Phytase: Anatomy of an invisible win-win technology

A Thesis

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

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JULY 2009

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ANATOMY OF AN INVISIBLE WIN-WIN TECHNOLOGY

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and hereby certify that, in their opinion, it is worthy of acceptance.

Associate Professor Laura McCann

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Associate Professor Marcia Shannon

To my wonderful wife Kelly: Thanks for being with me throughout this process.

ACKNOWLEDGEMENTS

I wish to thank my academic advisor, Laura McCann, for all her support and assistance she has provided me throughout the course of this research project. Our discussions yielded many interesting insights. Additionally, I'd like to thank Marcia Shannon who provided information that changed the course of this thesis. Haluk Gedikoglu, Ray Massey, and John Lory have also earned my gratitude for the assistance and information they provided. And last but not least, I'd like to thank Ken Ferrell, Jim White, and Donnie Campbell for taking time out of their busy schedules for an interview which gave information that was invaluable towards this thesis.

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LIST OF ABBREVIATIONS

CAFO – Concentrated Animal Feed Operation

CRP - Conservation Reserve Program

Dical – Dicalcium Phosphate

EPA – Environmental Protection Agency

FDA – Food and Drug Administration

IA - Iowa

IAA – Irrelevant Alternatives Assumption

MO - Missouri

NRCS - Natural Resources Conservation Service

OLS – Ordinary Least Squares

P – Phosphorus

USDA – United States Department of Agriculture

Y – Yes

N – No

DK – Don't Know

ABSTRACT

Phosphorous is necessary for crops and livestock, but excess phosphorous in rivers and lakes can result in eutrophication. The majority of the phosphorous in grains is in the form of phytate which cannot be digested by non-ruminants and is thus excreted in the feces. This requires adding inorganic phosphorous to the diet, representing an additional cost to the farmer. Phytase is an enzyme that frees the phosphorous and other nutrients that are in phytate so they can be digested and absorbed by the animals. Therefore phytase has the potential to decrease the cost of feed and decrease the phosphorous in feces, thus decreasing the potential for nutrient runoff. Phytase has been required in non-ruminant diets in some European countries since the 1990's. In the Midwest, phytase has been routinely incorporated in non-ruminant diets for several years based on cost savings. The knowledge of this win-win technology is affected by its relative invisibility; phytase easily blends in feed rations, requires no extra labor by the farmer, and has no visible effects on the animals. This study's focus is to examine the farmer's knowledge of phytase and the factors that affect its adoption. To our knowledge, there have been no studies which examine perceptions of phytase and the farm and farmer characteristics that affect stated adoption of phytase.

A mail survey of 3014 poultry and livestock farmers was conducted in Iowa and Missouri in spring of 2006. The effective response rate was 37.4 percent. Over 60 percent of the respondents neither agreed nor disagreed (i.e. were neutral, 3 on a Likert scale of 1-5) with four questions regarding their perceptions of phytase characteristics: if it is profitable, improves water quality, is time consuming, and is complicated. This would indicate that farmers are not very knowledgeable about the practice. Additionally,

while most non-ruminant farmers use phytase, no farmers with broilers, less than 5 percent of farmers with turkeys, and less than half of the swine farmers stated phytase use. Overall, only 18 percent of non-ruminant farmers stated phytase use, 46 percent stated they did not use phytase, and 36 percent stated they did not know. This suggests an information disconnect between farmers and feed manufacturers/contractors and that we are measuring knowledge rather than actual adoption.

Farmers are more likely to state phytase adoption if they think phytase is profitable or not time consuming. They are also more likely to state phytase adoption if they give manure to other farms, located in Iowa, or are a designated CAFO. The farmers are less likely to state phytase use if they have off-farm income between $10,000 and $99,999 (compared to no off-farm income) or have poultry or ruminant species (compared to swine < 55 lbs.).

Farmers are more likely to state “don’t know” (versus “no”) concerning phytase use if they earn $0 - $9,999 in off-farm income and remain neutral concerning the influence other farmers have on their decisions. Farmers are less likely to state “don’t know” if they view phytase as not profitable, have education beyond high school, have beef cattle on feed, or contractors/integrators have low influence on their decisions.

This study shows that surveys with “don’t know” response options can provide useful information to the researcher. It also shows the importance of understanding the technology, industry, and locus of decision-making in adoption research; phytase was able to be adopted automatically and nearly completely by non-ruminant farmers who remained uninformed of this win-win technology.

Chapter 1: Introduction

Phosphorus is one of the most significant water pollutants in national waters (Environmental Protection Agency, 2002). Although there are many different sources of phosphorus, such as naturally occurring phosphorus, lawn fertilizers, wastewater treatment, septic tanks, and detergents/cleaning agents, agriculture has been assessed as one of the most widespread sources of national water quality impairment (Environmental Protection Agency, 2002; Lory, 1999; State Environmental Resource Center, 2005). Phosphorus is essential in animal nutrition for bone and muscle formation, metabolism, and increasing energy levels (Church and Pond, 1988), and is also a necessary plant nutrient. However, the high quantities of phosphorus found in animal manure can overwhelm an aquatic ecosystem. High levels of phosphorus result in eutrophication, which is when algae blooms deplete the dissolved oxygen content below levels that other species need to survive and thus forms a dead zone (Environmental Protection Agency of Queensland, 2006).

Phosphorus is chiefly transported from agricultural land by surface runoff. Most of the phosphorus runoff is due to its attachment to soil particles, but some is due to leaching (U.S. Environmental Protection Agency, 2003). Due to this primary transportation method, some believe that phosphorus pollution can be controlled only by management practices and erosion control. Sharpley et al. (2003) found that the level of phosphorus in the soil is a major determinant of the level of the pollution; considerations need to be made for balancing phosphorus inputs and outputs in conjunction with best management practices. In other words, erosion control is a complement to balancing phosphorus levels in the soil and not a perfect substitute. They also emphasize that not all farms are equal; lands with different practices, topography, or vegetation can result in vastly different levels of pollution, as can the numbers and kinds of animals (Sharpley et al., 2003). Pionke et al. (1997) found that "in some agricultural watersheds, 90 percent of annual algal-available P export from watersheds comes from only 10 percent of the land area during a few relatively large storms" (cited by Sharpley et al. 2003, p. 22). This means that impacts farms have on water quality vary from place to place, even if they have the same management practices (Sharpley et al., 2003).

Non-ruminant animals, such as pigs and poultry, can have high phosphorus content in their manure because they are unable to digest much of the phosphorus naturally contained in their feed. Phytate is a salt in grains and oil seeds that binds nutrients, like calcium and phosphorus, in a form that non-ruminants cannot digest. Farmers add inorganic phosphorus, like monocalcium phosphate or dicalcium phosphate (dical), to feed because the grains did not provide the necessary nutrition required for animal growth. This addition became the third most costly item in feed; following energy and protein content (Biehl et al., 1995). New technology has given farmers another option; instead of adding inorganic phosphorus, a farmer could add phytase, an enzyme that breaks up phytate, saving money on feed and reducing phosphorus pollution.

Phytase was first discovered in 1907 by Suzuki, Yoshimura and Takaishi at the Tokyo Imperial University (Suzuki et al., 1907, cited by Vohra and Satyanarayana, 2003). However, the enzyme was not experimentally used in poultry diets until 1968 (Nelson et al., 1968). It took another 22 years to be used in experimental pig diets (Jongbloed and Kemme, 1990), but the year after that study saw its first commercial production in the Netherlands by Gist-Brocades under the brand name "Natuphos." Gist-Brocades was able to develop the technology that made phytase more economical and the delivery practical. The feed industries in the Netherlands were the first to use phytase. By 1992, 35 percent of all pig and poultry feed in the Netherlands used phytase, and it also became available in Germany, Belgium, Austria, and Switzerland (Institute for Applied Environmental Economics, 2007). Natuphos was finally approved by the U. S. Food and Drug Administration (FDA) in November 1995 (Kornegay, 1996) and is now estimated to be in 95 percent of all non-ruminant feeds in the United States (Campbell, Personal Communication, 2008).

Research Objectives

Whether or not a farmer adopts phytase is more complicated than simply comparing costs and benefits; as will be shown in the next chapter, it is a dynamic process involving information channels, choice structure, and perspectives. The characteristics of phytase make this adoption study unique; phytase has no visual effects, it is often automatically added in the premix of non-ruminant feed, and blends in with the feed so that a farmer wouldn't notice its presence. Additionally, since our survey includes farmers from two different states, Missouri and Iowa, the laws and regulations of each state may affect the farmer's knowledge of phytase differently. The original intent of this study was to determine the factors that affected phytase adoption, but the resulting data showed that most farmers were unaware of the technology and stated an adoption rate inconsistent with the inclusion rate of feed manufacturers. Therefore the objectives of this paper are to:

1) Determine the state of farmer knowledge about this new technology.
2) Examine the social and economic factors that impact the stated adoption, rejection, or lack of knowledge of phytase.

The answers to these questions will give further insight as to how win-win technologies like phytase are adopted and diffused.

Organization of Thesis

Chapter 2 will describe phytase and review the literature on factors that would affect its actual adoption and the farmers stated adoption. Chapter 3 builds on the factors in Chapter 2 to construct a conceptual model to be used for this study. Chapter 4 describes the method used to obtain the data and the manipulation of the data from the survey. Chapter 5 will review the data and discuss the results of the regression. Chapter 6 concludes by summarizing the study and its findings and discussing the implications.

Chapter 2: Background

Phytase is a win-win technology that has been unknowingly adopted by non-ruminant farmers. This literature review will discuss the characteristics of phytase that affect its adoption and the factors that affect a farmer's stated adoption. This review will provide the framework for the model to be used in this study and described in the next chapter.

Adoption Studies

Adoption is a decision to use an innovation. In sociology, this step is only one part of an innovation-decision process. The innovation-decision process is a model by which an individual or firm develops and gathers information on an innovation which can lead to its adoption or abandonment. The process includes the initial knowledge of the innovation, the changing attitude which leads to an adopt or not decision, and the implementation and confirmation of the innovation (Rogers, 2003). This process is affected by the attributes of an innovation and the decision maker. The innovation attributes are categorized into five factors: the relative advantage of the innovation, compatibility, complexity, triability, and observability (Rogers, 2003). Likewise, the innovator attributes are divided into socioeconomic factors like age, education, and farm size, personality factors, and communication factors including social participation and communication channels (Rogers, 2003). Adoption studies examine the attributes of the innovation and the decision maker that impact the decision to adopt or reject an innovation (Núňez, 2005).

In economics, the decision to adopt or not adopt an innovation is assumed to maximize the expected utility of a farmer (Feder et al., 1985). In its simplest form, a decision maker adopts a technology if the expected profits exceeded the expected costs (Stoneman, 2002). However, this model failed to accurately describe empirical adoption studies, thus the model became more complex (Feder et al, 1985). The model evolved to include constraints like credit, information, labor, and capital constraints, risk aversion, farm size, contract arrangements, and others (Feder et al., 1985). Additionally, the innovations were classified on their own characteristics, such as if an innovation was a stand-alone technology or if it needed to be adopted with other technologies (Stoneman, 2002). In many ways the economic approach is not all that different from the sociological approach; utility maximization is related to relative advantage since both approaches can include profitability and other factors that provide satisfaction, including social and environmental benefits. The differences can be seen as the result of the different objectives, and quantification methods necessary for different situations (Núňez, 2005; Feder et al., 1985).

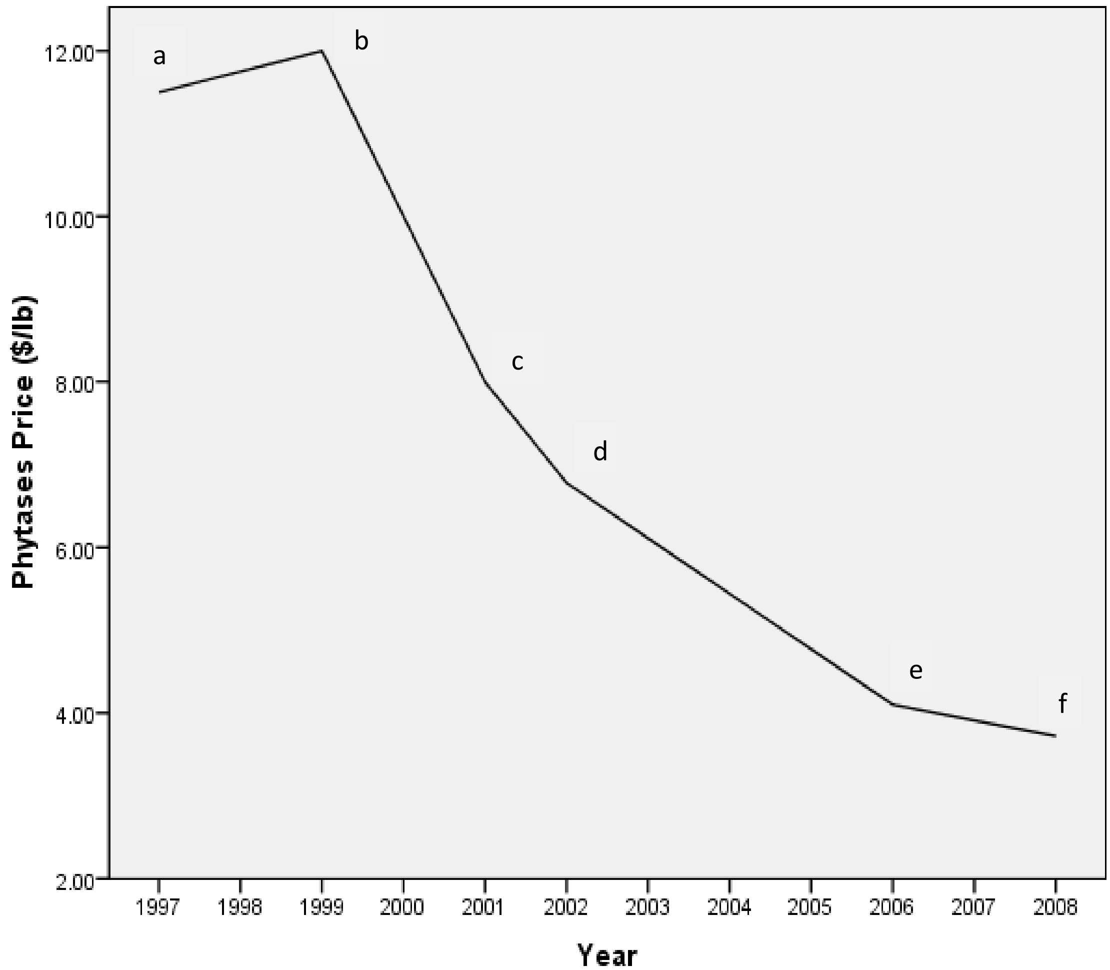
Attributes of Phytase

Phytase's relative advantage is its ability to replace phosphorus, which produces an environmental benefit by reducing phosphorus pollution and an economic benefit by saving money on feed. Dr. Marcia Shannon highlighted this point when she stated, "Today, everyone should be feeding phytase because of dical price" (Personal Communication, 2008). These advantages are dependent on the species of animal; phytase is intended for non-ruminants like pigs and poultry. Phytase would not provide any advantage to a ruminant animal since microorganisms in the rumen produce phytase which then hydrolyzes the phytate into a digestible form (Spears, 1996). The economic benefit does depend on the relative prices of phytase and dical. Phytase's historical price information is very scarce, but a rough price series was developed from various sources (see Figure 1). These prices have been converted to be equivalent to the price per pound of Natuphos 5000 in the United States (see Appendix A), and remain consistent with information from different sources. A European legal document concerning the merger of two phytase producers declared that phytase prices had been steadily declining from 1994 to 2001 (European Commission, 2003). A personal interview with Dr. "Jim" White of MFA said that Natuphos was introduced in the United States in 1995, and Ryozyme entered the market in 2000 which reduced prices over the next couple of years. Then other companies like Danisco entered in 2003 and JBS United entered around 2005 further lowering prices (Personal Communication, 2008).

As phytase prices dropped, phosphorus prices rose. Super-phosphate (44-46 percent phosphate), a fertilizer, stands in as a proxy for feed-grade phosphorus (see Figure 2). The fertilizer price seems to be approximately the same price as dical; a Virginia Tech Livestock Update placed dical at $280 per ton in 1999 (Harper, 1999), and a Purina Feed report from 2007 reported dical at $400 per ton (Tilstra, 2007). Combined with the decreasing cost of phytase, it can be seen that phytase became increasingly profitable in the last decade.

The rising phosphorus prices and falling phytase prices confirm that Dr. Shannon was correct in stating phytase use should be widespread (Personal Communication, 2008). Additional reviews of other studies note the increasing profitability of phytase. In 1989, Han estimated phytase as 17 times more expensive than inorganic phosphorus (cited by Kornegay, 1996). By 1997, two studies found phytase to be profitable if the manure was required to be disposed of in such a way that the nutrients were utilized in crop production (Bosch et al., 1997). A 2001 EPA study showed "the increase in feed cost required to reduce phosphorus excretion by 40 percent is expected to be less than 1 percent (U. S. Environmental Protection Agency, 2001)." Then in 2004, Canadians Murphy and de Lange estimated that phytase was mostly cost neutral, depending on relevant prices (Murphy and de Lange, 2004). A 2002 study by Saddoris and Crenshaw determined the breakeven prices of substitution between dical and phytase. Their results, shown in Table 1, indicate that given a price of phosphorus of $280/ton, phytase would need to be $9.33/lb for the farmer substitute at no profit or loss. Using this study and the prices from Figures 1 and 2, phytase would have become profitable between 2001 and 2002. This study is consistent with an interview of Dr. Ferrell who stated that phytase became profitable around 2001 (Personal Communication, 2008).

Figure 1: The Historical Price of Phytase in the United States.



* See Appendix A for discussion on conversion of phytase prices

Sources:

a) Stanislaw, C. (1997). "Impact of Microbial Phytase on Manure Disposal Costs." *Swine News, April 1997, Volume 20, Number 3.* http://mark.asci.ncsu.edu/Swine_News/1997/sn_v2003.htm#03 (29JAN09).
Risse, M. (1997). "More on Phytase." *University of Georgia, AWARE Volume 2, Number 3*. http://www.engr.uga.edu/service/extension/aware/vol2_3.html (29JAN09).

b) Harper, A. F. (1999). Feeding Phytase to Growing Pigs: A Preliminary Cost/Benefit Assessment." *Virginia Cooperative Extension, Livestock Update, February 1999.* http://www.ext.vt.edu/news/periodicals/livestock/aps-99_03/aps-0039.html (29JAN09).

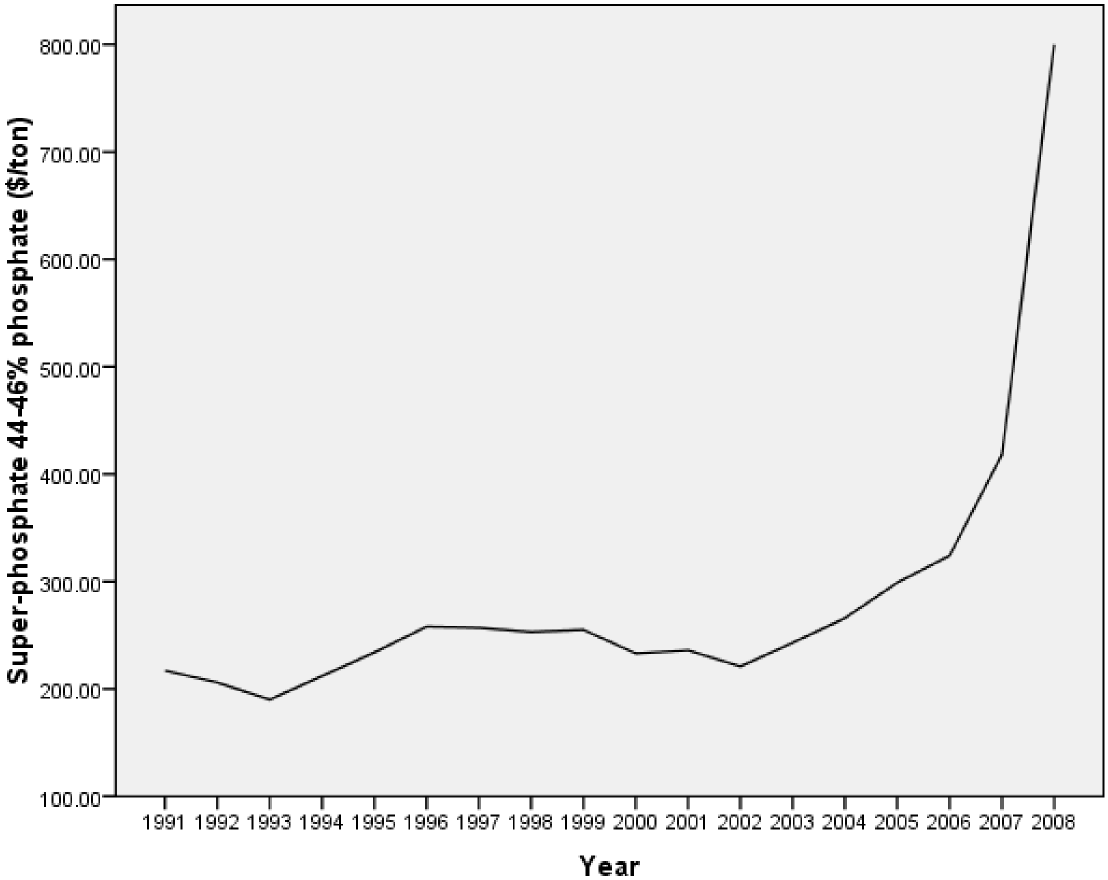
c) McMullen, L. K., Holden, P. (2001). "Phytase Fact Sheet." www.agronext.iastate.edu/immag/pubs/phytase.doc (29JAN09).

d) Keplinger, K., Abraham, J. (2002). "Duck Creek Watershed, Texas." *Texas Institute for Applied Environmental Research.* http://tiaer.tarleton.edu/projects_duckcreek3.cfm (29JAN09).

e) Campbell, D. Telephone Interview 15AUG08.

f) Campbell, D. Telephone Interview 15AUG08.

Figure 2: The Historical Price of Super-Phosphate in the United States.



Source: USDA Economic Research Service (2008). "U.S. Fertilizer Use and Price."

http://www.ers.usda.gov/Data/FertilizerUse/ (29JAN09).

Table 1: The Breakeven Price of Dicalcium Phosphorus for a Given Price of Phytase.

Year	1997	1999	2001	2002	2006	2008
Phytase Price ($/lb)*	11.5	12	8	6.78	4.1	3.72
Breakeven Price of Dical ($/ton)	354.5	367.0	246.6	209.0	126.4	114.7

a. "Assumes 500 FTU/kg diet fed which allows equal pig performance as supplemental inorganic P from dicalcium phosphate. Breakeven price can be calculated as 30.83 × cost of phytase, $/lb = cost of dicalcium phosphate, $/ton" (Saddoris and Crenshaw, 2002).

b. * See Appendix A for discussion on conversion of phytase prices.

Phytase also provides the calcium and other trace minerals bound in phytate. Nutritionists have included protein and energy in a matrix with phosphorus and calcium in evaluating phytase (Selle and Ravindran, 2006). One issue is that these benefits "depend upon several factors, including the raw materials used, the source of the phytase, the age of the animals, dietary content of calcium, phosphorus and Vitamin D, and the level of phytase activity present in the ingredients used (Bedford, 2000, p.7)." Due to these factors, larger safety margins have been placed on the nutritional values (Bedford, 2000).

The relative advantage of phytase can also be affected by the farmer's use of the manure. The reduction of phosphorus in manure can be viewed negatively if a farmer sells his manure based on high phosphorus content (Harper, 1999; Campbell, 2008). However, transferring manure can be expensive (Keplinger and Hauck, 2006). Phytase can be advantageous to farmers that transfer manure due to nutrient constraints.

The next attribute category is compatibility. Compatibility is the perception of an innovation being in line with the values, beliefs, needs, and previously introduced ideas (Rogers, 2003). In economics, this idea has been associated with the innovation meeting the objectives of the farmer and adoption costs (Núňez, 2005). Since phytase is incorporated in a feed mix in the same manner as dicalcium phosphorus, compatibility should not be a constraining issue.

The incorporation of phytase in feed is also related to the complexity of phytase. Complexity can refer to the difficulty or time intensity of incorporating it into the animal diets. Since the enzyme is added into the premix of animal feed, neither issue should be significant in the adoption practices of farmers. Compound feeds are composed of various feed grains and a premix. If a farmer decides to formulate their own animal feed, the farmer will usually still select a premix to ensure the animal is provided with the correct nutrition and antibiotics. Since the phytase is in the premix, it is no more complex or time intensive than dical.

Triability refers to the ability to experiment with the innovation on a limited basis (Rogers, 2003). Many farmers are not in a position to experiment with animal feed; they are under a production contract. Under a production contract, an integrator usually determines and provides the animals, feed, and medicine, while the farmer provides labor and facilities (MacDonald and Korb, 2006). Other farmers are also restricted in choice by the default options chosen by the feed manufacturer. As mentioned earlier, phytase is usually added in the premix. Farmers who formulate their own feed usually do not choose the contents of the premix (Ferrell and White, Personal Communication, 2008). At MFA, if a farmer desires to not use phytase, he/she can request a special formulation at a higher cost (Ferrell and White, Personal Communication, 2008). However, phytase is the current default option in premix; so many farmers have adopted phytase without their knowledge or consent.

This leads into the final category of attributes: observability. Phytase is relatively invisible in animal feed; it is slightly off white and is a small granule that easily blends in with the rest of the feed material (see Figure 3). A farmer can easily have it in his feed without realizing it. Secondly, phytase has credence qualities. A credence quality is a quality that is beneficial but cannot be valued through normal use (Darby and Karni, 1973). The term is distinguished from search and experience qualities. A search quality can be evaluated prior to purchase and experience qualities can be costlessly determined after purchase (Darby and Karni, 1973). The addition of phytase in an animal diet would result in no visible change to the animal and the change in water quality may be unobservable. Credence attributes are important because the full benefit of a good can remain unknown. The phosphorus reduction is a credence attribute since it is difficult for a farmer to evaluate phosphorus pollution; phytase may only be evaluated on its profitability. Phytase is relatively unobservable in its presence and in its effects.

Phytase may require some knowledge to determine its presence in feed. For example, in the sample tags for pig feed included in Appendix B, phytase is listed as "Dehydrated Aspergillus Oryzae Fermentation Extract." Phytase units are seldom displayed on feed tags because of disagreement on how phytase release should be counted and the proper units to use (White, Personal Communication, 2009).

Figure 3: Pig feed, Phytase, and Turkey Feed.

Regulatory History

As shown above, the economical and environmental benefits of phytase strongly encourage phytase adoption by non-ruminant farmers and there are very few discouraging factors. However, when the relative prices of phytase have discouraged adoption, states have historically resorted to regulations to encourage adoption when they have significant phosphorus issues. This is because the environmental benefits, although significant from a societal viewpoint, may not be a significant advantage for an individual farmer. Phosphorus pollution is an externality to the farmer; the farmer does not bear any cost from the pollution. Furthermore, Mancur Olson stated in his dissertation, The Logic of Collective Action, that "unless the number of individuals in a group is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, *rational, self-interested individuals will not act to achieve their common or group interests*" (Olson, 1971, p. 2). This is because the environmental benefits of phytase are a collective good; once the benefits are provided to a watershed, all people in that watershed have access. Even people in the Mississippi River basin or along the Gulf of Mexico could benefit from the reduction in nutrient pollution, although the impact of one farmer is quite small. These benefits do not provide the proper incentives to reward farmers for bearing the costs (Olson, 2007). These benefits only provide the incentive to free ride and other benefits are necessary to encourage group participation (Olson, 2007). If the relative prices of phytase and phosphorus do not encourage phytase adoption, then rational, self-interested farmers will not act to achieve common environmental interests. This view should be tempered by the fact that some farmers did adopt phytase prior to profitability for environmental reasons, as indicated by an interview with Ferrell and White (2008). However, most farmers did not adopt phytase until after phytase became profitable or regulations required it (Ferrell and White, Personal Communication, 2008).

Historically, European regulations encouraged farmers to adopt phytase well before American regulations. In particular, antipollution laws established for manure in the Netherlands made commercial phytase viable in that country. The Netherlands has significant issues with phosphorus due to high intensity animal agriculture and being at the mouth of the Rhine which is already loaded with phosphorus from other European countries (Bennett and Carpenter, 2002). In 1990, the Netherlands limited manure application based on phosphorus content and if the farmer exceeded that content, a fine was imposed on the farmer and the manure was shipped elsewhere (Kemme et al., 1997; Oenema, 2004). The laws raised the cost of phosphorus in manure, which raised demand for products that reduced phosphorus excretion.

While the European regulations made phytase practical in European countries, in the United States phytase use was initially limited because the pollution laws were less strict (Biehl et al., 1995). In the United States, the states are usually granted the authority to implement, monitor, and enforce regulations, as long as there are at least as stringent as the Environmental Protection Agency's standards (Sigman, 2003; Olexa et al., 2005). Currently, phytase related regulations vary from mandates to use phytase or an equivalent, as in Maryland (Code of Maryland Regulations, 15.18.05.03. 03, 2009), to voluntary programs as in Missouri (Lory, Personal Communication, 2008). Missouri developed a P index in 2001, but there are no specific limits on phosphorus and farmers are not required to use the index (Lory, Personal Communication, 2008). In 2003, only four states, North Carolina, Iowa, Minnesota, and Maryland, had adopted "some form of phosphorus-based regulations” (Tyrchniewicz, 2003). Minnesota declared in 2000 that a producer could not haul hog slurry if phosphorus exceeded a certain level (Ferrell and White, Personal Communication, 2008; Minnesota Administrative Rule, Chapter 7020.2225, 2003). Since one hog produces around three gallons of waste a day and a 6,000-sow hog farm will produce approximately 50 tons of raw manure a day, phytase begins to look more appealing (Cantrell et. al., 2001). Iowa mandated the P index in 2003. They chose the P-index because it was a flexible tool without built-in limits which allows producers to identify the best practices to minimize excess phosphorus from reaching area waters (Mallarino, 2003). The P-index also recognizes the differences between farms in their ability to pollute local waters; therefore stricter limits are placed on farms with higher potential to effect local waters. 2003 was also the year that the EPA attempted to update the Clean Water Act. This update met resistance by both the industrial and environmental representatives, and some of the bill was vacated by the Second Circuit court in Waterkeeper Alliance et al. v. EPA (U.S. Environmental Protection Agency, 2008). The EPA revised the regulations and the final rule became effective on December 22, 2008. The preexisting regulations in states like Missouri and Iowa largely meet the new rule and do not require any major changes in management (Lally, 2008).

These regulations may have played an important role in lowering the price of phytase because of induced innovation. Induced innovation is a theory credited to Sir John Hicks. He wrote, "A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind - directed to economizing the use of a factor which has become relatively expensive (1963, p. 124)." This theory is further refined by Schumpeter's delineation of invention, innovation, and diffusion. The act that creates a new technological possibility is an invention, while innovation is commercially introducing the idea, which is diffused by individuals and firm's gradually adopting the innovation (Newell et. al., 1998). In layman's terms, when energy prices rise, the theory states that improvements in energy efficiency should happen faster than it would have had energy prices not risen (Newell et. al., 1998). Regulations raised the cost of having excess phosphorus in manure, which raised demand for products that reduced phosphorus excretion. The induced innovation theory implies that phytase developed faster than normal because of the cost antipollution laws placed on phosphorus content. This induced development could then be seen in the lower prices of phytase over time, which resulted in phytase becoming more profitable and being adopted by more farmers. Although a higher demand resulting in lower prices is counterintuitive, the price drops can been seen as a result of more companies starting to produce phytase since the increased demand raised profits for the phytase producers. Additionally, although we do not know a company's supply curve, a company may also benefit from the economies of scale from the increased production. If this regulation did not exist, phytase may have still not been used significantly until the price of inorganic phosphorus began to spike around 2006. Therefore, places that did not regulate phosphorus pollution benefited from the European countries and American states that did.

Attributes of the Decision Maker

So far, this literature review has focused on the characteristics of phytase and the regulations that affect its adoption. As mentioned before, the decision maker's attributes also need to be considered in an adoption study. Rogers (2003) groups adopters into categories and associates general attributes to each category. The categories are the innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003). This categorization is more appropriate with a diffusion study, which is a macro-level view of how an innovation spreads across a particular population through time (Núñez, 2005). Since our study has no time variable, we cannot place an adopter in any particular category. However, the attributes of adopters can affect the perceptions of innovations and transaction costs, such as a farmer who is more socially active could have better access to information (Rogers, 2003). Rogers (2003) is also a sociologist, so there is a stronger emphasis on communication and social systems where economics focuses more on markets (Núñez, 2005).

Rogers' (2003) first category of characteristics considers the socioeconomic background of innovators. Early adopters tend to have more education, a higher social status, and to have larger farms than later adopters (Rogers, 2003). Rogers (2003) also notes that age is an inconsistent predictor of early adopters. Education is assumed to assist farmers in gathering information and handling complex issues. Gedikoglu (2008) found a positive effect on adoption rate of manure management practices associated with education, but that rate diminished after a high school education. One way to measure social status is by income (Rogers, 2003). Higher income can increase the amount of risk an agent will assume (Miao and Wang, 2004; Zimmerman and Carter, 2003). Additionally, Gedikoglu (2008) found that "off-farm work has positive impact on adoption of capital incentive practices and negative impact on adoption labor intensive technologies (p. xiii)." A higher off-farm income can be related to lower adoption of labor intensive practices since there is less time available for on-farm work. Gedikoglu

(2008) also cites Chang and Boisvert (2005) when they attribute a positive correlation between age and CRP participation to older farmers' willingness to reduce labor. Age is meant to capture experience and potential discount rate differences, but the relationship between age and adoption rates can vary depending on the innovation (Rogers, 2003; Núňez, 2005; Gedikoglu, 2008). Farm size is related to social status since larger farms can draw more income. Larger farms can also be more constrained by regulations, but have access to more credit and higher economies of scale (Gedikoglu, 2008). Socioeconomic factors need to be considered in an adoption model, but the type of innovation can be significant in determining how each characteristic is applied.

The second category of innovator characteristics is personality variables. These variables include an innovator's empathy, ability to deal with abstractions, attitude towards change, and aspirations (Rogers, 2003). These variables are difficult to measure in a survey and are not included, although some may be proxied by socioeconomic variables i.e. education could be related to the ability to deal with abstractions.

The final category discussed by Rogers (2003) is communication behavior. Many studies observe the communication channels of adopters; early adopters tend to have more social connections and contact with change agents (individuals who supply innovations) than later adopters (Rogers, 2003). Although usually not considered in economic diffusion studies, communication can be associated with lower information costs (Núňez, 2005). Núňez (2005) did find that farmers who used public information, such as University and NRCS extension programs, were more likely to test manure. Good communication with outside sources can also reduce risk. Although not normally in economic diffusion studies, communication channels can provide insight on an agent's risk and transaction cost.

Real and Stated Rates of Adoption

The literature review has discussed the theoretical reasons why a farmer would want to adopt or reject phytase, but has not discussed the farmers who answer "don't know." Given the characteristics of phytase discussed in the literature review, it may be possible for farmers to be unaware of phytase in their feed. Traditional adoption studies have not addressed a potential divergence between stated adoption and actual adoption.

Traditional adoption studies examine the process an individual uses to seek and process information to reduce uncertainty and quantify the benefits of adoption in order to weigh risk and return (Rogers, 2003). If the individual is boundedly rational, then the individual may not fully understand the technologies that are available (Wang et al., 2006). Bounded rationality is a term popularized by Herbert Simon that refers to individuals acting in a world where information has costs and needs to be gathered and processed (March, 1978). This simple notion has lead to several alternative rationalities. Process rationality emphasizes the attributes of the means in a decision process over the attributes of the final decision (March, 1978). Game rationality emphasizes the interactions of individuals within larger institutions and organizations (March, 1978). This rationality relates to the discussion of collective goods discussed earlier. Contextual rationality emphasizes the complex social structures in which an actor is embedded (March, 1978). Limited rationality emphasizes how individuals simplify a decision due to the difficulties of considering all possible alternatives and all information (March, 1978).

These rationalities emphasize that decisions can be based on limited knowledge, and so the actor is rational within certain constraints.

This notion that information has costs is also important in transaction costs. Transaction costs introduce the notion of ignorance (Allen, 1999). Transaction costs are the costs of making transactions in the market. These costs include the search and information costs associated with parties finding each other, communicating, and exchanging information (Allen, 1999). The information seeking and processing activities of the innovation-decision process are examples of transaction costs; a party must discover an innovation and gather more information to make an informed decision to adopt an innovation, change to the new innovation, and then verify that the innovation functions properly. Transaction costs can quantify the costs of an adoption decision.

The information costs can also depend on where the decision is made. Rogers (2003) recognizes that decisions can be made on different levels and references three types of innovation-decisions: optional, collective, and authority. The optional decision is one made by an individual, a collective decision is made by a consensus among members, and an authority decision is made by a few who possess some power over the rest (Rogers, 2003). However, as was discussed in the triability of phytase, the decision to use phytase is not in the hands of one particular group; the decision maker can be the farmer, feed manufacturer, or contractor. The information flow and contractual arrangements between these groups can determine the decision to adopt phytase and the level of knowledge about its use.

Information costs can also be affected by how the information is presented. Choice architecture is a development in pop-economics that recognizes information can be arranged in a way to affect other's choices. Nudge (2008) is one of the most recent books to cover this subject. In it, the authors Thaler and Sunstein list six principles of good choice architecture: incentives, understanding mappings, structure complex choices, defaults, give feedback, and expected error. Incentives ask who uses, chooses, profits, or pays. Understanding mappings is about putting information in an easy to understand and comparable context, such as listing a camera as providing quality photos at various picture sizes instead of megapixels. Structuring complex choices involves simplifying the choice set based on given information. Thaler and Sunstein discuss the thousands of colors available at a paint store, and that the arrangement by hue and shade is much simpler than an arrangement by alphabetical order. A default is a selection that is automatic unless the user specifies otherwise. Feedback informs the user of results, such as a digital camera that shows the picture just taken. Expected error anticipates mistakes made by the user, like leaving gas tank caps behind which was corrected by a small piece of plastic connecting the cap to the car. Choice architecture can affect the choice and the knowledge of a user.

The incentive, complex choice structuring, and default principles of choice architecture are important in the case of phytase. The incentive principle of who chooses was discussed earlier with contract farms. Structuring complex choices and defaults work together in animal feed. Farmers who buy their feed do not need to know the appropriate levels of energy, amino acids, phosphorus, vitamins, and the like in animal feed, but the choice has been simplified into a choice based on characteristics of the animal like species, age, and productivity. These choices contain a number of defaults; each animal needs a certain level of nutrition and the nutrition of each ingredient is defaulted so that a manufacturer can determine the best formulation for the customer (St-Pierre, 2001; Philippine Society of Animal Nutritionists, 1990; Blezinger, 2003). Currently, phytase is a default option included in the base mix for proper phosphorus levels (Ferrell and White, Personal Communication, 2008). Farmers can select phytase-free base mixes, but this requires the farmer to gather information beyond phosphorus content to be informed of phytase and to transact with the feed manufacturer to not use it. The use of defaults creates a "status-quo bias;" individuals are more likely to use the existing standards even when switching can be done at low cost (Camerer et al., 2003). If individuals are fully rational and the cost to switch is low, then defaults have virtually no effect on the outcomes. However, defaults are important for individuals who are boundedly rational and have a status quo bias (Camerer et al., 2003). Since phytase has been automatically incorporated in most non-ruminant premixes, it is possible that many farmers have accepted the status quo. Although these principles may have reduced the transaction costs in feed selection, the defaults in feed can make it more difficult to determine the presence of a specific ingredient.

A farmer faces significant information cost concerning a specific ingredient in animal feed. Since phytase has become an automatic default, many farmers automatically adopt phytase without specific consent. Additionally, the low observability of phytase raises the cost to be aware of its use. These transaction costs increase the likelihood that there is a divergence between a farmer stating the use of phytase and the real use of phytase.

Conclusion

Traditional adoption studies assume a decision maker with knowledge of the innovation. Phytase is unique in that there are multiple levels of potential decision makers, and the farmers that use the innovation may be unaware of its presence. This review has discussed the historical use and attributes of phytase. Additionally, it reviewed literature concerning the attributes of the farmer as a decision maker. This study is unique from other adoption studies by including a discussion on transaction costs and how it can cause a deviation between stated and actual adoption rates. These factors will be formulated into a conceptual model in the next chapter.

Chapter 3: Conceptual Model

Since phytase is a relatively invisible innovation, this model will examine if there is a divergence between the stated adoption rate and actual adoption rate. Since there are many scholarly fields that study agricultural adoption and each study may have different constraints and objectives, no single standard conceptual or theoretical model for studying adoption of agricultural innovations could be found. Additionally, no models discussed unwitting adoption. Cognition models in psychology focus on how an attitude towards an innovation changes over time or how a person reasons instead of considering a potential divergence between a stated answer and the actual practice (Au and Enderwick, 2000; Oaksford and Chater, 1998; Akerlof and Dickens, 1982). The proposed model will thus examine the normal characteristics of an adoption model but include variables to examine potential divergence in stated and actual adoption rates.

The conceptual model for this study is a modification of the innovation-decision process as discussed in the literature review. The characteristics of the innovation and decision maker will be examined, consistent with a traditional adoption study. Since a farmer can receive satisfaction from the perceived economic and environmental benefits of phytase, this model is based on utility maximization. This model will also include variables that might capture the transaction costs incurred by the farmer. As discussed in the literature review, the transaction costs allow the farmer to be ignorant of the actual adoption of phytase while being able to state a rejection of phytase or to remain unaware of phytase.

Based on the literature review, the following model is obtained:

U = f(Profitability, Time consuming, Complicated, Phytase water quality effect, Water quality concern, Off-farm income, Education, Age, Species, Manure Transfers, Animal units per acre, CAFO, State, Other farmers, NRCS, Contractor/Integrators)

<u>Variables</u>

The survey asked if the farmer uses phytase in feed rations and was given three options: yes, no, or don't know. If there is no divergence between the stated and actual adoption rates, then we would expect to see most non-ruminant farmers use phytase, ruminants to not use phytase, and very few "don't know" responses. If there is a divergence between a stated response and actual response, then the stated answers can be based on different situations. For instance, a farmer may select "don't know" because the farmer does not know what phytase is or the farmer may know about phytase but not know if the enzyme is in the feed. Additionally, farmers who state they do not use phytase can be motivated by knowing they do not use phytase or because they are not aware that phytase is in most premixes. Farmers who state they are using phytase are by-and-large expected to correctly state their adoption, but the number of farmers in this category would be reduced. Understanding the motivations for selecting a given answer can assist in determining how factors affect those choices.

Since the model allows for the farmer to state three possible answers regarding phytase adoption, two specific hypotheses are required for each independent variable. This is because the probabilities for the dependent variables must sum to one, so the probability of any one dependent variable can be determined by the probabilities of the other two dependent variables. The base for the dependent variable in this model will be "no;" the farmers who state they do not use phytase. The first hypothesis for each independent variable will examine how that variable affects the probability that a farmer states a use of phytase relative to the "no" base. The second hypothesis will examine how the variable affects the probability of a "don't know" response relative to the "no" answer.

Phytase Attributes

The attributes of phytase were rated on a five-point Likert scale with no non-response variable. The lack of a non-response variable forces the farmer to state an opinion on various phytase attributes. Ryan and Garland (1999) suggest that people that genuinely have no knowledge or opinion on a variable are likely to state a neutral response. Therefore it is expected that the farmers who are neutral on phytase attributes are likely to state "don't know" to a question concerning their phytase use.

Profitability is how the farmer perceives the bottom line economic benefits of phytase, related to the relative advantage of adoption. It is expected that perceived profitability is positively correlated to farmers who state they use phytase. Neutral responses are expected to be positively correlated with "don't know" responses since it is expected that a portion of these farmers lack knowledge on phytase.

Time consuming is if the farmer perceives the practice as time consuming or not. Time consumption is related to relative advantage since "time is money," but it may also be associated with the complexity of the practice since a complex practice takes time to understand. Responses that view phytase as time consuming are expected to be negatively correlated with phytase adoption and neutral responses are expected to be positively correlated with "don't know" answers.

Complicated measures how complicated the farmer perceives the phytase practice. It is different from time consuming since a practice may be perceived as time consuming but not complicated. As the name suggests, it is related to the complexity of the practice. Farmers who perceive the practice as complicated are expected to be negatively correlated with adoption. Again, the farmers who remain neutral are expected to state "don't know."

Phytase water quality effect measures the farmer's perception that phytase improves water quality. This variable is designed to capture the environmental benefits of phytase related to the relative advantage of phytase. Farmers who think phytase improves water quality are expected to be positively correlated with phytase adoption. The farmers with neutral responses are expected to be positively correlated with "don't know" responses.

Farmer Attributes

As mentioned in the literature review, the attributes of the decision maker can affect the perceptions of innovations and transaction costs.

Water quality concern is if the farmer is concerned about water quality in his/her county. This variable works with "phytase water quality effect" to capture the overall environmental benefit to the farmer. Higher concern about water quality is expected to be associated with farmers who have adopted phytase. Although a strong concern about local water quality can prompt a farmer to find ways to reduce water pollution, it is not anticipated that this concern will be significantly correlated with “don’t know” responses.

Off-farm income, as discussed in the literature review, measures how much income is earned off the farm. This is related with transaction costs since higher off-farm income can limit time available for on-farm work. Additionally, this variable can capture a farmer’s emphasis on farming. It is expected as off-farm income increases, the time to gather information about phytase decreases reducing the probability that a farmer will state phytase use and increasing the probability the farmer does not know.

Education identifies the farmer’s highest level of education which is significant in the adoption of new innovations. It is expected that higher levels of education are associated with higher levels of phytase adoption since a better educated farmer may have better access to good information and be more equipped to handle complex problems. By this same reasoning, it is expected that better educated farmers will be less likely to state “don’t know.”

Age identifies the age of the farmer. As mentioned in the literature review, the relationship between the rate of adoption and age is inconsistent. Since the age of the farmer wouldn’t change the advantages of phytase, it is expected to be insignificant for “yes” responses. Age is typically included in regression models, however the researchers were unable to locate literature that would discuss the direction and expected significance of age with respect to “don’t know” responses.

Farm Attributes

In the literature review, farm size was classified as an important factor in the socioeconomic attributes of the decision maker. This section separates characteristics of the farm from the farmer and describes how attributes of the farm affect the stated response.

Species identifies the types of species the farm produces. This variable captures the compatibility of phytase with the farm. It is expected that non-ruminant species, such as swine, broilers, turkeys, and other non-ruminants, are positively correlated with phytase use. Ruminants are expected to be negatively correlated with phytase use. Non-ruminants are expected to be negatively correlated with farmers who do not know if phytase is used since phytase is applicable to non-ruminants only. However, beef cattle on feed may also be negatively correlated with "don't know" responses since feed is important to the farmer's operation.

Manure transfers identify if the farm gives manure away or sells manure to other farms. As mentioned in the literature review, a farmer who sells manure may find phytase less desirable since the phosphorus content is lower which can mean less value in the manure. Therefore farms that sell manure as a product may be less likely to state an adoption of phytase, thus a negative correlation is expected. Farms that give manure to other farms may be more likely to be positively correlated with "yes" responses since transferring manure is costly. Since both of these responses affect the benefits to a farmer who transfers manure, both answers are expected to be negatively correlated with "don't know" responses.

Animal units per acre tries to identify farms that are limited in the ability to spread manure over large areas. This variable is expected to be positively related to phytase adoption since a farmer is limited to the amount of land on which he can spread manure as animal units per acre rise. These limitations could also prompt the farmer to search for solutions; therefore this factor is expected to be negatively correlated with "don't know" responses.

CAFO is if the respondent indicated that the farm is a concentrated animal feed operation. It is a measure of the size of the farm and also faces stronger regulations than non-CAFO farms. A farm that is a CAFO is expected to adopt phytase more than non-CAFO farms. For the same reasons as the factor above, this factor is expected to be negatively correlated with "don't know" responses

State identifies if the farmer is from Iowa or Missouri. This represents the different regulations between states and additional social system factors. Since the regulations for Iowa are P-based, it is expected that farmers from Iowa are more likely to adopt phytase. This same factor is expected to be negatively correlated with no knowledge of phytase adoption. In theory, regulations can prompt further interest in methods that would reduce exposure to regulatory costs.

Outside Influences

These variables measure the influence of outsiders on the agricultural production decisions of the farm.

Other farmers measures the influence that other farms have on their operation. As discussed in the literature review, good communication can reduce risk and information costs. Farmers who are influenced by other farms are likely to gather more information regarding recent innovations. Therefore we anticipate that farms with higher influence from other farmers are more likely to state phytase use and less likely to state "don't know."

NRCS measures how much influence the Natural Resource Conservation Service has on the farm. It is expected that farms with higher influence from the NRCS are going to be more likely to state phytase use because of its environmental benefits. It is also expected that these farms are less likely to not know if phytase is used in their feed since they are expected to be better informed by environmental issues.

Contractors/Integrators identify contract farms. As discussed in the literature review, contractors may provide the farms with feed. Therefore a farmer is less likely to know the formulation of the feed. Farms with higher contractor influence are expected to be less likely to state phytase use. These farmers are expected to be positively correlated with no knowledge of phytase use.

Conclusion

This model provides a conceptual basis that allows us to examine factors that affect stated adoption. By combining this model with our survey, we can examine two questions simultaneously. First, the model will examine factors that affect the adoption of phytase. Secondly, if there is a divergence between stated adoption and actual adoption rates, we can examine the factors that affect the divergence.

Chapter 4: Methods and Data

A mail survey was conducted among 3,014 randomly selected livestock producers in Missouri and Iowa by Haluk Gedikoglu (2008) and assisted by Dr. Laura McCann and Jessica Amidei in spring 2006. Farmers were stratified by farm sales and livestock prior to random sampling. Farmers with farm sales less than $10,000 were not sampled to eliminate most retirement / lifestyle farmers (Gedikoglu, 2008, citing Hoppe and Banker, 2006). The survey was designed and conducted following the methodology of Dillman (2000). The survey requested information on the farmer's adoption of selected conservation practices and characteristics of the farm and farmer. Pre-testing was conducted with 100 farmers to determine how farmers respond to the survey (Gedikoglu, 2008). One of the lessons learned from this pre-testing was that the question concerning phytase use required three options; they could use phytase, not use phytase, or state they did not know (McCann, Personal Communication, 2008). After revising the survey, the final survey was sent with a cover letter, a prepaid postage envelope, and a form to enter in a $200 gift certificate drawing (Gedikoglu, 2008). Farmers were later reminded by a postcard and after two weeks an additional package was sent asking farmers to participate. The response rate for the survey is 37.4 percent after correcting for the farmers that had stopped farming and undeliverable surveys (Gedikoglu, 2008). The full survey is available in Appendix C.

Since the dependent variable can be one of three values and there is no order to the responses, three multinomial regression models can be used: linear probability, multinomial logit, and multinomial probit. The linear probability regression model can be adapted by running two equations instead of one (Halcoussis, 2005). This model is a basic ordinary least squares (OLS) regression where the coefficients represent the marginal effects of the dependent variables on the independent variable. Only two regressions are necessary for the three choices since the final probabilities must sum to one and the coefficients sum to zero (Halcoussis, 2005). The advantages for this regression are that the interpretation of the regression is easy and the OLS software is readily available. Unfortunately this regression can also yield nonsensical results, such as probabilities greater than 100 percent and less than zero. The regression model also assumes a fixed linear relationship between the dependent variable and the independent variable (Halcoussis, 2005). This assumption can be unreasonable in many cases. For instance, if the probability of receiving an "A" on an exam was regressed to number of hours studying, the model would indicate the tenth hour of study would have the same impact as the first; there are no diminishing returns as the number of hours increase. All together, the problems of the linear probability model usually outweigh the benefits.

The multinomial logit model avoids the problems of the linear probability model. In this model, one of the choices is treated as a base, similar to the linear probability model (Halcoussis, 2005). This model is an extension of the logit regression model. In these models, the resulting dependent variable has a range from zero (0%) to one (100%) and the error terms are based on the cumulative logistic function (Wooldridge, 2006). The software is more complex and the interpretation is more difficult. For example, if the regression model for the stated response to phytase adoption is "yes" and the base is "no", a one year increase in age will increase the difference between the logarithm of the probability of stating "yes" and the logarithm of the probability of stating "no" by the coefficient of age (Halcoussis, 2005). The largest issue with the multinomial logistic model is if two or more of the choices are close substitutes. This requires the assumption of independence of irrelevant alternatives (Wooldridge, 2002).

The independence of irrelevant alternatives assumption (IAA) can be relaxed in the third model: multinomial probit. The classic example used to demonstrate the assumption is found in Wooldridge (2002) based on a model developed to determine a commuter's transportation method. The potential methods are a car and a red bus and the odds for either mode are split fifty-fifty. If a blue bus option is added, under IAA the odds for each method change to one-third. However, it is likely that the consumer does not care between a red bus and a blue bus and it is unrealistic that the odds for traveling by car would drop from 50 percent to 33 percent. Given those potential choices the multinomial probit model would be appropriate since it assumes arbitrary correlations between the potential independent variables (Wooldridge, 2002). However, the response probabilities are even more complicated than multinomial logit model and the maximum likelihood becomes infeasible after five alternatives (Wooldridge, 2002). Therefore, if the choices are not close substitutes, the multinomial probit model may not be the preferred model.

Dependent Variable

Since the choices in our survey regarding phytase adoption are not close substitutes, the multinomial logistic regression model is the best model to use. The farmer answers were placed into one variable for the regression where "Y" represents a farmer who uses phytase, "N" for a farmer who does not use phytase, and "DK" for a farmer who did not know. As mentioned above, one of the independent variables is needed to remain a base. For this regression, farmers who do not use phytase, “N,” will be the base. This is to ease the translation of which variables are significant to the use of phytase and examine the variables that affect the “don’t know” responses.

Independent Variables

The independent variables are also drawn from the survey and address the variables described in the conceptual model. The independent variables are divided into the same categories as was done in Chapter 3. Each variable includes information on how it was developed from the information in the survey and, if necessary, identifies the base category.

Phytase Attributes: Profitability, Time intensity, Complicated, and Improves water quality

Farmers were asked to rank their opinions about four statements of phytase characteristics on a Likert scale, from 1, meaning strongly disagrees, to 5, strongly agree. The four statements were: “This is a profitable practice, it improves my bottom line,” “This practice improves water quality,” “This practice is time consuming,” and “This practice is complicated.” These answers were then categorized into three dummy variables per attribute. For instance, for the responses to the profitability of phytase, responses 1 and 2 are combined into “Phytase Not Profitable”, 4 and 5 to form “Phytase Profitable,” and response 3 remains a neutral dummy variable. The neutral dummy will be the base for the regression. The neutral dummy is important in this study since it is expected that farmers who are not knowledgeable about phytase are likely to remain neutral on phytase attributes as mentioned in Chapter 3.

Farmer Attributes: Concern for water quality, Off-farm income, Education, and Age

The farmers were asked to rank their opinions regarding their concern about the water quality of local streams and lakes on a 1-5 Likert scale. Like the responses for phytase attributes, this was categorized into three variables; responses 1 and 2 combined for “Not Concerned about Water Quality,” responses 4 and 5 combined into “Concerned about Water Quality,” and response 3 remaining a neutral category that also serves as the base. The concern for water quality is a complement to “Improves water quality” variable since they can represent the farmer’s perception of the environmental benefits of phytase.

Farmers were asked to list their off-farm income at censored intervals of no off-farm income, between $0 and $9,999, between $10,000 and $24,999, between $25,000 and $49,999, between $50,000 and $99,999, and $100,000 or more. Each category has been assigned a dummy variable to represent the different levels of off-farm income. No off-farm income will serve as a base to observe how increasing levels of off-farm income affect the dependent variables.

Farmers were asked to identify the highest level of education they completed, categorized into “Less than High School,” “High School Diploma,” “Some College or Vocational School,” “Bachelor’s Degree,” and “Graduate Degree.” Like farmers, these categories have also been assigned a dummy variable representing the highest level of education obtained by the farmer. "Less than high School" will serve as the base for these variables.

Age is defined by 2006 (the year the survey was taken) minus the farmer's year of birth. The simple calculation results in a quantitative variable and requires no base.

Farm Attributes: Species, Manure Transfers, Animal units per Acre, CAFO, and State

Farmers were also asked to provide the species of livestock they used and the average number of livestock from that species on the farm from all age groups. The species categories are Dairy, Beef Cattle on Feed, Beef Cows, Swine 55 lbs. or less, Swine more than 55 lbs., Broilers, Turkeys, and Other Livestock. These animals were converted to animal units. One definition of a CAFO is a farm that has 1,000 animal units. The 1,000 animal units are equivalent to either 700 Dairy cattle, 1,000 Beef cattle, 10,000 Swine less than 55 pounds, 2500 Swine greater than 55 pounds, 30,000 Broilers, 55,000 Turkeys, or a combination of the above (Todd, 1996). Therefore, one dairy cow can be considered to be seven-tenths of an animal unit. The "Other" category was also converted by each case and an appropriate animal unit was assigned for each species. These numbers were consistent with the conversions in Gedikoglu (2008). To form a dummy variable, the animal units of each category were divided by the sum of all the animal units on the farm. If the number was larger than .25, then a "1" was entered into a category representing that species. This was done to exclude family use animals and to identify and include farmers that may have significant numbers of animals in different species. For instance, if a farm was 60 percent dairy and 40 percent swine, then the farmer would be identified as having both swine and dairy. Since the farm has a significant amount of swine, it would be expected that the farmer uses phytase and this categorization allows the farmer to be identified as a swine farmer, likely to use phytase, as well as a dairy farmer. The "Other" category was further split between ruminants and non-ruminants. Horses were treated as ruminants; they can process phytate in the hind gut fermenter although there is some indication that phytase is a benefit to horses (van Doorn et al., 2004; Westendorf and Williams, 2007). Additional ruminants in the other ruminant category include sheep and goats and other cattle. Different types of chicken formed the other non-ruminant species category. Altogether a set of nine dummy variables represent the different species on the farm.

Manure transfers, as discussed in the literature review, can affect the relative advantage of phytase. Manure transfers were split into two dummy variable categories; "Sell Manure" and "Give Manure." First, the farmer is asked if the farm provided manure to other operations. If the farmer was paid for the manure provided to other farms, then a "1" is indicated under "Sell Manure." If the farmer was not paid, then a "1" is indicated under "Give Manure." If no manure is provided to other farmers, then both categories are "0," which also serves as the base.

The Animal Units per Acre is a variable developed by dividing the total animal units developed for the species variables by the total amount of land the farmer uses. The total acres that a farmer uses are calculated by subtracting the land rented to other farmers from the total land owned by the farmer and also adding the land that the farmer leases from others. This results in a quantitative variable.

The CAFO and state variables were developed directly from the survey. The CAFO variable is a “1” if the farmer is a permitted CAFO, else “0,” not a permitted CAFO. Likewise, a “1” was entered if the farmer is from Iowa, “0” if from Missouri. The bases for the variables are not a CAFO and Missouri.

Outside Influences: Other Farmers, NRCS, and Contractors/Integrators

The farmer was asked to state the influence that others had on the agricultural production decisions based on a 1-5 Likert scale. Responses 1 and 2 were combined for a low to no influence dummy variable response. Responses 4 and 5 combined for a high influence dummy variable response. Response 3 is the third category representing some influence. The three groups of people are other farmers, NRCS, and contractors/integrators. The base for these categories is “3.”

Software

The software for the regression will be STATA 10.0. This software is used because of its convenience, relative ease of use, and provides the desirable output statistics. SPSS 16.0 is easy to use, but does not provide marginal effects. SAS 9.1 is also available, but the codes to develop marginal effects are somewhat complex.

Conclusion

The conceptual model forms the basis of selecting and categorizing the independent and dependent variables. The multinomial logistic regression is the most logical model to use since the dependent variable is not ordered and the answers are not close substitutes. The majority of the independent variables are categorized into dummy variables with the exception of age and animal units per acre. The formulation of these variables allows tests to be run on the hypothesis described in the previous chapter.

Chapter 5: Results and Discussion

This chapter is divided into two sections, each addressing one of the two objectives of the paper. First, the data will be analyzed to determine the state of farmer knowledge about this new technology. Then regressions will examine the social and economic factors that impact the stated adoption, rejection, or lack of knowledge of phytase.

The State of Farmer Knowledge

The state of farmer knowledge about phytase will be determined by examining the data and statistics. This examination will also prepare the data for the regressions to be completed in the next section. In total, 1030 surveys were received. In these surveys, 79 farmers stated adoption of phytase, 356 stated they did not know, 515 farmers stated they did not use phytase, and 80 farmers left the question blank. Over 43 percent of all 1030 farms had at least a quarter of the farm's animal units comprised of non-ruminants.

Blank data

Of the 1030 farmers, 356 had left responses blank at various places in the survey. Figure 4 shows the count of the survey questions that were left blank. As the figure shows, most blank responses were for the phytase characteristics. The next two significant categories are phytase use (80 blank responses) and whether the farmer is a permitted CAFO (77 blank responses). Since a significant number of responses were blank for phytase characteristics, an additional graph was made to compare the blank responses of other practices surveyed. Figure 5 shows the results, which is the average of the number of blanks of each attribute for each practice. This average was calculated by summing the blanks for the four characteristics of each practice and dividing by four. As can be seen, the attributes of phytase yielded more blank responses than any other category. The average number of blank responses for all categories was approximately 140; the average of phytase attribute blanks was nearly 50 percent higher. This implies that farmers are not knowledgeable about phytase. In addition, the questions regarding if the farmer performs the selected practice were examined to see if phytase use blanks were significantly different from other practices. The average blanks left regarding the performance of all practices was 85, and since there were only 80 blanks for phytase use, phytase yielded more responses than the other practices. Perhaps this is due to the fact that phytase has the option of a "Don't Know" response.

These surveys with blank responses for the questions to be used in the regression were separated from the complete surveys. The means of all the variables in both groups were taken and compared to the mean of the same variable in the opposite group. The resulting t-tests showed no significant differences between the two means of any category. This shows that there were no significant differences between the two groups; there wasn't any characteristic that made a farmer more likely to leave a blank response instead of completing the survey. Because of this result, and since blank responses cannot be used in a regression, it was determined that the observations with blank responses would be deleted. This technique, called Listwise deletion, reduces overall accuracy, but gives conservative parameter estimates (Tsikriktsis, 2005). Since the sample size is reduced, the statistical power is also reduced, therefore results in making fewer variables statistically significant (Tsikriktsis, 2005).

Figure 4: Count of Survey Responses Left Blank by Category.

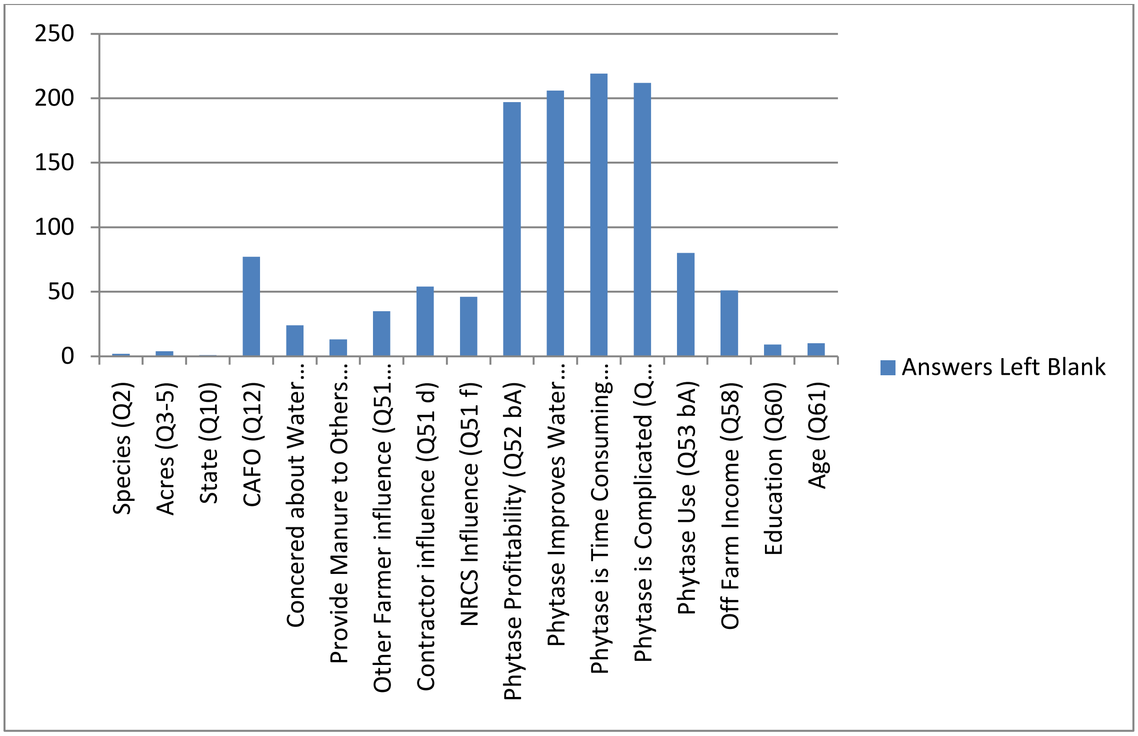
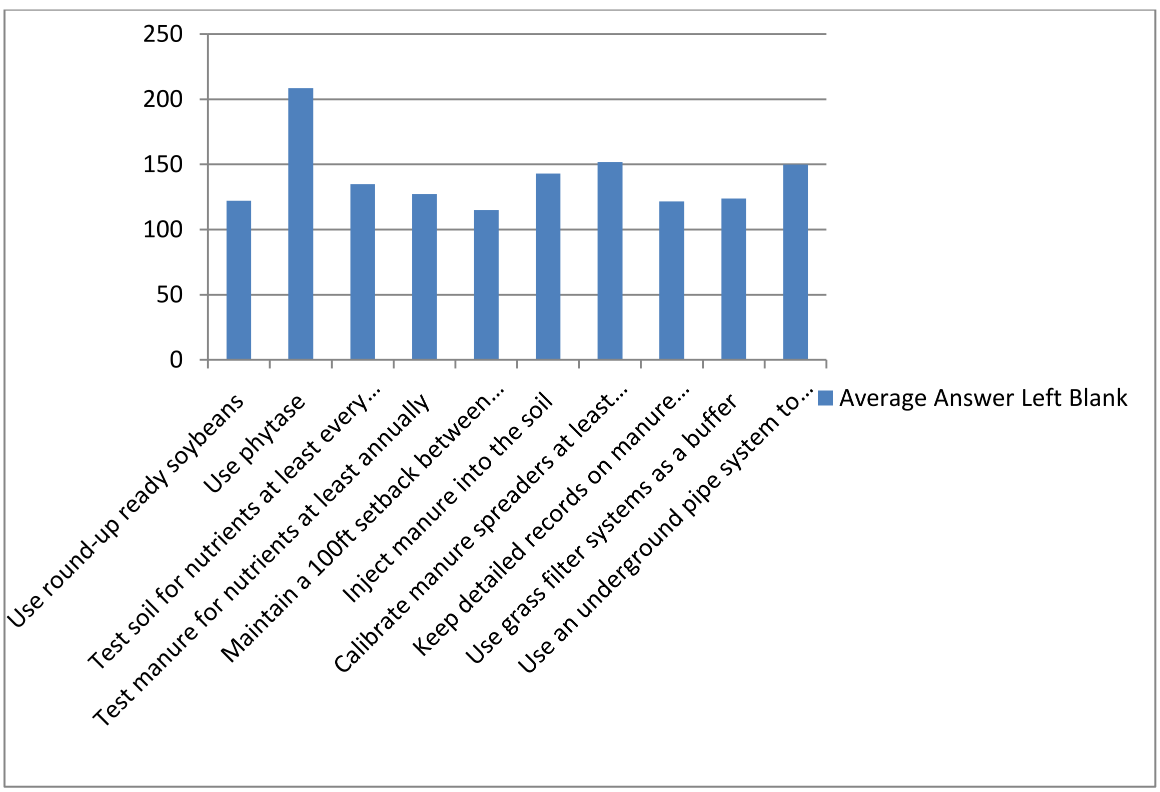


Figure 5: Average Count of Responses Left Blank across the Attributes of Select Practices in Survey.



Neutral Responses

The characteristics of phytase were further examined since a significant number of observations were blank. At least 450 farmers responded neutrally to each characteristic of phytase (see Figures 6, 7, 8, and 9). Since farmers who had no knowledge about phytase were expected to remain neutral, the large number of neutral responses suggests that farmers are unfamiliar with the enzyme. The farmer's concern about water quality was also graphed to contrast this question with the attributes of phytase (see Figure 10). Most farmers stated that they were concerned about water quality. Some of this may be due to observer bias; the farmer might desire to be viewed as environmentally conscious, but it is also true that the farmer hasn't had to evaluate this statement in reference to an opportunity cost.

Figure 6: Response Count of the Farmers' Opinions of Phytase's Profitability.

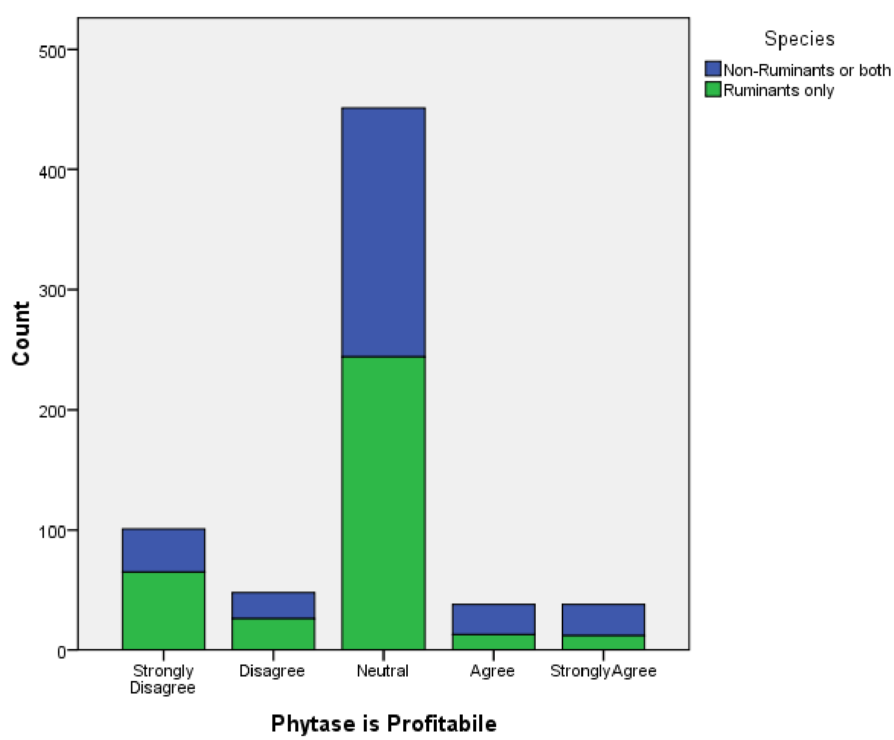


Figure 7: Response Count of the Farmers' Opinions of Phytase's Ability to Improve Water Quality.

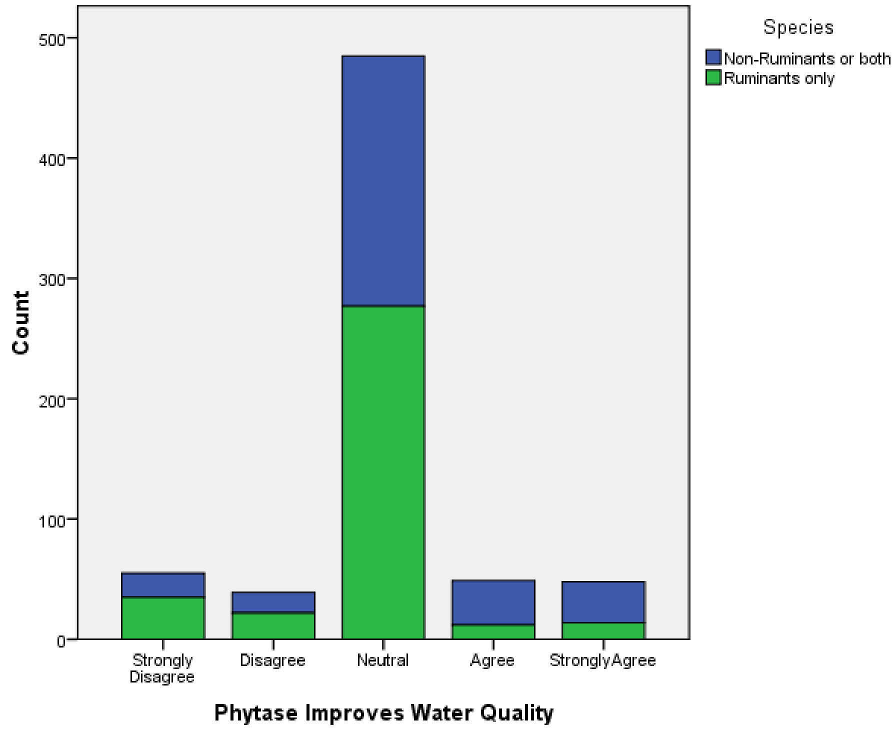


Figure 8: Response Count of the Farmers' Opinions of Phytase's Time Consumption.

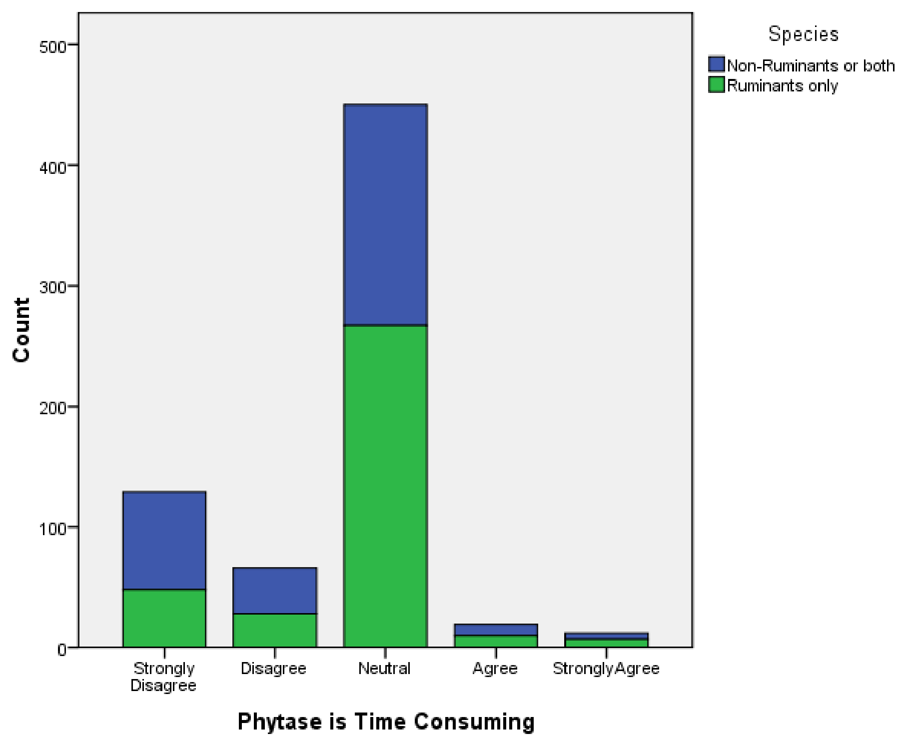


Figure 9: Response Count of the Farmers' Opinions of Phytase Being Complicated.

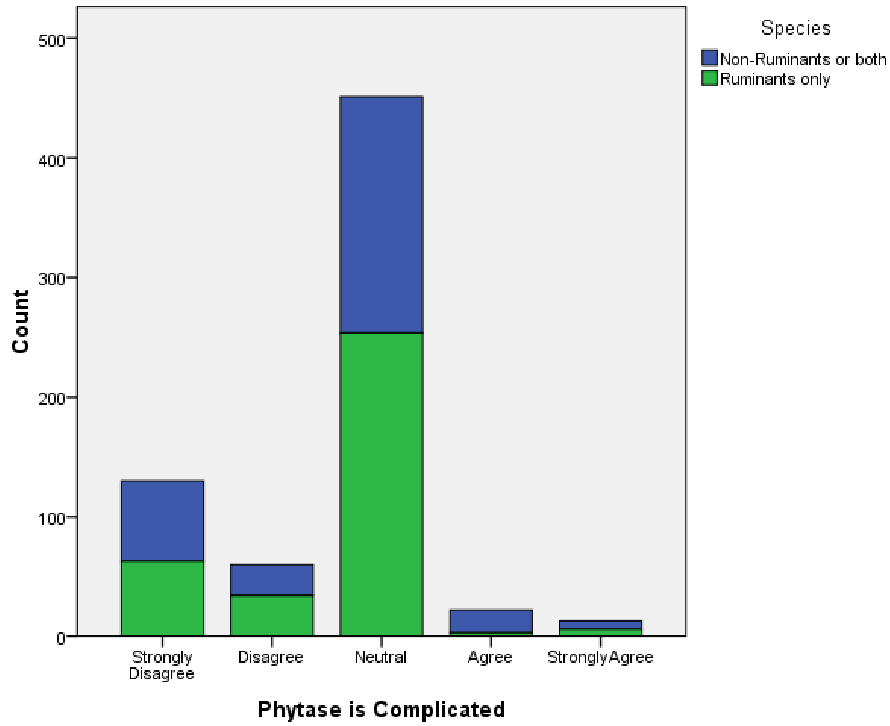
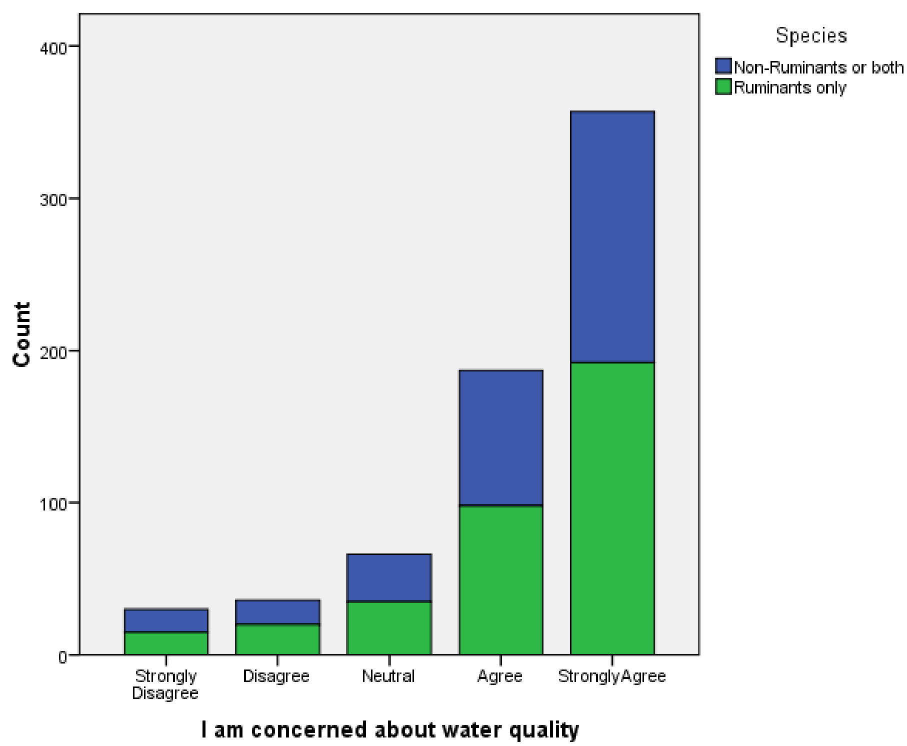
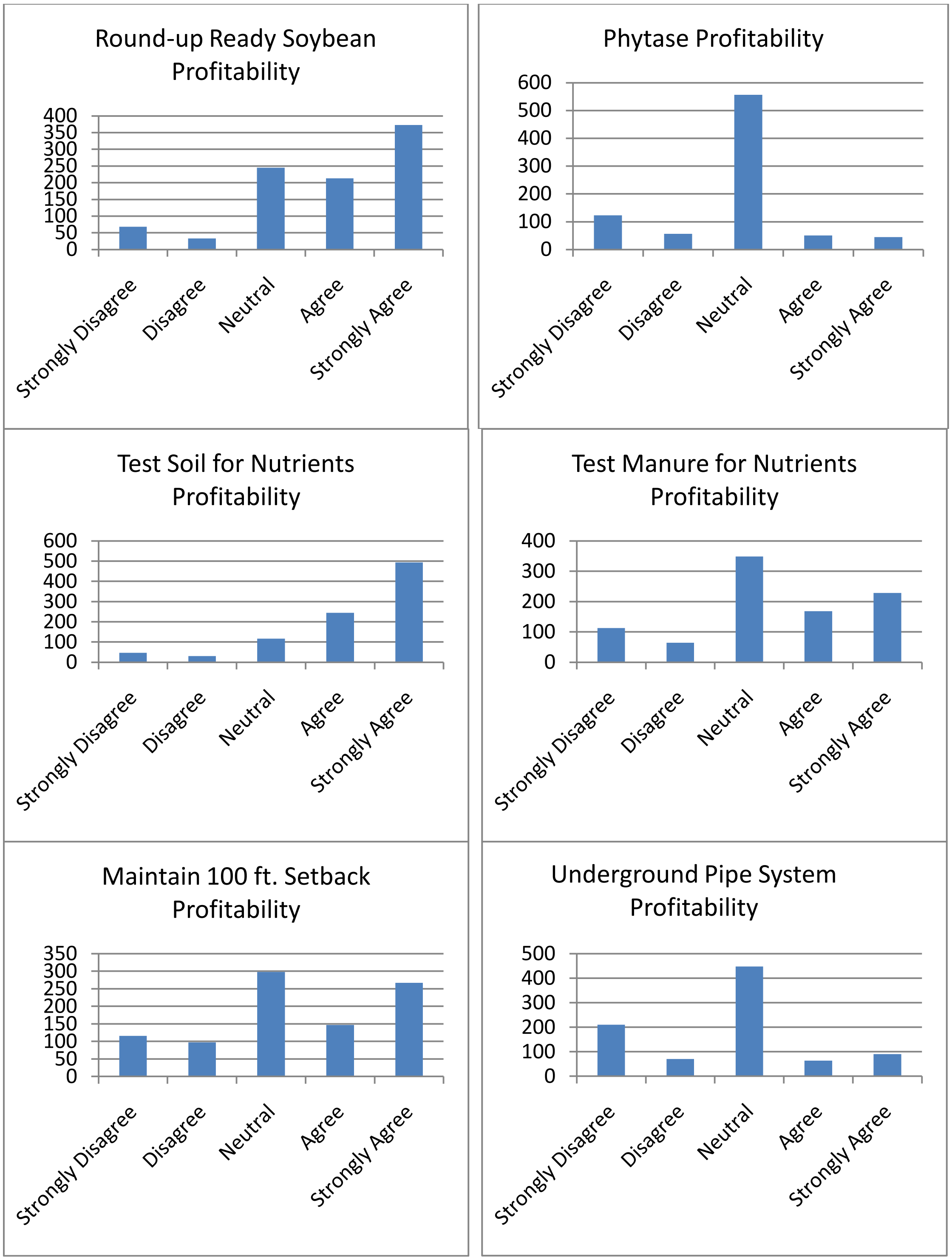


Figure 10: Response Count of the Farmers' Concern for Water Quality.



There are a significantly higher number of neutral responses to phytase characteristics than other responses. The responses to phytase characteristics were compared with the responses to the characteristics of other practices. Figure 11 includes graphs of the responses to the profitability of a few of the practices. The data came from all 1030 surveys received and excluded the blank observations for each practice characteristic. As can be seen in Figure 11, although there are many neutral responses for most practices, the proportion of neutral responses to phytase profitability are a lot higher than that of other practices. The practice of using an underground pipe system to move manure to fields received the second highest number of neutral responses; fifty-one percent compared to sixty-seven percent for phytase profitability. For all characteristics of each practice, none received a higher percentage of neutral responses than the characteristics of phytase.

Figure 11: Response Count of the Farmer's Opinion of Select Practice's Profitability.



As shown above, the attributes of phytase received more blank and neutral responses on average than other practices on the survey. As mentioned earlier, Ryan and Garland (1999) suggest that people who genuinely have no knowledge or opinion on a variable are likely to state a neutral response. Additionally, it is likely that a person with no knowledge may leave the question blank out of frustration. Since farmers responded with more blank or neutral responses to phytase characteristics, it is likely that farmers know less about phytase than the other practices.

Multicolinearity

A correlation matrix was created to find any multicolinearity issues in the independent variables. The matrix showed a high degree of correlation between complicated and time intensity (0.796). The data was reanalyzed to see if removing either one of the two categories would have resulted in a larger data set. Removing either the complicated variable or the time intensity variable would increase the data set by two responses. The complicated variable was thus dropped from the regression and the two additional observations were added resulting in 676 total observations. This was done because of previous research with this data set in "Adoption of Phytase by Livestock Farmers" (Stahlman et al., 2008). During that study, the regressions were run twice, once including "time intensive" and the other including "complicated." The results for the "time intensive" yielded better results, including better pseudo-R-squares. Thus it was determined to keep the "time intensive" category and drop "complicated."

Additional Variables

Additional insights on farmers' knowledge of phytase can be made by examining the remaining variables. Crosstabulations serve an important role in analyzing the data. First, crosstabulations can assist in identifying data that has been improperly entered, such as if a "2" was accidently entered instead of a "1" for a dummy variable. Secondly and most important, the crosstabulations serve an important role in determining which variables can be included in a regression; each independent variable must have at least one variation per dependent variable. As seen in Tables 2 and 3, none of the farmers with broiler, other non-ruminant and other ruminant indicate phytase use. Without this variation, the regression is in a situation analogous to a dummy variable trap; the non-variation yields a singularity in the matrices and the results cannot be accurately determined. Since the multinomial logistic regression is determined simultaneously, the variables broiler, other non-ruminant, and other ruminant must be recategorized. If the categories were simply not analyzed in the regression and there was no other primary species in the observation, then the information in these observations would be analyzed as if they were the same as the base category.

Of the 34 farmers with other species, only 10 farmers had only other species. All the animals in the other non-ruminant variable are various types of chickens. Therefore in order to save the observation information, other non-ruminants, broilers, and turkeys will be combined into "poultry." The majority of the other ruminant category is horses. Since horses do not fit well into any other category, farmers who were primarily horses with no other species were removed. This eliminated only one observation from the data set, resulting in 675 observations. The other species in the other ruminant category are sheep, goats, calves and bulls. These were grouped into the beef cow category since it is expected that they are primarily on forage.

It is interesting that no broiler farmers stated phytase use while almost all of the ruminant species had some phytase users. Most of these responses are because these farmers also have a non-ruminant species, such as a dairy farmer could also have a swine operation. Only six farmers that only had ruminants stated phytase adoption.

Table 2: Crosstabulation of Phytase Adoption Response and Ruminant Animal Species.

Adoption Response	Dairy	Beef Cattle on Feed	Beef Cow	Other Ruminant
Y	6	11	1	0
N	87	124	103	12
DK	61	61	64	3
Total	154	196	168	15

Table 3: Crosstabulation of Phytase Adoption Response and Non-Ruminant Animal Species.

Adoption Response	Swine < 55 lbs.	Swine > 55 lbs.	Broiler	Turkey	Other Non-Ruminant
Y	5	54	0	3	0
N	11	61	31	43	7
DK	13	49	14	33	6
Total	29	164	45	79	13

The same lack of variation problem occurs with farmers with graduate degrees (see Table 4); there are no farmers that stated an adoption of phytase and held a graduate degree. In this case, the graduate degrees were combined with the bachelor degrees to form one variable. Some studies have indicated that there are differences between people with graduate degrees and those with bachelor degrees (Gedikoglu, 2008), but most studies combine these categories together.

Table 4: Crosstabulation of Phytase Adoption Response and Farmer Education.

Adoption Response	Less than High School	High School Diploma	Some College or Vocational School	Bachelor's Degree	Graduate Degree
Y	3	21	24	15	0
N	32	156	111	66	5
DK	29	118	54	37	5
Total	64	295	189	118	10

Crosstabulations also allow observations to be made on the data prior to the regression. For instance, nearly all the farmers who stated phytase adoption had swine >55 lbs. It is also interesting that all the ruminant categories besides other ruminants had noted some adoption of phytase. Many of these are explained by the farmers having both ruminants and non-ruminants; however a few farmers only have ruminants. Additional crosstabulations are included below (Tables 5, 6, 7, 8, 9, and 10). It is interesting that all but seven farmers that stated phytase adoption were from Iowa (Table 7). The farmers that stated phytase use were split nearly evenly between permitted CAFOs and other farms, although CAFOs made up only 19.3 percent of the 675 farms.

Table 5: Crosstabulation of Phytase Adoption Response and Off-Farm Income.

	Off-Farm income					
Adoption Response	None	$0 - $9,999	$10,000 - $24,999	$25,000 - $49,999	$50,000 - $99,999	$100,000 or more
Y	19	9	6	17	9	3
N	108	45	58	102	47	10
DK	60	38	43	64	31	7
Total	187	92	107	183	87	20

Table 6: Crosstabulation of Phytase Adoption Response and Manure Transfers.

Adoption Response	Give Manure (Yes=1)		Sell Manure (Yes=1)	
	0	1	0	1
Y	47	16	56	7
N	343	27	318	52
DK	220	23	214	29
Total	610	66	588	88

Table 7: Crosstabulation of Phytase Adoption Response and State and CAFO.

Adoption Response	State (IA = 1)		CAFO (Yes=1)	
	0	1	0	1
Y	7	56	29	34
N	192	178	320	50
DK	123	120	197	46
Total	322	354	546	130

Table 8: Crosstabulation of Phytase Adoption Response and Influence of Other Farmers on Decisions.

Adoption Response	Other Farmers				
	None	Little	Some	Much	Very Much
Y	9	12	36	4	2
N	84	65	152	52	17
DK	49	36	133	20	5
Total	142	113	321	76	24

Table 9: Crosstabulation of Phytase Adoption Response and Influence of NRCS on Decisions.

Adoption Response	NRCS				
	None	Little	Some	Much	Very Much
Y	10	13	21	16	3
N	102	63	125	60	20
DK	71	38	77	42	15
Total	183	114	223	118	38

Table 10: Crosstabulation of Phytase Adoption Response and Influence of Contractors on Decisions.

Adoption Response	Contractors / Integrators				
	None	Little	Some	Much	Very Much
Y	24	15	16	6	2
N	222	60	51	24	13
DK	143	28	49	14	9
Total	389	103	116	44	24

Since animal units per acre and farmer age are continuous variables, they cannot be analyzed through crosstabulations. The histograms of animal units per acre and farmer age are included in Figures 12 and 13. In order to present the animal units per acre, it was necessary to transform the x axis into logarithmic form. This was because the majority of farmers had less than 5 animal units per acre, but the range continued to approximately 131 animal units per acre. Both variables have been color coded with adoption responses.

Figure 12: Histogram of Animal Units per Acre

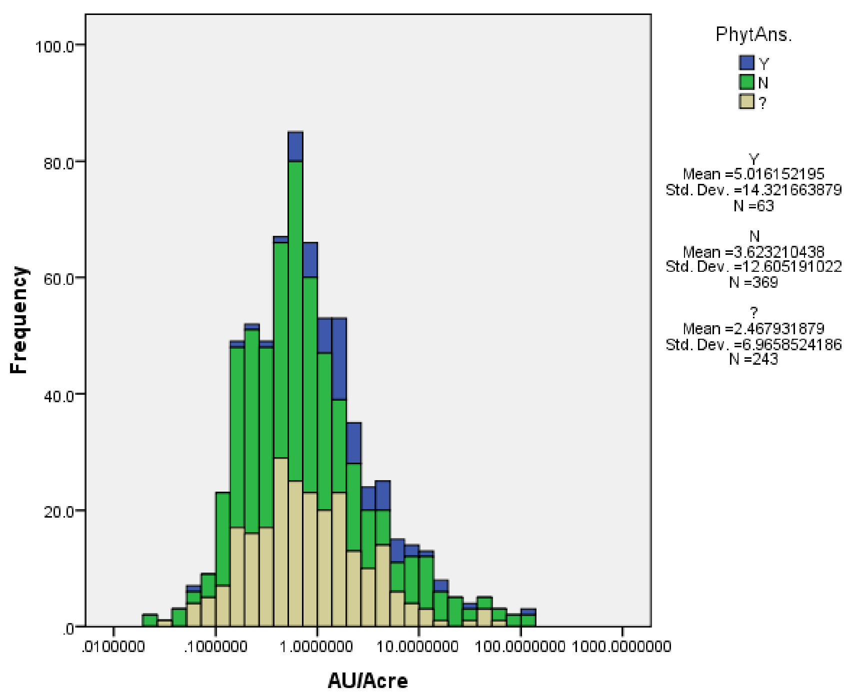
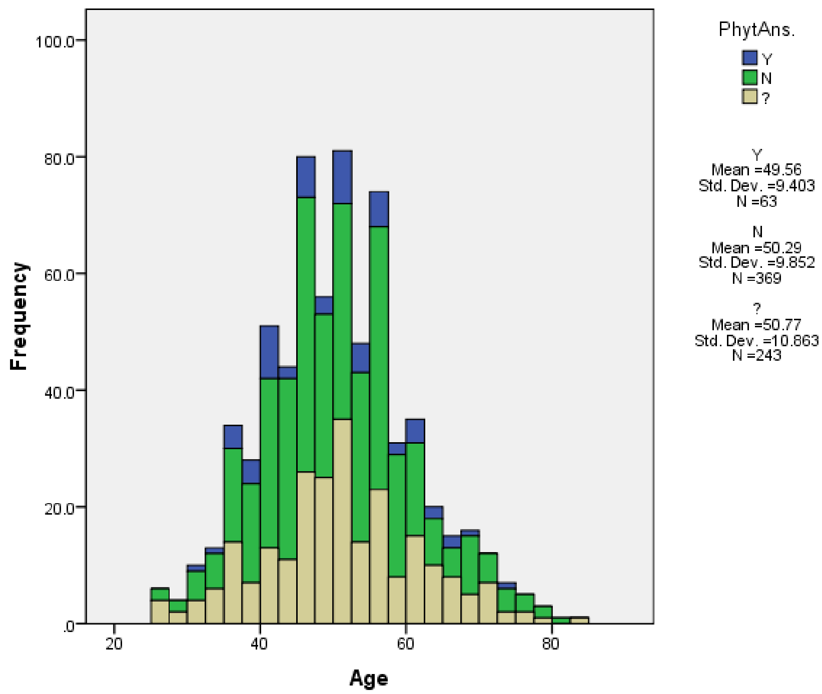


Figure 13: Histogram of the Farmer's Age



The descriptive statistics for each variable are shown in Table 11. Of the 675 remaining farmers, 63 (9.3 percent) affirmed phytase adoption, 369 (54.7 percent) stated they did not adopt phytase, and 243 (36 percent) farmers stated they did not know if they adopted phytase. Fifty-three percent of these farmers only had ruminant species. The average farmer is 50 years old. Most farmers have at least a high school diploma and 19 percent have also received a bachelor's degree or higher. Roughly half of the farmers are from Missouri, giving relatively equal representation between the two states. Only 19.2 percent of the farms are permitted CAFOs. The average farm in the survey has 648 animal units and access to 194 acres of land. In the 2007 USDA Agricultural Census, the average farmer in Missouri was 57.1 years old on 269 acres of land. In Iowa, the farmer was 56.1 years of age and on a farm of 331 acres. The farmers in the survey are thus, on average, younger and farm less land than the average of either two states. This may be related to the survey focus on famers with livestock rather than crops.

Conclusion

The review of the data and statistics affected the model by showing that the complicated and time intensity of phytase were highly correlated and that there were no variations for broiler, other ruminants and non-ruminants, and graduate education for a farmer who stated adoption. To fix these issues, the complicated variable was removed from the model; the bachelor degree and graduate degree were combined into one variable; broilers, turkeys, and other non-ruminants were combined into poultry. The other ruminant category was chiefly added to beef cow except for farms that were primarily horses and no other species; these farms were eliminated.

Additionally, the review has provided evidence that there is a divergence between stated and actual adoption of phytase. From the literature review, we would expect approximately 95 percent of all farmers with non-ruminants to state they use phytase in their feed rations. Instead, only 18 percent of all farmers with non-ruminants stated phytase use, 35.8 percent did not know, and 46.2 percent stated they did not use phytase. Less than half of the swine farmers and only 3 turkey farmers out of 136 poultry farmers stated phytase adoption. The increased level of blanks and neutral responses to phytase characteristics is also consistent with little knowledge concerning phytase (Ryan and Garland, 1999). These factors show that a technology that is beneficial to the environment and the farmer's bottom line has been able to be unknowingly adopted by non-ruminant farmers.

Table 11: Descriptive Statistics of the Dependent and Independent Variables.

Variable	Mean	Std. Deviation	Range
Stated Adoption			
Yes	0.093	0.291	0 - 1
No	0.547	0.498	0 - 1
Don't Know	0.360	0.480	0 - 1
Phytase Attributes (Likert, 1-5, Base 3)			
Profitability	2.799	0.955	0 - 5
Time Intensity	2.584	0.888	0 - 5
Phytase Effect on Water Quality	2.994	0.861	0 - 5
Farmer's Attributes			
Water Quality Concern (Likert, 1-5, Base 3)	4.193	1.097	0 - 5
Off-Farm Income			
None (Base)	0.277	0.448	0 - 1
$0 - $9,999	0.136	0.343	0 - 1
$10,000- $24,999	0.157	0.364	0 - 1
$25,000 - $49,999	0.270	0.444	0 - 1
$50,000 - $99,999	0.129	0.335	0 - 1
$100,000 or more	0.030	0.170	0 - 1
Education			
Less than High School (Base)	0.095	0.293	0 - 1
High School	0.436	0.496	0 - 1
Some College or Vocational School	0.280	0.449	0 - 1
Bachelor's Degree or Higher	0.190	0.392	0 - 1
Age	50.396	10.180	25 - 83
Farm Attributes			
Species			
Dairy	0.228	0.420	0 - 1
Beef Cat.	0.290	0.454	0 - 1
Beef Cow	0.255	0.436	0 - 1
Swine <55 lbs.	0.043	0.203	0 - 1
Swine >55 lbs. (Base)	0.243	0.429	0 - 1
Poultry	0.201	0.401	0 - 1
Manure Transfers (Base = No Transfer)			
Give Manure	0.098	0.297	0 - 1
Sell Manure	0.130	0.337	0 - 1
Animal Units per Acre	3.337	11.119	.023 - 131.11
CAFO (Base = Not CAFO)	0.193	0.395	0 - 1
State (Base = MO, IA = 1)	0.524	0.500	0 - 1
Outside Influences (Likert, 1-5, Base = 3)			
Other Farmers	2.596	1.050	0 - 5
NRCS	2.579	1.213	0 - 5
Contractor	1.834	1.141	0 - 5

Regression Results

In order to determine the effect that each variable has on the stated use of phytase, a multinomial regression was conducted. As mentioned before, the base category for the phytase response was the farmers who stated they did not use phytase. Although the regression is determined simultaneously, the results of the regression have been divided into two tables, Table 13 and Table 14, to clarify which results are being discussed. Table 13 shows the coefficients for the variables affecting "Yes' statements versus "No" statements, and the regression results are continued on Table 14 to show the coefficients for the variables affecting "Don't Know" responses versus "No" responses. Asterisks indicate the statistically significant results, with one asterisk representing significance at 10 percent, two at 5 percent, and three at 1 percent.

Regression Significance

The overall significance of the regression was evaluated by a likelihood ratio test, which compares the final regression model with an intercept only model. The resulting chi-square was 280.93 with 66 degrees of freedom, giving a very significant p-value of 0.0000. This means that at least one of our regression coefficients is not zero (Bruin, 2006). STATA also provides McFadden's pseudo R-squared, which is an attempt to give logistic regression a statistic similar to the R-squared of OLS regression (Bruin, 2006). The resulting pseudo-R-squared for this regression is .2264 which is relatively low, but caution should be used to interpret this statistic; survey data generally has a lower R-squared than experimental data and the statistic cannot be interpreted the same as in OLS (Bruin, 2006). A classification table was developed which compares the observed results with the predicted results (see Table 12). The overall accuracy of the model in correctly predicting the proper outcomes was 63.7 percent.

Table 12: Classification Table

Observed	Predicted			
	Y	N	DK	Percent Correct
Y	42	15	6	66.70
N	8	293	68	79.40
DK	9	139	95	39.10
Overall Percentage	8.70	66.20	25.00	63.70

Stated "Yes" versus "No"

The multinomial logistic results (Table 13) indicate that a farmer is more likely to state phytase use if the farmer views phytase as profitable or not time consuming. A farmer who gives manure to others, is more likely to state phytase adoption than a farmer who has no manure transfers. A farm that is from Iowa or a designated CAFO is more likely to state phytase adoption than a farm that is from Missouri or not a CAFO. A farmer who earns off-farm income in the categories of \$10,000 - \$24,999, \$25,000 - \$49,999, or \$50,000 - \$99,999 is less likely to state phytase use than a farmer who earns no off farm income. A farmer with dairy cattle, beef cattle on feed, beef cows, or poultry is less likely to state phytase adoption than a farmer with swine greater than 55 pounds. Swine < 55 lbs. is not significantly different from the base, swine > 55 lbs. This can be expected since there should not be a large difference between the types of swine operations. Although a p-value of thirteen percent is not statistically significant, the characteristic of phytase to improve water quality being positively correlated with phytase use is consistent with our conceptual model.

The most important variables by marginal effect magnitude are the profitability of phytase, the state in which the farm resides, and if the farm is a designated CAFO. The marginal effects measures the change in probability given a unit change in dependent variable. These are easier to interpret than the logarithmic changes associated with the coefficients. For instance, a farmer from Iowa is three percent more likely than a farmer from Missouri to state phytase use, ceteris paribus. The importance of profitability in adoption studies has been highlighted in the literature review. The common link between the state and CAFO variables is regulation. As discussed in the literature review, regulations played an important role in the early adoption of phytase; regulations were responsible for the adoption of phytase when relevant prices discouraged adoption. Although Iowa does not mandate phytase use, it does require the use of the P-Index while Missouri does not. Since profitability and regulation were the main motivations for the adoption of phytase (Ferrell and White, Personal Communication, 2008), it is interesting that variables associated with these motivations have the most significant impacts on a farmer stating phytase use in feed rations.

The results of the regression comparing stated “yes” versus stated “no” responses are mostly consistent with the conceptual model in Chapter 3. However, some variables contradict our hypotheses. For instance, the sign of poultry is contrary to the expected sign, and its significance is an interesting result. However, since the review of the data showed that, with the exception of three turkey farmers, no poultry farmer stated phytase use, this result is not entirely unexpected. It is also surprising that education was not significant for this new technology. Although not significant, the farmer’s concern for water quality is very interesting. The farmer’s concern for water quality implies that the more concern the farmer has about water quality, the less likely the farmer will state use of an innovation meant to improve water quality. As mentioned earlier with discussion of Figure 10, this variable may have suffered from a lack of variation. This may highlight the importance of profitability and regulations in phytase adoption rather than the environmental reasons.

Table 13: Results of Multinomial Logistic Regression on Stated Yes versus No. (N = 675)

Variable	Coefficient	Std. Error	P>|z|	Marginal Effect
Phytase Not Profitable (1-2)	-0.625	0.583	0.284	-0.004
Phytase Profitable (4-5)	1.879***	0.546	0.001	0.058
Not Time Consuming (1,2)	0.910*	0.494	0.066	0.014
Time Consuming (4,5)	-0.469	1.268	0.711	-0.006
Doesn't Improve Water (1-2)	-0.710	0.834	0.394	-0.007
Improves Water (4-5)	0.791	0.522	0.130	0.014
Not Concerned about Water Quality (1-2)	0.496	0.840	0.555	0.008
Water Quality Concern (4-5)	-0.640	0.655	0.328	-0.007
Off-farm income (Base: None)				
$0 - $9,999	-0.358	0.677	0.597	-0.006
$10,000 - $24,999	-1.183*	0.661	0.073	-0.011
$25,000 - $49,000	-1.145*	0.597	0.055	-0.011
$50,000 - $99,999	-1.309*	0.732	0.074	-0.011
$100,000 or more	-1.160	1.152	0.314	-0.009
Education (Base: Less Than High School)				
High School Diploma	-1.083	0.930	0.244	-0.011
Some College or Vocational	-0.693	0.943	0.462	-0.004
Bachelor's or higher	-0.183	0.945	0.847	0.000
Age	0.020	0.023	0.371	0.000
Species (Base: Swine >55 lbs.)				
Dairy	-1.379**	0.635	0.030	-0.012
Beef Cattle	-1.105**	0.533	0.038	-0.009
Beef Cow	-2.263**	1.073	0.035	-0.018
Swine (<55 lbs)	-0.284	0.785	0.718	-0.004
Poultry	-2.066**	0.853	0.015	-0.015
Give Manure (Base = No Manure Transfers)	1.005*	0.568	0.077	0.015
Sell Manure	-0.750	0.855	0.380	-0.006
Animal units per acre	-0.013	0.019	0.485	0.000
CAFO (Base = Not CAFO)	1.664***	0.461	0.000	0.029
State (Iowa = 1, Base = Missouri)	2.380***	0.604	0.000	0.030
Other Farmers (Low, 1-2)	-0.619	0.469	0.187	-0.005
Other Farmers (High, 4-5)	-0.794	0.650	0.221	-0.005
NRCS (Low, 1-2)	0.075	0.537	0.888	0.000
NRCS (High, 4-5)	0.594	0.515	0.248	0.006
Contractor (Low, 1-2)	-0.426	0.518	0.410	-0.003
Contractor (High, 4-5)	-0.923	0.765	0.228	-0.006
Constant	-2.703*	1.547	0.081	

*, **, *** indicate that the variable is significant at the 0.10, .05, and .01 level respectively. Variables followed by a (1-2) or (4-5) were variables categorized from a 1-5 Likert scale. The base category for these variables is response 3.

Stated "Don't Know" versus "No"

The multinomial logistic results continue in Table 11 and indicate that a farmer is more likely to state "don't know" than "no" concerning phytase use if the farmer views phytase as not profitable. If the farmer earns $0 - $9,999 in off-farm income, then the farmer is more likely to state "don't know" than a farmer with no off-farm income. The farmer is less likely to state "don't know" if the farmer has education beyond high school compared to a farmer with less than a high school diploma. If the farm has beef cattle on feed, the farmer is less likely to state "don't know" than a farmer with swine greater than 55 pounds. A farmer whose decisions are influenced very little or very highly by other farmers is less likely to state "don't know" than a farmer whose decisions are somewhat influenced by other farmers. A farmer whose decisions are not influenced by contractors is also less likely to indicate "don't know" than a farmer whose decisions are somewhat influenced by contractors. The variable "animal units per acre" just misses statistical significance at 10.3 percent, but it is consistent with the hypothesis discussed in the conceptual model. Additionally, the off-farm income level of $10,000 - $24,999 is insignificant at 12.2 percent and consistent with the conceptual model, but CAFO is insignificant at 12.1 percent and inconsistent with the expected signs; they are more likely to state "don't know" than farms that are not CAFOs. Perhaps CAFO farms reflect a relation to contract farms. Contract farms were expected to be positively correlated to "don't know" responses, however farms whose decisions were highly influenced by contractors were negatively correlated with "don't know" responses at just over 15 percent significance.

One of the significant differences between the two tables is that the marginal effects for stated “don’t know” versus “no” are significantly larger than the marginal effects for stated “yes” versus “no” responses. A farmer whose decisions are highly influenced by other farmers is 20.9 percent less likely to state “don’t know” than “no” as compared to a farmer who is somewhat influenced by other farmers. The largest marginal effect in Table 13 is 5.8 percent for the difference between a farmer who views phytase as profitable and a farmer who remains neutral.

The influence of other farmers on decisions is one of the most significant variables and the most interesting. If a farmer is highly influenced by other farmers, the probability the farmer will state “don’t know” to phytase use instead of “no” decreases 20.9 percent. On the other hand, if the farmer is not influenced very much by other farmers, the probability decreases 11.5 percent. The logic behind the significance of these two results is unclear. Perhaps this variable has captured a personality characteristic of the farmer.

Cognitive style, a concept from psychology, is a personality characteristic that refers to how a person thinks. A popular version of this derives from a fragment of the Greek poet Archilochus and used by Isaiah Berlin; “The fox knows many things, but the hedgehog knows one big thing” (Gartner, 2005). The principle is that foxes know many small things and use all the ideas that are available, whether these ideas are consistent or not. A hedgehog knows one big idea and applies that idea everywhere, ignoring any evidence that may contradict that idea (Begley, 2009). Philip Tetlock took this concept and applied it to a study relating to the accuracy of predictions made by pundits (Begley, 2009). In his study, he found that the pundits who shied away from overly confident, decisive, and ideological forecasts tended to be more accurate. These pundits were labeled foxes, and the pundits that tended to derive predictions from the one big idea were hedgehogs (Begley, 2009). The importance of this study was that the cognitive style may be the best predictor of accuracy.

Likewise, in this study the farmers that had strong opinions, one way or the other, about the influence of other farmers tended to be less likely to state “don’t know.” Perhaps this measured a cognitive style of the farmers, where neutral farmers can be like foxes and be more open to state “don’t know” than farmers that were strongly opinionated. Some farmers may be more reluctant than others to admit they don’t know something. Future research can be conducted on how a farmer’s personality affects a response to an invisible innovation.

Overall, although several of the variables are consistent with expectations, the overall results are weak in significance. Given these facts, the model seems to have not captured the motivations for a farmer to state “don’t know” when asked if phytase is included in feed rations. Since “don’t know” responses are not usually included in an adoption study, there may be variables that are not included that do explain the “don’t know” choice.

Table 14: Results of Multinomial Logistic Regression on Stated Don't Know versus No. (N = 675)

Variable	Coefficient	Std. Error	P>|z|	Marginal Effect
Phytase Not Profitable (1-2)	-0.769***	0.268	0.004	-0.167
Phytase Profitable (4-5)	-0.537	0.412	0.193	-0.134
Not Time Consuming (1,2)	-0.152	0.270	0.572	-0.040
Time Consuming (4,5)	0.441	0.448	0.325	0.109
Doesn't Improve Water (1-2)	0.059	0.332	0.858	0.017
Improves Water (4-5)	-0.207	0.362	0.568	-0.052
Not Concerned about Water Quality (1-2)	-0.243	0.397	0.541	-0.058
Water Quality Concern (4-5)	-0.289	0.298	0.332	-0.066
Off-farm income (Base: None)				
$0 - $9,999*	0.585*	0.301	0.052	0.144
$10,000 - $24,999	0.431	0.279	0.122	0.108
$25,000 - $49,000	0.189	0.254	0.456	0.049
$50,000 - $99,999	0.449	0.320	0.161	0.113
$100,000 or more	0.333	0.580	0.566	0.084
Education (Base: Less Than High School)				
High School Diploma	-0.271	0.334	0.418	-0.059
Some College or Vocational	-0.824**	0.354	0.020	-0.180
Bachelor's or higher	-0.632*	0.376	0.093	-0.139
Age	0.007	0.009	0.435	0.002
Species (Base: Swine >55 lbs.)				
Dairy	-0.039	0.263	0.882	-0.005
Beef Cattle	-0.469**	0.238	0.049	-0.103
Beef Cow	0.077	0.233	0.742	0.025
Swine (<55 lbs)	0.207	0.477	0.664	0.051
Turkey	-0.113	0.318	0.723	-0.021
Give Manure (Base = No Manure Transfers)	0.263	0.337	0.435	0.056
Sell Manure	-0.236	0.372	0.526	-0.052
Animal units per acre	-0.018	0.011	0.103	-0.004
CAFO (Base = Not CAFO)	0.411	0.265	0.121	0.085
State (Iowa = 1, Base = Missouri)	0.154	0.198	0.437	0.024
Other Farmers (Low, 1-2)	-0.510**	0.199	0.011	-0.115
Other Farmers (High, 4-5)	-1.015***	0.278	0.000	-0.209
NRCS (Low, 1-2)	0.236	0.219	0.281	0.055
NRCS (High, 4-5)	0.322	0.247	0.191	0.074
Contractor (Low, 1-2)	-0.425*	0.249	0.088	-0.100
Contractor (High, 4-5)	-0.519	0.367	0.157	-0.112
Constant	0.465	0.676	0.491	

*, **, *** indicate that the variable is significant at the 0.10, .05, and .01 level respectively. Variables followed by a (1-2) or (4-5) were variables categorized from a 1-5 Likert scale. The base category for these variables is response 3.

Conclusion

As mentioned in Chapter 4, the qualities of the third choice, “No,” can be determined from the regressions on the other two choices. For instance, the profitability of phytase is correlated with “Yes” statements in the first table. Since “phytase is not profitable” is negatively correlated with “Don’t Know” responses, it can be concluded that in general, farmers who view phytase as profitable are more likely to state “yes,” farmers who are neutral are more likely to state “Don’t Know,” and farmers that view phytase as not profitable are more likely to state “No.” Additionally, both tables agree that farmers with beef cattle on feed are more likely to state “No.” Perhaps these farmers are more likely to be knowledgeable about the contents of feed than other ruminant operations. Another interesting result is that although education is not significant in determining if a farmer states “yes” or “no,” higher education levels are associated with a farmer being less likely to state “don’t know.”

Although determined simultaneously, the regression results are very different between the two tables. In the first table, the regression results are largely consistent with the conceptual model developed in chapter 3, while the second table’s results are largely insignificant and inconsistent with the conceptual model. These results are reflected in the classification table that shows less than 40 percent of the “don’t know” responses were accurately predicted. If the conceptual model was correct to assume high information costs would be correlated with “don’t know” responses, then many of the variables used to predict the yes and no responses to phytase use may not accurately reflect information costs. Future studies will need to consider how to capture this information more effectively.

Chapter 6: Conclusions and Implications

One of the objectives for this study was to determine the state of farmer knowledge about this new technology. Since we know that approximately 95 percent of non-ruminant farmers have adopted phytase (Campbell, Personal Communication, 2008) and only 18 percent of non-ruminant farmers stated they used phytase in feed rations, it can be concluded that farmers are largely unaware of this innovation. None of the farmers with broilers, less than 5 percent of farmers with turkeys, and less than half of the swine farmers stated phytase use. This conclusion is also supported by the large number of neutral and blank responses regarding various phytase characteristics. And since 46.2 percent of the non-ruminant farmers stated they did not use phytase, it can be further concluded that a large portion of farmers don't know that they don't know. These facts mean that there is an information disconnect between the farmers and feed-manufacturers/contractors. It also means that it is possible for the stated adoption rate to be distinct from the actual adoption rate, especially for a non-observable technology.

This study also examined the social and economic factors that impacted the responses of phytase use. A conceptual model was developed and largely confirmed in the regression for farmers that stated phytase use. This study has successfully shown that there are significant differences between farmers who state "don't know" versus "no" and the farmers that state "yes" versus "no" to phytase use, however, the conceptual model failed to adequately capture why a farmer would state "don't know" instead of "no" to phytase use. Perhaps the results have been impacted by the large number of non-ruminant farmers that do not know that they use phytase but still answered "no" concerning its use. The confusion can also be due to the phytase source being listed on feed tags instead of the common term “phytase.” Determining the factors behind these responses can yield important information to researchers and policy makers concerning the adoption of invisible technologies. The regression results for “yes” versus “no” responses did complement the literature review in highlighting the importance of profitability and phytase. Combined with the other attributes of phytase and those of the farm and farmer, this study is in line with the expectations of normal adoption studies.

Survey Issues

As mentioned, the original intent of this study was to determine the factors that affected phytase adoption, but the resulting data showed that most farmers were unaware of the technology and stated an adoption rate inconsistent with the inclusion rate of feed manufacturers. Because the nature of the thesis changed after the survey was completed, there are several factors that could be improved in a subsequent study. One of the largest issues raised by this study is the determination of the proper level of analysis is for the decision maker. It may be more interesting and appropriate to see how feed manufacturers determine if phytase should be included in feed. The regulations in Maryland required feed manufacturers to include it in feed; it made no requirements on the farmers (Code of Maryland Regulations, 15.18.05.03. 03, 2009). Additionally, are feed manufacturers’ decisions controlled to some extent by decisions made by large contractors/integrators? How much sway does a small farmer have over what gets included in feed? It would be interesting to research where the level of analysis should focus to capture the motivations of including phytase in feed rations.

Another factor that could be improved in a subsequent survey is determining if the feed of the farmers actually contains phytase or not. This would inform us which farmers know they don't include phytase against those who just don't know. At first, we had assumed that the farmers would know the contents of feed. As stated earlier, Dr. Marcia Shannon was the first to indicate to the researchers that phytase use was very high among non-ruminant farmers. The numbers gathered from industry sources concerning actual phytase use indicated that almost everyone was using phytase (Brown, 2006, Campbell, Personal Communication, 2008). However, we cannot clearly identify the non-ruminant farmers who may knowingly not use phytase.

As shown in Figure 4, a large portion of blank responses were left on the questions concerning phytase attributes. The standard practice is to not include a "don't know" response for Likert scales (Ryan and Garland, 1999). Surveyors are reluctant to include a "don't know" response on a Likert scale since it reduces the effective sample size and representativeness for the item (Schuman & Presser, 1981, cited by Ryan and Garland, 1999). Due to the responses on the pilot survey, a "don't know" response was included for whether they used phytase, but the Likert scales were not adjusted. However in the case of phytase, a "don't know" option would have been more appropriate since one of the objectives was to determine the farmer's state of knowledge concerning phytase. Additionally, a "don't know" option on the Likert scales could have resulted in fewer blank responses if the farmer felt uncomfortable entering any answer. Including a "don't know" response for phytase could have increased the data set and provided better insight on farmer's knowledge.

One of the most interesting outcomes of this study is that there are a large number of farmers that stated “no” when it would have been more appropriate to state “don’t know.” During the literature review, the researchers sought advice from experts in the field of psychology, however, all references dealt with how individual perspectives change over the innovation-decision process.

Implications

The most significant aspect of this study is that an invisible technology was able to be quickly and nearly completely adopted by farmers. The centralized decision-making by feed-manufacturers/contractors resulted in automatic adoption of phytase. Although the decision was based on reducing dical costs, it probably had environmental benefits. This technology is a win-win for the environment and the farmer’s bottom line, but this story should also give warning to the possibility that environmentally hazardous technologies can be adopted without the farmer’s knowledge.

The success of this technology is based in part on induced innovation. The regulations that required phytase use in areas facing severe phosphorus issues helped to spur economies of scale in phytase production which lowered prices and encouraged adoption by other farmers. Further research needs to be conducted to develop other win/win technologies.

This study shows that surveys with “don’t know” response options can provide useful information to the researcher. It also shows the importance of understanding the technology, industry, and locus of decision-making in adoption research; phytase was able to be adopted automatically and nearly completely by non-ruminant farmers who remained uninformed of this win-win technology.

APPENDIX A

The Development of the Phytase Price Series

The prices of phytase have come from a number of sources. Unfortunately, these sources have also used different kinds of phytase. In order to compare the prices from year to year, all phytases were converted to an equivalent of one pound BASF Natuphos 5000 (5000 FTU/g). The conversions are below.

<u>1997</u>

Mark Risse (1997) in AWARE directly reports BASF Natuphos costing $11.50 per pound. Charles Stanislaw (1997) reports in note “b” of Table 2, “Based on a phytase price of $1.36 per pound. Each pound of premix supplies 600 U of phytase activity per g or 272,400 U/lb.”

($1.36 per lb of 600U phytase) * (5000U / 600U) = $11.33 per lb of 5000U phytase.

The prices from both sources, $11.50 and $11.33, are not identical, but close. For the purposes of the graph, I used $11.50 since it had fewer conversions.

<u>1999</u>

The only source available, Harper (1999), directly stated Natuphos 5000L® was currently priced at $12.00. The price rose since 1997, but this could be due to the mandated use of phytase in Maryland and Virginia during that time, as mentioned in the literature review.

<u>2001</u>

McMullen and Holden cite Natuphos 5000 available for $8.00/lb.

<u>2002</u>

Keplinger and Abraham (2002) state Natuphos 5000 can be purchased for $14.95 per kilogram.

($14.95 per kg) * (1 kg / 2.2046226 lbs) = $6.78 per lb

2006 and 2008

A phone interview with Donnie Campbell, who provided phytase for MFA, showed the price of Ronozyme (2500 FTU) to be $205 per 100 lbs on January 9th, 2006 and $186 per 100 lbs on that day, August 15th, 2008. Converting to one pound leaves the price at $2.05 and $1.86 per pound respectively. Since Ronozyme is 2500 FTU, multiplying the price by two should approximate the price of Natuphos 5000. Debra Neutkens of the National Hog Farmer reported that there was no effective difference between the two sources (2003). Therefore, the 2006 price of phytase is $4.10 per lb and the 2008 price is $3.72 per lb.

Sources not used

A report in 2005 by Roberson *et al.* stated that, "The price of the commercial source of phytase used in the study was $1.76 (U.S.)/kg." It further stated that this source was Natuphos® 600, which would convert to approximately $6.67 per pound of Natuphos 5000. However, the date of the study was not given, so the year for this price is not clear.

Saddoris and Crenshaw (2002) estimate Natuphos 5000 to be $12.00 as of January 17, 2002. This price is significantly higher than other prices given for 2001 and 2002. Additionally, since it is an estimated price, it seems unreliable.

Table 15: Phytase Price per Year

Year	1997	1999	2001	2002	2006	2008
Phytase Price ($/lb)*	11.5	12	8	6.78	4.1	3.72

APPENDIX B
Sample Feed Tags

Pig Pass VG Premix
A Premix for Growing and Finishing Swine

Guaranteed Analysis

Calcium (Ca)	Min	20.00	Max	21.00 %
Phosphorus (P)			Min	5.7 %
Salt (NaCl)	Min	17.00	Max	19.00 %
Copper (Cu)			Min	370 PPM
Selenium (Se)			Min	13.3 PPM
Zinc (Zn)			Min	4,180 PPM
Manganese (Mn)			Min	2,470 PPM
Iodine (I)			Min	10 PPM
Iron (Fe)			Min	3,740 PPM
Vitamin A			Min	74,000 IU/LB
Vitamin D			Min	14,900 IU/LB
Vitamin E			Min	370 IU/LB
Vitamin B-12			Min	0.3 MCG/LB
Phytase			Min	9,080 FYT/LB
Niacin			Min	440 MG/LB
Biotin			Min	0.2 MG/LB
Choline			Min	2,999.740 MG/LB
Riboflavin			Min	90 MG/LB
Pantothenic Acid			Min	300 MG/LB
Folic Acid			Min	4 MG/LB
Thiamine			Min	11 MG/LB
Vitamin B-6			Min	16 MG/LB

Ingredients

Calcium Carbonate, Dicalcium Phosphate, Salt, Magnesium Mica, Manganous Oxide, Zinc Oxide, Ferrous Sulfate, Copper Sulfate, Ethylenediamine Dihydriodide, Sodium Selenite, Choline Chloride, Dehydrated Aspergillus Oryzae Fermentation Extract, Vitamin A Supplement, Vitamin D-3 Supplement, Vitamin ESupplement, Vitamin B-12 Supplement, Riboflavin Supplement, Niacin Supplement, Calcium Pantothenate, Menadione SodiumBisulfite Complex, Folic Acid, d-Biotin, Thiamine Mononitrate, Pyridoxine Hydrochloride and Natural and Artificial Flavors.

Feeding Directions

Phase	Grower 1	Grower 2	Finisher 1	Finisher 2	Finisher 3
Weight Range	60-80	80-120	120-180	180-220	220 to MKT
Corn (lbs)	1500	1550	1600	1635	1670
48% SBM (lbs)	450	400	350	315	280
Pig Pass VG (lbs)	50	50	50	50	50
Total	2000	2000	2000	2000	2000
Approx. Lysine%	0.9	0.83	0.75	0.7	0.65

This product contains added copper. Do not feed to sheep.

Manufactured by

MFA INCORPORATED

Columbia, Missouri 65201

38215 1W 9/29/2004

Net Weight 50 Lb (22.68 kg) Or Bulk

G/F 100 Base Mix

A Base Mix For Growing and Finishing Swine

Guaranteed Analysis

Crude Protein			Min	29.0%
Crude Fat			Min	3.0 %
Calcium (Ca)	Min	11.0	Max	12.5 %
Phosphorus (P)			Min	3.9 %
Salt (NaCl)	Min	6.0	Max	7.0 %
Copper (Cu)			Min	190 PPM
Selenium (Se)			Min	6.2 PPM
Zinc (Zn)			Min	2,130 PPM
Manganese (Mn)			Min	1,280 PPM
Iron (Fe)			Min	1,870 PPM
Vitamin A			Min	37,000 IU/LB
Vitamin D			Min	7,400 IU/LB
Vitamin E			Min	180 IU/LB
Vitamin B-12			Min	0.2 MCG/LB
Niacin			Min	240 MG/LB
Biotin			Min	0.1 MG/LB
Riboflavin			Min	45 MG/LB
Pantothenic Acid			Min	150 MG/LB
Folic Acid			Min	2 MG/LB
Thiamine			Min	6 MG/LB
Vitamin B-6			Min	8 MG/LB
Phytase			Min	4,540 FYT/LB

Ingredients

Dicalcium Phosphate, Fish Meal, Calcium Carbonate, Pork Meat and Bone Meal, Blood Meal, Salt, Potassium Chloride, Manganous Oxide, Zinc Oxide, Ferrous Sulfate, Copper Sulfate, Ethylenediamine Dihydriodide, Sodium Selenite, Dehydrated Aspergillus Oryzae Fermentation Extract, Vitamin A Supplement, Vitamin D-3 Supplement, Vitamin E Supplement, Vitamin B-12 Supplement, Riboflavin Supplement, Niacin Supplement, Calcium Pantothenate, Menadione Sodium Bisulfite Complex, Folic Acid, d-Biotin, Thiamine Mononitrate and Pyridoxine Hydrochloride.

Feeding Directions

Mix at the rate below to make a complete feed for growing and finishing pigs.

Lbs	60-80	80-120	120-180	180-220	220-Mkt
Corn	1500	1550	1625	1650	1685
48% Soybean Meal	400	350	275	250	215
G/F 100 Base Mix	100	100	100	100	100
Total Lbs	2000	2000	2000	2000	2000
% Lysine	0.9	0.83	0.75	0.70	0.65

Caution

This product contains added copper. Do not feed to sheep.

Manufactured by

MFA INCORPORATED

Columbia, Missouri 65201

32955 13 7/11/2006

Net Weight 50 Lb (22.6 kg) Or Bulk

APPENDIX C
Manure Management Survey

Farm operators should complete this questionnaire. (For the purposes of this questionnaire, a farm operator is someone who is currently farming and makes major decisions regarding the farm operation.) If you are not a farm operator, please give this questionnaire to the farm operator in your household. If there is no farm operator in your household, answer only question #1 and return the questionnaire in the business reply envelope provided.

1. **Are you a farm operator with livestock (other than for your own use)? (Check your answer.)**

☐Yes ☐No → STOP and return the blank questionnaire in the business reply envelope provided.

Section 1: Information about farming systems is useful in the design of programs.

2. On average, **HOW MANY** of the following livestock animals of all ages did you have on your farm at one time in 2005 (other than for your family's use)? Please write number of animals on the line.

________ Dairy cattle
________ Beef cattle on feed
________ Beef cows
________ Swine 55 lb or less
________ Swine more than 55 lb
________ Broilers
________ Turkeys
________ Other livestock (please list) ________________________

3. How many acres of land did you own in January 2005? (Please write the number of acres on the line.)

________ Acres (crop, pasture, and forest)

4. How many acres of land did you rent out to other farmers in 2005?

________ Acres

5. How many acres of land did you rent from others in 2005?

________ Acres (if None, please skip to question **#8**)

6. Do you apply manure or poultry litter to land that you rent from others? (Check the appropriate box.)

☐ Yes ☐ No

7. In the rental contract, are there clauses that specify required manure application practices?

☐ Yes ☐ No ☐ There is no written contract

8. In 2005, how many acres of the following crops did you have planted? (Please write number of acres)

☐ **I don't have crops**

__________ Acres of corn
__________ Acres of soybeans
__________ Acres of wheat
__________ Acres of alfalfa
__________ Acres of other hay
__________ Acres of pasture
__________ Acres of other crop(s) (please list) ______________________

9. How many years have you been the primary farm operator?
_________ Years

10. Please list the county (or counties) and state(s) where your farm is located.
_______________________ County (or counties)
_______________________ State (or states)

According to the Environmental Protection Agency (EPA), an animal feeding operation (AFO) is a lot or facility where the following conditions are met:

- Animals are stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and

- A ground cover of vegetation is sustained over less than 50% of the animal confinement area.

11. Could your farm be considered an animal feeding operation according to the definition above?
☐ Yes ☐ No

12. Are you a permitted concentrated animal feeding operation (CAFO)?
☐ Yes ☐ No

13. Is there a lake or stream on the land that you own?
☐ Yes ☐ No

14. My land is mostly (check one);
☐ flat
☐ rolling hills
☐ steep hills

15. Which of the following changes do you expect to occur on your farm in the next 5 years? (Please check one box in each row. N/A means not applicable to your farm.)

In the next 5 years do you expect...	
a. you or a family member will continue farming this farm.	☐ Yes ☐ No ☐ Not Sure ☐ N/A
b. to sell the farm	☐ Yes ☐ No ☐ Not Sure ☐ N/A
c. to increase livestock numbers	☐ Yes ☐ No ☐ Not Sure ☐ N/A
d. to expand crop acreage	☐ Yes ☐ No ☐ Not Sure ☐ N/A
e. to invest in new buildings on your farm	☐ Yes ☐ No ☐ Not Sure ☐ N/A

Section 2: There are several incentive programs available through USDA's Natural Resource Conservation Service (NRCS) and we are interested in awareness among the farm population of these programs and what can be done to improve the programs. We are also interested in the availability of private financing for equipment.

16. Are you aware of the Environmental Quality Incentives Program (EQIP)?
☐ Yes ☐ No (if No, please skip to question **#20**)

17. Do you currently have an EQIP contract through NRCS?
☐ Yes (if Yes, please skip to question **#20**) ☐ No

18. Did you apply for EQIP?
☐ Yes ☐ No

19. If you have not applied for EQIP, why not?

20. Have you prepared a Comprehensive Nutrient Management Plan (CNMP) following NRCS guidelines?
☐ Yes ☐ No (if No, please skip to question #**26**)

21. What year did you develop a CNMP?
_________ Year

22. Who prepared the CNMP?
☐ A private technical service provider
☐ NRCS staff
☐ Myself since I received CNMP training

23. If you used a technical service provider how much did it cost?
_________ dollars

24. How much time did you spend in meetings with NRCS staff or your technical service provider?
_________ days **OR** _________ hours

25. How much time did you spend on reading, paperwork and pulling together information for the CNMP?
__________ days **OR** __________ hours

26. In your experience, are banks willing to loan money to farmers for improving water quality?
☐ Yes ☐ No ☐ Don’t know

27. Do you own equipment for injecting manure into the soil?
☐ Yes ☐ No (if No, please skip to question #**30**)

28. If you bought equipment for injecting manure into the soil, were you able to get a bank loan for it?
☐ Yes ☐ No ☐ Did not seek a bank loan

29. If you answered “Yes” to question **#28**, what percent of the cost was borrowed?
_________%

30. Do you have an underground pipe system to move manure to some or all of your fields?
☐ Yes ☐ No (if No, please skip to question #**33**)

31. If you installed an underground piping system to move manure, were you able to get a bank loan for it?
☐ Yes ☐ No ☐ Did not seek a bank loan

32. If you answered “Yes” to question **#31**, what percent of the cost was borrowed?
________%

Section 3: Questions about the use of manure as a fertilizer.

33. To how many acres of each crop do you apply manure?
☐ **I don’t have crops**

_________ Acres of corn
_________ Acres of soybeans
_________ Acres of wheat
_________ Acres of oats
_________ Acres of alfalfa
_________ Acres of pasture/hay
_________ Acres of another crop (please list) ____________________

34. Do you apply commercial fertilizer to any of your **manured** fields?
☐ Yes ☐ No

35. To what extent do you agree or disagree with the following statements? Please **circle** the number that best corresponds to your answer.

	Strongly Disagree		Neither Agree nor Disagree		Strongly Agree
a. The smell of manure bothers me or my family.	1	2	3	4	5
b. The smell of manure bothers my neighbors.	1	2	3	4	5
c. It is difficult to determine how much manure to apply to my crops, so I don't under or over apply nutrients.	1	2	3	4	5
d. Transportation costs and time affect which of my fields receive manure.	1	2	3	4	5
e. I'm not sure how my crops would respond to manure as compared to commercial fertilizer.	1	2	3	4	5
f. I am concerned about the water quality of streams and lakes in my county.	1	2	3	4	5
g. Properly managing manure improves water quality.	1	2	3	4	5
h. Agricultural regulations regarding water quality will become stricter in the next five years.	1	2	3	4	5

36. Have you provided manure to other farm operations or individuals in the past two years?

☐ Yes (if Yes, answer the following questions for the farm that received the most manure from you)

☐ No (if No, please skip to question #**44**)

37. What was the maximum distance the manure was transported?

About _________ Miles

38. Who applied the manure to the other farm?

a. ☐ Custom applicator

b. ☐ The farmer receiving the manure

c. ☐ I did

d. ☐ Other (please explain) _________________________

39. Were you paid for the manure?

☐ Yes ☐ No (if No, please skip to question #**42**)

.

40. How much money did you receive for the manure? (Check one measurement or indicate other quantity.)

$_______ ☐ per ton? ☐ per acre? ☐ per pick-up load? ☐ per spreader load? ☐ per semi load?

41. Did this price include application of the manure?

☐ Yes ☐ No

42. Was there a written contract between you and the other farmer involved with the manure transfer?

☐ Yes ☐ No

43. Did either you or the farmer receiving the manure test the manure for nutrient content before applying it?

☐ Yes ☐ No ☐ I don't know

44. What type of manure storage facility do you have? (Check all that apply.)

a. ☐ None
b. ☐ Lagoon(s)
c. ☐ Cement or glass-lined tank(s)
d. ☐ Earthen basin(s)
e. ☐ Stack house
f. ☐ Other (please specify) __________________________

45. Which of the following structures and/or equipment do you use to manage manure? (Check all that apply.)

a. ☐ Handle solid manure with a loader
b. ☐ Scrape manure with a tractor
c. ☐ Use a gutter scraping system
d. ☐ Apply manure using a solids spreader
e. ☐ Apply manure using a tank wagon
f. ☐ Apply manure by an irrigation system
g. ☐ Use traveling gun
h. ☐ Use dragline injection system
i. ☐ Other (please specify) __________________________

46. Given your typical livestock production, how many months of manure storage capacity do you have?

a. ☐ 0-3 months
b. ☐ 3-6 months
c. ☐ 6-9 months
d. ☐ 9-12 months
e. ☐ More than 12 months

47. Did you hire a custom applicator to apply manure on your farm in the past two years?

☐ Yes ☐ No (If No, skip to question # **49**)

48. What was the cost of having them apply the manure? (Put price and check one measurement.)

$___________ ☐ per ton ☐ per acre ☐ per pick-up load ☐ per spreader load ☐ per semi load

49. What period(s) of the year did you apply manure in 2005? (Check all that apply)

a. ☐ January-February
b. ☐ March-April
c. ☐ May-June
d. ☐ July-August
e. ☐ September-October
f. ☐ November-December

50. Approximately how many hours per year do you spend applying manure?
__________hours

51. How much influence does each of the following have on agricultural production decisions you make? (Please circle the number that best indicates the amount of influence.)

	None		Some		Very Much
a. Other farmers	1	2	3	4	5
b. Non-farming neighbors	1	2	3	4	5
c. Banking/Lending institutions	1	2	3	4	5
d. Contractors / Integrators	1	2	3	4	5
e. University	1	2	3	4	5
f. NRCS	1	2	3	4	5
g. Other government organizations	1	2	3	4	5

The following questions regarding manure management activities are very important to this study. Please answer them as completely and carefully as possible. Remember, only completed questionnaires will be considered for the Wal-Mart gift certificate drawing.

52. Please give your opinion regarding the following characteristics of the given practices even if you don't perform them. (**Circle** the number that best corresponds to your opinion about each of the characteristics.)

	Strongly Disagree		**Neither Agree nor Disagree**		**Strongly Agree**
Use this scale when answering the questions:	**1**	**2**	**3**	**4**	**5**

Practice	This is a profitable practice, it improves my bottom line	This practice improves water quality.	This practice is time consuming.	This practice is complicated.
a. Use Round-up Ready soybeans	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
b. Use phytase in my feed rations	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
c. Test soil for nutrients at least every THREE years.	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
d. Test manure for nutrients at least annually	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
e. Maintain a setback between streams and lakes and manure application areas of 100 feet	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
f. Inject manure into the soil during application	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
g. Calibrate manure spreaders at least annually	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
h. Keep detailed records on what day, how much and to what field manure was applied	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
i. Use a grass filter system as a buffer around water sources	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
j. Use an underground pipe system to move manure to some or all your fields	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

53. **Again, these questions are important to this study so please answer them and the questions on the following page as completely as you can.**
- Please check Yes or No in questions (A) and (C).
- In questions (B) and (D), please write the relevant years in the blanks.

Practice	**(A)** **Do you perform the practice?**	**(B)** **If you currently do the practice, when did you start doing it?**	**(C)** **If you don't currently do the practice, have you done it in the past?**	**(D)** **If you answered yes to question (C), what year did you start and end doing the practice?**
a. Use Round-up Ready soybeans	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
b. Use phytase in my feed rations	☐Yes ☐No ☐ Don't Know	Year ______	☐Yes ☐No	Start ____ End____
c. Test soil for nutrients at least every THREE years.	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
d. Test manure for nutrients at least annually	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
e. Maintain a setback between streams and lakes and manure application areas of 100 feet	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
f. Inject manure into the soil during application	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
g. Calibrate manure spreaders at least annually	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
h. Keep detailed records on what day, how much and to what field manure was applied	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
i. Use a grass filter system as a buffer around water sources	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____
j. Use an underground pipe system to move manure to some or all your fields	☐Yes ☐No	Year ______	☐Yes ☐No	Start ____ End____

→ **Over to last page**

Section 4: Off-farm employment is important for many farmers and may have an impact on the farming operation. Please answer the following questions for 2005.

54. Please check your answer for questions **a** and **b** and write the relevant hours for question **c**.

	Farm Operator	**Spouse** ☐Not Applicable	**Other Family Member #1** ☐Not Applicable	**Other Family Member #2** ☐Not Applicable
a. Contributes significantly to farm work	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
b. Has off-farm work (check one box per person)	☐ none ☐ seasonal ☐ year round	☐ none ☐ seasonal ☐ year round	☐ none ☐ seasonal ☐ year round	☐ none ☐ seasonal ☐ year round
c. Hours per week worked off the farm	______hours per week (during the weeks worked)	______hours per week (during the weeks worked)	______hours per week (during the weeks worked)	______hours per week (during the weeks worked)

55. Does your off-farm work interfere with the timing of your farming operations?
☐ Yes ☐ No (if No, please skip to question #**57**) ☐ Not applicable

56. What periods and activities cause severe time crunch problems? (Check the **two** worst problems.)
a. ☐ Planting in spring
b. ☐ Fall harvest
c. ☐ Cleaning out livestock facilities
d. ☐ Haying
e. ☐ Timing of manure applications
f. ☐ Other _________________

57. Did you hire non-family farm labor in 2005?
☐ Yes ☐ No

58. What is your household's annual **off-farm** gross income?
a. ☐ No off-farm income
b. ☐ Between $0 and $9,999
c. ☐ Between $10,000 and $24,999
d. ☐ Between $25,000 and $49,999
e. ☐ Between $50,000 and $99,999
f. ☐ $100,000 or more

59. What amount of gross farm sales did you have in 2005?
a. ☐ Between $0 and $9,999
b. ☐ Between $10,000 and $99,999
c. ☐ Between $100,000 and $249,999
d. ☐ Between $250,000 and $499,999
e. ☐ $500,000 or more

60. What is the highest level of education you have completed?

a. ☐ Less than High School
b. ☐ High School
c. ☐ Some college or vocational school
d. ☐ Bachelor's degree
e. ☐ Graduate degree, such as Master's

61. What year were you born? _________________

Thank you for your participation. Feel free to use the space below or above right to write any comments you have about the questionnaire or manure issues in general. Then, return the questionnaire in the business reply envelope.

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