ONSITE EVALUATION OF MANURE MANAGEMENT PRACTICES AND NUTRIENT COMPOSITION OF STALL WASTE PRODUCED BY FLORIDA HORSE OPERATIONS

By

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To the memory of B.H. Good

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Currently, a limited amount of data exists to describe the composition of stall waste produced by horse operations. Such information could serve as a useful reference for making nutrient management decisions. The aims of this study were to characterize the composition of stall waste generated by Florida horse operations and identify management factors that affect the nutrient content of stall waste. Samples of clean bedding and soiled stall waste were gathered from breeding farms (n=38), boarding and training facilities (n=56) and racetrack stables (n=45) distributed throughout the state of Florida. Soiled stall waste included bedding mixed with manure and was sampled from each facility's most recent stall cleaning. Samples were analyzed for dry matter (DM), total carbon (TC), nitrogen (TN), C:N ratio, total phosphorous (TP), potassium (TK) and organic matter (OM).

Across facilities, the most widely used bedding was wood shavings (95%), with only a small number of facilities using hay or straw bedding. Clean hay or straw bedding had greater ($P<0.05$) TN and TK than clean wood shavings. Stall waste was higher ($P<0.05$) in TN, TP, and TK than clean bedding alone. The mean C:N ratio of stall waste was 72:1 compared to the mean C:N ratio of clean bedding 683:1. Stall waste from breeding facilities had higher ($P<0.05$) levels of TN and TK compared boarding/training and racetrack facilities and higher ($P<0.05$) TP than

racetrack stables. Stall waste from north Florida was higher ($P<0.05$) in TN and TK when compared to south Florida. Although bedding type contributed to the differences in stall waste composition, stall cleaning practices (e.g., cleaning frequency) likely plays a large role in the nutrient content of stall waste.

Facility owners or managers were also questioned about their facility demographics, feeding programs, stall management, stall waste storage, stall waste utilization, and pasture and paddock management. Stall waste was generally removed off site on a regular basis or being land applied. It was not common (1.6%) for operations to compost stall waste prior to further use.

CHAPTER 1
INTRODUCTION

The Florida horse population numbers more than 500,000 head spread over more than 900 operations (AHC, 2005). The scope and size of this population makes it the second most populous livestock segment in the state with an economic impact, of more than $5 billion (AHC, 2005). Like Florida's human population, the horse numbers are seasonal in nature. This creates overcrowding during certain seasons of the year leading to complications related to waste disposal and management. Compounding manure management concerns is the sensitive nature of Florida's environment. Thousands of miles of coastline, high leaching potential of sandy soils, shallow aquifers, and migrating surface water all compound the difficulty of managing horse waste.

When manure is land applied benefits are apparent, including decreased use of inorganic fertilizers and increased carbon sequestration. However, inherent risks also exists, which include potential water quality problems due to runoff, uncertainty of nutrient availability and public perception issues (Risse et al., 2001). The specific nutrients that contribute the most to water quality problems are nitrogen (N) and phosphorus (P). Agriculture is identified as the leading source of pollution to rivers and streams and animal agriculture is currently under increasing pressure to reduce these sources (USEPA, 2003b). N and P can both lead to increased eutrophication and decreased dissolved oxygen levels in surface water. Groundwater can also be contaminated from percolation and direct seepage of nutrients (Risse et al., 2001). Therefore, it is important for Florida's horse industry to be proactive in addressing any problems that may currently exist or eliminating conditions that pose a future threat to the environment.

Some of the other concerns relating to horse waste management include, lack of knowledge about stall waste composition, high removal cost, limited land area for application, overgrazing and poor pasture management, and high water table and porous soil types. Other concerns relate to the role horse farms play in the nutrient management puzzle. Local, state and federal government agencies are constantly implementing nutrient management regulations that are general and specific in their scope. Each livestock species subgroup is deemed to have a different environmental impact. The determinants of this impact include data suggesting an average nutrient load, perceived and actual production practices, and past environmental problems that have occurred. It is important to do research that determines if the regulations are appropriate and applicable to the horse industry of Florida.

The objectives of this research were to address waste management concerns of the Florida Horse Industry by: 1) characterizing nutrient content of stall waste; 2) identifying the types of bedding commonly used and characterize the nutrient content of these beddings; 3) describe current manure management practices; 4) identify potential risks to water quality by current manure management practices; 5) use the information gathered to make recommendations on future composting research and pinpoint manure management practices that need to be addressed in the Best Management Practices Manual for Florida horse owners.

CHAPTER 2
LITERATURE REVIEW

Over the last 10 years, regulation of intensive livestock production across the world has increased. This has been done in the form of nutrient management plans, best management practices, and regulations for air and water quality. In the United States, environmental regulations have progressed from surface water quality to ground water quality and finally to air quality (Westerman and Bicudo, 2005). Nitrogen (N) and phosphorus (P) in manure are two elements that contribute to many environmental problems such as eutrophication, pollution of groundwater, and acidification.

Long term sustainability of animal agriculture as both a lifestyle and valuable commodity are important issues. The swine and dairy industries have had the highest public profile relative to the sustainability of animal agriculture. The swine industry has identified four levels of issues that will determine their long term sustainability: 1) the farms; 2) the community; 3) society in general; and 4) the environment (Honeyman, 1996).

Intense production practices, decreasing land mass available for production, and the advent of commercial fertilizers have resulted in manure generated by animal production systems to shift from a valuable resource to a waste product. However, when properly used, manure is a resource and should be regulated accordingly (Risse et al., 2001).

Waste Composition

The nutrient composition of animal manure is highly variable and dependent on species, stage of production and diet. Horses can be grouped into categories based on sex, weight and performance. However, to date, only enough info exists to describe the composition of manure for mature sedentary or mature horses undergoing intense exercise (Lawrence et al., 2003) Daily nutrient excretion from a 500 kg sedentary horse has been estimated at 0.089 kg N, 0.013 kg P, and 0.027 kg K on an as-excreted basis (Lawrence et al., 2003). By comparison, daily nutrient excretion from a 500 kg horse involved in intense exercise has been estimated at 0.125 kg N, 0.025 kg P, and 0.043 kg K on an as-excreted basis. Using a similar estimation model for other livestock, it was found that a beef cow would have a similar nitrogen excretion at 0.19 kg/day but a much higher phosphorus excretion of 0.044 kg/day and a lactating dairy cow produces 0.45 kg N, 0.078 kg P and 0.103 kg K per day (ASAE, 2005).

The average horse can produce up to 50 lbs of feces and 7-11 liters of urine per day on an as excreted basis (ASAE, 2005). The quantity of feces generated by the horse is less than a dairy cow (83 lbs/day). However, the quantity of feces produced by a horse is greater than that generated by a 423-lb lactating sow (25 lbs/day) and a laying hen (0.19 lbs/day) (ASAE, 2005).

Phosphorus excreted in feces can be in a water-soluble or insoluble form. The insoluble portion is presumed to be organic in origin and the water-soluble is the plant available P and is largely inorganic in origin (Hainze et al., 2004). Horses differ from other farm animals by having a greater proportion of insoluble P compared to cattle and poultry (Hainze et al., 2004). Less inorganic P may be present as a proportion of total P concentration in horse feces due to more extensive absorption in the large colon in horses compared to other animals (Schryver et al., 1971).

One common method of horse waste storage is stockpiling until there is an opportunity to land apply or to otherwise utilize. Several opportunities exist during this period of time for nutrient loss including leaching, ammonia nitrogen volatilization and microbial degradation of nutrients. Dry matter degradation may also be considerable. Petersen et al. (1998) stored swine and cattle waste for a period of 9-14 weeks in an open air facility and found a dry matter loss of 15%-24%, leaching losses of N and ammonia volatilization. The composition of horse manure and urine with clean bedding added may have a much higher dry matter percentage compared to swine or cattle waste stored in a liquid form. This may lead lowered levels of environmental concern for horse stall waste compared to other livestock manures.

Point Source vs Nonpoint Source Pollution

When considering the source of water quality contamination there are two possible types. First, there is point source pollution, which originates from a discernable source. Large livestock operations or concentrated animal feeding operations are considered point sources. This would include manure lagoons, ditches and pipes used to transport manure, etc. (Morse, 1996). By comparison, nonpoint source pollution includes potential sediment, nutrient and bacteria runoff into surface water, as well as leaching of nutrients into ground water or nutrient runoff after land application of manure or inorganic fertilizer (Morse, 1996).

Major Concerns Related to Soil

Current manure application guidelines for Florida forages are not based on soil test results for N (Mylavarapu et al., 2009). This means recommendations are made based on the N needs of the forage plants. Most forms of livestock manure have a higher P to N ratio than that needed by plants. Therefore, if applications are based on N needs then P is applied at an excess of the crop requirements (Intensive Livestock Operations Committee, 1995). Over application of P can lead to P accumulation in the soil as only a small portion of the total P is readily available to plants. Swine and poultry production have been labeled as causing excess P accumulation, which increased potential for P loss due to runoff (Sims, 1993).

Major Concerns Related to Water

Nitrogen and P that are present in manure and animal feeds pose a risk to surface and groundwater at low levels (Sharpley et al., 1994). When fertilizer is applied, N is generally applied in the largest quantities since it is usually the greatest need for growth of high quality of plants. Nitrogen can be found in the soil as nitrite (NO_2^-), nitrate (NO_3^-), ammonia (NH_3) or ammonium nitrogen (NH_4^+). The most soluble ion of N is nitrate (Watschke et al., 2000). Nitrate ions are generally not adsorbed within the soil and, as a result, move with the water as it passes through the soil.

Surface water contamination with N causes algae populations to grow or “bloom” (Lapointe and Bedford, 2007). When algae dies and decomposes, it consumes the dissolved oxygen which is essential for the survivability of aquatic animal life. Eutrophication is the enrichment of waters with excess mineral nutrients resulting in the over production of algae and cynobacteria (Lapointe and Bedford, 2007).

Another nutrient that is a concern to water quality is P. It can be transported from areas where it is highly concentrated to surface water via runoff (Sharpley et al., 1996). Phosphorus is also a contributor to algae blooms in freshwater, even at extremely low levels (Bush and Austin, 2001). Leaching of P into the ground water is also a concern because it can lead to contamination of lakes and streams. Studies have shown that sandy soils are susceptible to P leaching (Sims et al., 1998) through to the ground water. High risk areas are those with long histories of livestock waste application (Breeuwsma et al., 1995).

Major Concerns Related to Air Pollution

Air pollution includes odors that affect property values and quality of life in areas within the proximity of large scale animal production (Schiffman et al., 1995). As a result, the animal and food processing industries have been forced to control odor emissions. Toxic air pollutants are also a concern that is relevant in animal agriculture. Nitrogen can damage the environment in two forms; 1) nitrous oxide (N_2O) and 2) ammonia nitrogen. Ammonia can be returned to the soil and water by rainfall, which can disrupt the ecosystem and increase eutrophication (Lapointe and Bedford, 2007). In studies conducted in Europe, animal agriculture accounts for 15-75% of total ammonia volatilization into the atmosphere (Hartung and Phillips, 1994).

Uses of Organic Waste

Possible uses of organic waste include fertilizer, energy recovery, and production of chemicals. Utilization of organic waste has many benefits; however, there are also many factors that limit its use as a byproduct. These include quality control, economics, logistics, environmental regulations, and public acceptance (Westerman and Bicudo, 2005). Several of the limitations specific to the horse industry in Florida include limited land area, high carbon and low nutrient levels of stall waste, large particle size of wood chips and shavings, possible disease transmission to grazing animals, and close proximity of horse facilities to residential and urban areas.

Horse stall waste contains nutrients that could be used to fertilize pasture and other crops. Its use as a fertilizer is dependent on several factors, including rate of application, available soil nutrients and the fraction of nutrients that could be available to plants after mineralization (Newton et al., 2003; Eghball et al., 1997). The availability of N in horse manure has been reported to be 50% of the manure nitrogen in the first year, which is similar to dairy manure but less than swine (90%) and poultry (75%) (Kidder, 2002; Eghball et al., 2000). Bedding material makes up a large portion of materials removed from horse stalls as waste. Typically, this bedding is high in organic matter, bulky in nature but with a low N content (Ott et al., 2000) The inconsistency of nutrient concentration make the value of horse stall waste as a fertilizer source questionable.

Land Application

There are an estimated 9.2 million horses populating the United States, and over 500,000 reside in the state of Florida (AHC, 2005). The average horse can produce 14 kg of feces and 7-

11 liters of urine per day (ASAE, 2005). When horses are confined in stalls bedding is often added to absorb urine and feces. Soiled bedding is often removed daily and when stalls are cleaned and the total volume removed can be 30-45 kg of feces, urine, discarded feed and hay, and bedding. On an annual basis, the average horse can produce up to 13,000 kg of stall waste (Swinker et al., 1998). Bedding makes up a large portion of the volume removed and can include straw, wood shavings, sawdust, grass hay, peanut hulls, shredded paper or other products. Wood shavings have a high carbon content and a low N content as well as being bulky in nature (Ott et al., 2000). Nitrogen and P are excreted both in the feces and urine, and the amounts are dependent on the amounts contained in the diet (Mathews et al., 1996).

Research has shown manure application can have a significant impact on the physical and biological properties of the soil, as a result of increasing organic matter in the soil. Land application can also positively affect soil erosion and surface water runoff. Several negative factors include uncertainty of nutrient content and availability, runoff, transportation and handling costs, and public perception or odor issues (Risse et al., 2001). Where animal production is typically concentrated, the land available for manure application is often limited, which can create a nutrient surplus in a particular area. The major factor in exporting manure from an area of surplus to an area of deficit is the economics of transportation. Currently very little research is being done to address the economics of producing more transportable products or reducing the transportation costs (Risse et al., 2001).

Land application on the farm where the waste is generated is usually the most cost effective way to utilize of waste. Most livestock farms do not have adequate land to apply manure at agronomic rates (Gollehon et al., 2001). This is a nationwide figure for all livestock species and production facilities. The majority of Florida's horse population is located on small acreages near large urban areas. A concern specific to horse stall waste is the bulk. The concentration of N, P, and K are relatively low when compared to other types of livestock and poultry litter. This means that a greater volume of waste must be applied to meet the agronomic needs of the crop or grazing area.

When the quantity of waste to be applied is greater than the land available for application, transportation becomes an economic concern. About two thirds of the counties in this country have a farm that must remove animal manure from its site to avoid a nutrient excess (Gollehon et al., 2001). The waste must be hauled off site to be utilized. If the added cost is prohibitive this may result in less than desirable management practices. Public perception also limits the potential for utilization of animal manure in environmentally safe ways. Ammonia volatilization, odor drift and flies are all an air pollution concern that shrinks the acreage available for livestock waste application.

Limitations for use of stall waste

Limitations for using horse stall waste as a fertilizer source include land availability, season, spread of weed seeds and parasites, odor, suppression of forage growth and surface and ground water contamination. The most likely concern for land application of all animal waste is surface and ground water contamination. The mobile forms of nitrogen and phosphorus, organic matter, microbes and other materials on top of the soil following application can negatively affect the quality of runoff negatively. Runoff from areas treated with animal manure can contain elevated concentrations of nutrients, solids, and organic matter when compared to untreated areas (Westerman et al., 1983; Edwards and Daniel, 1993). Buffer strips, incorporating manure into the soil and timely application can reduce potential risks from pastures treated will stall waste or any form of livestock manure (Young et al., 1980).

Reducing Impacts of Animal Waste

Compost

Composting is the controlled acceleration of a natural process that converts organic matter into a stable material (Ott et al, 2000). Composting reduces volume and odor, kills unwanted microorganisms and weed seeds, creates a more stable nutrient source and adds value to the end product (Higgins et al., 1982; Chaw, 2002). Therefore, land application of compost is more environmentally friendly than stockpiling stall waste or land applying unprocessed manure or stall waste. The utilization of compost as a source of fertilizer on pastures or cropland could reduce the amount of commercial nitrogen fertilizer applied and decrease the potential for inorganic nitrogen to contaminate water sources (Diepeningen et al., 2006). While composting is a simple and efficient way to manage stall waste, smaller stables (30-40 horses) generally do not generate appropriate volumes of manure to merit specialized composting equipment (Chaw, 2002).

Two types of composting systems exist: aerobic and anaerobic. Aerobic composting uses oxygen in the decomposition process, whereas anaerobic composting is performed without oxygen. The most common form of commercial composting system is aerobic (Ott et al., 2000). Aerobic composting is more rapid and achieves the increase in temperature needed to kill weed seeds and pathogens. Factors that affect the rate at which material breaks down in the composting process are: 1) availability of air; 2) particle size; 3) moisture level; 4) temperature; 5) carbon:nitrogen ratio; and 6) pH (Ott et al., 2000).

Nutrient Management Planning

Nutrient management plans help to optimize the use of on-farm sources of nutrients (manure and residual nutrients from previous crops) by matching nutrient applications to crop needs, allowing a reduction in commercial fertilizer use while maintaining soil productivity and crop yields (Beegle et al., 2000). Nutrient management plans can vary but most include: soil test reports, assessment of on-farm nutrient resources, nutrient crediting, manure inventory and manure spreading plan (University of Wisconsin Extension, 1995).

Implementing nutrient management plans can be quite costly due to the increased compliance costs. It is possible for operations to realize a net reduction in operating costs as it would require less inorganic fertilizer than was previously being used to achieve agronomic levels (Weld et al., 2002). Under a comprehensive nutrient management plan operations can be categorized as nutrient deficient, nutrient balanced or nutrient surplus (Beegle et al., 2000). Nutrient deficient farms are usually low intensity, low animal density operations. Nutrient balanced farms would be characterized by nutrient imports being equal to nutrient exports. Nutrient surplus farms exist when nutrient imports significantly exceed the exports. It would be unlikely that operations that operate with a nutrient surplus would be able to utilize all of the manure produced on site. This would create a need to store nutrients onsite or find another method of utilization for excess manure.

Best Management Practices

Best management practices (BMPs) are specifically designed to address farm practices that may generate cause environmental problems. Focus is generally placed on the management of N, P and pesticides (Logan, 1993). Best management practices are environmentally sound practices that are, at a minimum, as profitable as existing management practices. There are usually fixed start-up costs associated with the implementation of many BMPs, therefore producers may see them as a detriment to farm profitability (Feather and Amacher, 1994). Two methods are in use to aide farms in implementing BMPs: 1) cost sharing from the federal or state government; and 2) producer education. Examples of BMPs for animal agriculture include grassed waterways, livestock exclusion from high risk areas, streambank and shoreline protection, rotational grazing, pesticide and nutrient management, and management of dead livestock (Gillespie et al., 2007). The Florida Department of Agriculture and Consumer Sciences is in the process of drafting a current best management practices manual for horse operations. Some proposed practices include, nutrient, manure, stormwater and grazing management (FDACS, 2008).

Animal Feeding Operation (AFO) and Concentrated Animal Feeding Operations (CAFO)

An AFO is any animal feeding operation where animals are confined for at least 45 days within a 12-month period and crops, forage growth and other vegetation are not grown in the area where animals are confined. To be considered a CAFO a facility must first meet the requirements of an AFO. The regulation sets thresholds for a certain number of animals an AFO must have in confinement to meet the requirements of a CAFO. AFOs are categorized as small, medium or large (USEPA, 2003a).

Table 2-1. Regulatory definitions of large AFOs, medium AFOs and small AFOs

	Size Thresholds (Number of Animals) [1]		
Animal Sector	Large AFOs	Medium AFOs	Small AFOs
Cattle or cow/calf pairs	1,000 or more	300-999	Less than 300
Mature dairy cattle	700 or more	200-699	Less than 200
Veal calves	1,000 or more	300-999	Less than 300
Swine (weighing over 55 lbs)	2,500 or more	750-2,499	Less than 750
Swine (weighing less than 55 lbs)	10,000 or more	3,000-9,999	Less than 3,000
Horses	500 or more	150-499	Less than 150
Sheep or lambs	10,000 or more	3,000-9,999	Less than 3,000
Turkeys	55,000 or more	16,500-54,999	Less than 16,500
Laying hens or broilers (Liquid manure systems)	30,000 or more	9,000-29,999	Less than 9,000

[1] USEPA, 2003a

It was reported by the EPA that according to the NAHMS nearly all of the large horse CAFOs are racetracks (USEPA, 2003a). Looking at Table 2-1 it is to be noted that the lowest threshold for any livestock species to be considered a small, medium or large AFO is for horses.

Presumably this is due to the large volume of bedding that is removed along with manure and urine from horse confinement areas. No literature exists to indicate that horse manure and urine has a higher concentration of nutrients relative to other livestock species.

Manure Management in the Equine Industry

Nationally, the highest percentage of horse operations disposed of manure and waste bedding by either applying it to fields where no livestock graze, applying it to fields where livestock graze and allowing it to accumulate and spread naturally (NAHMS, 2005). A very low percentage disposed of manure by routine garbage pickup. Large operations were most likely to do something with stall waste other than land apply such as sell it or have it hauled off site (NAHMS, 2005; Peters et al., 2003; HIAA, 2003). In a survey done in the state of Kentucky, 70% of respondents spread waste on crop land or pastures (Coleman and Janicki, 2003). The overwhelming majority of horse owners prefer to use wood shavings as clean bedding (Coleman and Janicki, 2003, HIAA, 2003). Other types of bedding that were reportedly used were straw, peat moss and shredded paper (HIAA, 2003).

CHAPTER 3
CHARACTERIZATION OF STALL WASTE COMPOSITION FROM FLORIDA HORSE OPERATIONS

Introduction

Numbering approximately 500,100, horses are second only to cattle (1.75 million) as the most established livestock commodity in the state of Florida (AHC, 2005; USDA-NASS, 2003). Nationally, Florida ranks third behind Texas and California in total horse numbers (AHC, 2005). Over 70% of Florida's horse population is concentrated in two regions located in the central (Alachua, Marion, and Levy counties) and southern (Broward, Dade and Palm Beach counties) parts of the state. In addition to a large number of full time residents, Florida's warm winter climate results in a seasonal influx of horses for training and competition. Much of this influx occurs in south Florida, where land availability is rapidly declining and concerns over water quality continue to increase.

Over 58% of the horses in Florida have been classified as being used for racing and showing (AHC, 2005). By extrapolation, this means a large number of horses spend a significant amount of time confined to a stall in a barn, where soiled bedding and manure must be regularly removed. Horses used for breeding, as well as those owned for recreation, may also be housed in stalls for some portion of the day, although this practice varies widely.

In developing their final rule on concentrated animal feeding operations (CAFO), the United States Environmental Protection Agency (USEPA, 2003b) rejected data supplied by the horse industry suggesting a 1000-lb horse generated a similar amount of manure as a 1000-lb beef cow on the grounds that the data did not differentiate between manure produced by racehorses and manure produced by other horses (USEPA, 2001, 2003b). The EPA suggested the diets of racehorses differed such that manure composition would be significantly altered. At the time of the ruling, the EPA's statement was pure speculation and data to characterize differences in manure composition between different types of horses was unavailable. Subsequently, a meta-analysis of research that had been designed to assess nutritional requirements was used to establish prediction equations to estimate nitrogen and phosphorus excretion from sedentary and exercising horses based on dietary intake (Lawrence et al., 2003; ASAE, 2005). Although differences in nutrient intake and excretion were found to exist between sedentary and exercising horses, these values (and the equations) only reflected feces and urine, without the inclusion of bedding.

Published values on the nutrient composition of horse stall waste are largely unavailable. Stall waste could include clean and soiled bedding, feces, urine, discarded feed, and residue from the stall floor (e.g., sand, clay). As a result, the composition of stall waste is likely not uniform. Nonetheless, characterizing the composition of horse stall waste would be useful for making local, regional and statewide nutrient management planning decisions. In addition, this information is necessary in order to make more accurate cross-species comparisons and to further clarify the risks to water quality posed by manure and/or stall waste generated from the horse industry.

The objectives of this study were to: 1) characterize the nutrient composition of stall waste produced by Florida horse operations; 2) determine if regional differences in the nutrient composition of stall waste exist in Florida (i.e., north, central and south); 3) identify the differences in nutrient composition of stall waste generated by different types of horse operations (i.e., breeding, boarding/training, and racetrack stables); 4) determine the impact of bedding type on stall waste composition; 5) characterize the nutrient composition of clean bedding used by Florida horse operations to help assess the influence horse manure has over stall waste composition; and 6) identify management trends specific to stall waste handling that may impact stall waste composition.

Materials and Methods

Experimental Design

Samples of clean bedding and stall waste were obtained from 139 horse facilities located throughout the state of Florida. Sampling was distributed between three types of horse facilities: 1) breeding farms (n = 38); 2) boarding/training facilities (n = 56); and 3) racetrack stables (n = 45). Breeding farms were defined as operations that participate in breeding, where horses are typically housed in stalls part-time on a seasonal basis (e.g., during foaling season; during sales preparation of young horses) or for short duration (e.g., during morning and evening feedings; during evenings when foals are young). Boarding/training facilities comprised several different riding/training disciplines and were defined as operations that board a minimum of 10 horses, where horses spend a significant amount of time confined to stalls (minimum of 8 hr/d). Racetrack stables were represented by horses managed under different trainers and housed at one of three racetracks with pari-mutuel wagering on live racing, including Calder Racecourse, Gulfstream Park and Tampa Bay Downs.

With the exception of racetrack stables, sampling of stall waste was also distributed in three regions within the state of Florida: 1) North Florida (n = 30) including the panhandle and near or north of Interstate-10; 2) Central Florida (n = 40) including Alachua and Marion counties, Orlando and Tampa; and 3) South Florida (n = 69) defined as the area south of the Interstate-4 corridor. Samples collected from racetrack stables were included in the analysis by region, with two of the racetracks located in South Florida and one in Central Florida. No racetracks were present in North Florida.

Sampling Protocol for Stall Waste

Stall waste was defined as the combination of feces, urine, bedding, and discarded feed removed from stalls during a typical cleaning. Samples of stall waste were obtained from the materials identified as being the most recently removed from horse stalls. When possible, stall waste was collected and sampled as it was being cleaned out of the stalls. Materials were thoroughly mixed with a stall fork or pitch fork prior to sampling. A representative sample was obtained by grabbing handfuls of material at random locations within the manure storage pile or wheelbarrow until enough material was obtained to fill a 7.5 L (2 gallon) plastic bag. Samples of stall waste were immediately placed in an ice-chilled cooler for transport to the University of Florida Animal Nutrition Laboratory for further processing and analysis.

Sampling Protocol for Bedding

To establish the impact bedding has on the composition of stall waste, samples of clean, unused bedding were also obtained. At each facility, the clean bedding storage pile was identified and thoroughly mixed with a stall fork or pitch fork prior to sampling. A representative sample of clean bedding was obtained by grabbing handfuls of material at random locations within the clean bedding storage area. For bulky beddings, such as straw, hay or wood chips, enough clean bedding was collected to fill a 7.5 L (2-gallon) plastic bag. For other bedding materials, such as shavings or sawdust, enough was collected to fill a 3.8 L (1-gallon) plastic bag. With the exception of racetrack stables, clean bedding samples were obtained from each facility. Each racetrack had contracted with a single bedding supplier; thus, the same type of bedding was used in every stall, regardless of the stable. Therefore, only one clean sample from each of the three racetracks was collected, analyzed and represented in the dataset. Clean bedding samples were immediately placed in an ice-chilled cooler for transport to the University of Florida Animal Nutrition Laboratory for further processing and analysis.

Nutrient Analysis

After transport to the Animal Nutrition Laboratory, ice-chilled samples of stall waste and clean bedding were placed in a 60ºC forced-air drying oven for 3 d or until the weight stabilized to determine dry matter (DM). Dried samples were ground through a Wiley mill, first passing through a 5 mm screen and then processed through a 1 mm screen. Throughout the grinding process, samples were thoroughly mixed at each step to maintain a representative proportion of manure to bedding.

Stall waste and clean bedding samples were analyzed for total nitrogen (TN) and total carbon (TC) using the Dumas combustion method (VarioMax N analyzer, Elementar Americas; TMECC methods 04.02-D and 04.01-A; (Thompson, 2001)). The Dumas type analyzer measures all forms of nitrogen in the measurement of nitrogen gas. The ratio of carbon to nitrogen (C:N) was calculated by dividing the %TC by the %TN in each sample. Total phosphorus (TP) was determined on samples that had been ashed prior to sulfuric acid digestion and then quantified colorimetrically (PowerWave XS spectrophotometer, Winooski, VT). Total potassium (TK) concentration in samples was determined using atomic absorption spectrometry (AAnalyst 800, PerkinElmer, Inc. Shelton, CT). Organic matter (OM) was determined after ashing samples for 12 h in a muffle furnace at 550ºC and then subtracting the amount of ash from the DM (TMMECC method 03.02-A; (Thompson, 2001)).

Statistical Analysis

Differences in TN, TC, C:N ratio, TP, TK, DM and OM were analyzed using the MIXED procedure of SAS (Version 9.1, SAS Inst., Cary, NC). The effects of facility type, sample type, bedding type and region were evaluated as fixed effects. The PDIFF option of the LSMEANS statement of PROC MIXED was used to compare means. Differences were considered significant at $P<0.05$. Data are presented as means ± SE.

Results

Clean Bedding

Samples of clean bedding were obtained from 96 different facilities. By far, the vast majority of horse operations sampled (91/96 facilities or 94.8%) used wood bedding products, including wood shavings, chips, sawdust, or pellets. Only two facilities (2.1%) used grass hay as bedding; one of these facilities was a boarding/training operation and the other was a breeding farm. Only three facilities (3.1%) bedded their horses on straw; two of these facilities were breeding farms and the other was a racetrack (n=15), which utilized a pelleted straw product.

The TN, TC, C:N ratio, and TK concentrations of clean bedding were different ($P < 0.05$) between bedding types (Table 3-1). The TN concentration in grass hay and straw bedding was greater ($P < 0.05$) compared to the TN content of wood bedding. The TC concentration of wood bedding was greater ($P < 0.05$) than straw, with hay bedding intermediate between the two but closer to wood. As a result, the C:N ratio in clean wood bedding was higher ($P < 0.05$) than the ratio in hay or straw. Clean straw bedding was higher ($P < 0.05$) in TK than hay and wood beddings. Although TP was numerically higher in clean hay bedding, the small sample size yielded no statistical difference in TP concentration between bedding types (Table 3-1). Organic matter was not different between clean bedding types.

With the exception of C:N ratio, the nutrient composition of clean bedding was not affected by facility type (Table 3-2) or region of the state (Table 3-3). The C:N ratio of clean bedding was higher in racetrack facilities ($P < 0.05$) compared to boarding/training operations and breeding farms (Table 3-2). This finding may be reflective of a lower, but not significantly different TN concentration in clean bedding from racetracks. The C:N ratio of clean bedding was also higher in operations located in South Florida ($P < 0.05$) compared to Central and North

Florida (Table 3-3). This finding may reflect a greater proportion of racetrack stables located in South Florida and the usage of the same bedding at each track.

Stall Waste

The nutrient composition of stall waste, across all bedding types, facility types and regions, is compared to the composition of clean bedding in Table 3-4. Stall waste was higher ($P < 0.05$) in TN, TP and TK and lower ($P < 0.05$) in C:N ratio and DM than clean bedding. The C content and OM did not differ between stall waste and clean bedding.

Differences in the composition of stall waste were observed when evaluated by bedding type (Table 3-5). The TN concentration of stall waste containing wood bedding was lower ($P < 0.05$) than stall waste containing hay or straw bedding. The TK concentration of stall waste containing either wood or hay bedding was lower ($P < 0.05$) than observed for stall waste containing straw. TP was higher ($P < 0.05$) in stall waste containing straw bedding compared to that containing wood bedding. Despite some numerical differences, the TC, C:N ratio, DM and OM concentrations in stall waste were not affected by the type of bedding used (Table 3-5). The small number of stall waste samples containing hay or straw bedding likely precluded detection of differences from stall waste containing wood bedding.

Facility type appeared to have a limited effect on TC, C:N ratio, DM and OM composition of stall waste (Table 3-6). In contrast, differences in the TN, TP and TK concentrations of stall waste were observed between facilities. Stall waste from breeding farms had the highest ($P < 0.05$) TN and TK concentration compared to boarding/training facilities and racetrack stables, and stall waste from racetrack stables had higher TN and TK content than boarding/training facilities ($P<0.05$). TP was higher ($P < 0.05$) for breeding operations compared to racetrack stables.

The nutrient composition of stall waste also differed by geographical region (Table 3-7). Stall waste obtained from North Florida had a greater TN ($P < 0.05$) and a lower TC ($P < 0.05$) concentration compared to South Florida, with stall waste from Central Florida being intermediate between the North and South regions. Despite these differences, region had no effect on the C:N ratio of stall waste. Stall waste from North Florida also had the greatest TK concentration ($P < 0.05$), followed by South Florida ($P < 0.05$), with stall waste from Central Florida having the lowest TK concentration ($P < 0.05$). The TP, DM and OM concentrations in stall waste were not different between North, Central or South Florida (Table 3-7).

Because wood bedding was the predominant bedding type used on Florida horse operations, stall waste containing hay or straw bedding were removed from the dataset to eliminate variation due to bedding type, and stall waste containing only wood bedding was evaluated for differences within facility type and region. Similar to the differences observed across all bedding types, stall waste containing wood bedding was higher ($P < 0.05$) in TN, TP and TK and lower ($P < 0.05$) in C:N ratio, DM and OM than clean wood bedding (Table 3-8). The TC content did not differ between stall waste containing wood and clean wood bedding.

The effect of facility type on the nutrient composition of stall waste containing wood bedding is shown in Table 3-9. Stall waste containing wood bedding from breeding farms had the highest ($P < 0.05$) TN and TK concentrations, followed by boarding/training operations ($P < 0.05$), with the lowest TN and TK found in stall waste containing wood bedding from racetracks ($P < 0.05$). The TP concentration of stall waste containing wood bedding was higher ($P < 0.05$) in breeding farms compared to racetrack stables or boarding/training facilities. The TC, C:N ratio, DM and OM content of stall waste containing wood bedding was not affected by facility type.

The effect of region on the nutrient composition of stall waste containing wood bedding is presented in Table 3-10. The TN content of stall waste containing wood bedding was highest in samples obtained from North Florida ($P < 0.05$), followed by Central Florida ($P < 0.05$), and was the lowest in South Florida ($P < 0.05$). The TK content of stall waste containing wood bedding was also the highest in North Florida ($P < 0.05$) compared to Central and South Florida. Stall waste containing wood bedding from Central Florida had a lower TK concentration than materials collected from South Florida ($P < 0.05$).The concentration of TP was higher ($P < 0.05$) and the TC and OM lower ($P < 0.05$) in stall waste containing wood bedding from North Florida compared to South Florida, with materials collected from Central Florida having intermediate concentrations of TP, TC and OM.

The frequency of stall cleaning may alter the proportion of clean bedding to manure generated as stall waste. Boarding/training facilities were most likely to clean stalls twice a day, whereas breeding farms were more likely to clean stalls once per day (Table 3-11). Stall cleaning frequency at racetrack stables was not evaluated. When evaluated by region, horse operations in South Florida were more likely to clean stalls twice a day, whereas facilities in North Florida were more likely to clean stalls once daily. Operations in Central Florida appeared to clean stalls once per day, twice per day or continuously with similar frequency (Table 3-11).

Discussion

The key findings from this study were: 1) wood products are the predominant type of bedding used on Florida horse operations; 2) the addition of manure (feces and urine) to bedding in the form of stall waste significantly alters the nutrient composition of clean bedding; 3) the concentration of TN and TK in stall waste, and to a lesser extent the TP content, were affected by the type of bedding used in stalls, the type of horse facility, the regional location of the facility, and perhaps the stall cleaning frequency.

In the current study, the predominant source of bedding used in horse stalls was wood shavings, chips or sawdust (94.8%). This finding differs from a USDA survey conducted as part of the National Animal Health Monitoring System (NAHMS, 2005), which found that majority of horse operations utilized hay or straw bedding (57.7%) followed by wood shavings, chips or sawdust (39.3%). Availability, cost, and ease of removing manure and soiled bedding were listed as the three most important considerations for selecting clean bedding type (NAHMS, 2005). The NAHMS study was a nationwide survey of all horse owners and types of facilities. The current study targeted larger, commercial operations (≥ 10 horses) that generate larger volumes of manure; smaller operations were not visited. The production of straw in the state of Florida and in bordering states is minimal. Any straw used as bedding must therefore be imported via truck or rail resulting in an increased cost and a greater difficulty to procure. In addition, much of the horse hay in the state of Florida is imported making it a high priced commodity. As a result, the use of hay as bedding is not economical unless it is grown onsite or purchased locally. At least one operation evaluated in the current study that bedded horse stalls with hay utilized their horse stall waste as an alternative feed for cattle, which were also reared on their property. The availability of wood products for bedding in the state of Florida is high, due to the extensive pine lumber industry within the state and in the southeastern U.S. Thus, the higher prevalence of wood beddings on Florida horse operations is likely based on greater availability and lower cost relative to other bedding sources.

In some situations the type of bedding used is by choice and in others it is decided by some other circumstance. Horses are commonly housed in facilities owned by another entity or individual who is responsible for choosing the bedding. For example, racetracks and show facilities often utilize a single supplier for clean bedding, thereby dictating what material horses will be stalled on. The reason may be to take advantage of bulk purchase pricing or to create a uniform stall waste product for ease of handling. If a uniform stall waste product can be achieved it will be easier to manage and may have more value as a composted or recycled product.

In general, the composition of clean wood and hay beddings in the current study was similar to that reported by others (Barringtion et al., 2002; Koon et al., 1992; Veverka et al., 1993). Others have reported higher TN and TP concentrations in straw compared to that found in the current study (Barringtion et al., 2002; Ward et al., 2000). These differences may be due to general variation in straw products, as well as the fact that one of the three straw beddings sampled in the current study was a pelleted product, which could have contained ingredients other than straw (e.g., clay binders to facilitate pelleting).

Expected differences in nutrient composition of clean bedding between hay and straw compared to wood products were detected in the current study, despite the small number of samples from facilities that utilized the former types of bedding. The TN and TK concentrations in hay and straw were higher than wood bedding, whereas the TC concentration and C:N ratio were higher in wood bedding compared to straw and hay. Wood products, including chips, shavings and sawdust are known to be low in TN and high in TC, yielding a very high C:N ratio (Barringtion et al., 2002; Veverka et al., 1993).

The ratio of C:N in clean bedding, but not the TC or TN concentration, was affected by facility type and region. The majority of facilities utilized wood products; thus, the differences are likely due to variation in the source of wood bedding rather than bedding type. The TC content in wood shavings, sawdust, chips or pellets may be affected by the processing technique, type of wood or stage of maturity. The TN content of softwoods, such as pine, may vary from 0.03% to 0.10% depending on the part of the tree sampled and its stage of growth at harvest

(Veverka, et al., 1993). Because the C:N ratio is determined by dividing the %TC by the %TN, small variations in TN can yield big differences in the C:N ratio. Suppliers of wood bedding in Florida are generally local lumber mills, which service many horse facilities in a given region. Thus, the lumber and processing methods used by a given mill may have a large influence on the bedding composition used by horse facilities in that region.

In the current study, stall waste was 2 to 10 times higher in TN, TP, TK and moisture than bedding alone, highlighting the impact that horse manure and discarded feed have on the nutrient composition of stall waste. The proportion of bedding to manure in stall waste was not estimated at the time of sampling; however, based on the nutrient composition of clean bedding from the current study and the composition of horse manure reported by ASAE (2005), proportions of each material can be estimated. Using TN as an example, clean bedding contained 0.13% TN and stall waste 0.71% TN in the current study. According to ASAE (2005), manure without bedding was estimated to contain 2.4% TN in sedentary horses and 3.85% TN in intensely exercised horses. Therefore, stall waste in the current study probably consisted of a 73-85% bedding and 15-27% manure mixture. Thus, although bedding likely made up a much greater proportion of stall waste than manure, the more concentrated nutrients in horse manure significantly influence the composition of stall waste. This is most apparent for TP, which was almost negligible in clean bedding (0.02%) but readily quantifiable in stall waste (0.19%); or almost 10 times greater than clean bedding.

The TN, TP and TK concentrations in horse stall waste are much lower compared to horse manure alone and manure from other livestock species (see Table 3-12). In fact, on a DM basis, horse manure contains more than three times the concentration of TN and TK and two times the concentration of TP compared to horse stall waste. Similar, but more dramatic differences in nutrient concentrations exist between horse stall waste and manure from other livestock species (Table 3-12). The bedding in stall waste increases the volume and DM of material, but also effectively dilutes the nutrient concentrations in horse manure. To evaluate the fertilizer value of horse stall waste, comparisons of TN, TP and TK per metric ton of material on an as-removed basis between stall waste and reported values for manure from horses and other livestock are presented in Table 3-13. Horse stall waste from the current study appears to contain more TN, TP and TK per metric ton on an as-removed basis than that estimated for manure generated by sedentary horses, but less TN and TP than manure from intensely exercised horses (ASAE, 2005; Table 3-13). Almost two-thirds of the stall waste samples in the current study were obtained from stalls housing horses that were undergoing some type of regular exercise training (e.g., dressage, hunter/jumper, western pleasure, polo, racing). Thus, with the small addition of nutrients from bedding, as well as some horse manure originating from horses in training, one might expect the quantity of nutrients present per metric ton of stall waste to reflect that which is intermediate between manure from sedentary and exercised horses. Compared to other livestock manures, horse stall waste contains less TN and TP per metric ton of material on an as-removed basis than manure from dairy, swine and poultry operations, but slightly more TN and TP than manure from beef cattle in confinement (Table 3-13). Swinker et al. (1998) estimated that a horse can produce around 13 tons per year of stall material. Using the mean stall waste composition from the current study, this would result in a total annual nutrient load per horse of 49.2 kg TN, 13.2 kg TN and 49.2 kg TK.

The type of bedding used in stalls for horses appeared to have a large impact on stall waste composition. Stall waste containing hay or straw bedding had approximately twice the amount of TN, as well as higher TK compared to stall waste containing wood bedding. As clean beddings, hay and straw had higher levels of TN and TK than wood bedding, which likely contributed to the higher concentrations of these nutrients when these beddings were a component of stall waste. In addition, hay and straw beddings are bulkier materials and strategies used to clean stalls bedded with these materials often differ from techniques used to clean stalls bedded with wood products. Removal of a greater proportion of bedding per unit of manure during cleaning could further alter the nutrient concentration of stall waste. Using similar calculations for estimating the proportion of bedding to manure described above, stall waste containing hay or straw bedding likely consisted of 60-75% bedding and 25-40% manure, whereas stall waste containing wood bedding likely contained 75-85% bedding and 15-25% manure. Thus, the initial composition of the bedding used in the stall, as well as stall cleaning practices inherent to that type of bedding appear to impact the composition of stall waste.

The composition of stall waste was also affected by the type of facility. Stall waste collected from breeding farms had higher TN and TK concentrations and slightly higher TP concentrations than stall waste obtained from boarding/training facilities or racetrack stables. Horses at these facilities are likely fed different diets, which would be expected to influence nutrient excretion (Lawrence et al., 2003; ASAE, 2005). The dietary protein and mineral requirements of pregnant and lactating mares and growing horses are higher compared to other classes of horses (NRC, 2007). To meet these requirements, horses on breeding farms are typically fed rations containing higher levels of TN (in the form of protein) and TP, which could subsequently result in greater excretion of these nutrients. In addition, the cleaning of stalls on breeding farms was found to be less frequent (1x/d) than that observed for boarding/training operations (2x/d). A greater frequency of stall cleaning could result in the removal of more clean bedding along with manure, which would dilute the nutrient concentrations in stall waste from boarding/training operations. In contrast, less frequent stall cleaning could result in less bedding per unit of manure removed, thereby concentrating the nutrients in stall waste from breeding farms.

When only stall waste containing wood bedding was evaluated, waste from racetrack stables had the lowest TN, TP and TK concentrations. In its final rule on CAFOs, the EPA speculated that manure generated from racetracks would have a higher nutrient composition than other horse facilities (USEPA, 2001, 2003b). While the manure itself (i.e., the feces and urine) from intensively exercised horses may have higher TN and TP than that of more sedentary horses (ASAE, 2005), the practice of housing racehorses in stalls where large amounts of bedding are mixed with the manure appears to effectively reduce the concentrations of nutrients.

In addition to the type of bedding or facility, the regional location of the horse operation within the state of Florida also influenced stall waste composition. Stall waste generated on horse operations in North Florida had greater TN, TP and TK and lower TC concentrations than stall waste from Central and South Florida. Because clean bedding did not differ in TC, TN, TP or TK between regions, differences in the composition of stall waste may be due to regional differences in the proportion of manure to shavings generated during cleaning. A greater number of horse operations in North Florida cleaned stalls 1x/d, whereas those in Central and South Florida were more likely to clean stalls two or more times per day. As mentioned above, a greater frequency of stall cleaning may result in the removal of more bedding, thereby diluting the nutrient concentrations on operations in Central and South Florida.

Conclusion

Horse stall waste is not a uniform material; it consists of varying quantities of feces, urine, bedding, and discarded feed, all of which can impact the nutrient content of stall waste. Nonetheless, reference values for stall waste composition would be useful for making nutrient management planning decisions in areas where large numbers of horses are housed. Across the State of Florida, horse stall waste appears to be comprised of approximately 75% bedding (predominantly a wood product) and 25% manure, with an average fertilizer N-P_2O_5-K_2O value of 0.41-0.25-0.49 on an as-removed basis. Relatively small differences in the TN, TP, and TK concentrations in stall waste were observed between breeding farms, boarding/training facilities and racetrack stables. In contrast, the type of bedding used in horse stalls, as well as cleaning practices to remove manure and soiled bedding from stalls appeared to have a larger impact on the nutrient composition of stall waste. Based on ASAE (2005) estimates, the composition of horse manure is similar to that of a beef cow, but much less than that of dairy, swine and poultry manure. With the addition of bedding, horse stall waste is even lower in TN and TP than other livestock manures. Although the volume generated by some horse operations may be quite high, the impact of stall waste on the environment and water quality is likely less than the risk posed by other livestock manures.

Table 3-1. Nutrient composition of clean bedding evaluated by bedding type

	Hay (n = 2)		Straw (n = 3)		Wood (n = 91)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.52[a]	±0.31	0.32[a]	±0.27	0.11[b]	±0.12
Carbon (%)	44.3[a,b]	±2.1	34.3[a]	±8.3	45.8[b]	±0.6
Carbon:Nitrogen Ratio	137:1[a]	±85	421:1[a]	±220	704:1[b]	±61
Total Phosphorus (%)	0.08	±0.03	0.01	±0.01	0.02	±0.004
Potassium (%)	0.29[a]	±0.26	1.12[b]	±0.24	0.11[a]	±0.02
Dry Matter (%)	94.7	±2.3	75.6	±10.1	80.0	±1.5
Organic Matter (%)	96.9	±2.8	93.1	±4.7	98.0	±1.0

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-2. Nutrient composition of clean bedding evaluated by facility type

	Boarding/Training (n = 55)		Breeding (n = 38)		Racetrack (n = 3)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.14	±0.02	0.12	±0.02	0.05	±0.01
Carbon (%)	46.1	±0. 8	45.0	±0.8	38.5	±9.9
Carbon:Nitrogen Ratio	546:1[a]	±42	860:1[b]	±126	952:1[b]	±382
Total Phosphorus (%)	0.02	±0.005	0.02	±0.01	0.01	±0.002
Potassium (%)	0.09	±0.02	0.22	±0.06	0.28	±0.27
Dry Matter (%)	79.8	±2.1	80. 8	±2.3	78.2	±5.4
Organic Matter (%)	97.1	±1.7	98.8	±0.5	99.3	±0.3

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-3. Nutrient Composition of clean bedding evaluated by region

	North (n = 30)		Central (n = 26)		South (n = 40)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.09	±0.01	0.16	±0.04	0.14	±0.02
Carbon (%)	44.1	±1.6	46.1	±0.5	46.0	±0.8
Carbon:Nitrogen Ratio	595:1[a]	±51	634:1[a]	±69	782:1[b]	±127
Total Phosphorus (%)	0.02	±0.01	0.03	±0.01	0.02	±0.01
Potassium (%)	0.12	±0.05	0.17	±0.07	0.15	±0.03
Dry Matter (%)	80.9	±2.9	79.7	±3.1	79.8	±2.1
Organic Matter (%)	96.6	±3.0	98.4	±0.7	98.4	±0.4

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-4. Nutrient Composition of clean bedding and horse stall waste

	Clean Bedding (n = 96)		Stall Waste (n = 139)	
Nutrient[1]	Mean	SE	Mean	SE
Nitrogen (%)	0.13[a]	±0.02	0.71[b]	±0.03
Carbon (%)	45.4	±0.6	41.7	±0.6
Carbon:Nitrogen Ratio	683:1[a]	±59	72:1[b]	±3
Total Phosphorus (%)	0.02[a]	±0.004	0.19[b]	±0.01
Potassium (%)	0.15[a]	±0.03	0.71[b]	±0.04
Dry Matter (%)	80.1[a]	±0.02	57.8[b]	±1.1
Organic Matter (%)	97.8	±1.0	87.0	±1.0

[1]With the exception of Dry Matter, all values are presented on a 100% DM basis.
[a,b] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-5. Nutrient composition of stall waste evaluated by bedding type

	Hay (n = 2)		Straw (n = 17)		Wood (n = 120)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	1.29[a]	±0.27	1.10[a]	±0.05	0.64[b]	±0.03
Carbon (%)	41.1	±0.8	40.1	±0.5	42.0	±0.65
Carbon:Nitrogen Ratio	33:1	±6	37:1	±2	77:1	±3
Total Phosphorus (%)	0.19[a,b]	±0.04	0.24[a]	±0.02	0.19[b]	±0.01
Potassium (%)	0.81[a]	±0.02	1.42[b]	±0.13	0.61[a]	±0.03
Dry Matter (%)	68.4	±18.4	51.4	±2.2	58.5	±1.2
Organic Matter (%)	93.7	±0.1	83.6	±1.2	87.3	±1.2

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-6. Nutrient composition of stall waste evaluated by facility type

	Boarding/Training (n = 56)		Breeding (n = 38)		Racetrack (n = 45)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.65[a]	±0.03	0.79[b]	±0.06	0.71[c]	±0.05
Carbon (%)	42.0	±1.0	41.4	±1.4	41.7	±0.6
Carbon:Nitrogen Ratio	75:1	±5	65:1	±6	73:1	±5
Total Phosphorus (%)	0.18[a,b]	±0.02	0.22[a]	±0.03	0.19[b]	±0.01
Potassium (%)	0.64[a]	±0.05	0.85[b]	±0.09	0.67[c]	±0.08
Dry Matter (%)	57.8	±1.8	60.7	±2.5	55.2	±1.5
Organic Matter (%)	87.1	±2.0	88.9	±1.8	85.3	±1.2

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b,c] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-7. Nutrient composition of stall waste evaluated by region

	North (n = 30)		Central (n = 40)		South (n = 69)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.82[a]	±0.07	0.70[a,b]	±0.05	0.67[b]	±0.04
Carbon (%)	39.1[a]	±1.7	41.7[a,b]	±0.6	42.9[b]	±0.8
Carbon:Nitrogen Ratio	59:1	±6	70:1	±6	78:1	±4
Total Phosphorus (%)	0.22	±0.03	0.19	±0.02	0.19	±0.01
Potassium (%)	0.95[a]	±0.08	0.52[b]	±0.08	0.72[c]	±0.05
Dry Matter (%)	61.5	±3.3	56.7	±1.6	56.7	±1.4
Organic Matter (%)	84.6	±3.0	86.5	±1.5	88.3	±1.4

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b,c] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-8. Nutrient composition of clean wood bedding and stall waste containing wood bedding

	Clean Wood Bedding (n = 91)		Stall Waste with Wood Bedding (n = 120)	
Nutrient[1]	Mean	SE	Mean	SE
Nitrogen (%)	0.11[a]	±0.02	0.64[b]	±0.03
Carbon (%)	45.8	±0.6	42.0	±0.7
Carbon Nitrogen Ratio	704:1[a]	±59	77:1[b]	±3
Total Phosphorus (%)	0.02[a]	±0.004	0.19[b]	±0.01
Potassium (%)	0.11[a]	±0.03	0.61[b]	±0.03
Dry Matter (%)	80.0[a]	±0.02	58.5[b]	±1.2
Organic Matter (%)	98.0[a]	±1.0	87.3[b]	±1.2

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-9. Nutrient composition of stall waste containing wood bedding evaluated by facility type

	Boarding/Training (n = 55)		Breeding (n = 35)		Racetrack (n = 30)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.65[a]	±0.03	0.75[b]	±0.06	0.52[c]	±0.03
Carbon (%)	42.0	±1.0	41.5	±1.5	42.4	±0.8
Carbon:Nitrogen Ratio	75:1	±5	68:1	±6	90:1	±6
Total Phosphorus (%)	0.18[a]	±0.02	0.23[b]	±0.03	0.15[a]	±0.01
Potassium (%)	0.64[a]	±0.05	0.77[b]	±0.07	0.36[c]	±0.02
Dry Matter (%)	57.9	±1.8	60.4	±2.6	57.2	±1.8
Organic Matter (%)	87.0	±2.1	88.7	±2.0	86.4	±1.7

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b,c] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-10. Nutrient composition of stall waste containing wood bedding evaluated by region

	North (n = 30)		Central (n = 36)		South (n = 54)	
Nutrient[1]	Mean	SE	Mean	SE	Mean	SE
Nitrogen (%)	0.82[a]	±0.07	0.64[b]	±0.04	0.55[c]	±0.03
Carbon (%)	39.1[a]	±1.7	41.9[a,b]	±0.7	43.6[b]	±0.9
Carbon:Nitrogen Ratio	59:1	±7	75:1	±6	88:1	±5
Total Phosphorus (%)	0.22[a]	±0.03	0.19[a,b]	±0.02	0.17[b]	±0.01
Potassium (%)	0.95[a]	±0.08	0.40[b]	±0.03	0.56[c]	±0.04
Dry Matter (%)	61.5	±3.3	56.3	±1.5	58.3	±1.7
Organic Matter (%)	84.6[a]	±3.0	85.9[a,b]	±1.6	89.8[b]	±1.7

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[a,b,c] Within a row, means followed by a different superscript differ at $P < 0.05$.

Table 3-11. Frequency of stall cleaning

Facility Type or Region[1]	1x/d n	1x/d %	2x/d n	2x/d %	3x/d n	3x/d %	Continuously n	Continuously %
Boarding/Training	13	27.7	26	55.3	3	6.4	5	10.6
Breeding	8	53.3	4	26.7	0	-	3	20.0
North	11	61.1	5	27.8	0	-	2	11.1
Central	9	39.1	7	30.4	1	4.4	6	26.1
South	1	4.8	18	85.7	2	9.5	0	-

[1]Cumulative percentage by row is 100%.

Table 3-12. Comparison of the nutrient composition of clean bedding and horse stall waste to manures produced by horses and other livestock

Material[1]	Nitrogen (%)	Total Phosphorus (%)	Potassium (%)	Dry Matter (%)
Clean Bedding[2]	0.13	0.02	0.15	80.1
Horse Stall Waste[2]	0.71	0.19	0.71	57.8
Horse Manure – Sedentary[3]	2.34	0.34	0.71	15.0
Horse Manure – Intensely Exercised[3]	3.85	0.85	2.44	15.0
Dairy Manure – Dry Cow[3]	4.69	0.61	3.02	13.0
Dairy Manure – Lactating Cow[3]	4.94	0.88	1.16	13.0
Beef Manure – Cow Confinement[3]	2.88	0.67	2.12	12.0
Swine Manure – Gestating Sow[3]	6.40	1.80	4.40	10.0
Poultry Manure – Layer[3]	7.27	2.18	2.64	25.0

[1]With the exception of dry matter, all values are presented on a 100% DM basis.
[2]Data from current study.
[3]Data adapted from ASAE, 2005.

Table 3-13. Comparison of nutrients per metric ton between clean bedding, horse stall waste, and manures produced by horses and other livestock on an as-removed basis

Material[1]	Nitrogen (kg/MT)	Total Phosphorus (kg/MT)	Potassium (kg/MT)
Clean Bedding[2]	1.0	0.2	1.2
Horse Stall Waste[2]	4.1	1.1	4.1
Horse Manure – Sedentary[3]	3.5	0.5	1.1
Horse Manure – Intensely Exercised[3]	5.7	1.3	3.6
Dairy Manure – Dry Cow[3]	5.9	0.8	3.9
Dairy Manure – Lactating Cow[3]	6.4	1.1	1.6
Beef Manure – Cow Confinement[3]	3.5	0.8	2.5
Swine Manure – Gestating Sow[3]	6.4	1.8	4.4
Poultry Manure – Layer[3]	18.3	5.5	6.5

[1]Values are presented on an as-removed basis per 1000 kg.
[2]Data from current study.
[3]Data adapted from ASAE, 2005

CHAPTER 4
CHARACTERIZATION OF MANURE MANAGEMENT PRACTICES ON FLORIDA HORSE OPERATIONS

Introduction

In today's animal production agriculture, large numbers of animals are often confined to relatively small areas to increase the efficiency of production. According to the Environmental Protection Agency, these operations are labeled Animal Feeding Operations (AFOs). AFOs congregate animals for production purposes and, as a result, concentrate feed, manure and urine and dead animals on a small area of land. It is estimated that there are 450,000 AFOs in the United States. AFOs are considered to be concentrated animal feeding operations (CAFO) when the number of animals crosses a particular threshold. AFOs can be classified as small, medium or large depending on the number of animal units. Specific to horses, a small AFO is less than 150 head, medium AFO 150-499 head and a large-scale equine AFO is 500 or more horses (USEPA, 2003a). CAFOs merit special consideration because the large volume of waste generated by the animals creates environmental concerns with regard to soil, water and air (Jongbloed and Lenis, 1998). The risk factors are dependent on many different variables, but in general, there is concern for nutrient accumulation in soil and water and the effects of ammonia, hydrogen sulfide, particulate matter and odor emissions and odor on air quality.

Horses have the lowest number of animal units required for each level of CAFO compared to all other species of livestock. Presumably this is due to the large volume of waste generated per animal unit when stall bedding becomes a factor. While many similarities exist between horse production and CAFOs of other livestock species, there are key differences. One main difference is the addition of some form of neutral bedding to the waste product usually in the form of hay, straw or wood shavings. Horses are commonly housed in individual units and are very seldom confined in a feedlot type setting. Therefore, manure management to reduce surface or groundwater contamination from the area where horses are housed is not a major concern. However, once the stall waste is removed these concerns come into play.

Manure storage on horse operations is different when compared to confinement swine or dairy operations due to the high dry matter content of horse bedding. Swine or dairy operations must contain waste in a lagoon, storage pond or tank due to the high liquid content. Horse or poultry litter mixed with bedding can be stored in a static pile with little risk of the majority of the solids traveling far from the pile.

It has been previously found that horse farms utilize two methods to dispose of stall waste: 1) stall waste hauled off site; or 2) stall waste is utilized on site (Peters et al., 2003). The 2005 NAHMS baseline reference of equine health and management survey found that nationally the greatest percentage of horse operations disposed of waste bedding or manure by applying it to non-grazing or grazing fields, allowing it to accumulate or leaving it to nature (NAHMS, 2005). A low percentage of operations managed manure by having it removed by routine garbage pickup or deposition in a landfill (NAHMS, 2005). The study also indicated differences by size of operations. The larger the operation was, the more likely they were to sell or give away the waste or apply it to the land where livestock grazed.

In 2002 an equine economic impact study was conducted in Pennsylvania (PDA, 2002a). Manure sales were treated as a source of income for the horse population and were divided between the racing industry and general population. Manure sales for the racing industry were less than 0.3% of the gross income. The manure sales for the total horse population in Pennsylvania were estimated to be 0.21% of the net income (PDA, 2002a). Interestingly, this survey did not treat waste handling and management as an expenditure. Specific to the racehorse industry in Pennsylvania, it was found that no large operations stockpiled manure on premises and smaller operations were more likely to stockpile and leave manure on site unused. It was also reported that commercial operations were more likely to have manure management plans (PDA, 2002b).

The Horse Industry Association of Alberta performed an extensive economic impact survey of the province's horse industry in 2003. Part of this impact survey evaluated manure management. Some of the most popular responses for manure disposal were spreading manure in fields or pastures or composting. In Alberta over half of horse owners purchased straw bedding. The second most common source of clean bedding was shavings/sawdust (HIAA, 2003).

In 2006, the United States Census Bureau reported that Florida's human population was 18 million and growing (USCB, 2006). Agriculture encompasses half of the state's 34.5 million acres. The growing population will create many issues, one of them being land availability. Urban sprawl will create many challenges for the horse industry. Finding space to land apply stall waste will become increasingly difficult. The result will be the need to create other venues to dispose of horse stall waste. Composting and incineration to generate electricity are two examples of ways to add value to a current waste product.

The primary reason for the current study was to collect information about the manure management practices on Florida equine operations. Very few assessments of manure management have been conducted and manure management practices specific to the state of Florida have not been quantified. The information gained in this study will be used to identify frequent practices that may lead to better utilization of stall waste and ways to minimize or eliminate their impact on the environment.

Equine operations can manage the stall waste in many ways. The hypothesis was that the most common ways horse operations were disposing of stall waste were land application, composting, hauling it off site or stockpiling waste on site. Each disposal or storage method poses challenges to the environment.

Materials and Methods

During visits to horse facilities for manure sampling (See Chapter 3), an onsite manure management evaluation was completed to characterize the manure management practices on Florida horse operations. The intent was to identify management practices that may pose a risk to water quality. The evaluation was composed of two segments: 1) verbal questioning, whereby the facility manager or other representative was questioned to obtain background information, (e.g. number of horses, total acres, percent protein of concentrate fed, etc.) as well as a description of how manure was handled, stored and disposed; 2) an on-site evaluation, conducted by the investigator to evaluate the effectiveness of the facility's manure management practices and potential risks to water quality (Table 4-1; Appendix A).

Survey data was obtained from 139 horse facilities located throughout the state of Florida. Sampling was distributed between three types of horse facilities: 1) breeding farms (n = 15); 2) boarding/training facilities (n = 56); and 3) racetrack stables (n = 45). Breeding farms were defined as operations that participate in breeding, where horses are typically housed in stalls part-time on a seasonal basis (e.g., during foaling season; during sales preparation of young horses) or for short duration (e.g., during morning and evening feedings; during evenings when foals are young). Boarding/training facilities comprised several different riding/training disciplines and were defined as operations that board a minimum of 10 horses, where horses spent a significant amount of time confined to stalls (minimum of 8 hr/d). Racetrack stables were represented by horses managed under different trainers and housed at one of three racetracks with pari-mutuel wagering on live racing, including Calder Racecourse, Gulfstream Park and Tampa Bay Downs.

With the exception of racetracks, evaluation of waste management practices was also distributed in three regions within the state of Florida: 1) North Florida (n = 18) including the panhandle and near or north of Interstate-10; 2) Central Florida (n = 38) including Alachua and Marion counties, Orlando and Tampa; and 3) South Florida (n = 60) defined as the area south of the Interstate-4 corridor. Data collected from racetrack stables were included in the analysis by region, with two of the racetracks located in South Florida and one in Central Florida. No racetracks were present in North Florida.

All responses and observations to survey questions were reported. Not every operation was able to provide enough information to fulfill each question. Most racetrack stables and several breeding and boarding facilities were omitted from many of the survey questions. Some of the reasons included no one present at time of collection, unwillingness to participate in the survey and an inability to communicate due to language barrier. This led to different n values for each question as well as by region and facility type.

Statistical Analysis

Survey responses were collected and a frequency of response was reported. Data was also reported as a percentage of respondents by region and by facility type.

Results

Facility Demographics

The most frequently surveyed operation was boarding/training (Table 4-2). Boarding/Training facilities may be more common throughout the state, although it was not the intent of the survey to determine the distribution of operations, only to attempt to equally sample all types of operations. A similar percentage of racetrack stables and breeding farms were surveyed (Table 4-2). South Florida had a greater frequency of facilities surveyed at nearly fifty percent (Table 4-2). The distribution was unequal due to the fact that two racetracks were located in South Florida. The remaining racetrack was in Central Florida.

Over 47% of operations surveyed were less than 50 acres in size and slightly over 18% were over 200 acres (Figure 4-1). Most horse operations surveyed were less than 200 acres. Breeding operations were larger than boarding/training (Table 4-3). More than half of the boarding/training facilities were on less than 50 acres. In contrast, the majority of breeding operations were over 50 acres in size, with approximately one-third of breeding farms more than 200 acres (Table 4-3). Breeding operations house broodmares and foals and utilize pasture and turnout more than most boarding/training facilities; therefore, it would be expected that the size of breeding operations would be the largest. Nearly all of the operations in North and South Florida were smaller than 200 acres (Table 4-3). Operations were largest in Central Florida, with about one-third of operations greater than 500 acres (Table 4-3). Operations were also queried on the acreage utilized by horses, which did not differ from the total acreage of the operation (data not shown).

Almost 30% of the operations surveyed had less than 20 horses, and almost 20% housed more than 200 horses (Figure 4-2). The number of horses housed at breeding facilities was evenly distributed between less than 20 and greater than 200; no category had greater than 27% of the distribution (Table 4-4). One-third of boarding/training operations housed less than 20 horses, which was the greatest frequency among any category (Table 4-4). Most Central Florida operations had greater than 40 horses and more than 60% had more than 100 head (Table 4-4). In both North and South Florida, most operations had less than forty horses (Table 4-4). North and South Florida operations were smaller in comparison to Central Florida.

The breed of horses maintained by all operations was surveyed. Across facilities, including racetrack stables, nearly 68% were Thoroughbreds. Other breeds of horses represented by the survey were Missouri Foxtrotters, Warmbloods, Quarter Horses, Polo Ponies and Arabians (Figure 4-3). Boarding/Training operations mostly had Polo Ponies, Quarter Horses, Thoroughbreds and Warmbloods (Table 4-5). The majority (73%) of breeding operations housed Thoroughbreds (Table 4-5). All data obtained from racetrack stables included Thoroughbreds (Table 4-5). North Florida was different from the other regions as Quarter Horses were the most prevalent breed on operations surveyed compared to Thoroughbreds (Table 4-5). Polo Ponies only appeared in the survey data in South Florida (Table 4-5). Over 97% of the operations who were surveyed in Central Florida had Thoroughbreds. North Florida had the most varied breed profile of the operations surveyed, making the population surveyed in North Florida the most diverse (Table 4-5).

Feeding Programs

Across all facilities, the type of hay utilized by over half of Florida horse operations surveyed was a legume-grass mix, followed by grass hay and then legume hay (Figure 4-4). When evaluated by facility type, the most prevalent type of hay fed at boarding/training facilities and breeding farms were grass and grass-legume mix (Table 4-6). Nearly all of the racetrack stables fed their horses a grass-legume mix hay. By region Central Florida fed the most legume hay compared to North and South Florida. More grass hay was fed to horses in North and South Florida than in Central Florida (Table 4-6). All regions fed a reasonably similar amount of grass-legume mix hay.

The percentage of crude protein in the commercial grain mix concentrate fed to horses at each operation was recorded. If multiple types of concentrate were used, the most prominent was recorded as the percent protein fed. The crude protein in concentrate products offered to horses ranged from 10-14% (Figure 4-5). Over half of all operations fed a 12% crude protein feed (Figure 4-5). Eighty six percent of boarding/training facilities fed horses a feed with 10-12% crude protein (Table 4-7). Breeding farms were more likely to feed horses a grain mix concentrate with a greater than 12% crude protein than other types of facilities; however feeds with 12% crude protein were still the predominant product offered on breeding farms. The crude protein in concentrate feeds offered to horses in racetrack stables was about evenly split between 10%, 12% and 14% crude protein. In all regions, the majority of operations (over half) feed a feed with 12% protein (Table 4-7).

Stall Management

Over 86% of the horse facilities surveyed used a wood product, such as wood chips, shavings, sawdust or pellets as bedding (Figure 4-6). By comparison, only two of the 139 facilities surveyed bedded stalls with hay or sand and 17/139 bed stalls with straw. The majority of all operations bed on pine shavings (Figure 4-7). Facilities surveyed in North Florida bed on only pine shavings and wood pellets (Table 4-8). The only facilities that bed on hay and straw were in Central Florida and sand bedding was used in South Florida (Table 4-8).

When asked a reason for using a particular type of bedding, farm managers and employees mostly frequently cited convenience and price (Figure 4-8). Two of the other reasons cited were tradition and environmental concerns (Figure 4-8).

Over half of all facilities surveyed used rubber mats as the base beneath the bedding in stalls (Figure 4-9). Sand and clay were also used as stall base materials. Over half the boarding/training facilities surveyed used rubber stall mats, followed by clay and sand at equal frequency (Table 4-9). Breeding facilities utilized rubber mats and clay in stalls nearly exclusively. By region, South Florida showed a clear preference for rubber stall mats, followed by sand (Table 4-9). Facilities in North and Central Florida showed a greater frequency of clay than South Florida, and facilities in North and South Florida utilized sand as a stall base, whereas those surveyed in Central Florida did not. Use of rubber mats and clay as the stall base was almost equally represented in Central Florida (Table 4-9).

The amount of clean bedding in stalls was a subjective observation made by the investigator and based on a visual ranking of light, moderate or heavy. A light amount of clean bedding was considered to exist when the stall base could be seen in several spots. Moderate bedding amount was observed when the entire stall base was covered and a horse standing in the stall would have a portion of its hoof covered up to the cornet band (i.e., the top of the hoof). Heaving bedding was noted when the bedding was deep enough to cover the horse's entire hoof and extend up to the pastern of the leg. Over half of the facilities surveyed used a moderate amount of bedding (Figure 4-10). Evaluation of bedding amount by facility type and region did not differ from the overall average across facilities (data not shown).

Over 78% of all operations surveyed housed horses in stalls for the entire day (Figure 4-11). When evaluated by facility type, breeding operations were less likely to house horses in stalls for a full day and more likely to have them in stalls only at feeding time than boarding/training and racetrack stables (Table 4-10). In contrast, on the racetrack horses were housed in stalls for a full day (Table 4-10). By region, no operations in South Florida kept horses in stalls only during feeding time, and over 92% kept them in stalls for half a day (Table 4-10). In Central Florida, the majority of operations kept horses in stalls for a full day (Table 4-10).

The frequency of stall cleaning may lead to a difference in the nutrient levels of waste, based on the proportions of bedding and manure removed. Almost half of all operations surveyed reported that they cleaned stalls twice a day and one third of facilities reported cleaning stalls once a day (Figure 4-12). The two other survey responses for frequency of stall cleaning were three times a day and continuously. When evaluated based on facility type, most boarding/training operations cleaned stalls twice a day and most breeding facilities cleaned stalls once a day (Table 4-11). As reported above, horses at breeding operations generally spent less time in stalls; therefore, less frequent cleaning may have been needed. By region nearly all facilities in South Florida cleaned stalls twice a day (Table 4-11). In North Florida, almost two-thirds of facilities cleaned stalls once a day, with the second most frequent response being twice a day. Stall cleaning frequency in Central Florida was fairly evenly split between cleaning stalls continuously, once a day and twice a day (Table 4-11).

The approximate volume of stall waste removed during cleaning was estimated by the investigator based on the number of wheelbarrow loads (approximately 6 cu ft.) removed per stall on a daily basis. Although this was an inexact measurement, it was an attempt to quantify the thoroughness of the stall cleaning and the volume of material generated. Across all facilities, most operations removed one wheelbarrow daily (Figure 4-13). Breeding operations removed a larger volume of stall waste than boarding and training operations (Table 4-12). Considering that a few breeding farms also reported bedding stalls on hay or straw, the greater volume might be a result of these bulkier materials compared to stall waste containing wood bedding. Additionally, when stalls are bedded with hay or straw they are typically stripped on a daily basis, resulting in the removal of more material. By region, facilities in Central Florida appeared to remove more stall waste per day than facilities in North and South Florida (Table 4-12).

Facilities were queried on their frequency of stall stripping to determine if operations had a set schedule for removing the entire volume of bedding. Stall "stripping" was considered to be the removal of the entire amount of bedding down to the stall base. By comparison, routine cleaning was defined as the removal of feces, urine, soiled bedding, and discarded hay and feed.

Over two-thirds of all operations reported stripping stalls "as needed" (Figure 4-14). The second most common response was stalls stripped weekly at just over eleven percent (Figure 4-14). When evaluated by facility type, boarding/training operations most commonly stripped stalls "As Needed" but more specific answers varied from daily to never (Table 4-13). Similarly, a greater percentage of breeding facilities cleaned stalls as needed, the same trend continued by region. In North and South Florida, the majority of operations stripped stalls as needed (Table 4-13). By comparison, operations in Central Florida appeared to strip stalls on more of a defined schedule, although the majority still stripped stalls as needed (Table 4-13).

Stall Waste Storage

When stall waste is removed, it is generally stored for a period of time before utilization. The amount of time may vary from years to hours, and the method of storage may vary from a concrete structure to no storage container. The method of storage was considered to be a structure when it was placed in an area that was constructed specifically to hold waste for a period of time. A common structure was a three sided bin with a concrete base. A free-standing pile would differ from a structure, as a pile would have no constructed barriers to contain the waste. A container was a dumpster which would be removed periodically by a waste management company. Across all operations, over 45% percent stored stall waste in some form of free-standing pile and one third stored the waste in a structure (Figure 4-15). Boarding/training operations were most likely to store waste in a free-standing pile or a structure (Table 4-14). Two thirds of breeding operations stored waste in a free standing pile (Table 4-14).

In addition to storage method, the length of time stall waste was stored before being disposed of was recorded for each facility. Almost 30% of all operations stored all waste for one week (Figure 4-16). No storage was reported by 18% of operations when waste was land applied, suggesting that stall waste was land applied shortly after removal from stalls or that some other form of disposal was used that required no storage (Figure 4-16). The majority of operations reported storage of three months or less. Boarding/training facilities and breeding farms most frequently stored waste for one week or less (Table 4-15). When evaluated by region Central Florida had the most operations storing waste for a year or longer (Table 4-15). The South Florida region typically had shorter periods of waste storage (Table 4-15).

Across all facilities surveyed, the material comprising the base of the storage area was mostly unimproved soil or concrete (Figure 4-17). Other facilities reported a base of sand, metal, limerock, or clay for manure storage; one facility reported storing their waste in a sinkhole (Figure 4-17). A metal storage base was considered to be a manure spreader or dumpster. The facilities that stored waste in areas with a concrete base were mostly boarding/training facilities in South Florida (Table 4-16). This would have most likely been the operations that had constructed a bin or three sided holding area for waste to be stored prior to being hauled off site. The next most common storage base material for boarding/training facilities was on top of unimproved soil. One boarding/training operation in Central Florida used a sinkhole as a waste storage or disposal area (Table 4-16). Breeding farms were more likely than boarding/training facilities to store stall waste on top of unimproved soil (Table 4-16). In North and Central Florida the consensus storage base was unimproved soil. None of the operations evaluated had a roof covering their waste storage area (Figure 4-18).

Ninety percent of all operations did not store stall waste in a low lying area (Figure 4-19). The investigator determined if the storage was in a low lying area by looking at the location of the waste storage in relation to other points on the same farm. No operations in North Florida stored waste in a low lying area (Table 4-17). With about the same frequency Central and South Florida had facilities with a waste storage area in a low lying area (Table 4-17). Two operations reported an annual problem with flooding in the waste storage area (Figure 4-20). By facility type, one of these operations was a breeding farm and one was a boarding/training operation. By region, one operation was in North Florida and the other was in Central Florida (Table 4-18).

Across all facilities, most stored stall waste more than 500 ft from surface water (Figure 4-21). Only 3 of 51 facilities surveyed stored stall waste within 100 ft of a surface body of water. All three respondents were boarding/training facilities, one in Central Florida and two in South Florida (Table 4-19).

The majority of all operations surveyed placed the stall waste storage area more than 500 ft from a residence (Figure 4-22). Two operations, both boarding/training facilities in South Florida stored stall waste closer than 100 ft to a residence, with another boarding/training facility in North Florida storing stall waste within 200 ft of a residence. Still, the vast majority of boarding/training facilities an all breeding operations situated their stall waste storage area further than 500 ft from a residence (Table 4-20).

The majority of all facilities surveyed stored stall waste more than 500 ft from a drinking water well, while only 10% stored manure within 200 ft of a well (Figure 4-23). Boarding/training and South Florida operations had a well within 200 ft of the waste storage area most frequently (Table 4-20). Ten percent of the respondents from boarding/training facilities had a well closer than 200 ft (Table 4-21). Over 15% of operations in South Florida had a waste storage facility within 200 ft of a well.

Waste Disposal

Over two-thirds of all operations surveyed had stall waste hauled off site as the primary method of disposal (Figure 4-24). The second most frequently reported method of waste disposal was land application. Composting and stockpiling were less frequently reported. Over 90% of operations in South Florida had the stall waste hauled off site (Table 4-22). Central Florida also had stall waste hauled off site at a response rate of over 65% (Table 4-22). North Florida's responses were split between those that hauled stall waste off site and those which land applied stall waste as their primary means of disposal (Table 4-22).

Removal services for hauling away stall waste were provided by two entities, either private contractor or commercial waste management service. It was expected that a commercial waste management service would be taking the stall waste to a landfill whereas a private contractor may be treating the product as a potential value added commodity. Across all operations, over 88% of waste that was hauled off site was done so by a private contractor (Figure 4-25). A private company performing waste removal was contracted by each individual farm to remove the waste, the end result of this waste was unknown. A commercial service was responsible for removing almost 12% of the waste hauled off site (Figure 4-25). No North Florida facilities used commercial waste management services to haul stall waste off site (Table 4-23). Boarding/training operations were most likely to use a commercial service to remove stall waste (Table 4-23). When evaluated by both facility type and region the overwhelming majority hired a private contractor to remove stall waste (Table 4-23).

If waste was hauled off site, the frequency of removal was categorized into daily, weekly, monthly, quarterly and yearly intervals. Thirty five percent of removal took place weekly, almost 17% took place yearly and almost 12% of waste was removed daily (Figure 4-26). Boarding/Training operations removed waste more frequently when compared to breeding facilities (Table 4-24). North Florida's distribution of waste removal frequency was highly variable and Central Florida had over 46% removed at least weekly and one-third removed yearly (Table 4-24). South Florida had two common responses weekly or monthly (Table 4-24).

When stall waste was land applied, the location of land application was recorded. The three areas where stall waste was spread were horse pastures, other pastures or un-harvested areas. Un-harvested areas would include any area not being used as a pasture or for harvesting any other crop. Some examples may include wooded areas, arenas or trails/roads. Across all facilities who dispose of stall waste via land application, most spread stall waste on horse pastures (Figure 4-27).The number of operations who land applied stall waste to un-harvested areas or other types of pastures was similar and accounted for the remaining locations. When evaluated by facility, boarding/training operations were more likely to spread manure on horse pastures than other locations, whereas breeding farms spread a significant amount of stall waste on other pastures not used by horses (Table 4-25).

The second consideration if waste was land applied was the frequency of land application. Over two-thirds of all operations surveyed spread stall waste as it was removed from stalls (Figure 4-28). Almost 30% of operations that land applied waste did so as it was needed (Figure 4-28). This was likely not as it was needed for a fertilizer but as the storage area became full or time was allocated for land application. The only other response for frequency of land application was monthly (Figure 4-28).

Pasture and Paddock Management

Management of pastures and paddocks was evaluated based on each facility's practice of removing manure, harrowing and fertilizing. A paddock or dry lot was considered to be an area with minimal grass that horses were turned out into for exercise purposes as opposed to grazing. Only 2 of 59 removed manure from pastures (Figure 4-29). More (8 of 59) operations removed manure from paddocks or dry lots (Figure 4-30).

A total of 16 facilities out of 59 responses harrowed their pastures. Of the facilities who did harrow pastures one-quarter of them were boarding/training facilities and one-third of them were breeding facilities harrowed their pastures (Table 4-26). By region, South Florida was less likely to harrow pastures (Table 4-26). Of those facilities that harrowed pastures, most performed this practice weekly or monthly (Figure 4-31).

By region, pastures were fertilized less frequently in South Florida (Table 4-27). Breeding operations were most likely to fertilize pastures (Table 4-27). A visual evaluation was made of the facilities that had pasture ranging from 100% (healthy) to 0% (no ground cover). This estimate was made by the same investigator for all evaluations. One-third of all operations surveyed with pastures that had scores of "healthy" (Figure 4-32). An equivalent number of facilities had pasture that scored less than healthy. One quarter of all operations surveyed had no pasture to evaluate (Figure 4-32). Facilities least likely to have pasture space available were located in South Florida, and Central Florida pastures were most likely to be healthy (Table 4-28). Breeding facilities were more likely to have healthy pastures when compared to boarding/training operations (Table 4-28). Boarding/training facilities more frequently had no pasture compared to breeding farms (Table 4-28).

Discussion

Facility Demographics

The American Horse Council reported roughly 500,000 horses in Florida. When these numbers are broken down approximately 27% are active in the racing industry, 32% in showing with the remainder involved in recreation and other activities (AHC, 2005). The purpose of the current study was not to quantify and categorize the use of horses in the state of Florida, but rather to give equal representation between breeding farms, boarding/training facilities and racetrack stables (Table 4-2).

The most frequent response for total acres of all facilities surveyed was less than 50 acres (Figure 4-1). This is very similar to previous studies in Alberta that reported the majority of responses between 11 to 80 acres (HIAA, 2003) and in Pennsylvania with over two thirds located on less than 50 acres (PDA, 2002). The larger acreage of horse facilities in Central Florida likely reflects a greater number of breeding farms in this region of the state and the land available for production agriculture, especially when compared to South Florida.

The number of horses per operation was very similar to previous studies. In Marin County, California it was reported that the average number of horses per stable was 33 (Murphy and Nicholson, 2002). A national estimate of 92.2% of operations had 19 or fewer horses (NAHMS, 2005). Horse operations in Central Florida may be larger in total horse numbers due to the fact that they are larger in total acreage.

The facility demographics of this survey were not intended to reflect the exact makeup and distribution of the horse population in Florida. The responses to the survey questions are the demographics of the facilities sampled and show us some trends that would most likely be found if the entire Florida horse population were surveyed.

Feeding Programs

Overall, the majority of operations surveyed fed a commercial grain mix concentrate with 12% crude protein along with a grass-legume mix hay. By region, more Central Florida operations fed a concentrate with a higher percent crude protein and legume hay. Selection of commercial feeds and hay with a higher level of protein may be due to the higher percentage of breeding operations in this region and the higher nutrient requirements of broodmares and growing horses. No breeding facilities reported feeding a grain mix concentrate containing higher than 14% crude protein, which was unexpected. A second unexpected response was that horses on the racetracks were mostly fed a blend of legume and grass hay and not a straight legume. A nationwide estimate was that over 90% of horse operations fed an energy source beyond hay or pasture (NAHMS, 2005).

Stall Management

The type of bedding used in stalls was similar to that reported in Alberta that reported mostly pine shavings (HIAA, 2003) but different than a national estimate which was predominately straw (NAHMS, 2005). In the survey done in Canada the operations had the opportunity to give multiple responses to type of bedding used. It was found more than half of operations surveyed used straw and wood shavings for various reasons throughout the year (HIAA, 2003). Surveys of Kentucky horse owners found that like Florida almost two thirds used some form of wood product as bedding (Coleman and Janicki, 2003). One other consideration may be that on the racetracks the bedding is supplied by singular vendors and is limited to only a few choices. Trainers would not be able to choose their ideal bedding type but would be forced to use what is required by track management.

The onsite survey in this study addressed stall management issues such as reason for using bedding type, stall base material, amount of bedding used, length of time horses were in stalls, frequency of stall stripping and volume removed that have not been addressed in any previous surveys. The volume of stall waste removed would likely be affected mostly by the person cleaning the stall and the bulk of the bedding, which differs between types. For example, a larger volume of stall waste might be generated with straw bedding vs. wood shavings. Three components would have an impact on the final nutrient makeup of stall waste, initial bedding type, amount of time horses spend in stalls and the proportion of manure to clean bedding removed. While the individual impact each of these practices has on the composition of stall waste is not known, it is likely that stall cleaning practices (e.g., frequency, proportion of clean to soiled bedding) may be the most important.

Stall Waste Storage

The amount of time stall waste spent in storage and the frequency of stall waste removal may be directly proportional to the size of the storage area and the amount of stall waste generated. Shorter waste storage period in South Florida may be due to the smaller sizes of operations or a greater amount of stall waste produced in this region. Therefore, the smaller the operation or the greater amount of waste generated would lead to a more frequent stall waste removal or land application schedule.

The base of the manure storage area is an important consideration as it is a barrier to prevent leaching of nutrients from stall waste into ground water. The larger the waste storage area, the more difficult and costly it is to improve the area beneath the waste pile. As a result, the operations that generate and/or store large amounts of stall waste typically did not improve or modify the base of the storage area (i.e., unimproved or native soil). Operations that generated smaller amounts of stall waste, or those that disposed of manure more frequently (shorter storage time) would require a smaller footprint for waste storage.

The operations in South Florida that diverted water away from the waste storage area did so by building concrete or cinderblock walls around three sides. This would still leave one open side for runoff. The covering of stall waste storage areas was not a common practice. This would lead to potential leaching and water runoff issues that could be a potential concern.

In an effort to identify any common practices that may lead to a greater than necessary risk to groundwater or surface water contamination several survey questions were asked. No overwhelming trend was observed for storage locations being close to surface water, wells or residences. In a study of the manure management of horse ranches in Marin County, California it was found that nearly half of the paddocks/stalls where horses were housed came within close proximity of surface water (Murphy and Nicholson, 2002).

Waste Disposal

Nationwide, the most frequent method of waste disposal was land application (NAHMS, 2005). This was the predominant method regardless of region or size of operation. Land application as the primary means of disposal of horse manure was also observed in several state surveys, including 52% in Pennsylvania (Peters et al., 2003), 70% in Kentucky (Coleman and Janicki, 2003) and over 50% in Alberta, Canada (HIAA, 2003). In the Pennsylvania study, the larger operations were more likely to remove the waste from the farm and smaller operations were more likely to stockpile waste (Peters et al., 2003). Florida horse operations that were surveyed differed greatly from other surveys because they more frequently had stall waste hauled off site. One reason that horse operations in Florida may have waste hauled off site more frequently is a greater availability of commercial service. Large concentrations of horses generate large volumes of stall waste that could be turned into a value added resource. The majority of stall waste that was hauled off site was done so by private companies. The high concentration of horse operations in several geographic regions around the state has created a demand for commercial services that haul waste offsite. Such services may not be available to all horse owners nationwide and land application may be the only alternative.

Two other responses for horse manure disposal in Florida were stockpiling indefinitely and composting. These responses were much less frequent than found nationally or by other state surveys. The waste management survey of Marin, County, California, reported that the operations who did not compost on site had little interest in doing so for several reasons including lack of knowledge or proper equipment (Murphy and Nicholson, 2002). It was also reported that on the ranches who composted, the management was minimal (i.e., letting waste breakdown through natural decomposition, rather than actively managed composting).

Pasture and Paddock Management

Pastures in Florida could be managed by harrowing, fertilizing and collecting manure, however, a very small percentage of operations performed these practices. In an Alberta, Canada, survey a very small percentage of respondents collected manure, fertilized or harrowed pastures. One other consideration for pasture management that was not looked at in the Florida survey is the location where hay is fed. The Kentucky survey took this into consideration and found that nearly 60% fed hay loose on the ground (Coleman and Janicki, 2003). This could be of concern as it encourages bare ground and increased erosion as well as wasted hay and spoilage.

Conclusion

The data collected in this survey would suggest that the vast majority of Florida horse operations are responsibly managing their waste. The main form of bedding used in stalls was some form of wood based product. Stall waste was either being removed off site in a timely fashion or being land applied. It was not common for operations to compost stall waste as a form of disposal. It was evident that considerations were being made regarding the environmental impact of stall waste storage and disposal. No overwhelming trend existed by region or facility type that would suggest that any single sector was being more or less responsible with stall waste management.

Although horse operations appear to be giving considerations to how they responsibly manage stall waste, improvements can still be made. One of the objectives of this study was to identify areas that a horse best management practices manual could target to help educate horse owners so they can make improvements upon current management practices. Pasture management along with land application considerations is one of these areas. Even if stall waste was land applied it was done so as an afterthought, as a way to reduce the storage pile or as a convenient way to get the waste out of sight. A best management practices manual could encourage soil and waste testing and education of how horse stall waste in combination with inorganic fertilizer could meet the nutrient requirements of pastures. Horse owners and managers could be further educated about potential risks related to waste storage. No operations attempted to cover the area of waste storage. The concern about this is that during periods of high rainfall and flooding waste storage areas are at an increased risk. Education about taking proactive steps, even as simple as covering the pile with a tarp would be beneficial.

Educating the horse operations about what the intent of best management practices are is another important consideration. They are not to be an additional cost to producers, however, an improvement on current management practices. While an initial cost may be involved in complying with BMPs a cost savings may realized over time. For example, if an operation can utilize harrowing, soil testing, controlled stocking rates, pasture rotation and land application of stall waste at agronomic rates, the end result may be healthier pastures. This could mean purchasing less hay each year. One other important consideration is the alternative to voluntary compliance, mandatory permitting. If horse operations refuse to be educated and make improvements voluntarily they could be perceived as a potential environmental risk and be forced to make management changes regardless of cost.

Continuing education could be provided about less wasteful stall cleaning practices. Clean shavings make up the majority of stall waste. If a lower proportion of what is removed from the stall is clean bedding this would increase the nutrient content of stall waste and lead to a more desirable product for land application as a fertilizer. In addition, this would reduce the amount of clean bedding utilized which is a cost to the horse owner or operation.

Horse stall waste disposal is currently perceived as cost of doing business. It is just that, a waste product. Can we evolve this thought process and change the waste stream into a commodity that has value? Education about how to set up a simple composting unit, pooling waste with other small operations for further processing or recycling the large portion of clean bedding in stall waste are changes in management practices that just begin to scratch the surface. The large percentage of horse stall waste that is stockpiled could be creatively managed and become an additional source of income.

Table 4-1. Categories of Information Included in the Evaluation of Waste Management Practices on Florida Horse Operations.

Category and brief description of survey questions
Facility Demographics
Total acres; acres utilized by horses
Number and breed(s) of horses
Region and Type of operation
Feeding Program
Percentage of crude protein in grain mix concentrate fed
Type of hay
Stall Management
Bedding type
Amount of time horses spend in stalls, on average
Method of stall cleaning
Frequency of routine stall cleaning and stall stripping
Estimation of volume of waste removed per stall daily
Type of stall flooring material
Amount of bedding in stalls
Stall Waste Storage
Method used to store stall waste (if stored)
Length of time stall waste is stored before disposal
Flooring and roofing material used in storage area
Location of stall waste storage and propensity for flooding
Distance of stall waste storage area from drinking water well, surface water, and residence
Diversion of clean storm water away from storage area or use of containment ponds
Slope of land away from storage area
Soil depth and type where stall waste is stored
Disposal of Stall Waste
Method of disposal
If land applied, where; is nutrient analysis performed on waste, are soil tests performed; frequency of application; time of year; distance from where stall waste is applied to drinking water wells, surface water, residence.
If hauled off site, who performs service; frequency of removal; annual cost
If composted on site, what type of system is used and how is it managed
Management of Pastures
Is manure removed regularly from pastures or exercise paddocks and how often
Are pastures harrowed or fertilized
Subjective evaluation of pasture quality, based on proportion of desirable grass cover

Table 4-2. Number of facilities evaluated by type and region (n=116)

Facility Type or Region†	n	%
Boarding/Training	56	40.3
Breeding	15	27.3
Racetrack	45	32.4
North	18	28.8
Central	38	21.6
South	60	49.6

†See text for definitions of facility type and region

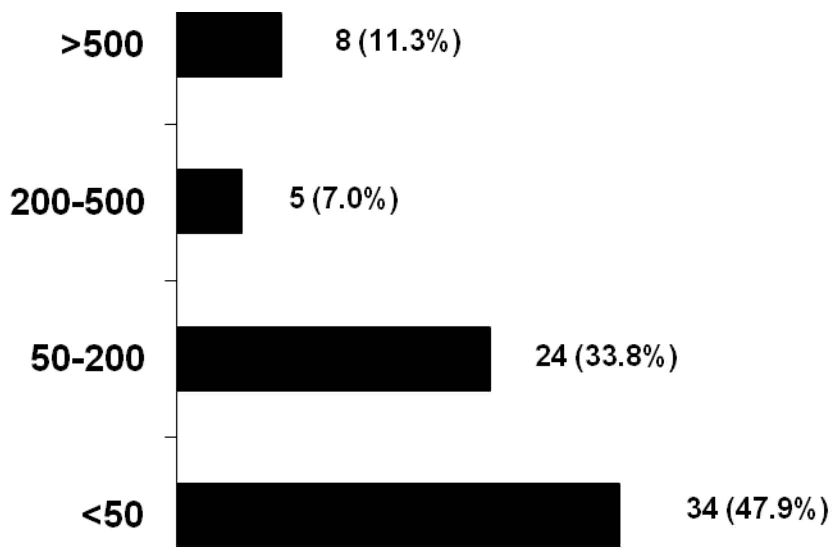

Figure 4-1. Total acreage of all facilities surveyed (excluding racetracks) (n=71)

Table 4-3. Total acreage of facility evaluated by facility type (excluding racetracks) and region (n=71)

Facility Type or Region†	<50 Acres		50-200 Acres		200-500 Acres		>500 Acres	
	n	%	n	%	n	%	n	%
Boarding/Training	31	55.4	17	30.4	4	7.1	4	7.1
Breeding	3	20.0	7	46.7	1	6.7	4	26.6
North	9	50.0	8	44.4	1	5.6	-	-
Central	1	4.4	10	43.5	4	17.4	8	34.7
South	24	80.0	6	20.0	-	-	-	-

†See text for definitions of facility type and region

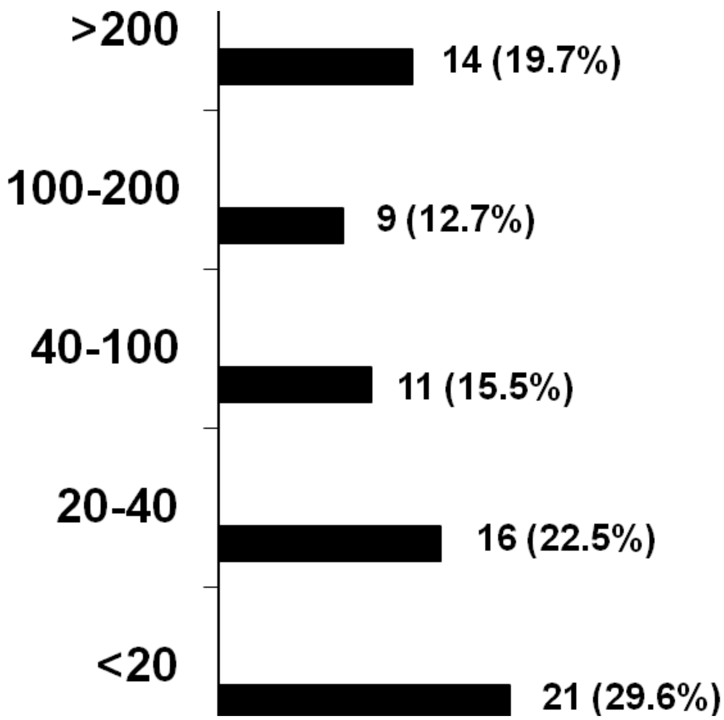

Figure 4-2. Total number of horses at all facilities surveyed (excluding racetracks) (n=71)

Table 4-4. Total number of horses evaluated by facility type (excluding racetracks) and region (n=71)

Facility Type or Region†	<20		20-40		40-100		100-200		>200	
	n	%	N	%	n	%	n	%	n	%
Boarding/Training	19	33.9	12	21.4	9	16.1	6	10.7	10	17.9
Breeding	2	13.3	4	26.7	2	13.3	3	20.0	4	26.7
North	8	44.4	5	27.8	3	16.7	2	11.1	0	-
Central	2	8.7	1	4.4	5	21.7	7	30.4	8	34.8
South	11	36.7	10	33.3	3	10.0	0	-	6	20.0

†See text for definitions of facility type and region

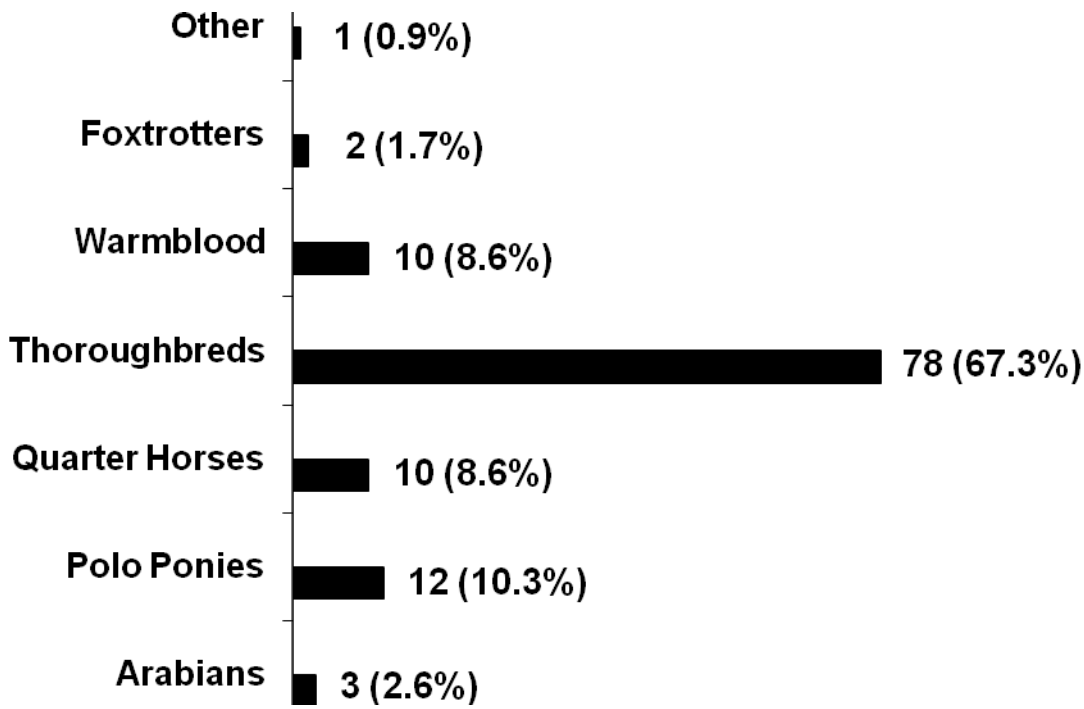

Figure 4-3. Breeds of horses across all facilities surveyed (n=116)

Table 4-5. Breeds of horses across all facilities surveyed (n=116)

Facility Type or Region†	Arabians		Polo Ponies		Quarter Horses		Thoroughbreds		Warmblood		Foxtrotters		Other	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Boarding/Training	2	3.6	12	21.4	8	14.2	22	39.3	10	17.9	1	1.8	1	1.8
Breeding	1	6.7	0	-	2	13.3	11	73.3	0	-	1	6.7	0	-
Racetrack	0	-	0	-	0	-	45	100	0	-	0	-	0	-
North	1	5.6	0	-	8	44.4	4	22.1	3	16.7	1	5.6	1	5.6
Central	0	-	0	-	0	-	37	97.4	0	-	1	2.6	0	-
South	2	3.3	12	20.0	2	3.3	37	61.7	7	11.7	0	-	0	-

†See text for definitions of facility type and region

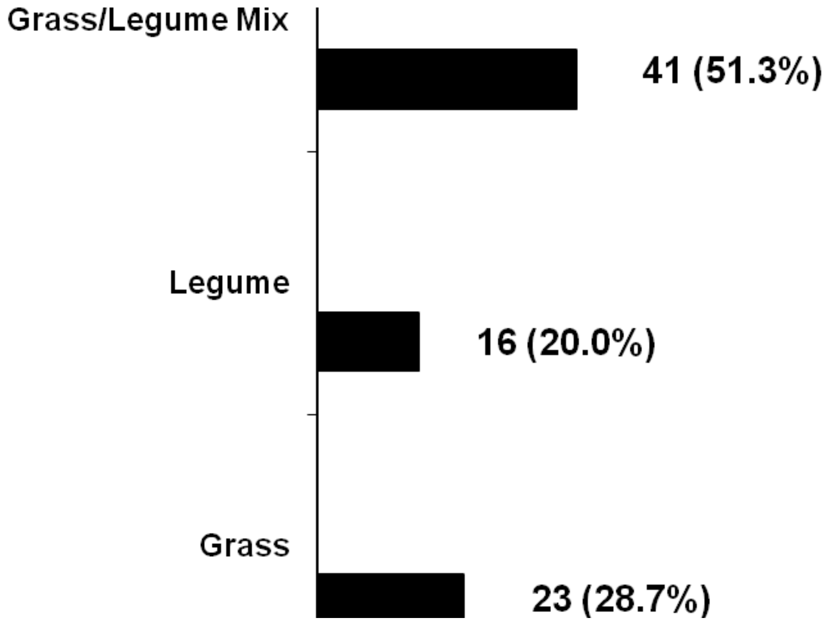

Figure 4-4. Type of hay fed to horses across all facilities surveyed (n=80)

Table 4-6. Type of hay fed to horses evaluated by facility type or region (n=80)

Facility Type or Region[†]	Grass		Legume		Grass/Legume Mix	
	N	%	n	%	n	%
Boarding/Training	20	40.0	10	20.0	20	40.0
Breeding	2	13.3	5	33.3	8	53.4
Racetrack	1	6.7	1	6.7	13	86.6
North	7	38.9	2	11.1	9	50.0
Central	1	4.4	11	47.8	11	47.8
South	15	38.5	3	7.7	21	53.8

†See text for definitions of facility type and region

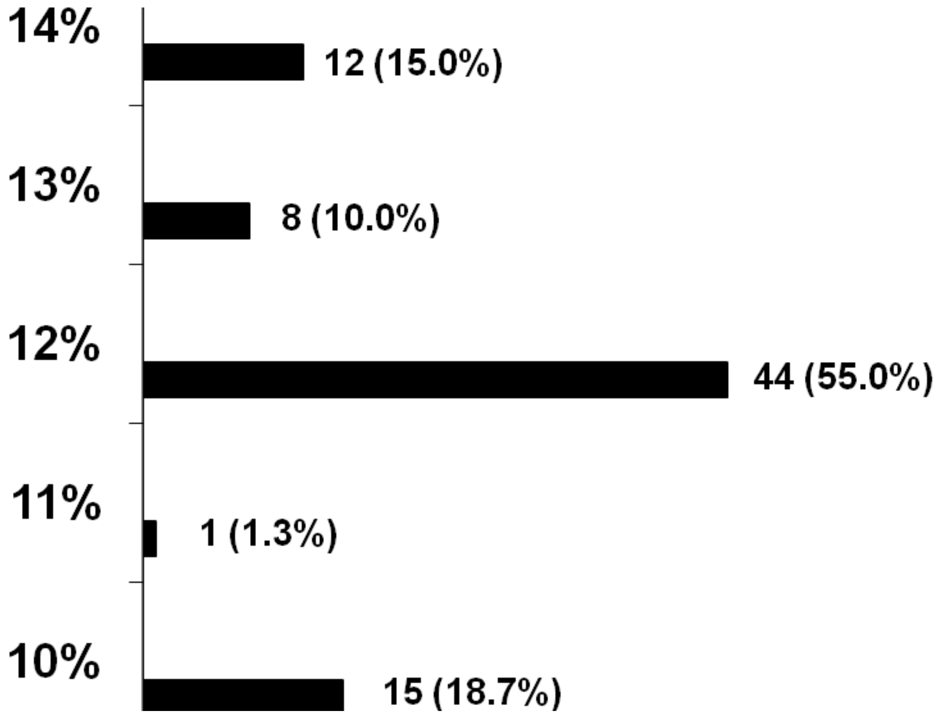

Figure 4-5. Percent crude protein in commercial feeds fed to horses across all facilities surveyed (n=80)

Table 4-7. Percent crude protein in commercial feeds fed to horses evaluated by facility type and region (n=80)

Facility Type or Region†	10%		11%		12%		13%		14%	
	n	%	n	%	n	%	n	%	n	%
Boarding/Training	10	20.0	1	2.0	32	64.0	4	8.0	3	6.0
Breeding	0	-	0	-	8	53.4	2	13.3	5	33.3
Racetrack	5	33.3	0	-	4	26.7	2	13.3	4	26.7
North	6	33.3	0	-	9	50.0	1	5.6	2	11.1
Central	0	-	1	4.4	15	65.2	3	13.0	4	17.4
South	9	23.0	0	-	20	51.3	4	10.3	6	15.4

†See text for definitions of facility type and region

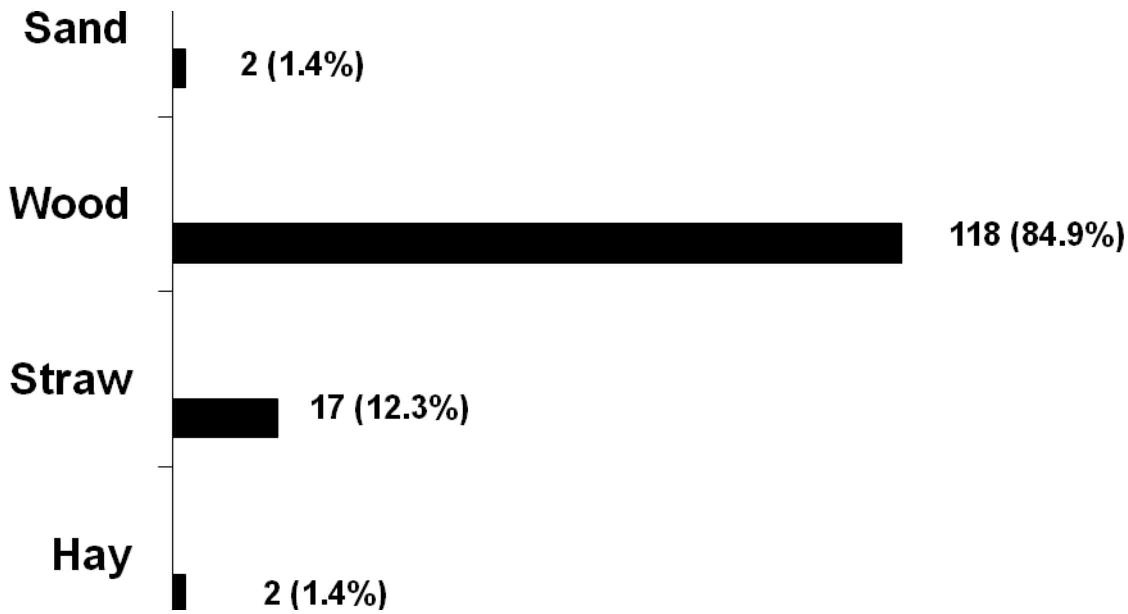

Figure 4-6. General type of bedding used in stalls across all facilities (n=139)

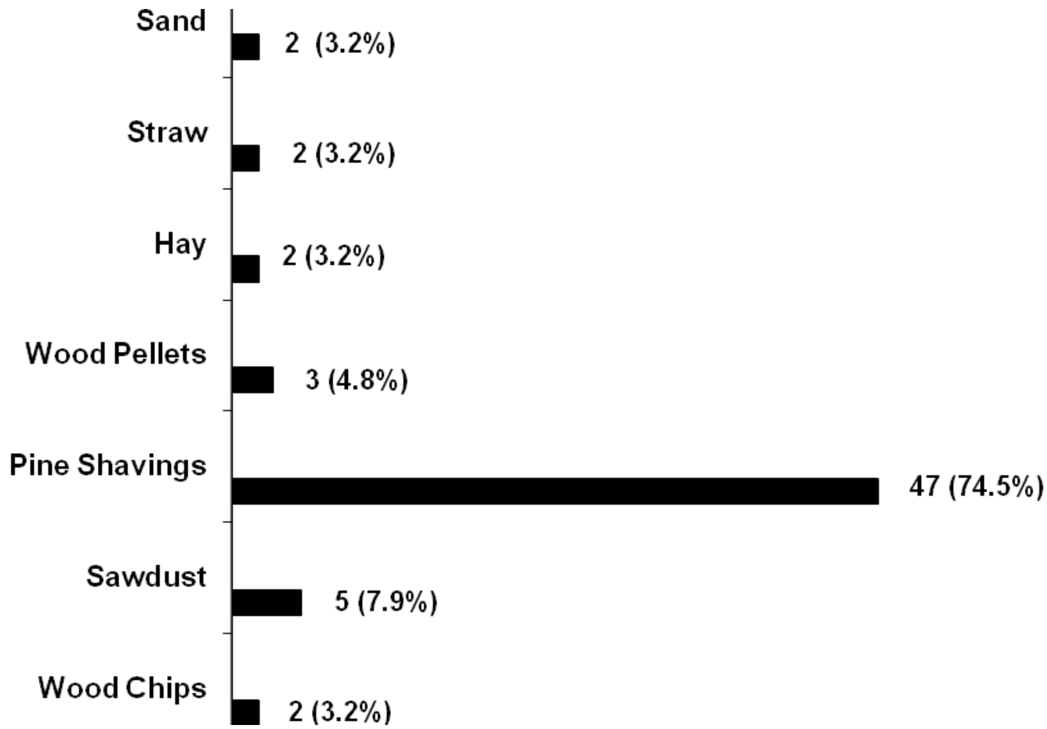

Figure 4-7. Specific type of bedding used in stalls across all facilities (excluding racetracks) (n=63)

Table 4-8. Specific type of bedding used in stalls, evaluated by facility type (excluding racetracks) and region (n=62)

Facility Type or Region†	Wood Chips		Sawdust		Pine Shavings		Wood Pellets		Hay		Straw		Sand	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Boarding/Training	1	2.3	4	8.4	38	80.8	3	6.4	1	2.1	0	-	0	-
Breeding	1	6.7	1	6.7	9	59.9	0	-	1	6.7	2	13.3	1	6.7
North	0	-	0	-	15	83.3	3	16.7	0	-	0	-	0	-
Central	1	4.4	3	13.0	15	65.2	0	-	2	8.7	2	8.7	0	-
South	1	4.7	2	9.5	17	81.1	0	-	0	-	0	-	1	4.7

†See text for definitions of facility type and region

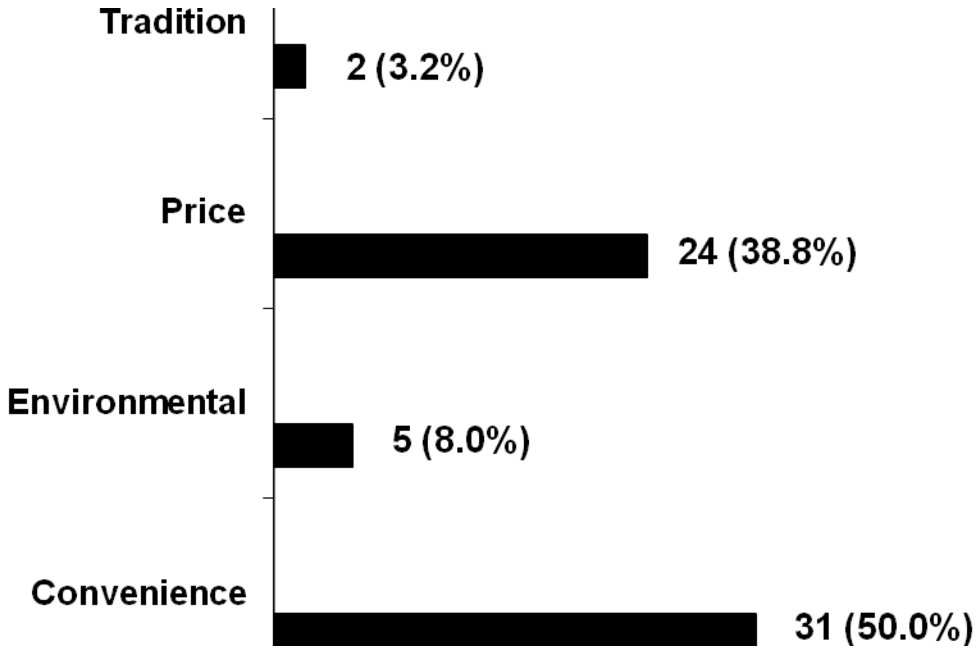

Figure 4-8. Reason given for using a particular type of bedding across all facilities surveyed (excluding racetracks) (n=62)

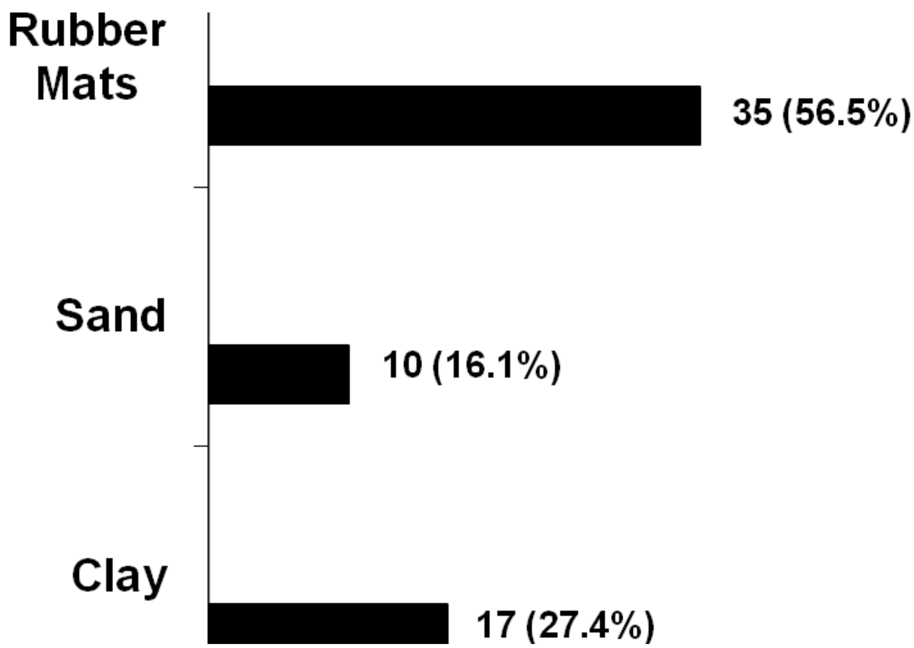

Figure 4-9. Stall Base material across all facilities surveyed (excluding racetracks) (n=62)

Table 4-9. Stall Base Material Evaluated by Facility Type (Excluding Racetracks) and Region (n=62)

Facility Type or Region†	Clay		Sand		Rubber Mats	
	N	%	n	%	n	%
Boarding/Training	11	23.4	9	19.2	27	57.4
Breeding	6	40.0	1	6.7	8	53.3
North	5	27.8	5	27.8	8	44.4
Central	11	47.8	0	-	12	52.2
South	1	4.8	5	23.8	15	71.4

†See text for definitions of facility type and region

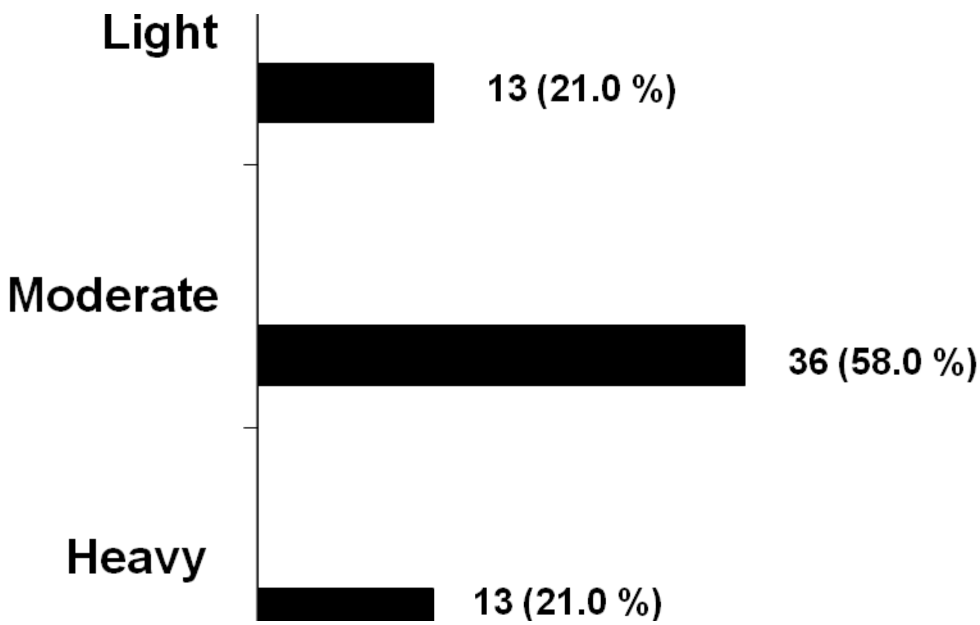

Figure 4-10. Amount of bedding in stalls across all facilities (excluding racetracks) (n=62)

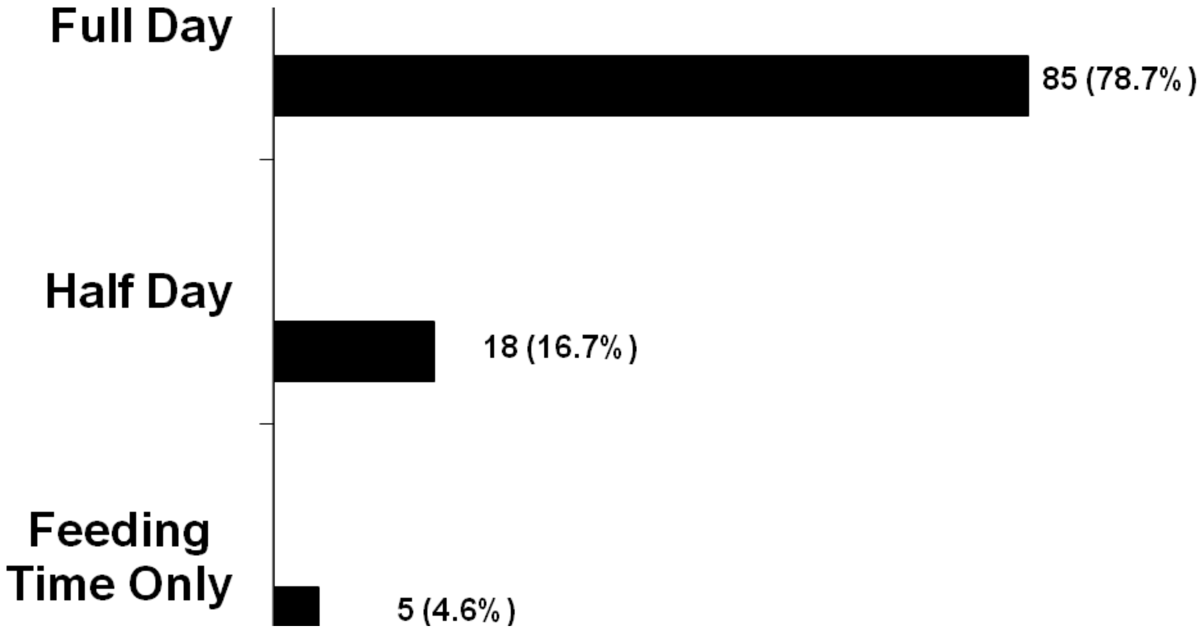

Figure 4-11. Time horses spent in stalls across all facilities (n=108)

Table 4-10. Time horses spent in stalls, evaluated by facility type and region (n=108)

Facility Type and Region[†]	Feeding Time Only		Half Day		Full Day	
	n	%	n	%	n	%
Boarding/Training	2	4.2	12	25.0	34	70.8
Breeding	3	20.0	6	40.0	6	40.0
Racetrack	0	-	0	-	45	100.0
North	1	5.6	9	50.0	8	44.4
Central	4	10.5	5	13.2	29	76.3
South	0	-	48	92.3	4	7.7

†See text for definitions of facility type and region

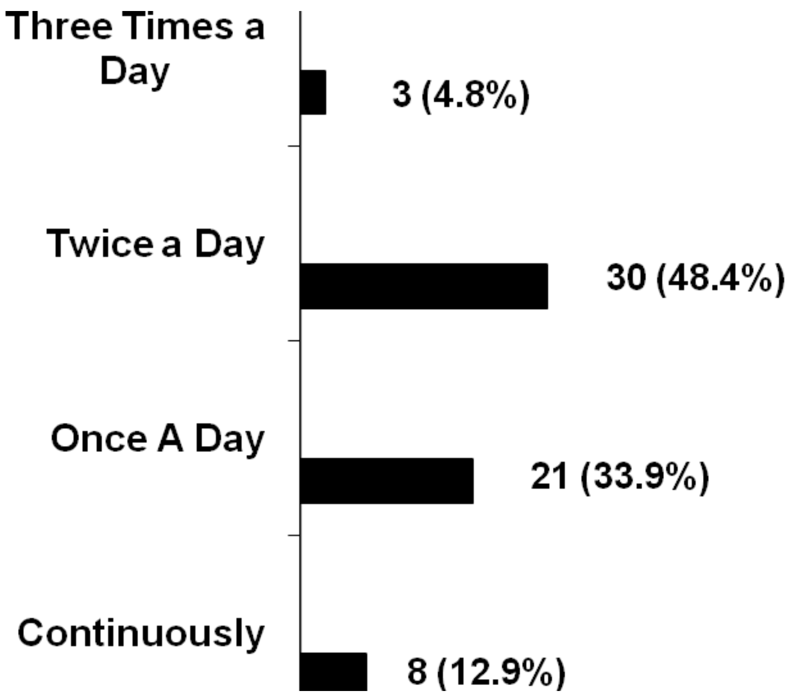

Figure 4-12. Frequency of stall cleaning across all facilities surveyed (excluding racetracks) (n=62)

Table 4-11. Frequency of stall cleaning evaluated by facility type (excluding racetracks) and region (n=62)

Facility Type or Region†	Continuously		Once a Day		Twice a Day		Three Times a Day	
	n	%	n	%	n	%	n	%
Boarding/Training	5	10.6	13	27.7	26	55.3	3	6.4
Breeding	3	20.0	8	53.3	4	26.7	0	-
North	2	11.1	11	61.1	5	27.8	0	-
Central	6	26.1	9	39.1	7	30.4	1	4.4
South	0	-	1	4.8	18	85.7	2	9.5

†See text for definitions of facility type and region

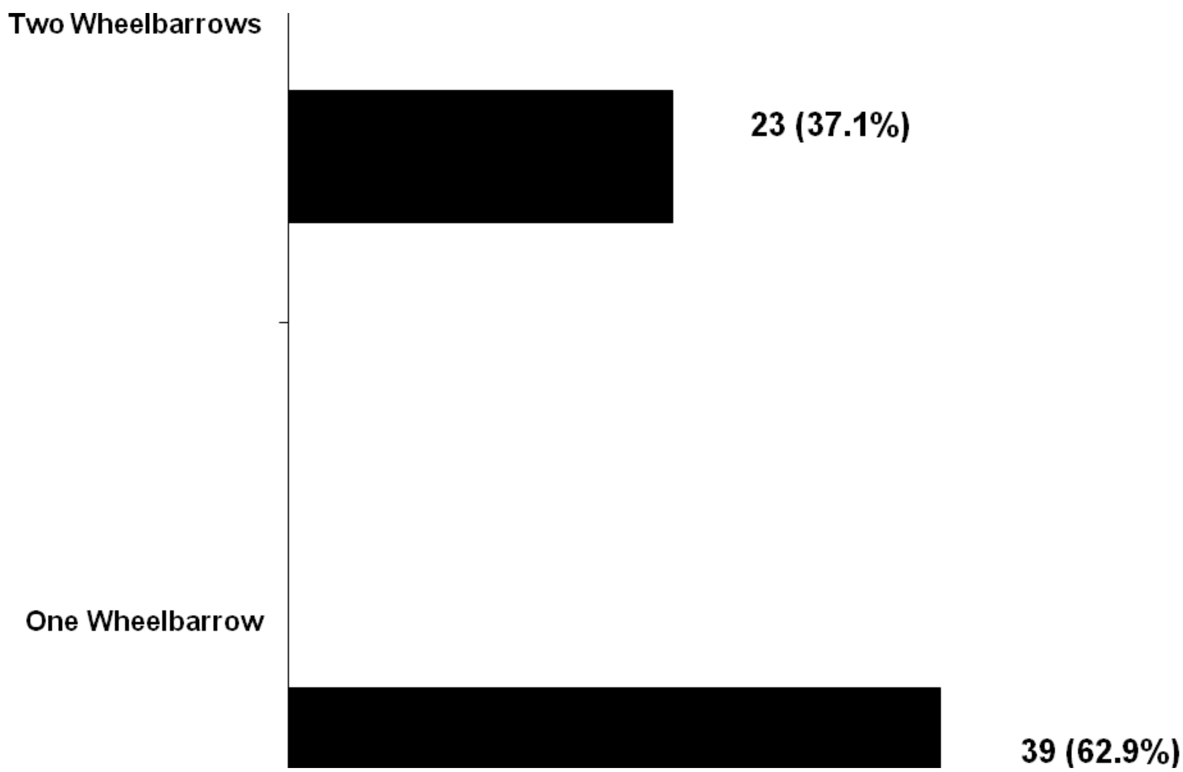

Figure 4-13. Approximate volume of stall waste removed daily per stall, evaluated across all facilities surveyed (excluding racetracks) (n=62)

Table 4-12. Approximate volume of stall waste removed daily per stall, evaluated by facility type (excluding racetracks) and region (n=62)

Facility Type or Region†	One Wheelbarrow		Two Wheelbarrows	
	n	%	n	%
Boarding/Training	33	70.2	14	29.8
Breeding	6	40.0	9	60.0
North	15	83.3	3	16.7
Central	8	34.8	15	65.2
South	16	76.2	5	23.8

†See text for definitions of facility type and region

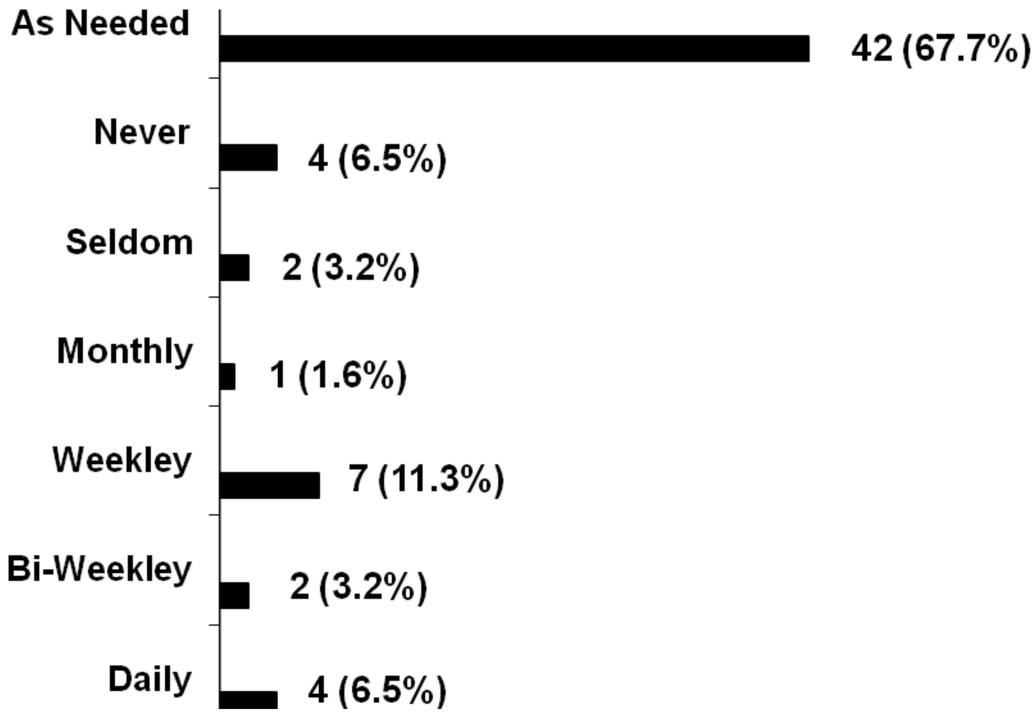

Figure 4-14. Frequency of stripping stalls of all materials evaluated across all facilities surveyed (excluding racetracks) (n=62)

Table 4-13. Frequency of stripping stalls of all materials, evaluated by facility type (excluding racetracks) and region (n=62)

Facility Type or Region†	Daily		Bi-Weekly		Weekly		Monthly		Seldom		Never		As Needed	
	n	%	n	%	n	%	n	%	n	%	n	%	N	%
Boarding/Training	2	4.2	1	2.1	7	15.0	1	2.1	2	4.3	3	6.3	31	66.0
Breeding	2	13.3	1	6.7	0	-	0	-	0	-	1	6.7	11	73.3
North	1	5.6	1	5.6	1	5.6	1	5.6	0	-	1	5.6	13	72.0
Central	3	13.0	1	4.4	5	21.7	0	-	2	8.7	3	13.0	9	39.2
South	0	-	0	-	1	4.8	0	-	0	-	0	-	20	95.2

†See text for definitions of facility type and region

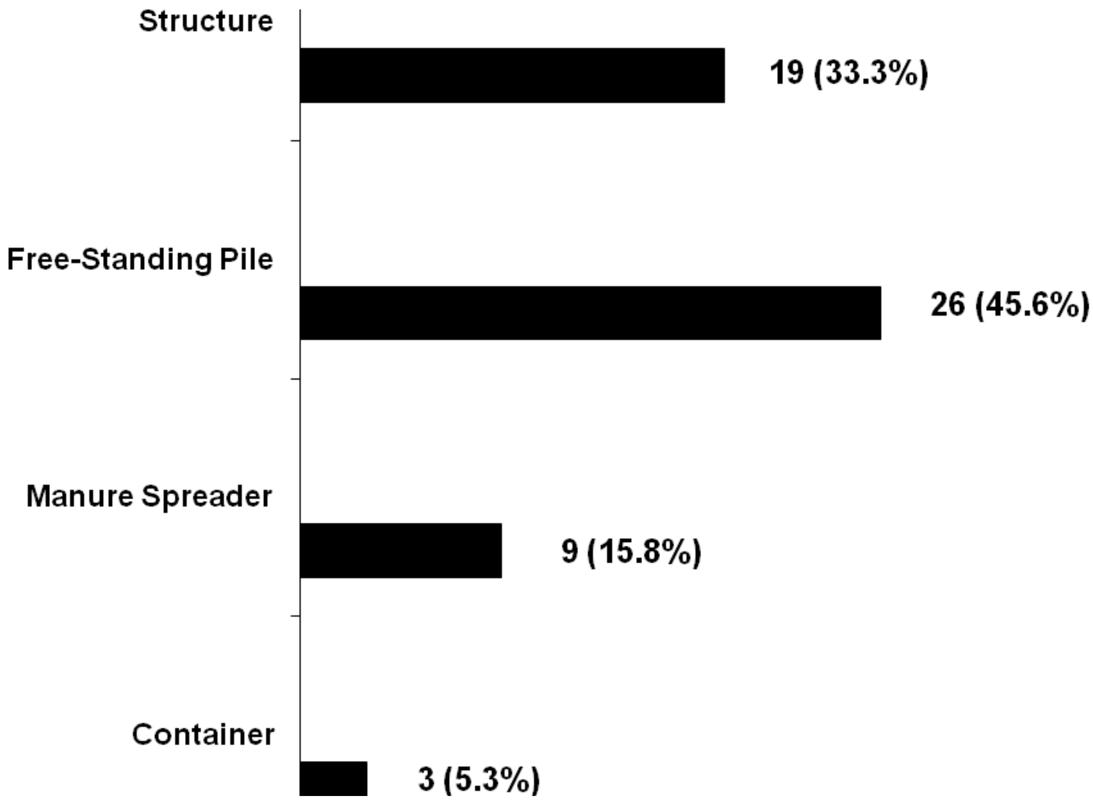

Figure 4-15. Method of stall waste storage, evaluated across all facilities surveyed (excluding racetracks) (n=57)

Table 4-14. Method of stall waste storage, evaluated by facility type (excluding racetracks) and region (n=57)

Facility Type or Region†	Container		Manure Spreader		Free-Standing Pile		Structure	
	n	%	n	%	n	%	n	%
Boarding/Training	2	4.4	7	15.6	18	40.0	18	40.0
Breeding	1	8.3	2	16.7	8	66.7	1	8.3
North	0	-	6	33.3	11	61.1	1	5.6
Central	3	16.7	1	5.6	14	77.7	0	-
South	0	-	2	9.6	1	4.7	18	85.7

† See text for definitions of facility type and region

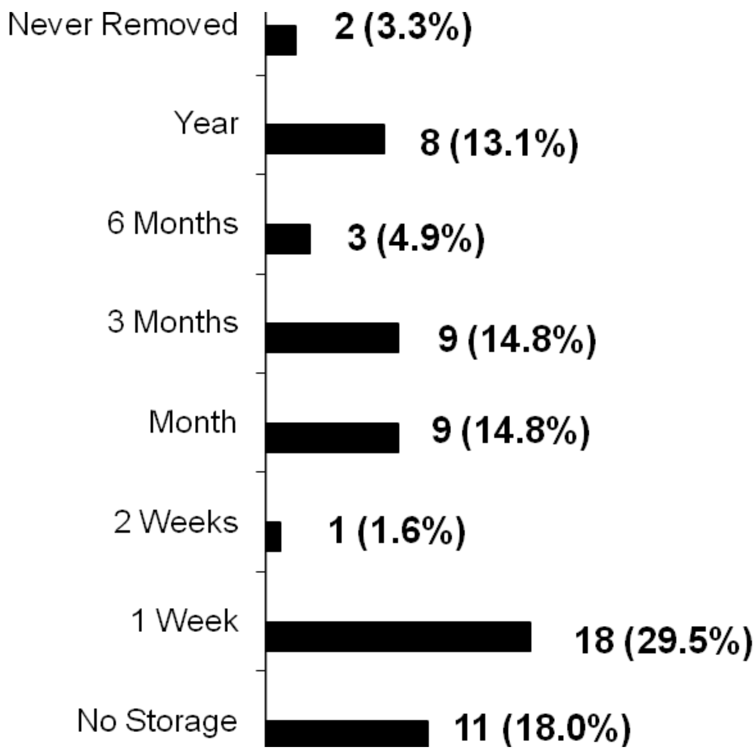

Figure 4-16. Time stall waste spent in storage before disposal, evaluated across all facilities surveyed (excluding racetracks) (n=61)

Table 4-15. Time stall waste spent in storage before disposal, evaluated by facility type (excluding racetracks) and region (n=61)

Facility Type or Region†	No Storage		1 Week		2 Weeks		Month		3 Months		6 Months		Year		Never	
	n	%	N	%	n	%	n	%	n	%	n	%	n	%	n	%
Boarding/Training	3	13.0	15	32.6	1	2.2	8	17.4	8	17.4	1	2.2	6	13.0	1	2.2
Breeding	5	33.3	3	20.0	0	-	1	6.7	1	6.7	2	13.3	2	13.3	1	6.7
North	3	17.7	5	29.4	0	-	3	17.7	3	17.7	0	-	2	11.7	1	5.8
Central	6	26.1	4	17.4	1	4.4	0	-	2	8.6	3	13.0	6	26.1	1	4.4
South	2	9.5	9	42.8	0	-	6	28.6	4	19.1	0	-	0	-	0	-

† See text for definitions of facility type and region

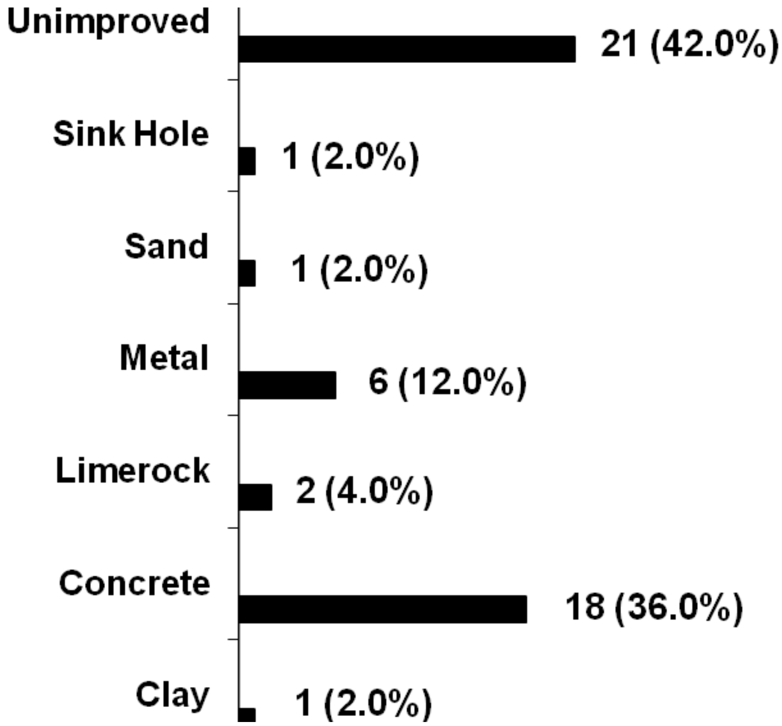

Figure 4-17. Base material of stall waste storage area, evaluated across all facilities surveyed (excluding racetracks) (n=50)

Table 4-16. Base material of stall waste storage area, evaluated by facility type (excluding racetracks) and region (n=50)

Facility Type of Region[†]	Clay		Concrete		Limerock		Metal		Sand		Sink Hole		Unimproved	
	n	%	n	%	n	%	n	%	n	%	N	%	n	%
Boarding/Training	1	2.5	17	42.5	1	2.5	5	12.5	1	2.5	1	2.5	14	35.0
Breeding	0	-	1	10.0	1	10.0	1	10.0	0	-	0	-	7	70.0
North	0	-	1	7.1	0	-	2	14.4	1	7.1	0	-	10	71.4
Central	1	5.9	0	-	2	11.8	3	17.7	0	-	1	5.9	10	58.7
South	0	-	17	89.4	0	-	1	5.3	0	-	0	-	1	5.3

† See text for definitions of facility type and region

Figure 4-18. Roof over waste storage area, evaluated across facilities surveyed (excluding racetracks) (n=51)

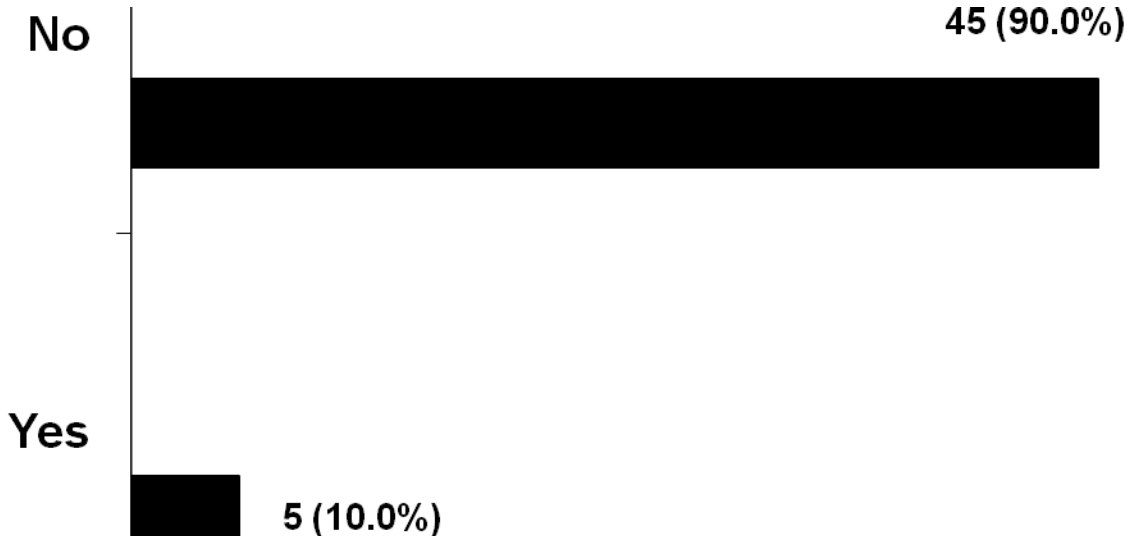

Figure 4-19. Stall waste storage in a low lying area, evaluated across all facilities surveyed (excluding racetracks) (n=50)

Table 4-17. Stall waste storage in a low lying area, evaluated by facility type (excluding racetracks) and region (n=50)

Facility Type or Region[†]	Yes		No	
	n	%	n	%
Boarding/Training	3	7.5	37	92.5
Breeding	2	20.0	8	80.0
North	0	-	14	100.0
Central	3	17.7	14	82.3
South	2	10.5	17	89.5

† See text for definitions of facility type and region

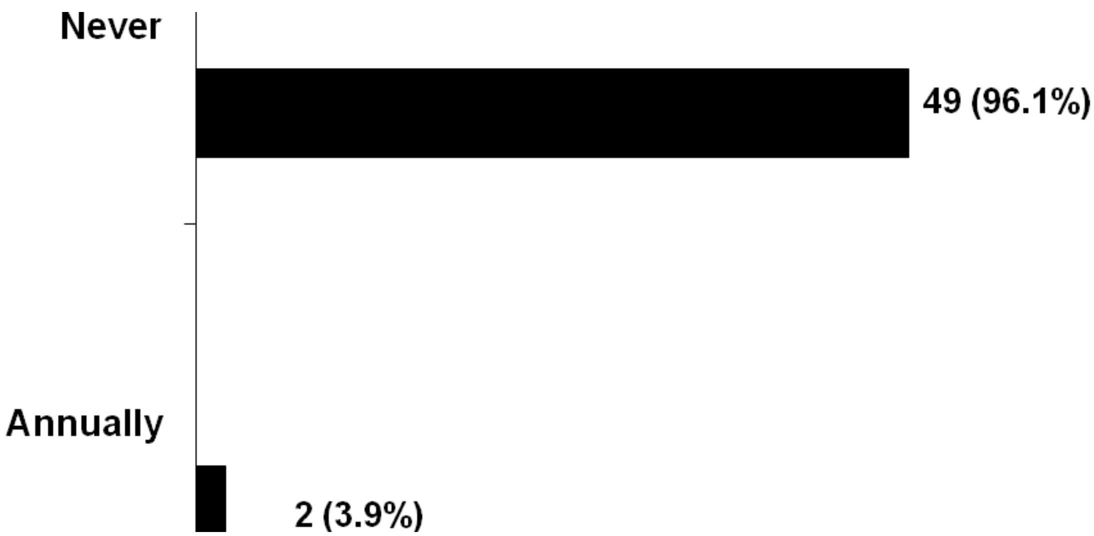

Figure 4-20. Frequency of flooding in stall waste storage area, evaluated across all facilities surveyed (excluding racetracks) (n=51)

Table 4-18. Frequency of flooding in stall waste storage area, evaluated by facility type (excluding racetracks) and region (n=51)

Facility Type or Region†	Annually		Never	
	n	%	n	%
Boarding/Training	1	2.5	39	97.5
Breeding	1	9.1	10	90.9
North	1	7.1	13	92.9
Central	1	5.6	17	94.4
South	0	-	19	100

† See Text for Definitions of facility Type and Region

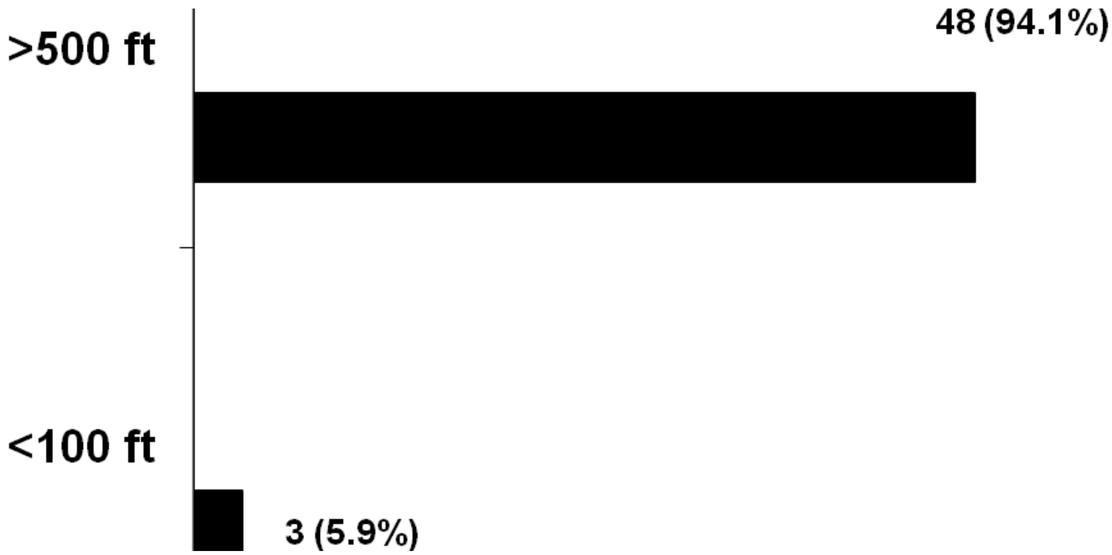

Figure 4-21. Distance of surface water from stall waste storage area, evaluated across all facilities surveys (excluding racetracks) (n=51)

Table 4-19. Distance of surface water from stall waste storage area, evaluated by facility type (excluding racetracks) and region (n=51)

Facility Type and Region†	<100 ft		>500 ft	
	n	%	n	%
Boarding/Training	3	7.5	37	92.5
Breeding	0	-	11	100.0
North	0	-	14	100.0
Central	1	5.6	17	94.4
South	2	10.5	17	89.5

† See text for definitions of facility type and region

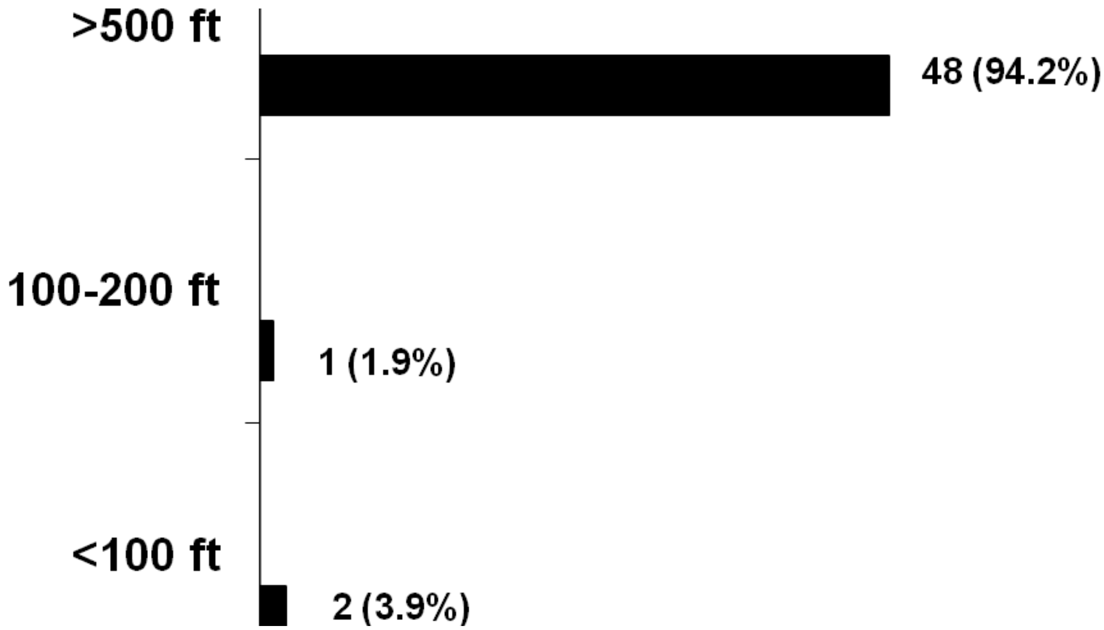

Figure 4-22. Distance of a residence from stall waste storage, evaluated across all facilities surveyed (excluding racetracks) (n=51)

Table 4-20. Distance of a residence from stall waste storage, evaluated by facility type (excluding racetracks) and region (n=51)

Facility Type and Region†	<100 ft		100-200 ft		>500 Feet	
	n	%	n	%	n	%
Boarding/Training	2	5.0	1	2.5	37	92.5
Breeding	0	-	0	-	11	100.00
North	0	-	1	7.1	13	92.9
Central	0	-	0	-	18	100.0
South	2	10.5	0	-	17	89.5

† See text for definitions of facility type and region

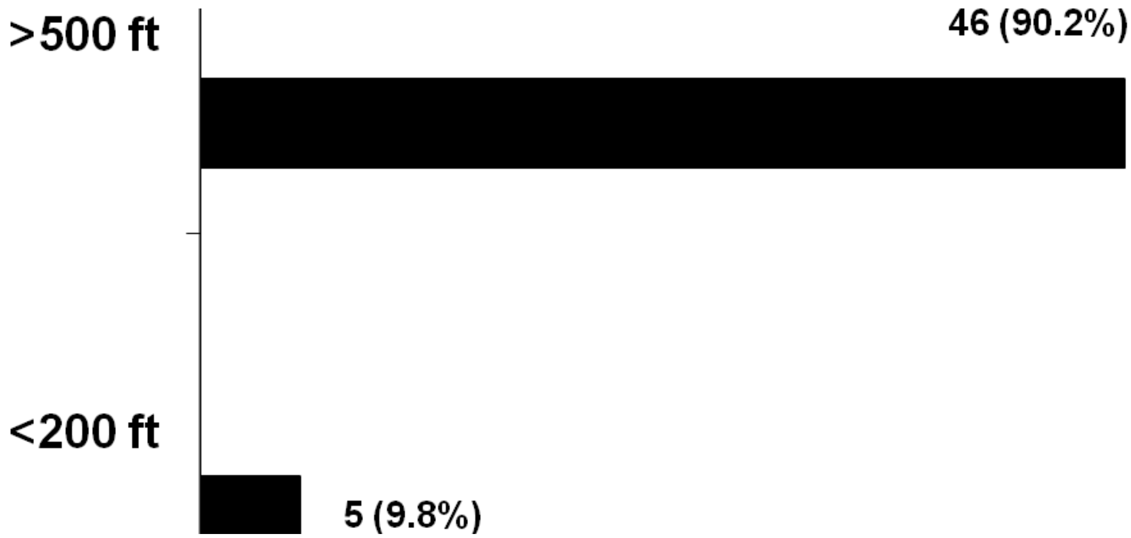

Figure 4-23. Distance of a drinking water well from stall waste storage area, evaluated across all facilities surveyed (excluding racetracks) (n=51)

Table 4-21. Distance of a drinking water well from stall waste storage area, evaluated by facility type (excluding racetracks) and region (n=51)

Facility Type and Region†	<200 ft		>500 ft	
	N	%	n	%
Boarding/Training	4	10.0	36	90.0
Breeding	1	9.1	10	90.9
North	1	7.1	13	92.9
Central	1	5.6	17	94.4
South	3	15.8	16	84.2

† See text for definitions of facility type and region

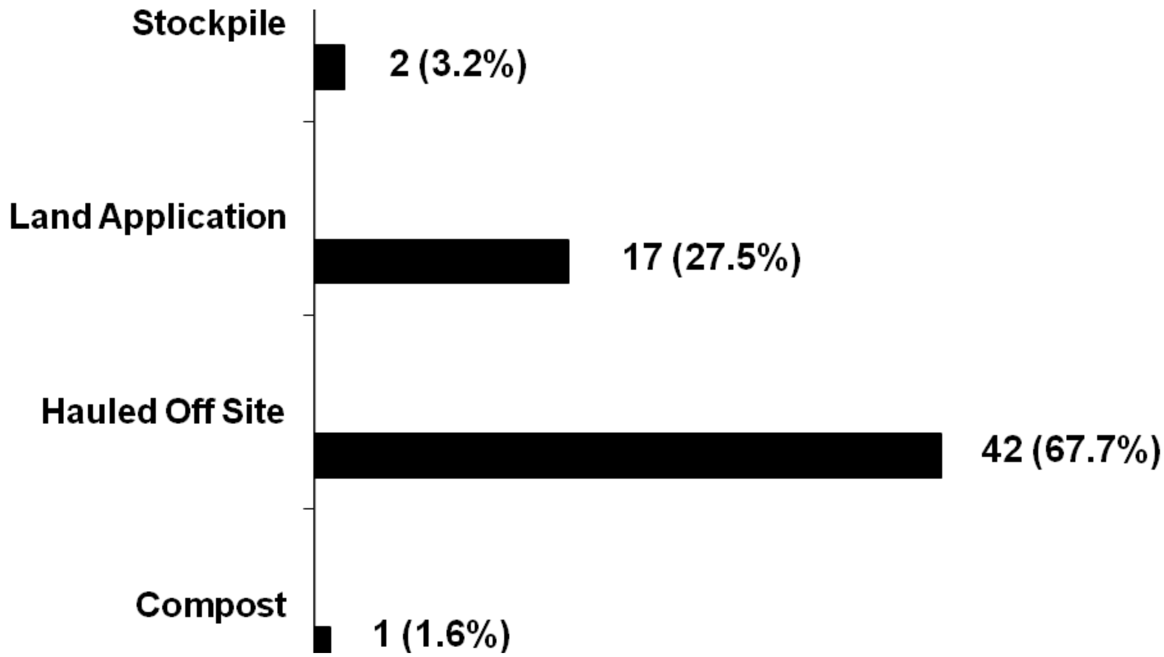

Figure 4-24. Method of stall waste disposal, evaluated across all facilities surveyed (excluding racetracks) (n=62)

Table 4-22. Method of stall waste disposal, evaluated by facility type (excluding racetracks) and region (n=62)

Facility Type and Region†	Compost		Hauled Off Site		Land Application		Stockpile	
	n	%	n	%	n	%	n	%
Boarding/Training	1	2.1	33	70.2	11	23.4	2	4.3
Breeding	0	-	9	60.0	6	40.0	0	-
North	1	5.6	8	44.4	8	44.4	1	5.6
Central	0	-	15	65.2	7	30.4	1	4.4
South	0	-	19	90.5	2	9.5	0	-

†See text for definitions of facility type and region

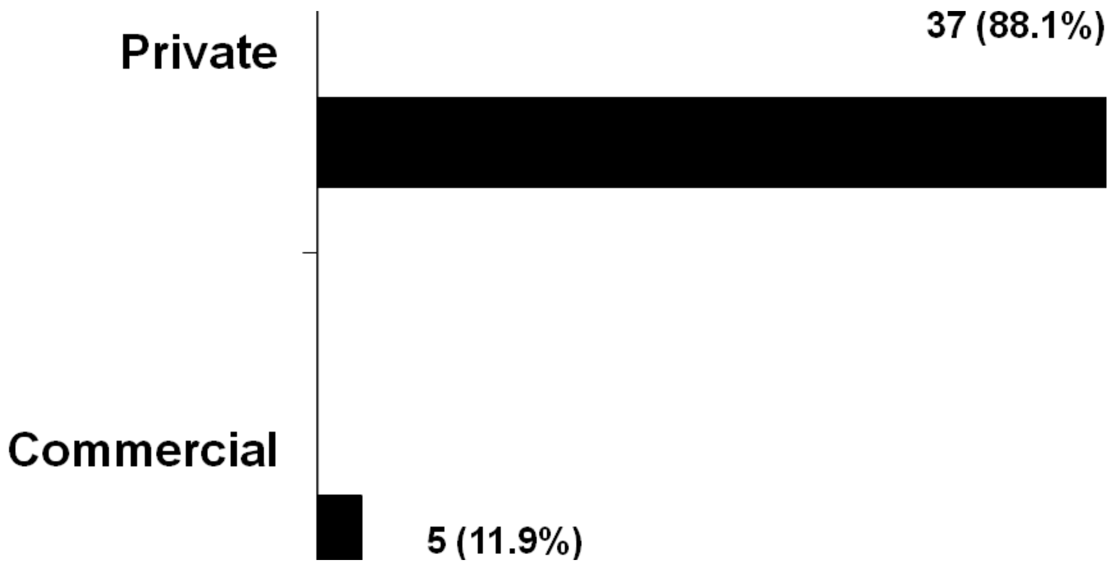

Figure 4-25. Type of waste removal service, evaluated across all facilities surveyed (excluding racetracks) (n=42)

Table 4-23. Type of waste removal service, evaluated by facility type (excluding racetracks) and region (n=42)

Facility Type or Region†	Commercial		Private	
	n	%	n	%
Boarding/Training	4	12.1	29	87.9
Breeding	1	11.1	8	88.9
North	0	-	8	100.0
Central	3	20.0	12	80.0
South	2	10.5	17	89.6

† See text for definitions of facility type and region

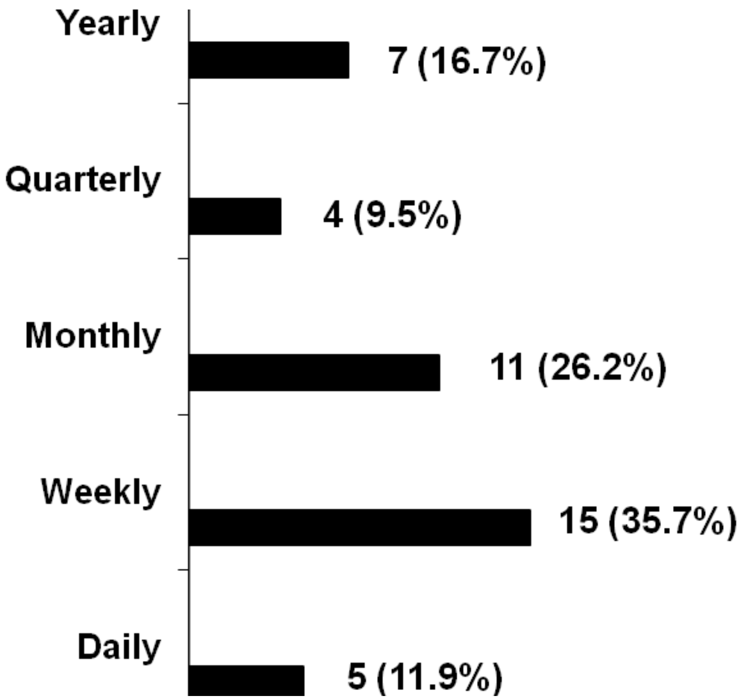

Figure 4-26. Frequency stall waste is hauled off-site, evaluated across all facilities surveyed (excluding racetracks) (n=42)

Table 4-24. Frequency stall waste is hauled off-site, evaluated by facility type (excluding racetracks) and region (n=42)

Facility Type of Region†	Daily		Weekly		Monthly		Quarterly		Yearly	
	n	%	n	%	n	%	n	%	N	%
Boarding/Training	3	9.1	13	39.4	10	30.3	3	9.1	4	12.1
Breeding	2	22.2	2	22.2	1	11.1	1	11.1	3	33.4
North	1	12.5	2	25.0	2	25.0	1	12.5	2	25.0
Central	3	20.0	4	26.7	1	6.7	2	13.3	5	33.3
South	1	5.3	9	47.4	8	42.0	1	5.3	0	-

† See text for definitions of facility type and region

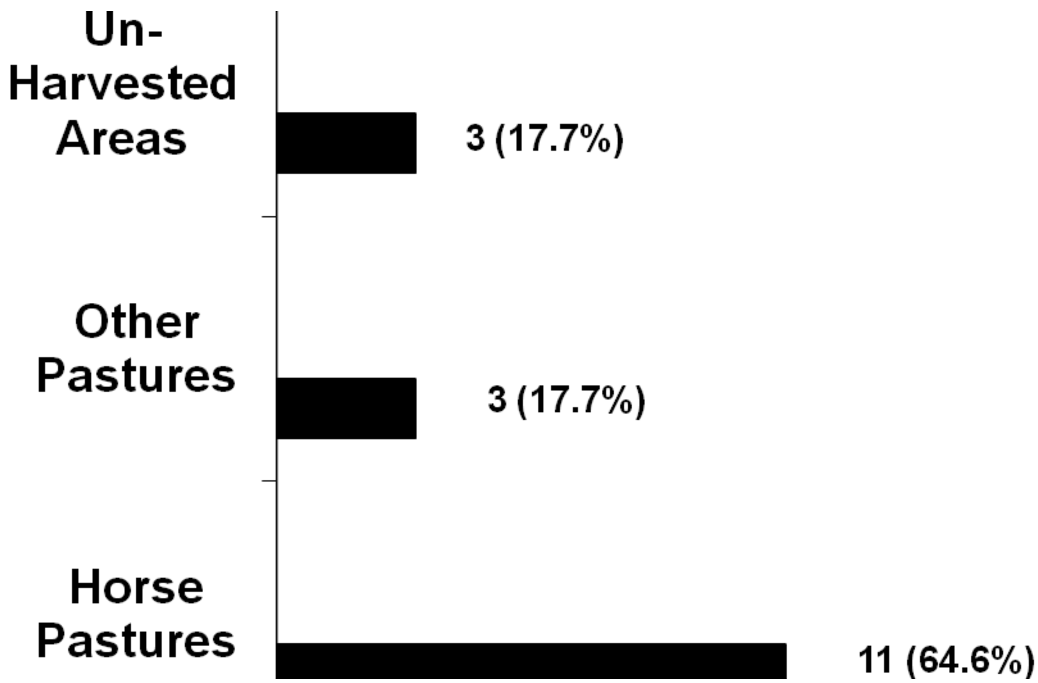

Figure 4-27. Location where stall waste is land applied, evaluated across all facilities surveyed (excluding racetracks) (n=17)

Table 4-25. Location where stall waste is land applied, evaluated by facility type (excluding racetracks) and region (n=17)

Facility Type and Region†	Horse Pastures		Other Pastures		Un-Harvested Areas	
	N	%	n	%	n	%
Boarding/Training	8	72.7	1	9.1	2	18.2
Breeding	3	50.0	2	33.3	1	16.7
North	5	62.5	1	12.5	2	25.
Central	5	71.4	2	28.6	0	-
South	1	50.0	0	-	1	50.0

† See text for definitions of facility type and region

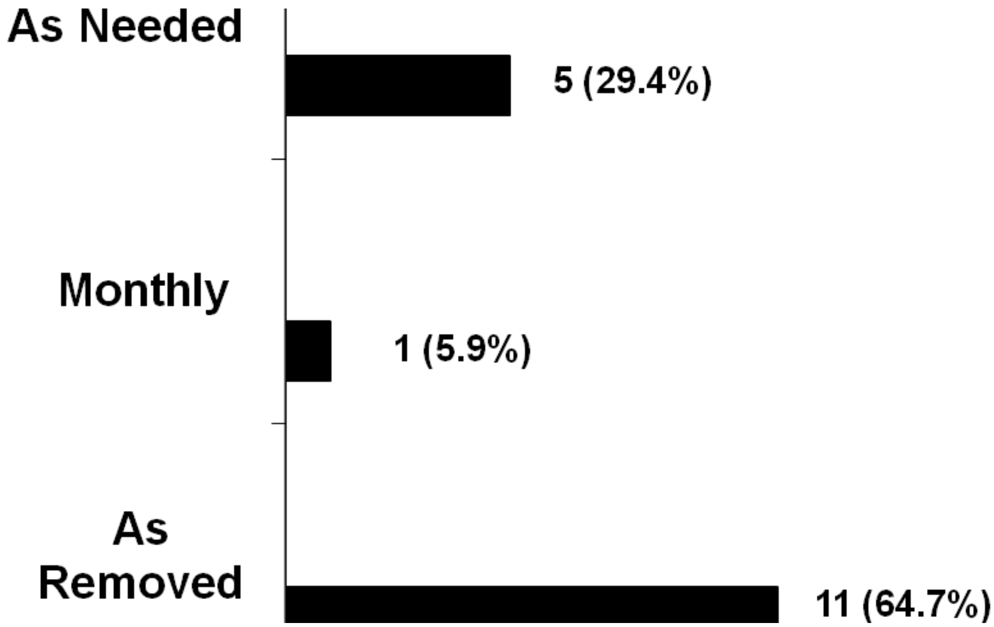

Figure 4-28. Frequency of land application of stall waste, evaluated across all facilities surveyed (excluding racetracks) (n=17)

Figure 4-29.Frequency of manure removal from pastures evaluated across all facilities surveyed (excluding racetracks) (n=59)

Figure 4-30. Manure removal from paddocks or dry lots, evaluated across all facilities surveyed, (excluding racetracks) (n=59)

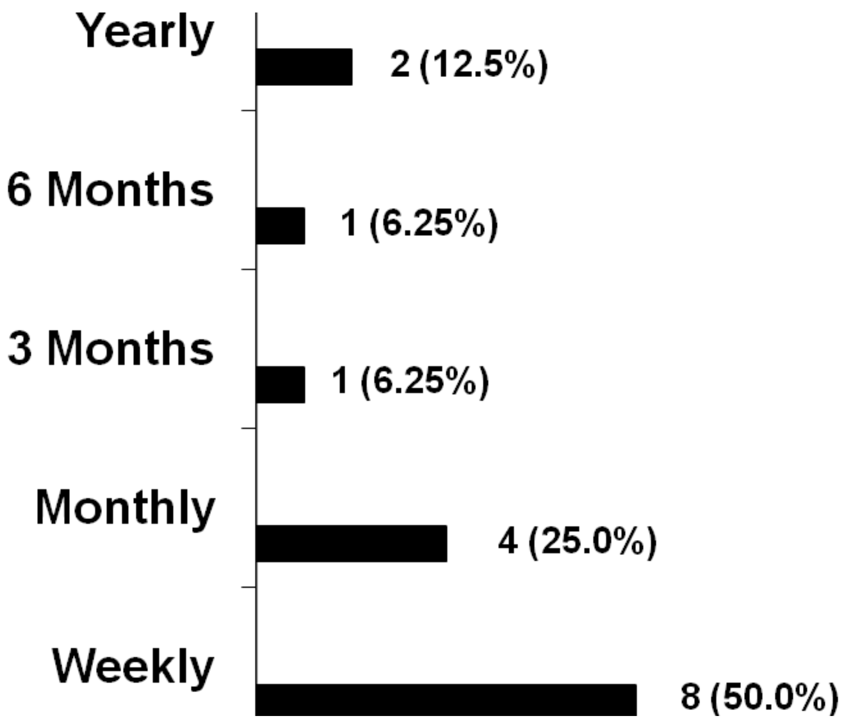

Figure 4-31. Frequency pastures are harrowed, evaluated across all facilities surveyed (excluding racetracks) (n=16)

Table 4-26. Frequency pastures are harrowed, evaluated by facility type (excluding racetracks) and region (n=59)

Facility Type or Region†	Yes		No	
	n	%	n	%
Boarding/Training	11	25.0	33	75.0
Breeding	5	33.3	10	66.7
North	6	35.3	11	64.7
Central	9	39.1	14	60.9
South	1	5.3	18	94.7

† See text for definitions of facility type and region

Table 4-27. Pastures fertilized, evaluated by facility type (excluding racetracks) and region (n=58)

Facility Type and Region†	Yes		No	
	N	%	n	%
Boarding/Training	10	22.7	34	77.3
Breeding	5	35.7	9	64.3
North	6	35.3	11	64.7
Central	8	36.4	14	63.6
South	1	5.3	18	94.7

† See text for definitions of facility type and region

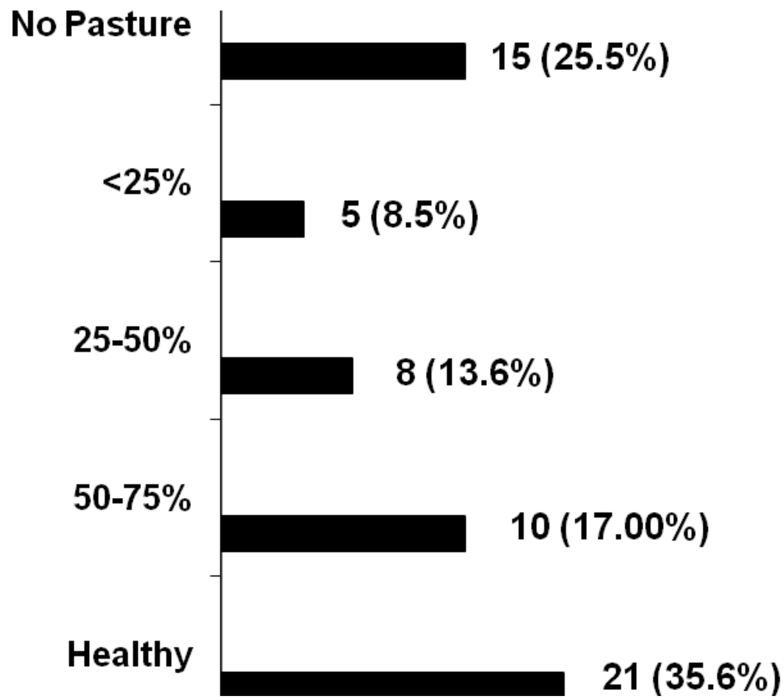

Figure 4-32. Pasture quality (overgrazing), evaluated across all facilities surveyed (excluding racetracks) (n=59)

Table 4-28. Pasture quality (overgrazing), evaluated by facility type (excluding racetracks) and region (n=59)

Facility Type of Region†	Healthy		50-75%		25-50%		<25%		No Pasture	
	n	%	n	%	n	%	n	%	n	%
Boarding/Training	11	25.0	8	18.2	6	13.6	5	11.4	14	31.8
Breeding	10	66.7	2	13.3	2	13.3	0	-	1	6.7
North	3	17.7	3	17.7	3	17.7	3	17.7	5	29.2
Central	15	65.2	3	13.0	3	13.0	0	-	2	8.8
South	3	15.8	4	21.1	2	10.5	2	10.5	8	42.1

† See text for definitions of facility type and region

CHAPTER 5
IMPLICATIONS

The studies in this thesis characterized the nutrient profile of horse stall waste and identified common manure management practices of the Florida horse industry. Some form of wood based bedding is the predominate type of bedding used by Florida horse operations. The addition of manure, urine, wasted feed and hay significantly alters the nutrient content of stall waste. The typical make-up of horse stall waste is 75% clean bedding and 25% other (manure, urine, etc.). Clean bedding type and stall cleaning practices likely lead to differences in nutrient content of stall waste. Nitrogen, phosphorus and potassium are lower in horse stall waste compared to other livestock manures. The majority of Florida horse operations either haul off site or land apply their stall waste. The majority of operations responsibly manage their stall waste.

New knowledge about the relatively low nutrient content of stall waste could lead to better recommendations about the lack of risk the horse industry poses to water quality. Due to the conclusion that stall cleaning practices affect the nutrient composition of stall waste, best management practices pertaining to less wasteful stall cleaning practices could be created. More consideration should be paid to the proportion of manure compared to clean bedding removed. This would reduce wasted clean bedding as well as create a more desirable product for composting or land application as fertilizer.

APPENDIX A
ONSITE SURVEY QUESTIONAIRE

On-Site Evaluation of Waste Management Practices

No.______

Total Acres: __________________ Acres Utilized by Horses: ____________

Number of Horses: ___________ Breed of Horses: _____________________

City: ________________ County: ______________________

Region:

A. North
B. Central
C. South

Type of Operation:

A. Breeding
B. Boarding/Training
C. Racetrack

Sampling:

Description of Grain Mix: ________ %CP

Type of Hay: A. Legume B. Grass C. Mix

Sample Obtained:

Bedding: __________ Stall Waste: _____________

Hours Between Stall Cleaning and Sample Collection: ______________

Housing of Horses:

Hours in Stall:

A. Feeding Time Only
B. Half Day
C. Full Day

Bedding

Describe the Method of Cleaning Stalls:

A. By Hand
B. Mechanical
C. Other: ______________

How Often are Stalls Cleaned (Per day)

A. Continuously
B. Two
C. One
D. <One Time

Volume of Waste Removed From Stall (Daily):

A. < 1 Wheelbarrow Load
B. 1 Wheelbarrow Load

How Often are Stalls Stripped:

A. Daily
B. Weekly
C. Bi-Weekly
D. As Needed
E. Never
F. Other: __________________

Do they Use:

A. Stall Mats
B. Concrete
C. Asphalt Sand/Clay
D. Nothing

Reason:

A. Price
B. Environmental
C. Convenience
D. Tradition

Amount of Bedding Used:

A. Light
B. Moderate
C. Heavy

Number of Bales/Stall: ________________

(1 Bale=25lbs=1wheelbarrow)

Bedding Type:

A. Grass Hay
B. Straw
C. Shavings
D. Sawdust
E. Peanut Hulls
F. Rice Hulls
G. Other:____________________

Waste Storage

Length of Storage:

A. < 1 Week
B. < 1 Month
C. 1-3 Months
D. 3-6 Months
E. 6 Month
F. Other: ___________________

Frequency of Flooding in area where waste is stored:

A. Annually
B. Every 5 years
C. Every 20 Years
D. Never

Distance from Storage area to Nearest Drinking Water Well:

A. Less than 100 Feet
B. 100-199 Feet
C. 200-500Feet
D. More than 500 Feet

Is their a Sink Hole on the Property: YES NO

Distance from Storage area to Nearest Surface Waste, Sink Hole or Drainage Way:

A. Less than 100 Feet
B. 100-199 Feet
C. 200-500 Feet
D. More than 500 Feet

Distance from Storage area to Nearest Residence:

A. Less than 100 Feet
B. 100-199 Feet
C. 200-500 Feet
D. More than 500 Feet

Method of Storage:

A. Pile
B. Structure(Pit/Bin)
C. Manure Spreader
D. Container
E. Other: __________________

Below the Waste Storage Area:

A. Unimproved Soil
B. Clay
C. Concrete
D. Wood
E. Other: ________________________

Roof Above the Waste Storage Area:

A. No Roof
B. Permanent
C. Tarp
D. Other:_________________________

Is the Clean Water Diverted from the Pile: YES NO

Are there Containment Ponds to Collect Run Off From the Pile: YES NO

Is the Storage Area in a Low Lying area: YES NO

Slope of Land from Storage area to Surface Water or Drainage Way:

A. 10%+
B. 6-10%
C. 1-5%
D. Flat or Upslope

Soil Depth Where Waste is Stored:

A. < 20 inches
B. 20-30 inches
C. 30-40 inches
D. 40 inches

Soil Type Where waste is stored:

A. Coarse textured
B. Well Drained Coarse textured
C. Fine Textured
D. Medium or Fine texture

Method of Waste Disposal:

Land Applied____ Hauled off Site_____ Composted Onsite______

Other:

If Land Applied:

Location of Application (Circle All That Apply):

A. Un-harvested Areas
B. Crop Land
C. Horse Pastures
D. Other Pastures
E. Riding Arena
F. On Farm
G. Off Farm
H. Landscape/Mulch
I. Other:

Number of Acres Applied to: ______________________

Is Nutrient Analysis Done on Waste Before Application: YES NO

Are Soil Tests Preformed on the Land Before Application: YES NO

Frequency of Application:

A. As Removed
B. Yearly
C. Yearly
D. Other:________________

Time of Year Applied (Circle All That Apply):

A. Spring
B. Summer
C. Fall
D. Winter

Distance From Waste Application Area to the Nearest Drinking Water Well:

A. Less than 100 Feet
B. 100-199 Feet
C. 200-500Feet
D. More than 500 Feet

Slope of Application Area to Surface Water or Drainage Way:

A. 10%+
B. 6-10%
C. 1-5%
D. Flat or Upslope

Frequency of Flooding for Areas Where Waste is Land Applies:

A. Annually
B. Every 5 years
C. Every 20 Years
D. Never

Distance From Waste Application Area to nearest Surface Water, Sink Hole or Drainage Way:

A. Less than 100 Feet
B. 100-199 Feet
C. 200-500 Feet
D. More than 500 Feet

If Hauled off Site:

What Type of Operation performs the Removal:

A. Private
B. Commercial (WasteManagment)
C. Municipal
D. Don't Know

E. Other

Is a Container Provided: YES NO

Frequency of Removal:

A. Daily
B. Weekly
C. Monthly
D. Yearly
E. Other:

Annual Cost: ________________

If Composted On Site:

What type of Composting:

A. Windrow
B. Bin
C. Static Pile
D. Other:

Is the Compost Actively Aerated/Turned: YES NO

Is Water Content Monitored: YES NO

Is Nitrogen Added: YES NO

Length of Process: < 4 Months >4 Months

End Use of Composted Material:

A. Pasture
B. Landscaping
C. Arena
D. Sold $__________
E. Other: ________________

Other Methods of Disposal:

A. Do Nothing
B. Burning
C. Feed to Cattle
D. Other:

Managing Pastures/ Exercise Paddocks:

Is Manure removed from Pastures: YES NO

How often:

A. Daily
B. Weekly
C. Monthly
D. >Monthly
E. Other:________________________

Is Manure removed from Exercise Paddocks: YES NO

How often:

A. Daily

B. Weekly

C. Monthly

D. >Monthly

E. Other: ________________________

Are Pastures Harrowed/Dragged: YES NO

How Often:

A. Monthly

B. 3 Months

C. 6 Months

D. Other: ________________________

Are Pastures Fertilized: YES NO

When:

A. Spring

B. Fall

C. Summer

D. Winter

Evaluation of Pasture Quality (Overgrazing):

A. <25%

B. 25-50%

C. 50-75%

D. Healthy

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BIOGRAPHICAL SKETCH

Drew Cotton is a native of St. Joseph, Missouri. He grew up involved in the purebred beef business. His father, Terry works for the American Angus Association and his mother Sarah is a homemaker. Drew and his brother, Adam raised registered Herefords as their FFA and 4-H Projects. Drew attended Kansas State University where he was on the Intercollegiate Horse and Livestock Judging Teams. He received his bachelors in agricultural economics and moved to Gainesville, Florida where he served as a graduate student in the Animal Science Department at the University of Florida from 2004-2009. His responsibilities included coaching the Intercollegiate Horse Judging team.