ABSTRACT

SMITH, JODY CEPHUS, Chopped Bermuda Grass Hay as an Alternative Bedding Material for Rearing Market Turkey Hens (Under the direction of Dr. C. Mike Williams and Dr. Jesse L. Grimes)

Shortages of pine shavings used as bedding materials in the poultry industry are presenting economic challenges to poultry producers. Therefore, the purpose of this research was to determine if chopped Bermuda grass hay can be an alternative bedding material and to determine the effect of a microbiological agent, Microtreat P® (MP) on litter quality and bird performance. The microbiological agent used (Microtreat P®, AgTech Products, Inc., Waukesha, WI 53186) is a biological waste treatment product containing specifically selected bacteria. Experiments were conducted to determine the effect of chopped Bermuda grass hay and MP on turkey hens from 0 to 13 weeks of age. Turkey hens were housed in a curtain-sided house with 4 rows of 12 pens per row for a total of 48 pens. Six litter treatments were: 1) control-new pine shavings (P), 2) 50/50 pine shavings/hay (50), 3) 100% hay (H), 4) pine shavings treated with MP (PMP), 5) 50/50 treated with MP (50MP) and, 6) hay treated with MP (HMP). Feed and water were available *ad libitum* throughout the trial. The birds were fed 6 diets, each of which met NRC requirements. The following parameters were measured for bird performance: body weight, feed consumption, breast blister score, and foot pad blister score. Litter quality parameters measured include: litter nutrient analysis, litter caking score, litter pH, moisture content, ammonia, water activity, total bacteria, molds, total gram negative bacteria, coliforms, and *E. coli*.

The results showed that neither body weight nor feed conversion was affected by the use of chopped Bermuda grass hay. Additionally, treatments did not affect pH, breast blister, foot pad blister, litter caking, moisture content or water activity. Microbiological treatment

did not significantly affect the litter condition, except for total gram negative bacteria for MP at wk 6 which was significantly lower than non-MP pens.

In conclusion, this study has shown that Bermuda grass hay maybe suitable as a litter material for turkey hens. Further studies are needed to evaluate the use of biological litter amendments used on alternative litter types.

CHOPPED BERMUDA GRASS HAY AS AN ALTERNATIVE BEDDING MATERIAL FOR REARING MARKET TURKEY HENS

by

Jody Cephus Smith

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Co-chairman of Advisory Committee

BIOGRAPHY

Jody Cephus Smith, son of Shelly and Lucinda Smith, was born September 27, 1977 in Albemarle, North Carolina. He grew up on a family operated dairy farm in Norwood, NC. He graduated from South Stanly High School in Norwood, NC in 1995. After graduating high school he began to follow issues that affect farmers. He decided to attend North Carolina State University to further extend his knowledge of the agriculture industry. He received the Bachelor of Science degree in Animal Science in 1999 with a minor in Agriculture Business Management at North Carolina State University. He continued his studies at North Carolina State University for the Master of Science degree in Poultry Science with a concentration in Animal Waste Management under the direction of Drs. C.M. Williams and J.L. Grimes.

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General Introduction

The poultry industry in the US has increased significantly in the past decade. The states of Alabama, Arkansas, Delaware, Georgia, North Carolina, and Oklahoma produce more than one-half of the country's poultry products (Robinson and Sharpley, 1995). The production of broilers increased from 6.4 billion head in 1996 to 8.15 billion head in 1999 (USDA-NASS). Increases in production have resulted from improved feed conversion, genetics, management practices as well as consumer demand (Gupta and Krishnamurthy, 1990). Increases in production have also resulted in increased co-products such as manure. For example, broilers produce between 0.5 to 0.7 pounds of litter (bedding material and manure) per pound of market weight (Mitchell and Donald, 1995). This increased manure production creates environmental concerns; however, proper litter management can alleviate environmental concerns. There are many factors which one can address for successful litter management. Such factors include type of litter, time of the year, depth of the litter, floor space per bird, feeding practices, disease, and kind of floor, ventilation, and watering devices (Snyder et al., 1958).

Broilers are normally the benchmark for testing alternative litter materials and little research has been conducted in this subject area of the turkey industry. Growing market turkeys on alternative litter materials are historically considered more difficult due to high poult mortality rates, older-heavier birds (which cause litter to become wetter) and longer growout periods. The best birds to work with when experimenting with alternative litter types are (ranked in order of least critical to most critical): layers, pullet replacement (layers), heavy roasters, broilers, capons, and turkeys (Allison and Jordan, 1973). This review discusses litter characteristics, nutrient content, ammonia control, and the advantages and disadvantages of various types of litter used in poultry houses along with alternative uses of used litter material.

Poultry Litter

Poultry litter is a mixture of excreta, feed, feathers, and bedding material (Stephenson et al., 1990). This material has the potential to be either a pollutant or a resource (Chapman, 1996). Poultry litter may include feed additives, metabolic wastes, and topical pesticides associated with the bedding material (Gupta et al., 1997). Litter microbial contamination, including antibiotic-resistant populations and accumulation of metals and other elements, may also limit litter reutilization (Kelley et al., 1988).

Poultry litter is usually considered a waste product that is high in nitrogen, phosphorus, trace metals, and microorganisms. It has been recognized as perhaps the most favorable animal manure due to its high nitrogen content (Sloan et al. 1996). However, nitrogen in broiler litter is probably the most difficult nutrient to determine because some of the nitrogen is in the ammonia form (NH_4) and the rest is in an organic form (Mitchell and Donald, 1995). Poultry litter nitrogen is primarily in the form of uric acid in which microorganisms can readily decompose. This forms ammonia, which escapes into the air under favorable environmental conditions (Moore et al., 1996). Schefferle (1965) also stated that a large portion of readily mineralizable nitrogen consists primarily of uric acid, which is converted to urea by many aerobic bacterial: urea is then hydrolyzed to NH_4 and HCO_3^- by the enzyme urease (Kissel et al., 1988). Since poultry litter is normally stored outdoors before applying to land, losses of inorganic nitrogen may occur during storage (Cabrera and Chiang, 1994). Bitzer and Sims (1988) found that inorganic nitrogen comprises from 19 to

55% of the total nitrogen with NO_3^- resulting 0.2 to 19% of the inorganic nitrogen. Both NH_3 and NO_3^- losses are important because they reduce the value of litter as fertilizer (Cabrera and Chang, 1994).

Researchers have found that utilizing spent poultry litter has a large impact on poultry producers and farmers not only because of its value as fertilizer but because of the need to find alternative methods of disposal. Since most spent poultry litter is land applied, increases in soil nutrients to excessive levels have become prevalent. Broiler litter is removed after one or more flocks (Kelley et al. 1995). However, Moore et al. (1996) report that 5 to 6 flocks can be grown over a one-year period and then the used litter can be used as fertilizer. There are several factors that influence the loss of nitrogen and phosphorus from land applied poultry litter. Such factors are properties and management of the soil, land surface, method of application, timing of application, rainfall intensity, and duration (McLeod and Hegg, 1984; Westerman et al., 1983; Edwards and Daniel, 1992). Broiler litter reutilization is of economic and environmental importance to the poultry industry because it can reduce production costs and reduce environmental degradation associated with land application of poultry wastes (Kelley et al., 1994, 1995, 1996). Warden (1963) reported that land application of poultry litter was the most predominant method of disposal, but that adequate acreage was required for effective coverage to avoid applying too much nitrogen. In many cases choosing a cropping system that maximizes nutrient uptake is very important. Grasses are known to produce large amounts of dry matter and they are efficient nitrogen users, which aid in the efficiency to utilize nitrogen (Mitchell and Donald, 1995).

General Compositions and Environmental Concerns

Alternatives for reducing the environmental impacts of poultry litter include reusing litter as a livestock feed, as a fuel, for use in the horticulture industry, pelletizing/extrusion of the litter product, or by use of a phytase enzyme (Ritter, 2000). Each of these approaches are dependent upon the composition of the litter and each have various environmental concerns. The use of litter as a feed ingredient for the livestock industry has become increasing popular due to the extensive management requirement of applying litter to fields. Litter can be a viable source of protein, energy, and minerals for beef cattle. Gerken (1987) developed a ration in using deep-stacked litter along with corn silage for beef cattle feed. Prior to feeding it is essential to process the litter to kill bacteria and pathogens. There are three methods of utilizing manure as a fuel: direct combustion, as a substrate for methane production, and for production of a synthetic gas (Overcash et al., 1983). The horticulture industry can use litter after composting in a variety of ways: as a potting mix for the substitution of peat moss, in field production or landscape bed preparation as a soil amendment, and as an organic fertilizer (Ritter, 2000). This material needs to be composted to reduce odor, insects and pathogens associated with poultry litter. When litter is readily available and transport cost is not a factor, (less than 48 km radius) CABE (1991), pelletizing or extrusion methods can also be a viable alternative. This method allows other ingredients to be added that would increase the value of the product. One major disadvantage of this process is the cost of the process, which ranges from $30-60/ton (Ritter, 2000).

Poultry manure in many cases has changed from an asset to a liability (Johnson and Mountney, 1969). Land application of poultry litter may result in pollution of groundwater (Ritter and Chirnside, 1984). Water quality concerns about poultry waste handling, land application rates, and storage include pathogens, nitrates and phosphorus (Boyd, 1990). In areas of intense poultry production, over-fertilization of land with poultry manure occurs. This results in surface and ground water problems due to excess nutrient runoff and leaching of the soils (Mitchell and Donald, 1995) and also increases the degradation of surface and ground water resources (Edwards and Daniel, 1992; Sharpley et al., 1993; Sims and Wolf, 1994).

Nitrogen

Poultry litter has long been used as fertilizer in the agriculture industry. Due to intense concentration of animal agriculture in the US, nutrients especially nitrogen and phosphorus, are being monitored. Nitrogen compounds in poultry waste may contribute to environmental impacts because microbial metabolism converts these products into nitrates and ammonia gas (Holthuijzen, 1993). Sims and Wolf (1994) described four forms of nitrogen present in poultry manures and litter: complex organic nitrogen (constitutents of undigested feed and feathers); labile organic nitrogen (uric acid and urea); ammonical nitrogen (resulting from the enzymatic hydrolysis of uric acid and urea); and nitrate nitrogen, generally present only if the manure or litter has been stored under aerobic and moist conditions. Nitrogen contained in poultry litter is either removed by the crop harvest after land application, or leaves the animal production facility, lagoon, or application field as a gas (NH_3, NO, NO_2, N_2O, or N_2), or is transported in the liquid state as nitrate nitrogen by surface runoff or leaching into groundwater (Williams et al., 1999). The conversion of dietary nitrogen to animal product is often inefficient and 50 to 80% of the nitrogen consumed is excreted (Arogo et al., 2001).

Nitrate nitrogen from poultry litter can negatively impact the environment via eutrophication. Eutrophication is the enrichment of natural waters with limiting nutrients such as nitrogen and phosphorus, resulting in the increased growth of algae or other aquatic plant species (Williams et al. 1999). Nitrates originating from poultry manures have been shown to contribute to eutrophication (Liebhardt et al., 1979; Ritter and Chirnside 1987; Margette et al.,, 1989; Weil et al., 1990; Edwards and Daniel 1992). Nitrate nitrogen has also been a concern in cattle consuming grasses that have been fertilized by increased concentrations of poultry waste (Williams et al., 1999).

Ammonia production is the result of catabolic reactions of microorganisms in the litter (Turnbull and Snoeyenbos, 1972). Ammonia is produced by bacterial activity on organic nitrogen substrates (uric acid, urea, and undigested proteins in feces). Uric acid and urea are the primary sources of NH_3 in poultry (Arogo et al., 2001). Arogo et al. (2001) also noted that below a pH of 7.0, ammonia volatilization will not occur because the form of nitrogen is NH_4^+. Various factors affect ammonia volatilization such as pH, temperature, moisture content, litter type, bird density, and age of the birds. For instance, as temperature increases ammonia volatilization increases due to reduced solubility. Reece et al. (1981) and Anderson et al. (1964a) reported that high NH_3 concentrations are more common in the winter due to decreased ventilation rates to conserve heat in the poultry house. Ammonia volatilization has the potential to impact the environment in several ways. Concerns include nutrient deposition in nutrient sensitive environments and the formation of aerosols such as ammonium sulfate particles that has the potential to cause haze and impair visibility (Arogo et al., 2001). Normally, ammonia in the atmosphere has a short life span (0.5 h to 5 d) because of rapid gas to particle conversion of NH_3 to NH_4^+ and deposition to natural surfaces, particularly vegetation and wet surfaces (Fowler et al., 1998; Walker et al., 2000).

Moore et al. (2000) stated that high levels of ammonia in poultry rearing facilities could be detrimental to the health of the birds and to the farm workers. Carlile (1984) indicated the critical level of ammonia for poultry is 25 μL/L. The Control of Substances Hazardous to Health in Europe has set ammonia exposure for an 8 hour day at 25 μL/L and 35 μL/L for 10 minute exposure (Williams 1992). Ammonia volatilization often occurs in poultry litter and may cause high levels of atmospheric ammonia in poultry houses. High ammonia in poultry houses causes decreased growth rates (Carlile, 1984; Charles and Payne, 1966; Quarles and King, 1974; Reece et al., 1980), reduced feed efficiency (Carlile, 1984; Caveny and Quarles, 1978; Caveny et al., 1981), damage to the respiratory tract (Anderson et al., 1964b; Carlile, 1984; Nagaraja et al., 1983), a rise in Newcastle disease (Anderson et al., 1964b) increased incidence of airsacculitis (Kling and Quarles, 1974; Oyetunde et al., 1976), increased levels of Mycoplasma gallespticum (Sato et al., 1973), and increased incidence of keratoconjunctivitis (Bullis et al., 1950; Faddoul and Ringrose, 1950).

In an attempt to address nitrogen management, research has been accomplished to pelletize poultry litter, from a fine-screened fraction, and to test against litter that only has been screened to determine if litter is affected by physical characteristics. The pelleted litter is used to facilitate movement, as well to provide a uniform cover of litter onto the land, although it may have an affect on nitrogen mineralization, denitrification, and NH_3 volatilization (Cabrera et al., 1993). These researchers also found that total nitrogen and phosphorus was equal in both the fine particles as well as the pelleted litter, but the inorganic nitrogen was higher in the fine particle litter. Other studies have found that pelletizing poultry litter and mixing with commercial fertilizers has been a feasible alternative for land application (Cabrera et al., 1993). This application allows for easier handling, uniform application, more economical transport, and for transporting longer distances, which redistributes excess manure nutrients to areas where there is greater need for these nutrients (Hamilton and Sims, 1995).

Phosphorus

Phosphorus is also one of the prevalent nutrients of concern in poultry and livestock waste management. Sauer et al. (2000) concluded that a typical broiler house containing 20,000 birds produces 5-6 growouts per year and has an average total P content of 14.7 kg/Mg litter. Other livestock manure P concentrations include: 9.0 g/kg for dairy manure, 25.0 g/kg for poultry manure, 20.0 g/kg for poultry litter and 30.0 g/kg for swine slurry (Barnett, 1994; Gilbertson et al., 1979). In addition, the concentrations vary greatly as a function of diet, treatment, manure collection, and storage (Barnett 1994; Eck and Stewart, 1995). Ritter (2000) reported that during the 1980s and early 1990s it was believed that when manure containing phosphorus was applied to agriculture land, phosphorus would bind to soil. It was also thought phosphorus loses could be controlled by using soil conservation practices to prevent erosion (Ritter, 2000). Soil P can be characterized into four categories: soil solution P, this part represents the fraction of the P in the soil that is dissolved in soil water; labile soil organic P, which represents the soil organic matter P and the microbial P; stable organic P, which is resistant to mineralization; and inorganic P, which consist of crystalline and amorphorus P minerals and physically entrapped P within the soil structure (Coale, 1999). Changes in concentration among any of these four categories can alter the partitioning of P among the remaining pools (Ritter, 2000). The majority of the P loss is caused by soil erosion and runoff. Sharpley et al. (1992) found the major portion of P transported from cultivated land (60-90%) is correlated with organic matter and soil particulates eroded during runoff events. In conventional pasture lands or no-till fields most P loss is dissolved P. However, this type of P can exceed those in runoff from fields that has a higher erosion rate (Sharpley et al., 1992).

Eutrophication has been identified as the main problem in polluting surface waters in the United States (Sharpley, 1999). The inputs of phosphorus from all sources to fresh waters have been linked to harmful algae blooms of drinking water throughout several areas of the USA such as inland waters of North Carolina and Delaware, the Chesapeake Bay, New York City reservoirs and several lakes in Florida, Oklahoma, and Vermont (Burkholder and Glassgow, 1997; Sharpley and Tunney, 2000). Eutrophication can also be caused by nitrogen; however phosphorus is often the nutrient limiting algae growth (Schindler, 1977; Sharpley et al., 1994). Increases in phosphorus in fresh waters can cause an increase in the rate of eutrophication, which can lead to fish kills and algae blooms (Sharpley, 1999). Eighty to 90% of phosphorus runoff is in the soluble form (Edwards and Daniel, 1993). Algae, however, often do not use dissolved organic phosphorus unless it is hydrolyzed to inorganic phosphorus (Sonzogni et al., 1982). Many factors are being considered to attempt to balance the amount of phosphorus used both in agriculture farming and in animal production. The use of riparian buffers or vegetative filter strips (VFS) along side of streams and waterways may help decrease the amount of soluble phosphorus as well as carbon and nitrogen that leeches into the water system. Westerman et al. (1983, 1985, and 1987) and Edwards and Daniel (1993) found improper manure application could increase runoff concentrations of these constituents. If rainfall exceeds the infiltration rate, phosphorus released from the manure by rainfall may be transported in surface runoff (Sharpley et al., 1996). Srivastava et al. (1996) demonstrated VFS have been widely used for retaining pollutants at or near the point of origin therefore minimizing entry into downstream waters. They also recognized that VFS length along with a specific pollutant depends on the mass rate entry, which is a characteristic of the pollutant. Dickey and Vanderholm (1981), Edwards et al. (1983), and Dillaha et al. (1986, 1988) studied runoff from feedlots and found that VFS removed as much as 95% (on mass basis) of nutrients and oxygen-demanding nutrients from the incoming runoff. Srivastava et al. (1996) conducted an experiment to determine if (1) length of pollutant source area has any effect of VFS performance and (2) VFS length has any affect on VFS performance. The pollutants measured were nitrate N (NO_3-N), ammonia N (NH_3-N), total Kjeldahl N (TKN), ortho-P (PO_4-P), total P (TP), total organic carbon (TOC), total suspended solids (TSS), and fecal coliforms (FC). The researchers concluded that NO_3-N, NH_3-N, TKN, PO_4-P, TP, and TOC all exhibited a first-order exponential declining response to increasing VFS length. NO_3-N, TKN, and TOC concentrations did not decrease significantly beyond VFS lengths of 3 m. However, NH_3-N, PO_4-N, and TP runoff concentrations decreased up to a VFS of 6 m, beyond which there were no significant reductions. In summary, pollutant concentrations decreased with increasing VFS length, however mass transport was not affected by VFS length. Sharpley (1997) reported when there was an increase in the length of time between applying waste and surface runoff event there was a reduction in the amount of nitrogen and phosphorus runoff. These delays range from 1h to 3d after application. Westerman and Overcash (1980) found a reduction of these runoffs to be approximately 90%. Sharpley (1997) also stated that phosphorus is conserved in the litter-soil mix by sorption process: thus the decrease in phosphorus is due to a function of soil type as described by phosphorus sorption saturation.

Alternative Litter Materials

Most meat-type poultry are grown on dirt floors covered with some type of bedding material. These bedding materials include wood by-products, plant by-products and other waste by-products. Common products include pine shavings, recycled paper products, rice and peanut hulls, and other absorbent materials introduced into the poultry houses to facilitate moisture control and manure removal at the end of the grow-out period (Kelley et al. 1995). Oat hulls, corn cob litter, sand, diatomaceous earth, cocoa shells, chopped hay, peat moss, and bagasse (crushed sugar cane stalks) are other plant by-product litter materials used in the poultry industry (Snyder et al., 1958). Research has identified several characteristics that create an effective litter. These characteristics include a litter which is: dust-free, nontoxic, absorbent, difficult to consume, inexpensive, easily shipped and received, and plentiful (Brake et al., 1992). Malone (1982) also noted that the absorption of moisture was an important characteristic of litter materials. Other specifications noted, in order of their importance, include a litter that must be: absorbent of moisture, uniform in size (less than 0.16 cm in length), able to reduce moisture, and free of mold spores or disease-producing organisms (Allison and Jordan, 1968; Clark, 1971; Herbert, 1968; Reed and McCartney, 1970). Some other important litter considerations include: availability in quantities needed, no toxicity, ease in handling, use in manure as a crop fertilizer, affordability, and distance from processor to poultryman. In addition, if litter is used for layers, a litter with little or no staining effect should be selected (Allison and Jordan 1973). Howes (1967) and Scroggins (1971) concluded that prices for litter are calculated as follows:

per bird per weight or cubic volume of material delivered and/or applied in the poultry house, per weight of bird produced, or per square footage of area covered. Such characteristics as mentioned previously are important criteria in determining which bedding alternative is the most beneficial for the poultryman to consider. Litter moisture needs to be controlled. If litter moisture is not controlled, the moisture content becomes elevated and the litter becomes "sealed." Sealed litter is known as caking (Butcher and Miles, 1996). Caking causes birds to be grown on a surface which is sticky, slippery, and damp.

Softwood species including sawdust and pine shavings are the primary materials used as bedding materials, but the cost of these materials has been increasing due to the competition for these materials to make composite board (Malone, 1982). Pine shavings, the most common bedding material, is the bedding of choice due to performance and the abundance of the product. Reed and McCartney (1970) compared eleven potential litter materials: pine shavings, pine sawdust, pine bark, bark and chips, pine stump chips, pine straw, chopped pine straw, rice hulls, peanut hulls, ground corn cobs, and clay. They tested all the litter materials for eight physical properties including bulk density, moisture holding capacity, and drying rate. Results of the bulk density test were interesting in that it was shown before use that there was a great range in density from 2.3 lbs/ft^3 for pine straw to 35.9 lbs/ft^3 for clay, with pine shavings at 6.1 and sawdust at 13.2 lbs/ft^3, respectively. Malone et al. (1992) also determined that the bulk density of sawdust is twice that of pine shavings and it also has a greater moisture holding capacity. However, after use with three flocks of broilers, the range in density decreased with densities ranging from 17 lbs/ft^3 for rice hulls to 26 lbs/ft^3 for pine bark (clay was not tested after usage). After all testing, the authors ranked the litter materials as follows from best to worst: pine shavings, rice hulls, corn cobs, stump chips, pine sawdust, bark & chips, pine bark, and clay. Pine straw (long and chopped) and peanut hulls were not included in the final ranking. Pine straw was found to be especially lacking in that it caked over quickly. While bird performance is the ultimate test for a litter material, availability and cost also have a big impact when deciding which litter material to use.

Pine shavings and sawdust are often very difficult to distinguish between. Even though pine sawdust ranked 5th in the data produced by Reed and McCartney (1970), growers are continuing to use a lot of this material. Malone (1992) concluded that sawdust is second to pine shaving as a bedding material. The use of sawdust has emerged based on the decline in the quality and availability and increase in costs of pine shavings. As the quality of pine shavings declines, the amount of sawdust in the shavings usually increases. In many cases, the switch from shavings to sawdust has occurred without input, and in some cases in spite of input, from poultry growers or the poultry industry as a whole. For broiler production, sawdust has generally received a satisfactory grade. Many producers are resigned to using sawdust because it is available from shavings suppliers and is cost competitive. In many cases it is the only litter material available. In addition, broilers usually perform well although there are some incidences of litter consumption. Research has found that poultry may consume 3 to 5% of their diet in the form of bedding, which they prefer as small particles like sawdust (Kubena, et al., 1974; Malone et al., 1983). Peacock et al. (1984) established that chickens reared on small litter fractions were more likely to consume the litter therefore compromising feed conversion and weight gains. While it is usually possible, and desirable, to avoid hardwood shavings, hardwood sawdust mixed in with softwood sawdust is difficult to avoid or to even detect. In many areas of the country, growers are rearing their birds two or more years prior to clean out. After one or two flocks, many people can not differentiate between originally based sawdust and pine shavings. For turkey poult brooding, however, sawdust is not desirable because poults are more susceptible to litter consumption and are more susceptible to contracting aspergillosis from wood products, especially sawdust, compared to broiler chickens. However, in many cases, turkey growers are using sawdust, or pine shavings that closely resemble sawdust, because other materials are not available, including good quality pine shavings. Another type of bedding material that has been tested is the use of softwood chipping fines. Passing through a 1.11 cm screen creates these softwood chipping fines in an early processing stage of paper making. These fines are too small to be used in the paper making industry therefore creating a waste product. Parsons and Baker (1985) grew day old chicks to forty-nine days of age on the softwood chipping fines and found no difference in body weight or feed conversion compared to pine shavings. They also concluded one drawback of the softwood chipping fines is that it seemed to have higher moisture content; however there were 58% fewer breast downgrades and 64% more Grade A carcasses than those raised on pine shavings.

Hardwood species are used on occasion in the poultry industry; however this type of bedding can cause an increase in mold and has also been associated with Aspergillosis, particularly in turkeys (Dyar et al., 1984). Researchers also reported that breast blisters, litter caking, Aspergillosis, and other performance factors are related to bedding type (Chaloupka et al., 1967; Pope et al., 1969; Dendy et al., 1968; and Dick et al., 1976). In 1966, the amount of hardwood bark generated in the United States was calculated to be 14 million tons, dry weight basis (Mater et al., 1969). In 1973, there was roughly 200,000 green tons of unused hardwood bark in the state of South Carolina (Labosky et al., 1975). Much of this material is a waste product and since land disposal cost is so high alternative methods need to be discovered. Using hardwood bark in the poultry industry hopefully will reduce the disposal problem for sawmills and increase bedding types in the poultry industry. Hardwood bark has been an acceptable bedding material in poultry production due to a reduction in dust, mold, and caking with moisture content of 52% (Jordan et al., 1968). Allison and Jordan (1973) found the bulk density of hardwood bark to be 37 lbs/ft^3 at 50% moisture levels and Labosky et al., (1977) found bulk density to be 6.0 lbs/ft^3 at 13.2% moisture. The vast differences in bulk densities between the hardwood bark is due to the moisture content and the different kinds of bark used in the experiments. Brake et al. (1992) found pine shavings absorbed nearly twice the moisture as hardwood bark on a dry weight basis. However, planer shavings and hammermilled hardwood bark consistently showed elevated water-holding capacity as compared to the other litters, where pine shavings were the lowest (Labosky et al., 1977). Brake et al. (1992) concluded there were physical and chemical differences between hardwood bark and pine shavings, but these differences did not influence the effect of carcass quality. In conclusion, hardwood bark seems to be a satisfactory bedding product if the bark is dried to 50% or lower before placement of birds (Allison and Jordan, 1973). These researchers reported on field trials using bark under layers, pullet replacements, heavy roasters, breeder replacements, capons, and broilers and noted that birds reared on bark performed as well as birds reared on shavings. Thornberry et al. (1970) compared processed pine bark to pine shavings using 24,000 broilers, 10,000 broiler breeders, and 8,000 layer replacements. Broilers reared on bark were consistently heavier than those reared on shavings with no differences for breast blisters or mortality. Bark litter with particles sizes greater than one inch resulted in more litter cake. They concluded that, if properly sized, pine bark compared favorably with pine shavings as a litter material. However, particle size, moisture content (and, therefore, mold content) and the amount of wood splinters in bark can be major concerns (Allison and Jordan,1973; Labosky et al.,1977). When these issues are addressed and a supplier is educated on what is needed in the broiler house, bark might serve as a satisfactory litter material.

Carter et al., (1979) performed an experiment using green wood chips from standing pines, hardwood, and a 50/50 pine-hardwood mix to shavings as a bedding material. Each of the litter types were placed 10.0 cm deep. They reported that by the end of the trial shavings had settled down to 3.75 cm while the wood chip treatments only settled to 8.75 cm. Broiler performance was the same regardless of litter material. However, breast blisters were significantly increased for the broilers reared on the wood chips. The moisture of the shavings (10%) was lower than that of the chips (42%) at the beginning of the study but by the conclusion of the eight week growth period the litter moisture was the same (27%). Mold counts were also similar for the different litter materials especially by the end of the study. Parsons and Baker (1985) reported that broilers reared on softwood chipping fines, a by-product of paper manufacturing, had equal body weights and feed conversions compared to birds reared on pine shavings. They also had 58% fewer carcass downgrades and 64% more Grade “A” carcasses than birds reared on shavings. They also found there were no significant differences between feed conversion, weight, and mortality. However, Wisman and Beane (1965) found breast blisters to increase when the litter was 15.0 cm deep versus 7.5 cm and damp rather than dry. May and Noles (1965a) and Smith (1956) also found that wet litter had a greater impact on breast blisters than dry litter.

Wood pallets, a product used to ship goods, has become a potential waste disposal problem for many areas of the country. With the increasing rate of solid waste produced in landfills alternative methods of disposal are becoming an important aspect to target. In 1987 wood pallets estimated to produce 2.9 billion board feet of wood waste (White and McLeod III, 1989). McCurdy et al., (1988) estimated that the average wood pallet contained 13.9 board feet of lumber. This study evaluated several different properties of the pallet, which include; moisture content, moisture holding capacity, higher heating value, particle size distribution, ash content, and the level of chemical contamination. Chemical contamination can become a major problem if the pallets absorbed any of the chemicals on which they were hauled. If the pallets are then used as bedding material this could potentially have a detrimental affects on the poultry as well as leaving residuals in the tissues. White and McLeod III (1989) also compared shredded pallets to pine shavings and sawdust and reported that shredded wood pallets have good moisture holding capacity, an acceptable level of fines, and low levels of chemical contamination, which collectively should make this a material suitable for poultry bedding purposes. Nakaue et al. (1985) compared wood fiber pellets (65 mm diameter) and wood shavings as litter materials. There were no significant differences in broilers reared to 49 days of age for bird performance, ammonia levels, litter pH, or litter moisture. Pens with wood fiber pellets had less severe caking than pens with shavings. Godwin et al. (2000) reported on using a wood pallet product (LitterPlus®) as a broiler litter material. This product (LP) is made by grinding and processing wood pallets through a patented thermal friction process and then dried. Two trials were then conducted to compare the growth and performance of broilers reared on two depths (2 and 5 cm) of both pine shavings and LP. The second trial utilized the litter from the first trial top dressed with new material. A sample of birds from each pen was examined for breast blisters, foot pad blisters, and hock discoloration. In the first trial, birds reared on 2 cm of bedding regardless of type had significantly more hock discoloration than those reared on 5 cm of bedding. Pens with LP had more caking than those with pine shavings. There were no other differences in trials 1 and 2. The authors concluded that LP is a viable alternative to pine shavings as a bedding material, however, no commercial product is available at this time. Watkins (2001a) reported using a wood fiber by-product from paper manufacture. This material was used as a top dressing and as a sole litter source. All birds performed well on this material, however, the initial moisture content was quite high (68%). When placed in the brooder end and heated the moisture content decreased within nine days; but, when placed as a sole source of litter in the off brood end the material never dried to a satisfactory level causing increased caked litter and increased gas and electrical use. Currently, efforts are underway to determine if the material can be dried prior to placement.

Materials such as recycled sheetrock have been found to be an alternative for bedding (Wyatt and Goodman, 1992). This study was conducted to evaluate the utilization of recycled sheetrock as a bedding material and this product showed no significant influence on feed conversion, chick mortality, condemnations, or incidence of leg abnormalities. The study showed that the recycled sheetrock may be a better alternative if used as a topdressing with pine shavings than when used alone. In addition, recycled paper products such as processed paper, processed newspaper, processed cardboard, recycled paper, shredded newspaper, and chopped newspaper have been used as alternative bedding materials where smaller particle sizes are advantageous (Lien et al., 1992). These recycled paper products that are being utilized are cheap and readily available, which make them a viable source of bedding in the poultry industry. Production parameters such as feed conversion, body weight, and mortality were not affected by the treatments of recycled sheetrock (Lien et al., 1992). Malone (1982) reported that with high moisture and caking levels, paper-based products may be most practical when used as a base or used as a top dressing with other conventional wood-based beddings at relative low bird densities.

Recycled paper products may continue to increase in popularity as a source for poultry litter as interest in recycling waste streams continues and tipping fees for landfill disposal continue to increase (Lien, 1992; Malone, 1992). Considering reports that the use of some paper products result in high litter moisture and caking levels which can, in turn, result in increased breast blisters or other carcass defects (May and Noles, 1965b), it has been suggested that paper-based products might be most practical when used as a top dressing or mixed with other conventional wood-based beddings (Burke et al., 1993; Malone et al., 1982; Scheidler and Hawkins, 1991).

Recycled paper chips (RPC) have also been studied for use as bedding. Lien et al. (1992) reported on using RPC, which is a product of reprocessed waste newspaper, as a broiler bedding material. The particle size for this product was 40x10x3 mm. These RPCs, have been known to cause carcass defects such as breast blisters and leg abnormalities, however, growth or production parameters were not affected. Processing the RPC into smaller forms would allow a litter material to be more suitable for bedding in the poultry industry (Lien et al., 1992). Malone et al. (1982) also reported that recycled paper showed higher levels of moisture and caking than hardwood sawdust, although breast blisters were not increased. However, body weight and feed conversion had improved while using the

RPC. Litter caking was greater in trial one but not trial two for RPC. Lien et al. (1992) concluded that RPC are a viable alternative to shavings.

Burk et al. (1993) reported that shredded newspaper and wood shavings have also been studied as a possible alternative for wood shavings as a litter source. A primary concern associated with using shredded newspaper is the moisture holding capacity of the paper. The particle size of processed newsprint may also affect carcass quality and bird performance (Smith, 1956; Malone and Chaloupka, 1983). Malone and Chaloupka (1983) reported that particles sizes of less than 0.64 cm resulted in the best broiler performance compared to birds reared on sawdust or process newsprint with particle sizes 0.64 to 1.27 cm and 1.27 to 2.54 cm. Malone et al. (1982) found broiler growth was improved while using shredded newspaper as a bedding material, but due to the high levels of caking, shredded newspaper may not be a practical source of bedding.

The use of chopped computer and bond paper mixed with wood shavings has also been studied. Martinez and Gernat (1995) found no effect on weight gain, body weight, feed consumption, or mortality among the treatments used. They also found that if wood shavings were added to computer and bond paper it would make a suitable source of bedding as long as there was good water management involved, which leads to decreased caking of the litter. Malone and Chaloupka (1983) and Malone et al. (1982) reported that birds reared on paper-based litter had significantly higher feed efficiency and body weights compared to those grown on wood shavings.

Processed cardboard has also been studied as bedding material. Several different treatments of processed cardboard have been used to find a bedding material that may be used for litter. Sawdust, shredded newspaper, and processed newspaper were all used in an experiment by Malone and Allen (1982). They reported that processed cardboard is not a suitable litter due to litter caking, decreased broiler growth, and increased incidence of breast blisters.

Grimes et al. (2001) and Carter et al. (2000) reported on studies using a bedding material manufactured from agriculture residue and old newsprint (ARNP). Two studies were conducted with male broilers. The first study examined the use of three formulations of ARNP at two depths (5 and 10 cm) compared to pine shavings at 10 cm. The second study was conducted over three flocks and examined ARNP at different pH levels (low, neutral and high) as well as with and without plastic liners and a liner made from the ARNP material. There were no differences in 42 day body weight in study one (6.48 lbs) or 49 day body weight for the three flocks in study two (6.66 lbs). There were also no differences for ammonia levels, mortality, fed conversion, breast blister index, hock condition index, or foot pad condition index. In some instances, the ARNP had a higher incidence of litter caking. However, under commercial conditions with forced air ventilation, this might not occur. Therefore, field trials utilizing ARNP as a litter material are needed.

As noted previously, there are many other sources used as bedding material, including by- products from the agriculture sector where these products are readily available. Examples include; oat hulls, corn cobs, peat moss, stazdry, bagase, and rice hulls. Oat hulls are generally used as a litter source when oats are inexpensive and when there is little use of the oats in a ration. Oat hulls seem to be nearly a dust free litter, however they have a low absorption capacity. Corn cobs, another alternative litter source, are normally used in areas where there is a lot of corn produced so that the abundance of cobs is high and easily accessible. Corn cobs need to be cut to a size a slightly larger than 0.5 cm to eliminate breast blisters in the bird. Screening to remove the fine particles can reduce dust in the corn cobs. Smith (1956) found that corn cobs caused more breast blisters in chickens than finer ground corn cobs approximately 0.96 cm in diameter. Corn cobs have a high absorption capacity, but when the cobs become oversaturated they are known to mold which can cause problems in the house and affect bird health (Snyder et al., 1958). Peat moss can be used as a litter source where peat is at low cost and in states where peat is readily available (Enueme et al., 1987). Peat moss is also very dusty although it has greater absorptive capacity than any other litter on the market (Snyder et al., 1958). Bagasse, another litter source, is very fluffy and is difficult to pack down. Although this material does not have a high fertilizer value, it has a long life span (Snyder et al., 1958). It is highly absorbent but has been described as having a tendency to cake easily in one case (Ruszler and Carson, 1974) while in another report it is characterized as drying readily (Watkins, 2001b). Watkins (2001b) reported that bagase had greater moisture initially compared to shavings, but bagase dried to a lower moisture level than shavings after only one flock of broilers. Broilers reared in two trials performed as well on bagase as those reared on shavings (Watkins, 2001b). As with most litters, management is obviously very important. Heating during cool weather and adequate airflow during warm weather will facilitate the drying of many litter materials.

Clay and clay products have also shown to be useful as a litter material. Reed and McCartney (1970) ranked clay 8th out of 11 potential litter materials tested but included clay as being acceptable as a poultry bedding material. Andrews and McPherson (1963) included clay in the evaluation of seven potential litter materials. They reported that pens with clay floors had no litter caking after eight weeks of broiler growth while other organic litters had significant caking. Malone and Martin (1999) studied a clay-based litter material used in three broiler trials. The product contained both clay (35%) and cellulose (50%) in addition to calcium carbonate (12%) and titanium oxide (3%). In pen broiler trials the clay product resulted in significant increases in body weight in two out of three trials. Feed conversion and mortality were significantly increased in one trial. The average in cake area in the pens was decreased for all three trials. There were no differences for ammonia, feathering score, or foot-pad score. The authors concluded that more research was needed to evaluate different forms of the clay product under different litter management programs.

Rice hulls basically fall into the same category as pine shavings in that they work well and are readily available in certain areas of the country. As previously stated, Reed and McCartney (1970) ranked rice hulls immediately behind pine shavings as a desirable bedding material. Morgan (1984) reported that broilers reared on rice hulls performed as well as broilers reared on pine shavings and that rice hulls were as easy to manage as shavings. Rice hulls can be mixed with pine shavings or used alone (Watkins, 2001a). Rice hulls also serve as a good litter material for turkey production (Hester et al., 1987; Hester et al., 1985; Veltmann et al., 1984). Ground rice hulls have been reported to cake over and adhere to the toes of turkey poults. This was associated with an increase in poult mortality; however, after about three to four weeks of age the birds began to scratch the litter breaking up the cake (Veltmann et al., 1984). However, birds with trimmed toes or no toenails might have a problem breaking up caked material. Rice hull ash is also receiving some attention as a litter material. Chamblee et al. (2000) found no performance problems for broilers reared on rice hull ash or a mixture of ash and shavings compared to shavings alone. This material has a granular consistency and is mostly silicon dioxide (60%) and carbon (35%) and, therefore, has a black sooty appearance. This resulted in some black discoloration of feathers, shanks, and feet. However, no problem was noted with carcass quality as all of the black material was removed during processing. Unfortunately, as with the timber industry and pine shavings, the rice industry is finding more profitable avenues for rice hulls other than usage as poultry litter (Watkins, 2001a).

There have been numerous other plant by-products tested as litter material including: kenaf core (Malone et al., 1990), coca bean shells (Chaloupka et al., 1967), cotton by-products (Gyles and Andrews, 1964), corn stalks (Malone, 1992), citrus pulp (Harms et al., 1968), peanut hulls (Chaloupka et al., 1967; Lacy, 1991), soybean stalks (Morgan, 1984), and wheat bran (Gyles and Andrews, 1964). While many of these materials performed to various levels of satisfaction most have not received large-scale commercial adoption for use as litter. The exception would be peanut hulls. Peanuts hulls can be managed as a satisfactory litter material (Lacy, 1991) and are used in regions of the U.S. where peanuts are grown.

Kelley et al., (1995) found that re-utilization of a stored, coarse litter fraction (litter particles <3.33 mm) as a supplement for wood shavings bedding in broiler houses did not significantly increase pathogens and indicator microorganisms in litter compared to that of wood shavings. However, the researchers found significant increases in concentration of pathogens and indicator microorganisms in litter 40 days after re-utilization. Initial litter microorganisms were higher in fresh litter than in wood shavings or stored litter, but there were no consistent significant differences in fresh, stored, or wood shavings found during re-utilization.

Deep stacking of litter, which is an incomplete composting process, can eliminate *E. coli* and *Salmonella* providing that the internal stack temperature reaches 140 to 160^{o} F (Carter and Poore, 1995). Re-spreading the stacked litter and allowing it to dry would be expected to extend litter life. Some broiler producers are simply removing cake and excess litter after house washing and then placing broilers on old litter for an extended number of flocks (personal communication with producers). Their expectation is that total clean out is not needed unless there are diseases or other bio-security issues. However, producers doing this should be aware that total disinfection under these conditions might not be possible. Grimes et al. (2000) conducted a study to determine if heat-treated turkey litter can be reused as a litter material. Pine shavings, which had been used for one flock of tom turkeys from hatch to 20 weeks of age was heat processed at either 204 or 427^{o} F in an enclosed system. The heat-processed litter was then used to rear turkey hens to 14 weeks of age with three litter treatments compared to clean pine shavings. The treatments were 1) new pine shavings, 2) litter processed at 204^{o} F, 3) a 70:30 mixture of litter treated at 204 or 427^{o} F, and 4) a 95:5 mixture of litter processed at 204 or 427^{o} F. There were no differences in body weights (19.1$\pm$0.16 lb) or feed conversion (2.22$\pm$0.04). The authors concluded that heat processing of used turkey litter provides for a litter equal to new pine shavings. However, this process has not been scaled up to a commercial level to date.

Sand as a litter material is not new to poultry production (Snyder et al., 1958) yet it is receiving renewed interests, especially in the southern U.S. (Hess et al., 1996). Bilgili et al. (1999) reported successful rearing of several broiler flocks on sand compared to pine shaving in a research setting. They noted that male broilers were significantly heavier with no differences in female weight. There were also no differences in feed conversion or mortality. Initially sand moisture levels were higher but there were no differences after several weeks. Ammonia levels were also not different. Coliform bacteria, including *E. coli*, and aerobic plate counts were lower for sand than shavings in the one trial where litter microbiology was determined. Carcass grade and paw (foot) quality were not affected. Further studies were conducted in the field under commercial conditions (Bilgili et al., 2000; Hess et al., 2001). In multiple tests, broilers reared on sand performed as well as those reared on pine shavings. Foot pad quality and male broiler body weights were improved when reared on sand in some cases. Moisture and ammonia levels were similar to pine shavings with significantly lower levels of bacteria in the sand litter compared to shavings. Darkling beetle populations are reduced with sand litter. Growers using sand also wash the house once birds are marketed, the cake litter is removed thoroughly, sand added if needed, and then houses are set up for the next group of birds. However, this practice is not universal and may or may not prove to be practical. Certainly, sand litter would have to be totally removed in cases of disease out-breaks or if performance shows signs of a drop-off. Sand is currently under review in several areas of the country other than the south, with mixed results (Malone et al., 2001a; Malone et al., 2001b; Watkins, 2001a). While broiler performance was similar or better, in some cases, than for broilers reared on litter, some issues raised included poorer chick starts on sand compared to shavings and dustier air conditions. Other issues include sand used as litter is not cost effective for all farms, the economics of using sand may depend on location of sand versus the farm, and sand is not compatible with composting, combustion, or pelleting. Continued field trials will help determine the best management guidelines for using sand as litter.

Straw, refers to any grass stubble material from any grain type plant including, wheat, barley, rye, oat, flax, and Bermuda grass. However, wheat straw is by far the most commonly used as a litter material. Straw is often viewed as a questionable litter product due to its characteristics (Andrews and McPherson, 1963; Chaloupka et al., 1967; and Nakaue et al., 1978). It has been described as difficult to manage and prone to caking (Malone, 1992). However, straw is being used successfully on a commercial basis in several areas of the country. Nakaue et al. (1995) produced a video on the proper use and management of grass straw in Oregon and Washington. As in many areas, sawdust has been the primary litter material in the recent past. However, the decline of the timber industry in that area of the country along with increased usage of shavings for other purposes or markets put increased pressure on the cost and availability of sawdust and shavings. Recently, public pressure resulted in substantial legislative mandated reductions in field burning of grass stubble. Therefore, the grass industry in the two states was forced to find uses for approximately one million tons of straw annually. The use of chopped grass straw as broiler litter has been evaluated under research and field trials at Oregon State University. Some recommendations on the use of the straw include:

- Straw should be chopped to one inch or less,
- Straw is best used as a top dressing over old litter,
- 1000 lbs of straw over old litter saved 15 ft^3 of sawdust,
- Chopped grass straw is a very effective litter material,
- Straw is cheaper than sawdust,
- Growers may need to run more gas brooder time to keep straw dry,
- Length of straw is more important than type of straw,
- If the straw is to long it will bridge (mat over) quicker, and
- Payback on using straw is quick (Nakaue et al., 1995).

Straw does not have the best physical characteristics, although it has a good fertilizer value. Further processing of the straw may be an additional step in using straw as a bedding material. Producers have found straw may be a better absorbent material if it gets rained on one time to wash off the waxy coating on the exterior surface of the straw shaft. Straw is normally taken from the field via round bales or square bales of hay. These bales range from 18 to 453 kg respectively. Approximately 18,144 kg of chopped straw are required for a 20,000 ft^2 house. Optimum performance from straw may work best when used half and half with shavings or some other type of bedding material. Link (2002) stated that straw is being used as a successful litter alternative for raising commercial turkeys. It is a common practice in turkey production to move starter or brooder house litter into the grow-out house. In this operation, straw is not used in the brooder house. As in the Oregon case studies, all of the straw comes from local sources. In eastern North Carolina, hog lagoon effluent is sprayed on Bermuda grass hay fields to utilize hog manure nutrients. However, there appears to be more hay produced than can be utilized. It is not uncommon to observe large bales of unused hay accumulating and deteriorating around these lagoon spray-fields.

Alternative litter materials will continue to be researched and evaluated. Comparisons to pine shavings or sawdust will probably continue as the benchmark test. However, while bird performance will always be a threshold criterion, cost and availability as well as environmental impacts will ultimately determine the adoption of a new or alternative litter material by poultry growers and the poultry industry.

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Manuscript: Effect of Using Chopped Bermuda Grass Hay as a Litter Material and a Microbiological Litter Treatment for Rearing Turkey Hens

ABSTRACT

An experiment was conducted to test the hypothesis that Bermuda grass hay can be used as an alternative for rearing commercial turkeys. The objectives included determining if Bermuda grass hay was suitable as a litter material for rearing female turkeys and a critical evaluation to determine the effect of a microbiological agent, Microtreat P®, (MP) on litter quality and bird performance. Turkey hen poults were housed in a curtain-sided house with 48 pens (30 birds per pen). The experimental design was a 2 X 3 factorial with a completely randomized block design with 2 levels of a microbiological agent and 3 litter treatments. Each treatment was replicated in each block, 8 replicates per treatment overall. Six litter treatments were: 1) control-new PS (P), 2) 50/50 PS/hay (50), 3) 100% hay (H), 4) PS treated with MP (PMP), 5) 50/50 treated with MP (50MP), and 6) hay treated with MP (HMP). The density of PS and hay were: 13.7 and 5.5 lbs/ft^3 – loosely packed, 16.9 and 7.3 lbs/ft^3 – packed, and 18.9 and 9.8 lbs/ft^3 – tightly packed. Data were recorded on a pen basis. The following bird performance parameters were measured: body weight, feed consumption, foot pad blister score, and breast blister score. Litter performance parameters include: litter caking score, litter nutrient analysis, litter pH, water activity, moisture content, ammonia, total bacteria, molds, total gram negative bacteria, coliforms, and *E.coli*.

Results showed that bird performance was not affected by the treatments. Additionally, treatments did not affect litter caking, body condition, pH, moisture content, or water activity at the end of the study. Microbiological analysis showed no significant treatment impact on litter condition, except that total gram negative bacteria for MP at wk 6 were significantly lower than non-MP treatments. It was concluded that Bermuda grass hay

is suitable as a litter material for turkey hens, especially during the brooding period. Continued study of biological litter treatments used in the poultry industry and how they affect alternative litter material quality may be beneficial.

INTRODUCTION

The poultry industry has grown tremendously in the past twenty years. Poultry is one of the largest agribusiness industries in the southeast US, generating more than 25% of the agricultural income (Thompson and Merka, 1992). This industry has typically concentrated itself geographically to increase efficiency. While this concentration can reduce production cost; a concentration of litter waste will also be generated. Poultry litter is a combination of bedding material and manure. The litter waste is typically land applied. As such, a greater amount of land is needed for land application of the waste material produced. Most poultry produced in the United States, except table egg chickens, are reared on some type of bedding material. Typically in North Carolina pine shavings are the bedding material of choice due to its availability and the performance birds achieve on this medium. However, shortages in pine shavings and an increase in cost are anticipated to become more prevalent as new and more economical uses for pine shaving are developed. This leads to a search to find alternative litter materials that may equal or exceed the performance of pine shavings. Many factors are examined when determining if a litter alternative is feasible in the poultry industry. One of the major factors in finding alternative litter materials is the proximity in which the product is produced and how economically the material can be transported to the poultry farms. Since there are limited options in regard to extended waste by-products in the animal industry, using products from one animal production sector for another greatly improves waste management practices in North Carolina. Currently, liquid swine manure produced in North Carolina is irrigated onto fields to grow Bermuda grass hay. However, more hay is being produced than can be utilized, and it is not uncommon to observe large bales of unused hay accumulating and deteriorating around lagoon spray-fields. Since poultry have been successfully reared on other types of chopped straw, the hypothesis in this study is that chopped Bermuda grass hay produced as a by-product may have the potential to serve as an alternative poultry litter material.

The use of litter amendments in the poultry industry has become increasingly important since poor litter quality factors, such as high levels of ammonia and moisture, can lead to decreased bird performance and carcass downgrades such as foot pad, hock, and breast burns and blisters (Smith, 1956; Charles and Pain, 1966; Quarles and King, 1974; Reece *et al.*, 1980; Caveny and Quarles 1978; Caveny *et al.*, 1981; Anderson *et al.*, 1964; and Nagaraja et al., 1983). While there are several different types of litter amendments available, Microtreat P® is a biological waste treatment product that utilizes the activity of specifically selected bacteria to control the decomposition of poultry litter. Biological litter treatments offer the potential to provide a cost effective alternative to current litter treatments for poultry litter quality control, however, their efficacy has not been well studied. The objective of the current study was to determine if chopped Bermuda grass hay could serve as an alternative litter material equal to that of pine shavings with and without the addition of Microtreat P® as a litter amendment.

MATERIALS AND METHODS

Day of hatch, Large White Hybrid female turkey poults were obtained from a commercial hatchery. These poults were housed in a curtain sided house with 4 rows of 12 pens per row for a total of 48 pens. Each row of 12 pens served as a block. The dimensions of each pen were approximately 64 ft^2. The experimental design was a 2 X 3 factorial arrangement with a completely randomized block design with 2 levels of a microbiological agent, Microtreat P® (MP), 0% or 100% of agent, and 3 litter treatments: Bermuda grass hay, pine shavings (PS), and a 50/50 mixture. The six litter treatments were: 1) control-new PS (P), 2) 50/50 PS/hay (50), 3) 100% hay (H), 4) PS treated with MP (PMP), 5) 50/50 treated with MP (50MP), and 6) hay treated with MP (HMP). Each treatment was replicated twice in each block, 8 replicates per treatment overall. Bermuda grass hay was collected in 800-1000 lb bales from a swine facility in eastern North Carolina. The bales were un-rolled, the hay chopped with a silage cutter into 0.5-1.0 inch lengths, and then stored in a commodity shed for two weeks until use. New pine shavings were obtained from a lumber mill and also stored in a commodity shed until use.

Natural air movement through curtain sides and stirring fans located throughout the house provided ventilation. Brooder lamps were placed in each pen for supplemental heat while room temperature was controlled by space heaters. For the first 2 weeks house temperature was 26.7°C, and then decreased as the birds grew. The birds were grown on 24 hours of light for the first 7 days and on natural day length light through 13 wk. Feed and water were provided *ad libitum* throughout the duration of the study. The birds were fed 6 diets, each of which met NRC requirements (Table 1).

Litter Sampling Procedure

Litter samples were collected from nine places per pen each collection time. The sampling areas are described as follows: 3 samples were taken from the front of the pen, 3 in the middle, and 3 in the back of the pen. These 9 samples were pooled, mixed thoroughly and placed in gallon Ziplock® polyethylene bags. Composite samples were obtained by mixing the same treatment pens together for each block for a total of 24 samples.

Microtreat P® Application

Microtreat P® was applied at 1 and 6 weeks of age. The application of MP is dependent upon expected manure production, which is determined by the type and age of the bird. At week one, 30 grams of MP and week six, 120 grams, of MP was thoroughly mixed with 12 liters of deionized water. Five hundred milliliters of solution was sprayed into each MP pen. Per manufactures specifications this freeze dried bacteria was rehydrated prior to use and was allowed to thoroughly dissolve and rehdrate for 10 minutes prior to use. The solution was sprayed directly onto the birds and the litter in each of the MP pens. The same volume of deionized water was also sprayed into each of the non-MP pens so all pens would be obtain the same amount of moisture.

Body weight and Feed conversion

Birds were weighed at 0, 3, 6, and 13 wk of age. Culled birds and mortality were accounted for to adjust feed conversion.

Litter Caking

Caked litter was removed from pens at wk 8, wks 8-13, and wk 13. Total cake removed was calculated at the end of the trial. A pitchfork was used to remove the caked litter from the pens. The amount of litter removed was weighed on a pen basis. Additional, new bedding was added to pens on an as-needed basis only.

Body Scoring

Body scoring (foot pad and breast blisters) was performed at 13 wks. Five birds chosen at random were analyzed for body scoring. Body scoring was performed on a subjective system. Foot pads were scored on a 0-4 scoring system. Zero being no discoloration or burn present. One through four was scored on the degree of burn of the foot pad: 1) 25% burn, 2) 50% burn, 3) 75% burn, 4) 100% burn.

Breast blisters were also scored on a subjective system. Each bird was scored on a 0-3 basis. No indication of breast blister received a 0; 1 = a slight thickening of skin over keel, 2 = a definite breast blister condition with a slight accumulation of fluid under skin, and 3 = a severe breast blister with a large accumulation of fluid under skin.

Nutrient Analysis

Nutrient content of the litter was analyzed prior to placement and at 6 and 13 wks of age. This assessment was performed at the North Carolina Department of Agriculture Agronomic Division, (Waste Advisory Section, Reedy Creek Rd., Raleigh, NC). Analysis included total nitrogen (N), inorganic N, ammonium N, nitrate N, organic N, urea, and phosphorus.

Microbiological Analysis

Enumeration of bacteria was conducted at 0, 6, and 13 weeks of age. Bacteria were also enumerated by AgTech Products, Inc. at 6 and 13 weeks of age. Six grams of each composite litter sample was transferred into sterile whirlpak bags and 54 ml of 0.1% peptone solution was added for a 1:10 dilution. The sample was thoroughly masticated (IUL Instruments, Tekmar-Dohrmann, Cincinnati, OH 45242) for approximately 90 sec. Contents of this bag were allowed to settle for 2 to 3 minutes. One ml of this sample was serial diluted (1:10) into test tubes containing 9.0 ml of 0.1% peptone water to the appropriate dilutions for duplicate plating. The following media were inoculated: tryptic soy agar (TSA), potato dextrose agar, (PDA), MacConkey agar, (MAC), (Difco Laboratories, Detroit, MI). These media yield: TSA-total bacteria, MAC-coliforms, and PDA-molds. TSA and MAC plates were inoculated by spiral plating (Spiral Biotech, Autoplate 4000, Bethesda, MD) 50µl aliquots onto each duplicate plate. These plates were incubated at 37ºC for 24 hours. PDA plates were inoculated by spread plating 0.1ml aliquots onto each plate. Plates were incubated at room temperature for 5 days. Counts of colony forming units (CFU/ml) were determined for the bacteria and mold. TSA and MAC were enumerated by Autoplate 4000 Colony Counter Version 2.06 (Spiral Biotech, Inc, Bethesda, MD). AgTech Products, Inc. inoculated the following media: total gram negative agar (TGN), violet red bile agar (VRBA), and CHROM agar. These media yield: TGN-total gram negative, VRBA-coliforms, and CHROM-*Escherichia coli* (*E. coli*).

Water activity and pH

Water activity, an indicator of unbound or available water in litter, was analyzed (AgTech Products, Inc) at 6 and 13 weeks of age. Water activity has been determined to be a useful measurement because it describes the amount of water available for microbial growth. Water activity is measured on a scale from 0-1, with 1 being the highest degree. Litter samples were analyzed for pH at 0, 6, and 13 weeks of age. For pH analysis, ten-gram samples of litter from the composite were placed into a whirlpak bag and 100.0 ml of distilled water was added. The sample was thoroughly masticated for approximately 90sec. The pH probe was then placed in the solution allowing the reading to stabilize. Five pH readings were performed to obtain an average sample value. The pH was measured using a Fisher Scientific Accumet® pH/ion Meter 25 (Fisher Scientific, Norcross, GA 30091) and a Accumet® pH electrode (Fisher Scientific, Norcross, GA 30091). Fisher pH 4 and pH 7 standards were used for calibration, after which a standard was checked every 12 samples.

Moisture content

Moisture content of the litter was analyzed at 0, 6, and 13 wks. Two gram sub samples were placed in an oven at 100°C for 24 hours. Samples were placed in a desiccator and allowed to cool for 15 minutes. The samples were weighed and then placed in the oven for an additional hour. Subsequently the samples were removed from the oven and allowed to cool in the desiccator. Samples were weighed a second time to determine if there was a change in moisture content.

Ammonia

Pens were sampled for aerial ammonia concentration at 6 and 13 wks. The samples were performed in one pen per treatment per block for a total of 24 samples (6 samples per block). An inverted 5 gallon bucket was used to trap the air for one minute, subsequently a paddle inside of the bucket was turned 5 times to ensure air mixing. Samples were measured by a Dräeger Accuro-Gas Detector pump using Dräeger Ammonia 5/a tubes. These tubes have a detection range of 5-70 ppm.

Statistical Analysis

All data were analyzed using the General Linear Models procedure of SAS® software (SAS Institute, 1990). Differences between means were tested using lsmeans and were considered statistically different at ($P \leq 0.05$) unless otherwise stated. All microbial counts from litter samples were transformed to Log_{10} prior to statistical analysis.

RESULTS AND DISCUSSION

No differences in body weights were measured throughout the trial except at wk 6 (Table 2). At week 6 there was a litter by MP interaction. Birds on 50 and HMP had significantly higher body weights than birds on H. Feed conversion (Table 3) did not show any difference throughout the trial and were consistent with industry standards. This is consistent with earlier studies, e.g. in 1967, Chaloupka et al. tested a variety of litter materials including cocoa bean shells, ground polystyrene, a mixture of equal parts of the two, chopped barley straw, with pine shavings as control and found no unfavorable effects on growth, feed conversion, or mortality. Nakaue (1992) found there were no differences in feed conversion on poultry raised on chopped grass.

Caking of litter is defined as the layer of droppings and moisture over the surface of the litter (Ruszler and Carson, 1974; Labosky et al., 1977). Litter caking values fluctuated in this trial according to type of litter and age of the birds (Table 4). Litter caking was monitored and cake was first removed at wk 8 of the trial. Caking of litter increased as the moisture levels in the pens increased and occurred in all pens. However, certain litter types built up more cake than others. At wk 8, birds on P had significantly lower cake than birds on hay or 50/50. There was no MP difference throughout the trial. However, there was a litter by MP interaction. At wk 8 birds on 50MP had significantly lower cake than HMP. Birds on HMP had significantly higher cake than birds on P, H, PMP, and 50MP. The interaction between litter type and MP showed pine and 50/50 with MP resulted in a decrease in litter caking, however hay with no MP had significantly lower litter caking values than with MP being 28.1 kg and 42.5 kg, respectively. Between wks 8-13 litter caking was significantly different by litter and by litter by MP interaction. Pens with hay had significantly more cake than those with pine, cake was also higher for pens with 50/50. For the litter by MP interaction HMP was significantly higher in cake than treatments P, H, PMP, and 50MP. As observed during wk 8 the MP interaction resulted in no significant difference between pine or 50/50, however, hay with no MP had significantly lower litter caking values than MP with numerical values of 108.1 kg and 150.7 kg respectively. Week 13 showed a litter by MP interaction. Birds on 50 and HMP were significantly higher in cake than birds on H and 50MP. Total litter caking showed no significant difference for litter or MP, however there was a litter by MP interaction. Birds on 50MP were significantly lower in cake than birds on 50 and HMP. Birds on HMP were significantly higher in cake than birds on P, H, PMP, and 50MP.

Body scoring, including breast blisters and foot pad blisters, was minimal during this growout trial (Table 5). On the subjective scale, breast blisters received a grade of 1. Using turkey hens as a model, this grow-out trial showed no sign of breast blisters at wk 13. Reed and McCartney (1970) considered breast blister incidence one of the parameters in deciding if a litter material is acceptable in the poultry industry. Increase incidence of breast blisters has been noted to be higher in damp litter conditions than dry. Studies reported by Wisman and Beane as early as 1965 shown wet litter conditions had an effect on breast blisters. These findings were also in agreement with May and Noles (1965) and Smith (1956). Martland (1985), Abott et al. (1969), Harms and Simpson, (1977), and Harms et al. (1977) discovered wet litter has been shown to cause scabby hocks and breast blisters in turkeys and broilers. Foot pad blisters however, showed higher degree of burns. Foot pad scoring in the current study showed that there was a significant interaction effect (Table 5). Birds on hay had the lowest degree of foot pad burn, which was significantly lower than birds on HMP. Birds on hay did not have any MP applied while PMP, 50MP, and HMP contain this agent in the litter. Birds on HMP had significantly higher scores than birds of P and H. Harms and Simpson (1975), Schmidt and Lüders (1976) reported that foot pad burns were more severe in heavier birds and rarely seen in female turkeys. Martland (1985) found that birds transferred from wet to dry litter conditions recovered quickly with healing of the foot pad and as a result foot pad blisters and breast blisters were not a significant problem throughout the trial while keeping wet litter to a minimum.

Understanding the nutrient values of alternative litter materials will determine if the end product can be used as a fertilizer material, and if so what amount would be considered optimal for plant uptake. In this trial, nutrient analysis was performed on all treatments (Tables 6, 7 and 8). There were significant differences at wk 0 on all nutrient analysis performed, therefore differences were taken into account when comparing values throughout the trial. These differences were due to the different types of litter materials used in this study. As such, when determining wk 6 and 13 values, differences were obtained by subtracting wk 0 differences from wk 6 and wk 13. The results show that litter values were significantly different at wk 0 with hay being consistently higher on all parameters measured.

At wk 6 (Table 6) litter total N for hay (2.27%) and 50/50 (2.08%) were significantly lower than pine (3.81%). This supports previous results reported by Andrews and McPherson (1963) who concluded that the total nitrogen content of broilers raised on oak straw to be 5.46% and shavings averaged 4.95%. As early as 1944, White et al. also reported hen broiler litter at 6.35 months was 2.79% total nitrogen. Parker et al. (1959) analyzed broiler litter samples from 82 farms and found the litter contained 2.27% total nitrogen. Yushok and Bear (1943) found hen litter to be 1.43% total nitrogen. Litter treatments without MP at wk 6 had a significantly higher effect on total N (32129ppm) versus no-MP (22315ppm). Hay was significantly lower in total N at wk 13 than pine and 50/50. Total N for wk 13 showed significantly lower levels for MP versus MP not applied to the litter. Inorganic N (Table 7) at wk 6 had a litter effect with all three litter types being significant, hay (1039.5ppm) being the lowest followed by pine (1371ppm) and 50/50 (1823ppm). Inorganic N values for hay were significantly lower at wk13 (2360ppm) than pine (4177ppm) or 50/50 (3873ppm). Microtreat P® had an effect on inorganic N at wk 6 and wk 13 with MP applied to the litter being the lowest. Ammonium N (Table 7) at wk 6 resulted in pine being significantly lower than 50/50. The MP applied to the litter at wk 6 and wk 13 resulted in a significant decrease in ammonium-N in the litter. As ammonium N decreased with MP at wk 6 and 13, ammonia levels increased at these time intervals. Ammonium N at wk 6 also had a litter by MP interaction. Birds on P, PMP, 50MP, and HMP had significantly lower ammonium-N values than birds on 50 and H. Birds on 50 (2513ppm) was significantly different having the highest ammonium-N content. Observing the MP interaction between each treatment showed pine was not different, although 50/50 and hay had a significantly lower NH_4-N content of MP versus non-MP. At wk 13 ammonium-N for hay was significantly lower than pine or 50/50. These results are noteworthy in that the nitrogen partitioning between ammonium ion and NH_3 can influence the amount of NH_3 that is volatile from litter.

Nitrate N (Table 7) at wk 6 had a litter difference with 50/50, hay, with pine being significantly different, while pine was significantly higher than the other two litter types. The MP applied to the litter at wk 6 and wk 13 resulted in a significant change in the nitrate-N content of the litter. Nitrate-N at wk 6 also had a litter by MP interaction. Birds on hay were significantly lower than all the other treatments. Birds on pine were the same as PMP and 50MP for nitrate-N. For pine, there were no differences in nitrate-N in the MP versus non-MP interaction. However, non-MP for both the 50/50 and hay had the lowest difference in nitrate-N than the MP applied to the litter. Nitrate-N at wk 13 had a litter by MP interaction. Birds on H and HMP were significantly lower in nitrate-N than all the other treatments. Birds on P and PMP were significantly higher in nitrate-N than from 50, H, 50MP, and HMP. However, the MP interaction for pine and hay did not have any significant difference although 50/50 with no MP had the highest difference than MP in nitrate-N. Week 6 organic N (Table 8) values resulted in 50/50 being significantly higher than pine and hay. However, organic N values for pine and 50/50 at wk 13 were significantly higher than hay. Organic N values also illustrates that MP had a significantly lower value than non-MP at wk 6 and wk 13. Urea (Table 8) at wk 6 and wk 13 showed a treatment effect as well, with hay being significantly lower than pine and 50/50. Litter phosphorus (Table 8) levels were not significantly different at wk 6 however; wk 13 pine levels were significantly higher than hay and 50/50.

Initial pH values of the litter at wk 0 were significantly different from each other (Table 9). Hay (6.23) had the highest value followed by 50/50 (5.76) and pine (4.72). Week

6 pH values for pine were significantly lower than hay and 50/50. However, at wk 13 there were not any significant differences between any of the treatments. It is likely that the increase in pH during the trial is attributed to the calcium and ammonium salts found in the feces (Patrick, 1967). This researcher noted that an increase in pH is beneficial in that it reduces the yeast and mold population and in effect "salts-out" many microorganisms, which can affect bird health. Average litter pH throughout the nation was shown to be 8.0, and average moisture content was 25.1% (Terzich et al., 2000). Average pH in the Carolinas was 6.7 with 26.2% moisture (Terzich et al., 2000). As noted earlier however, increased pH can enhance the volatilization of NH_3.

In this study, water activity (Table 9) at wk 6 and 13 were not significantly different due to treatments. Pine shavings had a water activity of 0.86 and hay and 50/50 were 0.90 at wk 6. Week 13 water activity levels were 0.96 for pine, 0.95 for hay, and 0.94 for 50/50. Normal water activity ranges from 0.85 to 0.99 (Rehbeger, 2002).

Moisture content (Table 10) of the litter varied by litter types. At wk 6 there were significant differences in percent moisture among pine, hay, and 50/50. Pine shavings showed the lowest percent moisture at 11.67% while hay and 50/50 was the highest at 16.67% and 17.50%, respectively. With the addition of the MP the litter was significantly lower in percent moisture 13.89% versus 16.67% without MP. Week 13 moisture showed a litter by MP interaction. Birds on 50 and HMP interacted differently on percent moisture than H, 50MP, and P. Also, birds on 50MP resulted in a significant decease in percent moisture than 50; however it was the opposite for the litter treatments with hay. There were no significant differences between P and PMP on percent moisture at wk 13.

During this trial ammonia levels in the house were very low (Table 10) but, the results show that litter ammonia was significantly different due to treatments at wk 6 and 13. At week 6, ammonia levels in hay were significantly higher than pine, but not 50/50. However, at wk 13 50/50 ammonia levels were significantly higher than pine or hay. Microtreat P® ammonia levels were also significantly higher than non-MP at wk 13. There was an interaction between the litter and MP. Birds on 50MP had significantly higher ammonia levels than all other treatments. All other treatments were not significantly different.

Microbiological analysis was performed in order to determine the bacteria and mold content of the litter (Table 11). At wk 0 total bacteria values for pine were significantly lower than 50/50 and hay. Week 6 and 13 values were not significantly different for total bacteria. This is consistent with previous studies which found bacteria counts in organic material are often extremely low prior to use, but increased rapidly after placement (Grier, 1985).

Mold values at wk 13 were significantly higher for pine than hay or 50/50. Previous research has indicated used poultry litter contained fewer yeast, molds, or coliform bacteria than new litter (Halbrook et al., 1951 and Harry, 1964). Moldy litter has the potential to be harmful to poultry (Arafa et al., 1982), particularly if high levels of aflatoxins are synthesized by the fungus *Aspergillus flavus* (Veltmann et al., 1984).

Coliform (Table 12) values at wk 0 were significantly lower in pine than hay or 50/50. Coliforms enumerated at wk 6 and wk 13 between each media type showed no significance difference. Previous research has found total gram negative bacteria in the environment can contaminate the bedding and use the organic matter as a source of nutrients and moisture (Zehner et al. 1986).

Total gram negative bacteria (Table 12) was significantly different at wk 6 with MP being lower than non-MP. Previous research has determined that gram negative bacteria in litter are diminished by alkaline conditions and especially if the litter is well buffered (Schefferle, 1965). The use of Microtreat P® as a biological agent for litter treatment significantly improved the microbiological quality of the litter by reducing total gram-negative bacteria. In other studies with turkeys, Microtreat P® resulted in reduced carcass condemnations and improvements in body weight gain and feed efficiency (AgTech Products, Waukesha WI).

E. coli (Table 12) a smaller subgroup of coliform bacteria is also a potential pathogen to poultry. *E. coli* had a litter by MP interaction at wk 6. Birds on H and 50MP were significantly higher in *E. coli* than treatments P, 50, PMP, and HMP. Birds on H had significantly higher values in *E. coli* than HMP. Pine showed no difference in *E. coli* whether it has MP or non-MP. However, previous research has found bacteria such as total gram negative, mold, and *E. coli* values were very low in poultry litter (Martin et al., 1998).

Collectively, it is concluded that using chopped Bermuda grass hay as an alternative litter source is comparable to that of pine shavings. Parameters measured including bird performance and litter characteristics were not significantly affected. The use of MP as a biological litter amendment did not significantly affect litter characteristics; however, wk 6 total gram negative bacteria was reduced. There are many factors that must be taken into account for successful litter management. These include the type of litter used, the time of the year, depth of the litter, floor space per bird, feeding and watering devices used, kind of flooring, ventilation system, litter amendments, and the incidence of disease, which can affect a litter's suitability for use with poultry.

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Table 1. Composition of turkey diets fed from 0-13 week of age.

Ingredients	Starter 1	Starter 2	Grower 1	Grower 2	Finisher 1	Finisher 2
	0-3 wk	3-6 wk	6-8 wk	8-10 wk	10-12 wk	12-13 wk
Corn	48.3	50.0	57.5	66.0	65.2	67.3
Soybean meal (48%)	39.8	37.0	29.5	20.3	23.8	20.0
Limestone	1.5	1.5	1.1	1.0	1.0	1.0
Dical Phosphate	2.5	2.1	1.7	1.45	1.5	1.25
Poultry fat	1.6	2.7	3.0	3.5	4.5	5.0
Poultry meal	8.0	8.0	8.0	8.0	5.0	5.0
DL-methionine	0.25	0.2	0.15	0.14	0.16	0.10
Lysine	0.15	0.15	0.15	0.15	0.13	0.13
Salt	0.3	0.3	0.3	0.3	0.35	0.35
Choline Chloride	0.2	0.2	0.1	0.1	-	-
Minerals (TM-90)[1]	0.2	0.2	0.2	0.2	0.2	0.2
Vitamins (NCSU-90)[2]	0.2	0.2	0.2	0.2	0.2	0.2
Coban	0.07	0.07	0.07	-	-	-
Virginiamycin	0.02	0.02	0.02	0.02	0.02	-
Total	100	100	100	100	100	100
Calculated Analysis						
Crude Protein	28.0	26.0	22.6	21.8	19.3	17.6
ME(Kcal/lb)	1302	1342	1382	1437	1473	1511
Calcium (%)	1.44	1.40	1.28	1.13	1.12	1.07
Available P (%)	0.74	0.76	0.64	0.57	0.58	0.52
Methionine (%)	0.72	0.65	0.57	0.53	0.50	0.42
TSAA (%)	1.16	1.07	0.94	0.89	0.83	0.73
Lysine (%)	1.83	1.66	1.52	1.43	1.21	1.09
Sodium (%)	0.19	0.18	0.19	0.19	0.19	0.19
Feed Form C-Crumble P-Pellet	C	C	P	P	P	P

[1]Supplied the following per kilogram of feed: 120 mg Zn as $ZnSo_4$ H_2O; 120 mg Mn as $MnSO_4$ H_2O; 80 mg Fe as $FeSO_4$ H_2O;
10 mg Cu as $CuSO_4$; 2.5 mg I as $Cu(IO_3)_2$; 1.0 mg Co as $CoSO_4$.
[2]Supplied the following per kilogram of feed: vitamin A, 6000 IU; vitamin D_3, 2000 ICU; vitamin E, 33 IU; vitamin B_{12}, 19.8 µg; riboflavin, 6.6mg; niacin, 55 mg; d-pantothenate, 11 mg menadione, 2 mg; folic acid, 1.1 mg; thiamine, 2 mg; pyridoxine, 4 mg; d-biotin, 126 µg; ethoxyquin, 50 mg.

Table 2. Effects of Litter Material and MicroTreat P® (MP)[1] on Body Weight (kg) of Turkey Hens at Different Weeks of Age.

		Weeks of Age			
		0	3	6	13
Litter					
Pine[2]		0.048	0.59	2.00	7.72
Hay[3]		0.048	0.57	2.00	7.75
50/50[4]		0.049	0.58	2.02	7.84
SEM		0.001	0.01	0.02	0.04
MP					
(+)[5]			0.58	2.01	7.77
(-)[6]			0.58	2.01	7.77
SEM			0.01	0.01	0.03
L X MP[7]					
Pine(+)	PMP		0.59	2.01[ab]	7.77
Pine (-)	P		0.59	2.00[ab]	7.68
Hay (+)	HMP		0.59	2.04[a]	7.77
Hay (-)	H		0.56	1.97[b]	7.73
50/50(+)	50MP		0.58	1.99[ab]	7.78
50/50 (-)	50		0.59	2.05[a]	7.91
SEM			0.01	0.02	0.06

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b]Means within a column and within litter, MP, and L X MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 3. Effects of Litter Material and MicroTreat P® (MP)[1] on Feed Conversion of Turkey Hens at Different Weeks of Age.

		Weeks of Age		
		3	6	13
Litter				
	Pine[2]	1.34	1.49	2.25
	Hay[3]	1.38	1.49	2.20
	50/50[4]	1.36	1.50	2.21
	SEM	0.024	0.019	0.027
MP				
	(+)[5]	1.36	1.48	2.23
	(-)[6]	1.37	1.50	2.22
	SEM	0.03	1.48	1.50
L X MP[7]				
Pine(+)	PMP	1.35	1.48	2.25
Pine (-)	P	1.33	1.49	2.26
Hay (+)	HMP	1.35	1.45	2.19
Hay (-)	H	1.41	1.52	2.21
50/50(+)	50MP	1.36	1.52	2.24
50/50 (-)	50	1.37	1.49	2.18
SEM		0.03	0.03	0.038

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction

Table 4. Effects of Litter Material and MicroTreat P® (MP)[1] on Litter Caking (kg) of Turkey Hens at Different Time Intervals.

		Week			
		8	8-13	13	Total
Litter					
Pine[2]		20.2[b]	91.1[b]	223.5	334.8
Hay[3]		35.3[a]	129.4[a]	222.7	388.7
50/50[4]		30.7[a]	101.0[a]	222.2	353.4
SEM		3.20	8.20	10.90	21.90
MP					
(+)[5]		28.7	109.6	225.9	364.8
(-)[6]		28.8	104.7	219.7	353.2
SEM		2.62	6.60	8.80	18.1
L X MP[7]					
Pine(+)	PMP	18.3[c]	93.7[b]	225.6[ab]	337.6[bc]
Pine (-)	P	22.1[c]	88.6[b]	221.4[ab]	332.1[bc]
Hay (+)	HMP	42.5[a]	150.7[a]	252.4[a]	448.3[a]
Hay (-)	H	28.1[bc]	108.1[b]	193.0[b]	329.2[bc]
50/50(+)	50MP	25.2[bc]	84.6[b]	199.8[b]	308.6[c]
50/50 (-)	50	36.2[ab]	117.5[ab]	244.6[a]	398.3[ab]
SEM		4.5	11.58	15.0	30.0

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b,c]Means within a column and within litter, MP, and L X MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 5. Effect of Litter Material and MicroTreat P® (MP)[1] on Body Scoring of Turkey Hens at Week 13.

		Week 13	
Litter		Foot Pad	Breast Blisters
Pine[2]		1.33	1
Hay[3]		1.29	1
50/50[4]		1.14	1
SEM		0.07	0.0
MP			
(+)[5]		1.3	1
(-)[6]		1.2	1
SEM		0.05	0.0
L X MP[7]			
Pine (+)	PMP	1.13[b]	1
Pine (-)	P	1.15[b]	1
Hay (+)	HMP	1.48[a]	1
Hay (-)	H	1.10[b]	1
50/50 (+)	50MP	1.30[b]	1
50/50 (-)	50	1.35[ab]	1
SEM		0.09	0.0

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b]Means within a column and within litter, MP, and L X MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 6. Effects of Litter Material and Microtreat P® (MP)[1] on Total Nitrogen (ppm) and Percent Total Nitrogen (%) of Turkey Hens at Different Weeks of Age.

		Total N			% Total N		
Weeks of Age		0	6*	13*	0	6*	13*
Litter							
Pine[2]		10846.1[b]	38131.8[a]	43039.5[a]	1.08[b]	3.81[a]	4.30[a]
Hay[3]		23204.1[a]	22698.6[b]	26396.4[b]	2.32[a]	2.27[b]	2.64[b]
50/50[4]		1602.1[c]	20836.1[b]	49522.3[a]	0.16[c]	2.08[b]	4.95[a]
SEM		404.1	2424.7	2363.9	0.04	0.24	0.24
MP							
(+)[5]			22315.3[b]	36550.3[b]		3.37	4.80
(-)[6]			32129.1[a]	42755.1[a]		4.45	5.51
SEM			1979.8	1930.1		0.20	0.19
L X MP[7]							
Pine (+)	PMP		18772.5	44310.8		2.04	4.60
Pine (-)	P		22899.8	54733.8		2.44	5.63
Hay (+)	HMP		19558.5	21808.8		4.24	4.47
Hay (-)	H		25838.8	30984.0		4.94	5.45
50/50 (+)	50MP		28614.8	43531.5		3.84	5.33
50/50 (-)	50		47648.8	42547.5		5.96	5.45
SEM			3429.0	3343.1		0.34	0.34

[1]MP-a biological waste treatment product
[2]Pine-new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
*Means difference took from week 0. Ex: Wk 6-Week 0.
[a,b,c]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 7. Effects of Litter Material and Microtreat P® (MP)[1] on Inorganic Nitrogen (ppm) and Ammonium Nitrogen (ppm) of Turkey Hens at Different Weeks of Age.

		Inorganic N			NH4-N			NO3-N		
Week		0	6*	13*	0	6*	13*	0	6*	13*
Litter										
Pine[2]		62.5[c]	1371.7[b]	4177.1[a]	8.15[c]	1193.0[b]	4152.0[a]	54.4[c]	178.8[a]	25.23[b]
Hay[3]		1319.3[a]	1039.5[c]	2360.9[b]	981.4[a]	1525.1[b]	3229.5[b]	337.8[a]	(485.5)[c]	(868.1)[c]
50/50[4]		750.5[b]	1823.7[a]	3873.0[a]	523.4[b]	1943.8[a]	4331.5[a]	227.3[b]	(120.3)[b]	(458.4)[a]
SEM		33.8	108.6	271.8	31.5	112.9	279.3	13.9	43.8	40.3
MP										
(+)[5]			1204.8[b]	3118.2[b]		1206.8[b]	3501.7[b]		(1.89)[a]	(383.1)[a]
(-)[6]			1618.4[a]	3822.4[a]		1901.1[a]	4307.0[a]		(282.8)[b]	(484.4)[b]
SEM			88.7	221.9		92.2	228.0		35.7	32.9
L X MP[7]										
Pine (+)	PMP		1255.0	3506.5		1097.1[c]	3470.2		158.2[a]	36.5[a]
Pine (-)	P		1488.4	4847.7		1289.0[c]	4833.8		199.4[a]	14.0[a]
Hay (+)	HMP		844.9	2355.8		1148.9[c]	3238.5		(303.8)[b]	(882.2)[d]
Hay (-)	H		1234.1	2366.0		1901.3[b]	3220.5		(667.1)[c]	(854.1)[d]
50/50 (+)	50MP		1514.5	3492.5		1374.6[c]	3796.3		140.0[a]	(303.6)[b]
50/50 (-)	50		2132.8	4253.5		2513.1[a]	4866.8		(380.6)[b]	(613.1)[c]
SEM			153.6	384.4		159.7	395.0		61.9	57.0

[1]MP-a biological waste treatment product
[2]Pine-new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[*]Means difference took from week 0. Ex: Wk 6-Week 0.
[a,b,c,d]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 8. Effects of Litter Material and Microtreat P® (MP)[1] on Organic Nitrogen (ppm), Urea (ppm), and Phosphorus (ppm) of Turkey Hens at Different Weeks of Age.

		Organic			Urea			Phosphorus	
Week	0	6*	13*	0	6*	13*	0	6*	13*
Litter									
Pine[2]	1539.75[c]	19464.3[b]	44094.9[a]	0.009[c]	96.7[a]	46.7[a]	158.3[c]	4707.5	13952.4[a]
Hay[3]	21884.9[a]	21659.1[b]	24035.5[b]	39.19[a]	44.6[b]	6.75[c]	2241.0[a]	5037.6	11359.8[b]
50/50[4]	10095.5[b]	36308.2[a]	39166.5[a]	16.55[b]	82.5[a]	33.2[b]	1170.5[b]	6291.5	12178.1[b]
SEM	398.2	2352.7	1976.7	.764	12.3	2.91	61.3	464.5	296.8
MP									
(+)[5]		21110.5[b]	33432.2[b]		71.0	25.7		4329.3[b]	12293.6
(-)[6]		30510.6[a]	38099.1[a]		78.3	32.1		6361.8[a]	12699.9
SEM		1920.9	1613.9		10.0	2.37		379.2	242.4
L X MP[7]									
Pine (+) PMP		17517.5	40804.3		79.9	42.7		4474.8	13725.8
Pine (-) P		21411.1	47385.5		113.5	50.8		4940.3	14179.0
Hay (+) HMP		18713.7	19453.0		54.2	7.08		3783.5	11262.0
Hay (-) H		24604.6	28618.0		34.9	6.43		6291.8	11457.5
50/50(+) 50MP		27100.5	40039.3		78.7	27.3		4729.8	11893.0
50/50(-) 50		45516.0	38293.8		86.4	39.2		7853.3	12463.3
SEM		3327.2	2795.4		17.4	4.11		656.9	419.8

[1]MP-a biological waste treatment product
[2]Pine-new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
*Means difference took from week 0. Ex: Wk 6-Week 0.
[a,b,c]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 9. Effects of Litter Material and MicroTreat P® (MP)[1] on pH and Water Activity of Turkey Hens at Different Weeks of Age.

		pH			Water Activity	
		Weeks of Age				
		0	6	13	6	13
Litter						
Pine[2]		4.72[c]	7.33[b]	8.32	0.86	0.96
Hay[3]		6.23[a]	8.42[a]	8.46	0.90	0.95
50/50[4]		5.76[b]	8.20[a]	8.40	0.90	0.94
SEM		0.03	0.15	0.09	0.01	0.01
MP						
(+)[5]			7.96	8.44	0.87	0.95
(-)[6]			8.00	8.36	0.89	0.95
SEM			0.12	0.08	0.01	0.004
L X MP[7]						
Pine (+)	PMP		7.25	8.27	0.88	0.95
Pine (-)	P		7.40	8.36	0.92	0.94
Hay (+)	HMP		8.53	8.48	0.87	0.95
Hay (-)	H		8.30	8.44	0.92	0.95
50/50 (+)	50MP		8.11	8.57	0.88	0.95
50/50 (-)	50		8.30	8.27	0.85	0.96
SEM			0.20	0.12	0.02	0.01

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 10. Effects of Litter Material and MicroTreat P® (MP)[1] on Moisture Content (%) and Ammonia (ppm) of Turkey Hens at Different Weeks of Age.

		Moisture (%)			Ammonia (ppm)	
		Weeks of Age				
		0	6	13	6	13
Litter						
Pine[2]		8.34	11.67[b]	23.75	2.69[b]	3.94[b]
Hay[3]		9.17	16.67[a]	25.83	4.63[a]	3.50[b]
50/50[4]		8.33	17.50[a]	25.84	3.16[ab]	5.31[a]
SEM		0.78	0.81	1.15	0.53	0.31
MP						
(+)[5]			13.89[b]	25.56	3.63	5.13[a]
(-)[6]			16.67[a]	24.72	3.35	3.38[b]
SEM			0.67	0.94	0.43	0.26
L X MP[7]						
Pine (+)	PMP		10.83	25.0[ab]	2.63	3.88[b]
Pine (-)	P		12.50	22.50[b]	2.75	4.00[b]
Hay (+)	HMP		14.17	28.34[a]	5.75	3.75[b]
Hay (-)	H		19.17	23.33[b]	3.50	3.25[b]
50/50 (+)	50MP		16.67	23.34[b]	2.50	7.75[a]
50/50 (-)	50		18.33	28.34[a]	3.81	2.88[b]
SEM			1.15	1.63	0.75	0.44

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 11. Effects of Litter Material and Microtreat P® (MP)[1] on Total Bacteria and Molds (log cfu/ml) of Turkey Hens at Different Weeks of Age.

		Total Bacteria			Molds		
Week		0	6	13	0	6	13
Litter							
Pine[2]		6.30[b]	10.43	9.94	4.86	7.39	3.03[a]
Hay[3]		8.70[a]	10.56	9.90	4.42	7.03	(0.03)[b]
50/50[4]		8.45[a]	10.83	10.15	4.86	7.27	0.00[b]
SEM		0.33	0.16	0.15	0.15	0.13	0.74
MP							
(+)[5]			10.67	10.10		7.29	1.02
(-)[6]			10.55	9.90		7.16	0.98
SEM			0.13	0.13		0.11	0.64
L X MP[7]							
Pine (+)	PMP		10.51	9.99		7.44	3.12
Pine (-)	P		10.36	9.89		7.34	2.95
Hay (+)	HMP		10.61	9.86		7.05	(0.05)
Hay (-)	H		10.51	9.95		7.00	0.00
50/50 (+)	50MP		10.89	10.45		7.39	0.00
50/50 (-)	50		10.77	9.85		7.15	0.00
SEM			0.22	0.21		0.19	1.04

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).

Table 12. Effects of Litter Material and Microtreat P® (MP)[1] on Coliforms, Gram Negative Bacteria, and *E. Coli* (log cfu/ml) of Turkey Hens at Different Weeks of Age.

		Coliforms*			Coliforms**		Gram Negative		*E. Coli*	
Week		0	6	13	6	13	6	13	6	13
Litter										
Pine[2]		4.32[b]	8.18	8.30	7.47	5.49	8.37	7.09	7.21	4.56
Hay[3]		6.86[a]	8.02	8.11	7.64	4.75	8.51	6.72	7.33	4.50
50/50[4]		7.18[a]	8.13	8.16	7.60	4.91	8.64	6.83	7.35	4.59
SEM		0.46	0.10	0.15	0.23	0.26	0.12	0.13	0.18	0.24
MP										
(+)[5]			8.07	8.11	7.57	5.21	8.35[b]	6.70	7.15	4.65
(-)[6]			8.16	8.27	7.57	4.90	8.66[a]	7.06	7.45	4.45
SEM			0.08	0.13	0.19	0.21	.096	0.11	0.14	0.19
L X MP[7]										
Pine (+)	PMP		8.19	8.16	7.63	5.37	8.39	6.76	7.26[bc]	4.26
Pine (-)	P		8.18	8.44	7.31	5.62	8.35	7.43	7.17[bc]	4.87
Hay (+)	HMP		7.88	8.01	7.37	5.33	8.18	6.75	6.70[c]	4.92
Hay (-)	H		8.17	8.21	7.91	4.17	8.85	6.68	7.97[a]	4.08
50/50 (+)	50MP		8.14	8.15	7.71	4.91	8.49	6.59	7.50[ab]	4.79
50/50 (-)	50		8.13	8.16	7.49	4.92	8.79	7.06	7.20[bc]	4.40
SEM			0.14	0.21	0.33	0.37	0.17	0.18	0.25	0.34

[1]MP-a biological waste treatment product
[2]Pine- new pine shavings
[3]Hay-Bermuda grass hay
[4]50/50-50% Pine and 50% Hay
[5](+) with MP
[6](-) no MP
[7]L X MP- litter X MP interaction
[a,b,c]Means within a column and within litter and MP sections with different superscripts are significantly different ($P \leq 0.05$).
*Analysis performed at NCSU Laboratory using MacConkey agar
**Analysis performed at AgTech Laboratory using Violet Red Bile agar

SUMMARY

Identifying litter materials for use in the poultry industry is becoming increasingly critical due to the shortage and the increase in cost of pine shavings. In North Carolina, the animal and production by-product Bermuda grass hay may be excessive in the eastern part of the state due to the concentration of swine operations. Extending the use of this by-product of the swine industry into the poultry industry may lead to a more sustainable situation for both industries. The objective of the current study was to determine if chopped Bermuda grass hay could serve as an alternative litter material equal to that of pine shavings with and without the addition of Microtreat P® (a microbiological enhancement agent as a litter amendment).

Litter performance was measured for female turkeys raised to 13 weeks of age. Litter treatments consisted of 0, 50 and 100% pine shavings and hay with the addition of MP. Bird performance as measured by body weight, feed conversion, total litter cake, body scoring, pH, water activity, moisture, and ammonia was unaffected by litter treatments. Microbiological treatment showed that total gram negative bacteria were significantly lower at wk 6 with MP than without MP. Nutrient analysis for total nitrogen, inorganic N, NH_4-N, NO_3-N, organic N, urea, and phosphorus was significantly higher for hay at the beginning of the study. However, by the end of the trial total nitrogen levels at wk 13 resulted in pine being significantly higher than hay and 50/50.

CONCLUSION

Collectively this investigation indicates that Bermuda grass hay is an alternative litter material for the poultry industry. Results from this study also indicated Bermuda grass hay with or without the addition of MP did not significantly affect litter performance. Biological litter amendments, such as MP, may need to be evaluated more effectively when finding alternative litter materials used in the poultry industry. However, MP did significantly decrease total gram negative bacteria in the litter at wk 6, which could decrease ammonia production within a poultry facility.

Alternative litter materials for poultry such as Bermuda grass hay will continue to be researched and evaluated. Comparisons to pine shavings or sawdust will probably continue as the benchmark test since these materials are commonly used by the poultry industry. Bird performance will continue to be the primary threshold criterion. However, cost and availability will ultimately determine the adoption of any new or alternative litter material.