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Agriculture, Ecosystems and Environment 105 (2005) 401–411

Agriculture Ecosystems & Environment

www.elsevier.com/locate/agee

Short communication

Reducing phosphorus in dairy diets improves farm nutrient balances and decreases the risk of nonpoint pollution of surface and ground waters

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Received 29 December 2003; received in revised form 8 June 2004; accepted 28 June 2004

Abstract

Reducing phosphorus (P) in dairy diets may result in different types of manure with different chemical composition. Application of these manures to soils may affect the soil P solubility and lead to different environmental consequences. A laboratory incubation study determined the impact of 40 dairy manures on P dynamics in two soil types, Mattapex silt loam (Aquic Hapludult) and Kalmia sandy loam (Typic Hapludult). The manures were fecal samples of lactating cows, collected from commercial dairy farms located in Northeastern and Mid-Atlantic United States, with a wide range of dietary P concentrations (from 2.9 to 5.8 g P kg^{-1} feed dry matter, DM). Dried and ground fecal samples were mixed with surface horizon (0–15 cm) of soils at 150 kg P ha^{-1} and the mixtures were incubated at 25 °C for 21 days. At the end of incubation, water soluble P (WS-P) and Mehlich-3 P (M3-P) in the soil–manure mixtures were substantially higher than the control (soil alone) but were lower than the soils receiving fertilizer KH_2PO_4 at 150 kg P ha^{-1}. Similarly, the relative extractability of P in soils amended with low- and high-P manures was always lower (<93%) than KH_2PO_4 suggesting that fertilizer P is more effective at increasing soil solution P in the short-term. Concentrations of WS-P or M3-P in soil–manure mixtures did not differ regardless of the source of manure (i.e. different farms and different diets). This suggests that when the same amount of P is added to soils through manure applications, the solubility or bioavailability of P in soils will be the same. However, P concentrations in feces correlate significantly with that in diets ($r = 0.82^{**}$); and when the manures were grouped into high-P diets (averaging 5.1 g P kg^{-1}) versus low-P diets (3.6 g P kg^{-1}), manure P was 40% greater in the high-P group (10.6 g kg^{-1} DM) than the low-P group (7.6 g kg^{-1} DM). Thus, lowering excess P in diets would reduce P excretion in manures, P accumulation in soils, improve P balance on farms, require less area for land disposal, and decrease potential for P loss to waters.

Keywords: Dairy diets; Manures; Soil incubation; Farm balances

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0167-8809/$ – see front matter
doi:10.1016/j.agee.2004.06.003

1. Introduction

Eutrophication has been linked with many aspects of water quality degradation, including fish kills, loss of biodiversity and recreational uses of waters, and the onset of harmful algal blooms that can pose a threat to human health (Burkholder et al., 1999). Phosphorus (P) losses from agricultural production systems are known to contribute to accelerated eutrophication of natural waters (Sims et al., 1998; Toor et al., 2003). This is especially true in areas with intensive animal farming, where repeated manure applications have led to excessive accumulation of P in soils. Substantial evidence exists to show that higher P concentrations in soils can result in increased P losses to natural waters (Sharpley and Tunney, 2000; Sims et al., 1998). Given this, there is an urgent need to develop best management practices (BMPs) that prevent P accumulation in soils to values that are of concern for water quality.

One of the most important BMPs for animal agriculture is the need to strike a balance between P inputs and outputs in farms and/or watersheds. Many modern animal operations have surpluses of P on the farm because P inputs (feed, fertilizer) exceed P outputs in animal and crop products. Research has clearly shown that the principle P input on most US and European dairy farms is animal feedstuffs. For example, annual P surpluses for Brittany (92 kg P ha^{-1}), The Netherlands (39 kg P ha^{-1}) and Belgium (38 kg P ha^{-1}) are due to import of animal feeds on farms (Sibbesen and Runge-Metzger, 1995). Farm P surpluses often cause regular over-application of P to soils, increasing the potential for P loss to surface and shallow ground waters. In the UK, Withers et al. (2001) reported that an average P surplus of ca. 1000 kg ha^{-1} has accumulated over the last 65 years in grasslands and arable areas because of continued applications of P inputs to soils that contain adequate amounts of P for optimum crop yields. Sharpley and Smith (1995) reported 35 years of manure applications (37–270 kg P ha^{-1} $year^{-1}$) to soils in Oklahoma and Texas increased soil test P (Olsen P) from 15 to 187 mg kg^{-1}.

Fortunately, research has begun to develop practical means to reduce P accumulations in soils by reducing P excretion in manures. For dairy farms, feeding P closer to the animal's nutritional requirement has been shown to reduce manure P concentrations and P surpluses on farms, and have no adverse effects on animal health or performance (Karn, 2001). The National Research Council (National Research Council, 2001) recommends 3.2–3.8 g P kg^{-1} in the diets of lactating dairy cows. However, on many US dairy farms, P is often formulated to contain 4.5 to 5.0 g P kg^{-1} (20–25% excess P), with levels sometimes as high as 8.0 g P kg^{-1}. The reasons for overfeeding P are mainly related to concerns that the amount of available P in the feedstuff may be inadequate for satisfactory animal health and reproduction (Dou et al., 2003; Wu et al., 2000). A recent survey in the Mid-Atlantic USA by Dou et al. (2003) concluded that P fed to lactating cows averaged 34% above NRC recommendations. The excess P in diets is excreted in manures that must be applied to cropland because of the lack of alternative off-farm uses. This results in the accumulation of P in soils to values that can increase the potential for P losses. Ebeling et al. (2002) studied the influence of two dairy diets (3.1 and 4.9 g P kg^{-1}) on P losses in runoff from a manure-amended silt loam soil in Wisconsin. Dissolved reactive P (DRP) concentrations in a June runoff event from the high-P diet manure were four times higher (1.18 mg l^{-1}) than the low-P diet manure (0.30 mg l^{-1}); similar trends were seen in subsequent runoff events. In addition to increasing the potential for P loss to water, excessive additions of P to dairy diets annually costs \$10–15 per cow or over \$100 million in the US alone (Council for Agricultural Science and Technology, 2002). Thus, reducing the P content in dairy diets will have both environmental and economic benefits and, if done properly, should have no deleterious effects on animal performance or crop production.

Many approaches can be taken to reduce P in dairy diets, such as reducing the amount of mineral P supplemented or using forages, grains, and by-products with lower P concentrations. Changing the sources of P fed to dairy cows may also alter the forms of P in manures and thus affect the potential for P loss from manured soils by runoff, erosion, or leaching. In this study, we evaluated the effects of manures produced on a wide range of Mid-Atlantic and Northeastern dairy farms, where low- or high-P diets were fed, on the forms and solubility of soil P. Our hypothesis was that reducing dietary P to reduce P excretion would not affect the solubility or plant availability of P in manure-amended soils, when manures are applied at the same P rate.