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Summary: Lower Dietary Phosphorus Levels Are Economically and Environmentally Beneficial

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Traditionally, high levels of dietary phosphorus (0.45-0.50 percent) were utilized in an effort to increase the reproductive efficiency of dairy cattle. Recent studies have shown that there is limited, if any, correlation between high dietary phosphorus (P) levels and reproductive efficiency. The over-feeding of dietary P is costly and contributes to environmental concerns of P build-up in the soil and contamination of water from fields and feedlot run-off. Utilizing diets with less P (0.35 percent) has no significant effect on reproductive efficiency or production.

A direct correlation does exist between the amount of dietary P fed to dairy cattle and the amount of P excreted in the feces. Any dietary P fed in excess of the requirements for dairy cattle does not boost reproduction but is eliminated as waste. Since the phosphorus to nitrogen (P:N) ratio in manure is greater than that needed by crops, manure spread according to nitrogen content results in a build-up of phosphorus in the soil. This can result in local surface water contamination when run-off or erosion occurs, or in ground water contamination through leaching. Application of manure based on phosphorus content increases the land area required for manure application and reduces the benefits gained from the application of nitrogen.

National Research Council Recommendations for Dietary Phosphorus

The National Research Council (NRC) in 2001 recommended that dairy cow rations have a maximum of 0.42 percent P, with average levels between 0.32 to 0.36 percent for optimal reproduction and milk production (NRC, 2001). Previously nutritionists and producers have overfed P to provide a "safety net" due to low bioavailability of P in feedstuffs (Shaver and Howard, 1995). Producers have historically fed an average of 0.48 percent with some herds receiving up to 0.60 percent. Excess dietary P fed to dairy cattle is excreted in the feces. Feeding excess dietary P costs $8 to $15 per cow annually (Gamroth et al., 2006). With 84,000 milking cows in Utah, this costs Utah dairy producers up to $1.26 million per year (National Agricultural Statistics, 2009).

Effect of Phosphorus on Milk Production, Reproduction, and Fecal Excretion

Milk Production

In a study conducted in 1999, milk production was analyzed for 26 lactating dairy cows being fed varying rates of dietary P as monosodium phosphate (Wu et al., 2000). Table 1 illustrates the differences in milk production under the different P rates (0.31, 0.40, and 0.49 percent of DMI). Averaged over the entire lactation, there were no significant statistical differences among the groups. Milk production in the group fed 0.31 percent P averaged 77.1 lb/day over the 40 week lactation. Cows in this group excreted more dietary P than they were receiving during early lactation, through the 7th week. However, during the last weeks of lactation a positive P balance was noted; suggesting that lactating cows can mobilize and restore larger amounts of P than previously thought (Wu et al., 2000). The group of cows fed the most dietary P (0.49 percent) failed to perform above the other groups fed lower P levels and showed a slight decrease in milk production of 0.7 lb/d compared to the 0.40 percent group. Additional studies have shown that an increase in dietary P can actually decrease overall milk production. Several of these studies are summarized in Table 2.

Table 1. Milk production performance of cows fed diets differing in P content (modified from Wu et al., 2000).

Performance of 26 cows fed diets differing in P content				
	Treatment			
Item	**0.31% P**	**0.40% P**	**0.49% P**	**P>0.10**
Dry Matter Intake, lb/d	50.7	49.4	51.6	NS[3]
Milk Produced, lb/308-d	23,788	24,749	24,546	NS
Milk Produced, lb/d	77.1	80.5	79.8	NS
3.5% FCM[1], lb/d	80.3	82.7	83.5	NS
Milk Fat %	3.66	3.69	3.71	NS
Milk Fat lb/d	2.932	2.963	2.972	NS
Milk Protein %	3.14	3.07	3.11	NS
Milk Protein lb/d	2.487	2.423	2.476	NS
Body Condition Score [2]- Initial	3.31	3.5	3.47	NS
Body Condition Score - Ending	3.53	3.94	3.75	NS
Change	0.22	0.44	0.28	NS

[1] 3.5% Fat content adjusted
[2] Body condition score (thin=1 to fat=5)
[3] NS – no significant difference

Table 2. Milk production responses to diet P concentrations, a summary of feeding trials and literature data (modified from Dou et al., 2002).

	Dietary P Groups				Milk Production					
	A	B	C	D	A	B	C	D		
	Percent of DMI				lb per day					
Trial Features	(<0.35)	(0.35 – 0.40)	(>0.41)	(>0.52)					Significance	Reference
4 cows per treatment, 11 wk early lactation	0.34	--	0.51	0.68	109.1	--	105.4	101.0	NS	Knowlton and Herbein, 2002
10 cows per treatment, 2-3 year	0.31	0.39	0.48	--	93.1 (a)	85.3 (b)	86.9 (ab)	--	*	Wu et al., 2001
6 cows per treatment, one complete lactation	--	0.37	0.48	--	--	76.9	76.7	--	NS	Kohn, unpublished data, 2001
8 cows per treatment, one complete lactation	0.31	0.40	0.49	--	77.2	80.5	79.8	--	NS	Wu et al., 2000
26 cows per treatment, two lactations	0.33	0.39	--	--	56.0	54.0	--	--	NS	Brintrup et al., 1993
23 cows per treatment, 12 wk mid lactation	--	0.39	--	0.65	--	52.7	--	53.8	NS	Satter and Wu, 1999

Data cited here are for one of several sampling periods. For the study details, refer to the original publications.
*Different letters within trials indicate significant differences (α=0.05), NS – no significant difference

Reproductive Performance

As illustrated in Table 3 there is relatively little difference in reproductive performance between the groups of cows fed different P concentrations. Table 3 is taken from a study involving two groups of cattle each being fed the NRC recommended amount of P (0.37 percent) or an excess amount of P (0.57 percent) (Lopez et al., 2004). Cows fed excess P exhibited similar performance for several reproductive traits. Higher

reproductive performance was not observed when dairy cows were fed higher dietary P (0.57 percent). Additionally, data from Wu et al., 2000, indicate that reproductive performance is not impaired at diets of 0.31 percent P.

Table 3. Reproductive parameters of dairy cows fed different dietary P levels (modified from Lopez et al., 2004).

Reproductive parameters (mean ± standard error) for cows fed diets containing recommended (0.37%) or excess (0.57%) P.

Reproductive Parameter	0.37% P	0.57% P	Significance[2]
Overall conception rate at 60 d[1],%	29.1	31.8	NS
Pregnancies lost 30 to 60 d, %	15.2	16.2	NS
Pregnancies lost after 60 d, %	7.1	7.5	NS
Days open for pregnant cows	112 ± 3.5	116 ± 3.8	NS
Gestation length, d	279	279	NS
Multiple ovulation rate, %	21.6	19.5	NS

[1]Number of pregnancies detected at 60 d divided by the total number of services.
[2]NS – no significant difference

Fecal Excretion

Table 4 illustrates the effect of overfeeding P to dairy cows and the concentration of P in manure (Powell and Satter, 2008). As the percent of dietary P increases, the amount of P excreted in manure and the land area required to properly utilize the P increases exponentiall

Table 4. Fecal excretion of P with different dietary P levels (modified from Powell and Satter, 2008).

Amount of P fed and excreted by one lactating cow producing 20,000 lbs milk in 305 days, and the amount of land required to effectively use manure P.			
Dietary P	**Manure P**	**Land area needed to recycle manure P**	**Increase in land area needed**
%	**(lbs/lactation)**	**(acres)**	**%**
0.35	34.8	1.3	Base
0.40	42.3	1.6	23
0.48	54.5	2.0	53
0.55	60.0	2.4	83

Environmental Effects of Excess Phosphorus in Manure

Environmental concerns of manure application pertain mainly to a buildup of soil P levels, nutrient run-off, and nutrient deposition in surface water (Hatfield, 2004). Excess P in surface waters causes overproduction of algae and aquatic vegetation, restricting available dissolved oxygen and leading to premature eutrophication. The United States Environmental Protection Agency considers 0.05 mg P/L in lakes, and 0.10 mg P/L in streams to be the critical P level at which degradation will occur. In Utah, many water bodies are identified as impaired and are consequently regulated specifically for P level.

Broadcasting manure on soil or on frozen ground provides the highest potential for surface run-off contamination, especially when rain occurs shortly afterwards or snow melt carries manure off farm fields and into nearby surface water. Good practices are those

that reduce soil erosion and precisely supply dietary P, not oversupply P. Both actions work toward keeping P out of waterways and available to crops. Further information on best management practices to reduce soil erosion is available at your local NRCS office.

Recommendations to Dairy Producers

For high producing cows, 0.33-0.40 percent dietary P is recommended for optimal reproduction and milk production. This concentration of dietary P can be obtained with minimal or no supplementation depending on feed ration ingredients. Feeding the previously recommended levels of 0.48 percent or greater dietary P is unnecessary (Wu et al., 2000). Feeding P closer to animal nutrient requirements has been shown to reduce manure P concentrations and P surpluses on farms with no adverse affects on animal health or performance (Toor et al., 2005). The reduction of phosphorus in the diet of dairy cattle will in turn reduce the excretion of P in the manure and the build-up of P in the soil and water. In addition, reduction of dietary P has saved U.S. dairy farmers $30-35 million annually and has the potential to save dairy farmers another $65-70 million (Powell and Satter, 2008).

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