Hay				
Rolled	781^{a}	696^{ab}	635^{b}	650^{b}
Macerated	648^{ab}	675^{a}	589^{bc}	534^{c}
Silage				
Rolled	879^{a}	861^{a}	817^{b}	736^{c}
Macerated	827^{a}	808^{a}	749^{b}	707^{c}

Means within rows with unlike letters differ ($P < 0.05$).

- In both hays and silages, red clover with *o*-quinones ≤ High tannin trefoil < Alfalfa
- Macerated < Roll conditioned
- Polyphenol–protein interactions not enhanced by maceration

Optimal vs. excessive protein protection



Use trefoils with 15 to 40 g/kg tannin, but similar protein and fiber

- Ruminal degradability: In situ kinetics, single time-point in situ, in vitro protease, inhibitor in vitro with rumen bacteria
- Intestinal degradability: In situ mobile bag, in vitro pepsin-pancreatin, acid detergent insoluble protein
- Intestinal availability: protein degraded vs. available amino acids

Impacts on milk production

	Milk (kg/day)	Protein (%)	Fat (%)
Alfalfa	30.2[c]	3.16	3.77
Red clover with *o*-quinones	31.1[c]	3.02	3.71
Birdsfoot trefoil			
8 g/kg tannin	32.9[b]	3.18	3.64
12 g/kg tannin	34.6[a]	3.16	3.80
16 g/kg tannin	34.3[a]	3.14	3.62
Tannin impact	+1.7 to 4.4	None	None

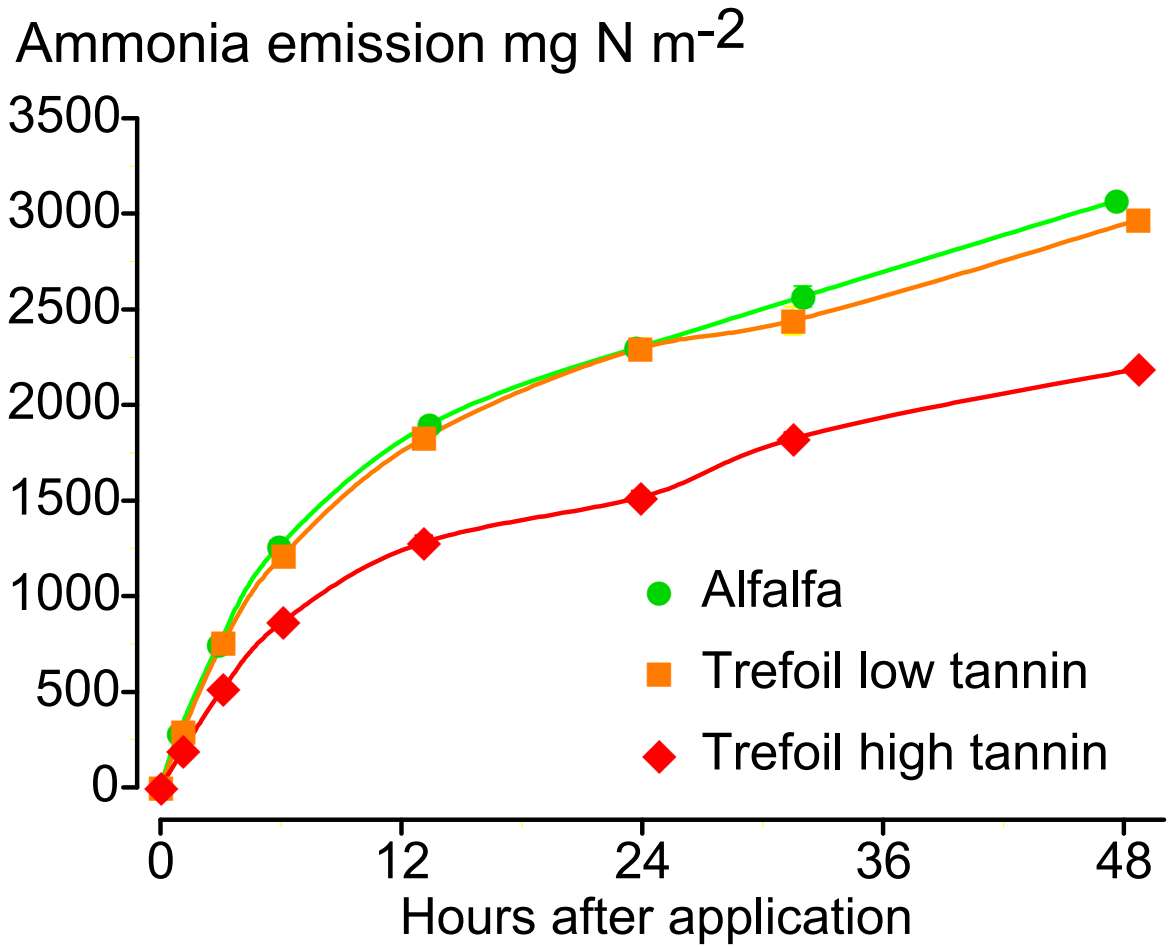
Means within rows with unlike letters differ ($P < 0.05$).

- Forage type did not affect intake of total mixed rations containing ~17.5% crude protein and ~28% neutral detergent fiber
- As in previous trials, *o*-quinones in red clover did not enhance milk yields–over protection of protein?
- Tannin in trefoil increased milk yields–observed in some but not all trials

Data from Hymes-Fecht et al.

Nitrogen excretion and losses from manure

Ammonia emission from manure slurry applied to soil



Polyphenols shift nitrogen excretion from urea in urine to more stable fecal nitrogen forms

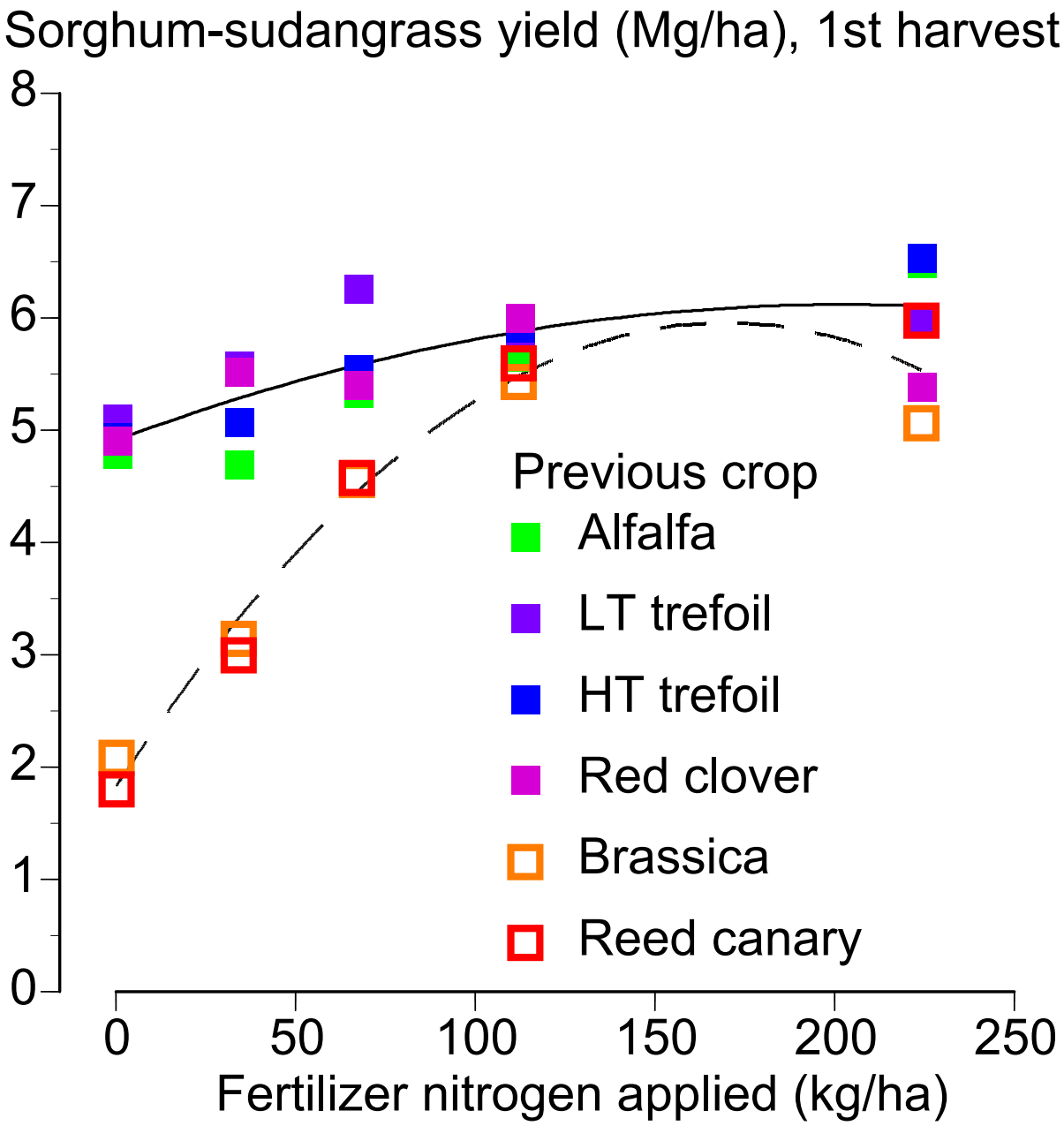
- Ammonia emission is lower from polyphenol containing diets

Data from Misselbrook et al.

Nitrogen use and growth of crops

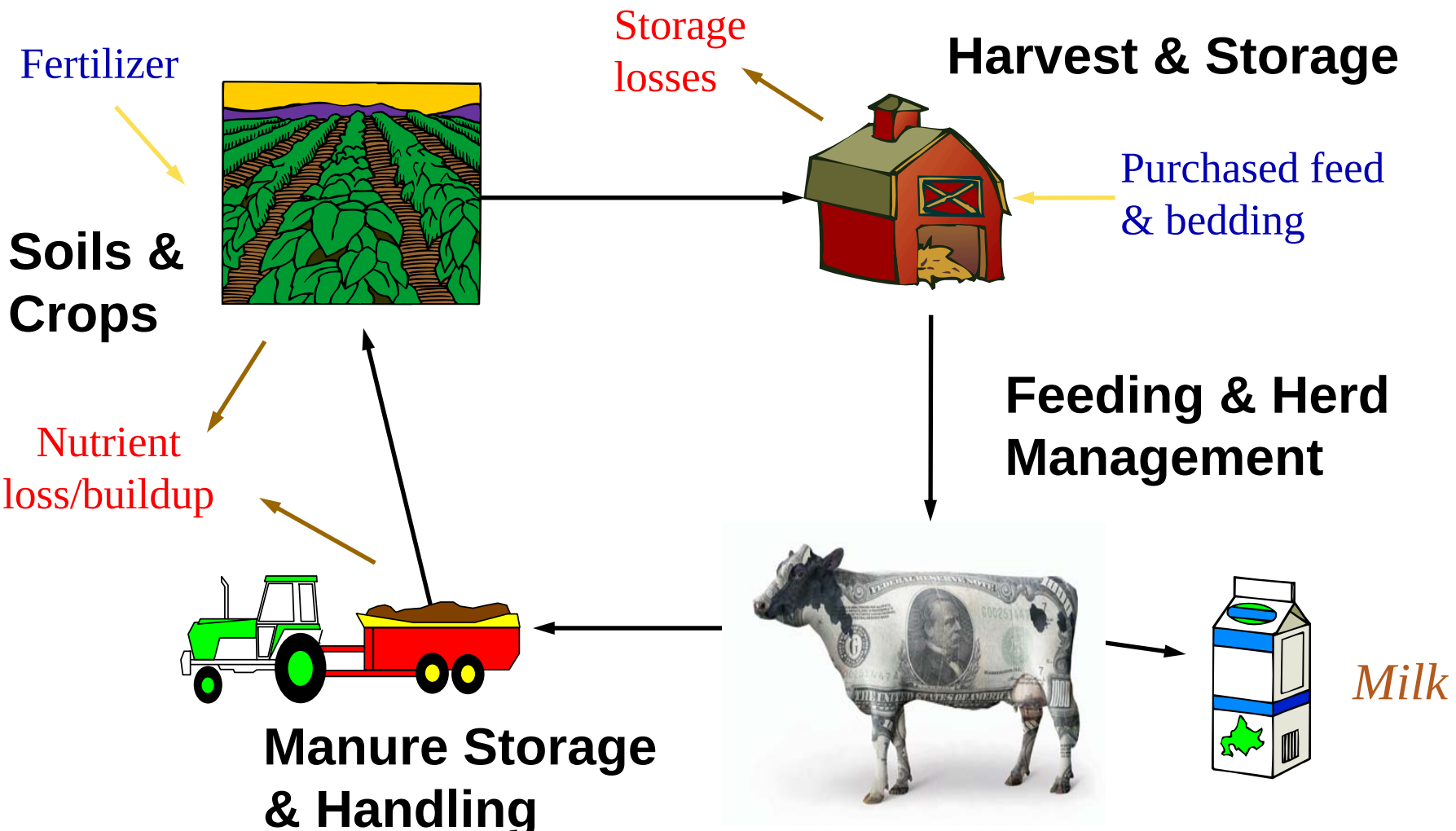
Yield response of annual grass crops to nitrogen from polyphenol containing forages

- Polyphenols delay the soil mineralization of nitrogen from legume tops and roots, but yields are usually not influenced



Whole-farm impacts

Model impact of polyphenol-containing alfalfa on dairy farm (e.g Integrated Farm System model)



Predicted performance if alfalfa fed as 45% of diet

	Net return $/cow	Milk yield kg/cow	Soybean fed kg/cow	Corn fed kg/cow	Total N loss kg/cow
Normal alfalfa	1145	12330	1026	2433	157
Tannin alfalfa	1270	12540	436	3060	118
Tannin impact	+125	+210	-590	+627	-39