



Animal Nutrition Association of Canada

What are the Consequences to Defining the Minimum  
Levels of Phosphorus in Animal Diets?

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*November 15, 2010*



## SUMMARY

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There are estimates that 80% of the finite inorganic phosphorus (90% utilized in food production) is wasted and contributes to eutrophication of our water sources. Research has demonstrated that by both reducing the amount of phosphorus in animal diets and increasing its bioavailability that phosphorus excretion by farm animals can be decreased by >50%. A significant concern for the feed industry in Canada is that CFIA has directed minimum phosphorus levels in the feed. The consequence of this is that hundreds of tonnes of excessive phosphorus are being excreted and it discounts the incentive to industry to increase bioavailability of phosphorus and reduce inorganic phosphorus use. In fact, it forces the industry to be less sustainable. We have not found any reference to other countries defining the minimum phosphorus use in diets; however, we have found many references defining use of lower levels of phosphorus.

## REVIEW

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Phosphorus is one of the key elements in the food chain and essential to plants, microorganisms and animals. In animals, phosphorus is found throughout the body; approximately 85% of the total phosphorus is in the skeleton. This store of phosphorus in the skeletal system provides a basis for the body to regulate phosphorus and long-term disruption of phosphorus intake will result in skeletal disease. Actual phosphorus requirements are dependent on species, age, level of production and environmental conditions (e.g., heat stress). There are estimates that demand for phosphorus (90% is for food production) will surpass supply of known phosphate rock reserves in the near future (~2035; Cordell, 2010). There has been a significant impact on availability and price of phosphorus due to the increase in biofuel production (conversion of grain into ethanol to supplement oil-based fuels) that has increased demands for fertilizer. As a consequence, the sources of phosphorus for the feed industry are directly impacted and four to eight -fold increases in phosphorus prices have been experienced over the last three years.

Dietary phosphorus that is not retained by the animal is excreted. Manure from our animals is a valuable source of fertilizer but needs to be carefully managed to prevent it from entering water systems. The amount of phosphorus in water is an environmental concern as this leads to eutrophication (“over fertilization of waterways”) and algae growth – defined typically as overt pollution. Cordell (2010) reported that approximately 80% of the phosphorus actually used in food production never actually is consumed by humans, and that a large percentage of this enters our waterways. Research such as Cordell’s indicates that there are significant system inefficiencies that require careful thought and examination of all aspects of phosphorus utilization.

In livestock diet formulation, our goal is to balance nutrient (phosphorus) intake to meet the requirement of the animal, typically with a “safety margin”. In the case of phosphorus, the safety margin will depend on factors such as:

- interactions between phosphorus and other nutrients;
- variation in bioavailability of phosphorus from the diet (e.g., inorganic or available vs. phytate phosphorus);
- variation in requirements of individual animals and;
- mistakes in formulation and distribution of diets.

These same factors are important in interpreting book values for nutrient requirements, these are estimates based on studies using small numbers of animals and many of the original studies were conducted with commercial animals that do not resemble today’s high performing animals. Leeson (2007) indicated that nutrient requirements of today’s high performing animals must increase in order to meet requirements, particularly when less feed (improved feed efficiency) is actually being consumed per unit of gain or output (e.g. milk or eggs). However, in practice, diet formulations have not changed significantly; and in some instances as for phosphorus, genetic potential is achieved with significantly less dietary phosphorus than is recommended. Arguments based on book values are not valid for today’s animals; however, these values are effective guidelines to build databases using epidemiological (field and research trials) data.

The above has highlighted that there are three key dietary phosphorus issues facing the animal industry:

Price of phosphorus input has increased dramatically and is predicted to remain high due to demand as well as recognition of future limits in supply.

The efficiency of utilization of phosphorus in our food system is low and as a consequence, 80% of the phosphorus we use in food production is not consumed in food.

Phosphorus losses in the food production system can cause serious water pollution (it is estimated that water demand for food production is or will shortly surpass potable water supply; Cordell, 2010).

Augsburger and Baker (2008) indicated that a majority of all dietary supplements of phosphorus in the animal industry are used by swine and poultry, and poultry consume in excess of 50% of all supplemented inorganic phosphorus. Depending on the age and production rate, phosphorus requirements can vary from 0.25 to 0.60% in poultry and 0.15 to 0.55% in swine. These requirements must be met with sources of phosphorus from the diet. Dietary phosphorus must be bioavailable and the animal must be capable of absorbing them, distributing them to where they are required and maintain that balance precisely. Otherwise, the excess phosphorus is excreted; and in the cases of some deficiencies of other nutrients, such as calcium, the redistribution of calcium from bone may actually exacerbate phosphorus excretion.

The major portion of animal diet is based on grain and oilseed protein meals, and the bioavailability of phosphorus in these dietary components is low (approximately 2/3 of phosphorus is bound to phytate). Historically, diets were balanced for estimated phosphorus requirements by supplementing diets with mined phosphate sources (85 to 100% bioavailable phosphorus).

There are three main dietary sources of rock phosphate:

1. dicalcium phosphate (33% calcium: 18.5% phosphorus) used typically in swine and laying hen diets;
2. deflorinated rock phosphate (33:18) mostly used in diets fed to meat poultry and as a pellet binder; and
3. monocalcium phosphate (16:21) used for ruminants and often the phosphate of choice in pre-mixes designed to provide phosphorus.

On an industry wide basis, the sources of rock phosphate are respectively used are 40, 30 and 30% for dicalcium, deflorinated and monocalcium phosphate. Other ingredients in the diet that can contribute high amounts of bioavailable phosphorus are meat and bone meal (may be variable due to variation in bone included) and dried distillers grains with solubles (DDGS; a consequence of fermentation during ethanol production releasing phytate phosphorus – similar to what happens in ruminants). Meat and bone meals from ruminants are prohibited in all diets in the EU; however, the destruction of this valuable nutrient source is being reconsidered.

Poulsen et al. (1999) estimated that excretion of phosphorus in pigs could vary from 50 to 70% of the phosphorus consumed as a consequence of low digestibility (retention) and/or over supplementation of the diets with phosphorus. Similar dramatic reductions in phosphorus excretion have been reported in poultry based on both reductions in use of expensive inorganic phosphorus and better utilization of phytate phosphorus by using exogenous phytase (Selle and Ravindran, 2007). There is also recognition that endogenous phytase from seeds can also contribute to increasing bioavailability of phosphorus in the diet; however, this source is variable and its bioactivity is reduced during typical processing conditions.

In order to reduce the excretion of phosphorus in manure and reduce inputs of phosphorus (cost) the industry has developed applications of enzymes to hydrolyze phytate and increase bioavailability of phosphorus. An international phytase summit was recently (October, 2010) held in Washington DC. One of the conference organizers (M Bedford, interviewed by FeedInfo) estimated that phytase saves the world feed industry \$2B USD/yr and that this could be doubled by extending phytase applications. With respect to enzyme supplementation, phytase accounts for the majority of feed enzymes and its usage is expected to increase three-fold. Phytase applications are also associated with reducing the antinutritional impact of phytate on other minerals (calcium, zinc, iron) as well as amino acids and starch. For an extensive discussion on the use of phytase in animal nutrition, the proceedings of the summit can be accessed at <http://www.ips2010.com/>. Selle and Ravindran (2007) estimate due to the short transit time and low exposure to optimum pH in the gut of broilers that phytase may only have time to hydrolyze approximately 1/3 of phytate phosphorus. As a consequence further research is being conducted to improve the release of phosphorus from phytate, particularly in poultry.

Research on the use of phytase has highlighted that negative effects of phytase application can be extensive and costly (Coweison, 2010; personal communication). In order to avoid this, diets must be carefully formulated to provide optimal calcium: Phosphorus balance, correct levels of sodium and that assessments of dietary phytate would be beneficial. There is some controversy with respect to the health benefits of total elimination of phytate from our diets and the diets of our animals. Phytate is considered a potent antioxidant and may be important sink for reactive oxygen (or nitrogen) species produced during oxidative stress.

Based on personal experience, as the global director of poultry research for Provimi (one of the world's major suppliers of vitamin and mineral premixes and complete diets (estimate 7-8% of all domestic animals are fed diets containing Provimi products)), there are marked differences in nutritionists' use of phosphorus. In 2008 we surveyed Provimi nutritionists from 30 countries and developed recommendations for adapting dietary phosphorus based on field and in-house research experiences and usage of enzymes. As expected, the Dutch nutritionists used the least amount of phosphorus - a direct consequence of years of compliance with strict regulations on manure applications to land.

In comparison to CFIA minimum standards, the Dutch diets contained significantly lower phosphorus levels, particularly for swine. Based on Canadian broiler (600 M birds/yr), layer (19 M birds/yr) and grow/finish pigs (30 M animals /yr) stocks, the reductions in dietary phosphorus consumed when diets were formulated to contain different levels of phosphorus were calculated (Table 1).

The different levels of phosphorus were based on:

- CFIA's minimum total phosphorus for diets;
- a typical Dutch diet without or with phytase; and
- an estimate of what savings could be achieved if the CFIA levels were reduced by 0.1%.

A 0.1% reduction in phosphorus is recognized as the minimum most nutritionists expect from phytase hydrolysis of phytate (Bedford, 2010; personal communication). It is evident that the Dutch are recognizing considerable reductions in dietary phosphorus compared to the CFIA minimum. This achievement is even more extensive in pigs as compared to laying hens or broilers.

**Table 1.** Estimates of total dietary phosphorus consumed in diets if diets were formulated to meet CFIA's minimum P values, an estimate based on typical Dutch diets without or with phytase and the CFIA minimum value reduced by 0.1% (0.1 % is estimated as the expected contribution of P from diet through phytase activity).

Animal Class	Dietary Phosphorus Consumed (MT) based on different dietary requirements (MT P difference from CFIA Table 4 values)			
	CFIA Minimum P % Table 4, February 2010	Typical Dutch diets	Typical Dutch diets + Phytase	CFIA Minimum + Phytase (0.1%)
Broilers 600M/yr 2.2kg (4.0 kg feed)	1008	860 (148; 14.6%)	834 (174; 17.3%)	768 (240)
Laying Hens 19M/yr 0 to 72 wks of age (47kg diet)	345	268 (57; 16.5%)	275 (70; 20.3%)	259 (86)
Grow/Finish Pigs 30M/yr 0 to 160kg (350kg diet)	4137	1728 (2408; 58.2%)	1663 (2474; 59.8%)	3323 (815)
Total Phosphorus in above diets	5490	2856	2772	4350
Percent reduction compared to CFIA minimum		48.0%	49.5%	20.8%

The phosphorus of Dutch diets for broilers, laying hens and grow/finisher pigs is less than that utilized in Canada. Based on that example there are 148 MT less phosphorus used for the production of 600M broilers consuming 4.0kg feed each per year. This is equivalent to 14.6% less phosphorus if Dutch standards were applied (without phytase). When phytase is used in typical Dutch diets the levels of phosphorus are further reduced (174 MT; 17.3% less than based on the minimum CFIA levels).

The last column in Table 1 illustrates the expected phosphorus utilizations for the respective species if the CFIA minimum was removed and the industry was able to formulate for 0.1% less phosphorus. In this case, there would be 240 MT less phosphorus used for broilers; 86 MT for layers and 815 MT less for grow / finish pigs in Canada. A 0.1% reduction in phosphorus is recognized as the minimum increase in bioavailability of phosphorus with phytase supplementation. This implies that before levels were reduced, at least this amount is being excreted (e.g., 240 MT for broilers; 86 MT for laying hens; and 815 MT for pigs in Canada, Table 1) - unavailable to the animal or in excess of its requirement. Therefore, by removing this phosphorus minimum you would reduce the amount being excreted significantly.

The contribution of phytase is not as significant in pigs as it is in poultry (in part due to longer transit time of the pig gut facilitating digestion of phytate from endogenous phytase and microbial fermentation). The microbial fermentation of phytate enables these animals to get more of their phosphorus from the diet. In Canada, if phytase was incorporated into broiler, hen and swine diets, and the minimum requirements of Table 4 were eliminated, a 20.8% reduction of total dietary phosphorus would be realized.

To estimate the value for phytase supplementation, the average phytase has typically a matrix value of 0.1 to 0.13% based on 500 FTU addition of exogenous phytase (personal communication (Bedford, 2010 speaker at October 2010 International Phytase Summit). In some cases there are claims that higher levels of phytase supplementation can increase the availability of phosphorus by 0.17 to 0.20% of the diet. In recognition of this, the industry will apply higher levels of phytase (to reduce demand for expensive sources of inorganic phosphorus), but the release of phytate phosphorus with phytase is not linear (Remus, 2006). With high phosphorus prices it can be economical to “super supplement” with phytase to reduce levels of inorganic phosphorus. Based on costs of phosphorus alone, Bedford (personal communication) estimated that diet costs can be reduced by 3-4\$ / MT diet with phytase supplementation (the cost of phytase supplementation is ~1\$/MT). Canada produces an estimated 2.5 MMT of broiler feed / year, phytase could reduce an equivalent of 5 to 7 M\$ in phosphorus costs alone (if not held to the minimum addition rates listed in CFIA Table 4); similar figures for growing finishing pigs would be >20 M\$. Reductions in total phosphorus by better managing available phosphorus will significantly reduce (e.g. 60 to 70%) phosphorus excretion.

Points of concern regarding phosphorus use in livestock diets:

Based on previous personal research experience to optimize phytase response, the diets typically have to be formulated to contain relatively low levels of available phosphorus so that the ‘without phytase’ diets are marginal or deficient in available phosphorus. With typical wheat and/or corn based diets (particularly if meat and bone meal protein supplements or DDGS are included) it is probably not possible to decrease total phosphorus levels below 0.40 to 0.45 for broilers; and the CFIA minimum is 0.50 % total phosphorus. So, the above estimates of being able to reduce total phosphorus from the CFIA minimum (0.5%) by 0.1% may be excessive for poultry.

We have reasonably good indications that NIR (Near Infrared Reflectance) is capable of accurately estimating phosphorus of ingredients, diets and excreta (Scott, personal observation from Provimi who maintain >250 NIRs worldwide and have P calibrations of >20,000 diets). There are also peer publications indicating that NIR can also predict phytate. Enzyme companies have worked hard to increase their capacity to conduct in vitro estimations of phytate level and optimum or required phytase activity. In recognition of the economic and sustainability value of accurately predicting minimum levels of phosphorus in diets, should the feed industry and public research priority. In addition, processing can impact phosphorus and phytate levels as well as phytase activity. Understanding the contribution of processing to improve bioavailability of all nutrients, including those highlighted by CFIA in their Table 4, should be given appropriate research support.

A total nutrient management program will recognize the level and value of phosphorus in manure and make appropriate applications that will reduce environmental pollution.

It is fully recognized that the feed industry actively applies technology to improve their efficiency and the efficiency of the animal industry, the health and wellbeing of the animals we grow and for the safety of the food they produce. This initiative is further recognition of the responsibility the industry takes for stewardship of the environment.

## REFERENCES:

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Augspurger, N.R. and Baker, D.H., 2008. High phosphorus costs: What are the options?

Feedstuffs (June 2, 2008),80 (issue 22) 6 pages.

Canadian Food Inspection Agency, Table IV, February 2010.

Cordell, D., 2010. The story of phosphorus: Sustainability implications of global phosphorus scarcity for food security. PhD Thesis Linkoping University.

On-line <http://liu.diva-portal.org/smash/record.jsf?pid=diva2:291760>

Leeson, S., 2007. Vitamin requirements: is there basis for re-evaluating dietary specifications? World's Poultry Science Journal 63: 255 – 266.

Poulsen, H.D., Jongbloed, A.W., Latimer, P. and Fernandez, J.A., 1999. Phosphorus consumption, utilization and losses in pig production in France, The Netherlands and Denmark. Livestock Production Sciences 58: 251 – 259.

Remus, J. 2006. Software provides feed cost savings with phytase. Feedstuffs (September 4, 2006), 78 (issue 36) 4 pages.

Selle, P.H. and Ravindran, V., 2007. Microbial phytase in poultry nutrition. Animal Feed Science and Technology 135: 1-41.

## APPENDIX

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See attached excel sheet to review calculations and assumptions relating to dietary phosphorus reductions and phytase responses to reduce dietary phosphorus.

References from CV that relate to phytase / phosphorus utilization by poultry.

## PEER REVIEWED

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Afsharmanesh, M., Scott, T.A. and Silversides, F.G. 2008. Effect of wheat grinding, heat treatment and phytase supplementation of wheat-based diets for broilers. *Canadian Journal of Animal Science* 88: 57-64.

Selle, P.H., Ravindran, V., Bryden, W.L. and Scott, T.A. 2006. Influence of dietary phytate and exogenous phytase on amino acid digestibility in poultry: A review. *Journal of Poultry Science* 43(2): 89-123.

Selle, P.H., Cresswell, D.C., Cadogan, D.J., Partridge, G.G. and Scott, T.A. 2006. Phytase supplementation of wheat-based broiler diets reduces dependence on meat and bone meal. *Journal of Poultry Science* 43(4) 330-338.

Silversides, F.G., Scott, T.A., Korver, D.R., M. Afsharmanesh and Hruby, M. 2005. A study of the interaction of xylanase and phytase enzymes in wheat-based diets fed to commercial white and brown egg laying hens. *Poultry Science* 85:297-305.

Silversides, F.G. Scott, T.A. and Bedford, M.R. 2004. The effect of phytase enzyme and level of nutrient extraction by broilers. *Poultry Science* 83:985-989.

Scott, T.A.; Kampen, R.; Silversides, F.G. 2001. The effect of adding exogenous phytase to nutrient-reduced corn- and wheat-based diets on performance and egg quality of two strains of laying hens. *Canadian Journal of Animal Science* 81:393-401.

Scott, T.A., R. Kampen, and F.G. Silversides, 2000. The effect of phosphorus, phytase enzyme, and calcium on the performance of layers fed wheat-based diets. *Canadian Journal of Animal Science* 80:183-190.

Scott, T.A., R. Kampen, and F.G. Silversides, 1999. The effect of phosphorus, phytase enzyme, and calcium on the performance of layers fed corn-based diets. *Poultry Science* 78:1742-1749.

## NOT PEER REVIEW

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Scott, T.A., 2000. The use of phytase enzyme supplements in wheat-based poultry diets. BASF Canada Facts & Figures Seminar, Guelph, Ontario; and Alberta Poultry Service Workshop Pre-Symposium, Banff, Alberta.

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