THE INFLUENCE OF BEDDING MATERIAL AND COLLECTING PERIOD ON THE FEEDING VALUE OF BROILER AND LAYER LITTER

by

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CONTENT

PREFACE

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I, the undersigned, declare that the dissertation hereby submitted by me for the degree M.Sc.Agric. at the University of the Free State is my own independent work and has not previously been submitted by me at another university/faculty. I further cede copyright of the dissertation in favor of the University of the Free State.

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CHAPTER 1

GENERAL INTRODUCTION

Poultry litter is a solid waste composed of bedding material, excreta, wasted feed and feathers. Poultry manure refers to pure excreta from layers in batteries. Poultry manure/litter has a potential use as a ruminant feed in addition to its traditional use as fertilizer. It has been shown that poultry manure/litter is more valuable as a feed ingredient than as a fertilizer. In fact, the economic value of poultry manure/litter as a feed ingredient in balanced diets for several classes of ruminants is up to four times greater than its value as a fertilizer (Jacob *et al.*, 1997). In addition to offering an economic advantage, using poultry manure/litter as animal feed is environmentally friendly. Many of the nutrients in the broiler litter are redistributed on pastureland as cattle manure.

The dramatic growth of the poultry industry over the last 40 years created a serious waste disposal problem. The utilization of the waste through ruminant animals became a convenient option of disposing of the waste (Mavimbela, 2000). Ruminants have the ability to digest low-cost feedstuffs that are not usable by other livestock species. One such foodstuff is poultry manure/litter, which provides opportunities for both the poultry producer and the beef or lamb producer. The large quantities of litter produced during modern poultry production are expensive to dispose of safely. However, protein is typically the most expensive ingredient in ruminant diets. Feeding poultry manure/litter is a means of disposing of a waste product while concurrently supplying a low-cost protein feed to ruminants.

In South Africa the trading with poultry manure/litter as an animal feed is illegal, except if the specific product is registered as an animal feed according to Act 36 of 1947. Furthermore, nutritional consultants are not permitted legally to recommend the feeding of unregistered manure/litter. A farmer however can use poultry manure/litter that is available on his farm as a crude protein and mineral source for ruminants. This practice occurs primarily because litter is usually relatively cheap non-protein nitrogen (NPN) source (Van Ryssen, 2000). Bamberger (1998) is of the opinion, that not even half of the poultry manure/litter is sustainable used in South Africa. A major problem is the variation in the chemical composition, as well as the feed quality of poultry manure/litter. This is due to different production systems (i.e. layers and broilers), diets of poultry, wastage's (i.e. feed spillage), moisture content of manure/litter, different bedding materials and collection period of litter, especially layer manure.

In South Africa different types of bedding material such as sunflower- and peanut hulls, wood shavings and wheat straw are generally used for broilers. In contrast to the United States of America where broiler houses are cleaned once a year, they are cleaned in South Africa after every production batch of broilers. These different bedding materials as well as cleaning practices could influence ammonia production, performance of broilers and digestibility of poultry litter by ruminants. No research on the comparable efficiency of wood shavings, peanut hulls, sunflower hulls and wheat straw as bedding material for broilers could be found in the available literature. Accordingly no information could be found regarding the influence of these bedding materials on the nutritive value of poultry litter for ruminants. Both aspects need further investigation.

The period that layer manure gathers under cages (batteries) could influence ammonia losses, nutritional value and the presence of pathogens and mycotoxins. This aspect also needs further investigation.

Guidelines for poultry production enterprises to increase the efficiency of broiler production and optimize the nutritional value of poultry litter and manure for use in ruminant nutrition is urgently needed. Therefore the following aspects were investigated in this study:

In Chapter 3 the effect of wood shavings, wheat straw, peanut- and sunflower hulls as bedding materials on the performance of broilers was investigated.

In Chapter 4 the effect of different types of bedding materials and collecting period on the feeding value of broiler and layer hen manure for ruminants were investigated.

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CHAPTER 2

LITERATURE REVIEW

The dramatic growth of the poultry industry over the last 40 years created a serious waste disposal problem. The utilization of the waste through ruminants became a convenient option of disposing of the waste (Mavimbela, 2000). Ruminants have the ability to digest low-cost feedstuffs that are not usable by other livestock species. One such feedstuff is poultry manure/litter, which provides opportunities for both the poultry producer and the beef or lamb producer. The large quantities of manure/litter produced during modern poultry production are expensive to dispose of safely. However, protein is typically the most expensive ingredient in ruminant diets. Feeding poultry litter is a means of disposing of a waste product while concurrently supplying a low-cost protein feed to ruminants.

1. POULTRY MANURE/LITTER PRODUCTION IN SOUTH AFRICA

Poultry production in South Africa is a highly successful business. Due to this successful business there is a large amount of poultry manure/litter produced as well. Taiganides (1977) stated that layer hens in production, produce 100-150 g waste products per day, with a 25 percent dry matter content. The weight of fresh poultry manure is an estimated 15 percent of the total dry matter intake. According to the National Department of Agriculture (2000), the most recent projected figures for total layers per annum and broilers slaughtered per week in South Africa are 15.8 and 9.8 million respectively. According to North & Bell (1990) a layer produce an estimated 0.0456 ton dry matter per year. If this formula were used for the number of layers, there would be an estimated 37.46496 metric tons of dry layer manure produced annually in South Africa. The Department of Agriculture also stated that the broiler industry contributes 16.2 percent to the total gross value of agriculture production. There is not much literature available on the use of poultry litter in South Africa, but it seems that less than half of it are used sustainably in South Africa (Bamberger, 1998).

2. CLASSIFICATION OF POULTRY DROPPINGS

Poultry manure refers to pure excreta from layers in batteries and poultry litter as a mixture of excreta and bedding material obtained largely from broiler houses, but also from houses where pullets and layers are kept on deep litter systems (Van Ryssen, 2000). A small amount of feed spillage may be present in the material. In this discussion both products will be referred to as poultry litter in general

Not all broiler litter is acceptable for use as a ruminant feedstuff. Only good quality broiler litter should be fed. The litter should be low in ash (soil) and should be free of hardware, glass, and other foreign material. Labourers should be instructed not to contaminate litter with light bulbs, wire, glass, tools, and screws, nails, cigarette butts and plastics. Litter used for ruminant feed should include only waste feed, manure, feathers and bedding (Jacob *et. al*, 1997). It is however possible to enhance the quality of poultry litter by means of sterilization and composting.

Poultry litter is classified as a bulky protein supplement. The product is of an alkaline nature with positive cation, -anion balance, resulting in a high buffering capacity in the rumen of animals. The commercial value of poultry litter as a feedstuff is based usually on its crude protein and ash content (mineral). More than 40 percent of the crude protein in litter can be in the form of non-protein nitrogen (NPN). The non-protein nitrogen is mostly uric acid, which is excreted by poultry. Poultry litter is not as palatable as other common feed sources, and cattle and sheep require a period of time to get adjusted to the poultry litter. To make poultry litter diets more palatable in order to increase consumption, maize or other feeds are added (Bagley & Evans, 1998). Caswell *et al.* (1978) estimated that broiler litter as a feed is worth two to three times more than its value as a fertilizer for pastures.

Act 36 of 1947 states that no product originating from animals can be sold as an animal feed unless it has been registered as an animal feed. This requires that the product meet certain nutritional and hygienic standards (Table 1).

Table 1 **Specifications for poultry manure as animal feed according to the South African Farm Feed Act (Act 36 of 1947)**

	Broiler %	Layer %	Limits
Moisture	12	12	max
Crude Protein (CP)	24	22	min
CP from uric acid	60	60	max
Fat	1.5	1.5	min
Fibre	15	15	max
Ash	15	25	max
Feathers	1	1	max
Calcium	3.5	8	max
Phosphorus	1.5	2	min
Sodium	0.5	0.5	max
Silica	0.5	0.5	max
Copper (mg/kg)	50	50	max

Pathogen-free: 20000 microorganisms per gram

3. BEDDING MATERIAL

Litter serves a number of important functions. For example, it:

1. Absorbs moisture and promotes drying by increasing the surface area of the floor.
2. Dilutes fecal material, thus reducing contact between birds and manure.
3. Insulates chicks from the cooling effects of the floor and provides a protective cushion between the birds and the floor (Lacy, 2002).

Many products have been used as bedding material. Regardless of the material used, it should be water absorbent, inexpensive, readily available, and not create problems for the birds or for use as manure (Parkhurst & Mountney, 1988). Lacy (2002) lists various materials that have been tried with at least some degree of success and briefly discuss the advantages and disadvantages of particular bedding material sources.

3.1 Advantages and disadvantages of various bedding materials (Lacy 2002)

3.1.1 Pine shavings & sawdust

This is the most preferred litter material but limited in supply and expensive in some areas.

3.1.2 Hardwood shavings & sawdust

Often high in moisture and susceptible to dangerous mold growth if stored improperly prior to use.

3.1.3 Pine or hardwood chips

Used successfully but may cause increased incidence of breast blisters if allowed to become to wet.

3.1.4 Rice hulls

A good litter material where available at a competitive price. Young chicks may be prone to litter eating (not a serious problem).

3.1.5 Peanuts hulls

It is a very inexpensive litter material in peanut-producing areas. Some problems with pesticides have been noted in the past.

3.1.6 Sugarcane pomace (bagasse)

Prone to caking during the first few weeks but can be used effectively.

3.1.7 Crushed maize cobs

Limited availability. May be associated with increased breast blister problems.

3.1.8 Chopped straw, hay or maize stay-over

Considerable tendency towards caking. Mold growth can also be a disadvantage.

3.1.9 Processed paper

Various forms of processed paper have proven to be good litter material in research and commercial situations. In using shredded newspaper for animal bedding, there is a concern about possible harm to animals from the newspaper ink and treatment in the manufacturing process (Heimlich & Howard, 2002). It may become more available and less costly with increased recycling. Slight tendency to cake. Top dressing paper base with shavings may minimize this problem. Careful management is essential.

3.1.10 Sand

According to Ross Broiler Management Manual (1996), sand can also be used. It is commonly used in arid/desert areas on concrete floors. According to Bilgili *et al.* (2000) using sand as litter can help poultry producers reduce pollution, improve production, lower costs and create a side product to sell. Sand can work well, but birds have difficulty moving about if spread to deep.

3.2 Depths of bedding material

Different authors recommend different depths of floor material, i.e.:

Table 2 Bedding material depths

Author	Depth (cm)
Swain & Sundaram (2000)	5
Cilliers (1995)	5
Ross Broiler Management Manual (1996)	5 – 10
Parkhurst & Mountney (1988)	7.5 – 10
Lohmann Broiler Management Program (1990)	5 –10

Where carcass quality is at a premium, a depth of 10 cm would be beneficial. If the bedding is spread to deep, the birds will have problems moving about (> 10 cm) (Ross Broiler Management manual, 1996).

3.3 Ammonia

Broilers do not perform to their genetic potential in a poor environment. Dust is a big problem especially in bedding material like sawdust or fine grinded/ chopped wheat straw or hay. Another problem with wheat straw chopped longer than 30 mm is breast blisters during the first two weeks. The factor that influences bedding material conditions the most is moisture. Excess moisture in the bedding material increases the incidence of breast blisters, skin burns, scabby areas, bruising, condemnations and downgrades. Wet bedding material is also the primary cause of one of the most serious environmental factors affecting broiler production today and resulted in excessive ammonia (NH3) production (Lacy, 2002).

Ammonia in poultry houses is formed by the breakdown of uric acid by bacteria in the poultry litter. Many producers underestimate the detrimental effects of ammonia. High ammonia levels have been proven to cause increased susceptibility to Newcastle disease, as well as depressing growth rates while allowing *E.coli* organisms to proliferate. Prolonged exposure to high levels (50 to 100 ppm) is the cause of keratoconjunctivitis (blindness) observed in some broiler flocks reared during the cooler months of the year (Lacy, 2002). When levels are as high as this, production is seriously affected. Ammonia levels of just 25 ppm have been found to depress growth and increase feed conversion in broilers. Poultry litter moisture is the key to controlling ammonia levels since litters at 21 – 25 percent moisture levels produce little ammonia. When poultry litter moisture exceeds 30 percent, ammonia production starts and increases as temperature goes up. Bagley & Evans (1998) stated that ideally poultry litter moisture should be maintained at 12 to 25 percent. The rule of thumb in estimating litter moisture content is to squeeze a handful of litter. If it adheres in a ball, it is too wet. If it adheres slightly, it has the proper moisture content. If it will not adhere at all, it may be too dry. Parkhurst & Mountney (1988) gave a general guide used by many poultry men for determining ammonia levels (Table 3).

Table 3 Determining ammonia levels (Parkhurst & Mountney, 1988)

10-15 ppm	Detected by smell
25-35 ppm	Eyes burn
50 ppm	Watery and inflamed eyes of the broilers appear
75 ppm	Broilers show discomfort, and one can observe the broilers jerking their heads

3.4 Moisture content of bedding material

It is important that litter is kept in a dry and friable condition throughout the life of the flock. If the litter becomes caked or too wet (> 50 percent moisture) the incidence of hockburn and breast necrosis will increase substantially. Every effort should be made to keep litter in good condition to minimize carcass downgrading.

Figure 1 shows the likely causes of poor litter quality, any of which may be the reason for hockburn or breast burn (Ross Broiler Management Manual, 1996).

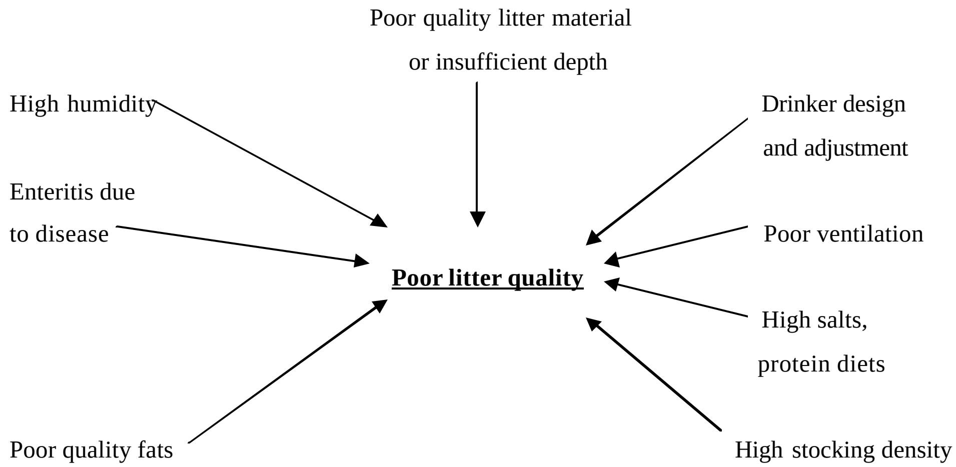

Figure 1 **Reasons for poor quality litter (Ross Broiler Managemant Manual, 1996)**

Many factors affect litter moisture. For instance, if new bedding material is not stored properly and becomes damp before it is spread in the broiler house, it may be difficult to avoid wet litter problems. Nutrition also influence litter quality. Certain dietary ingredients (especially salts), when fed in excess, cause broilers to consume and excrete large amounts of water and result in wet litter conditions (Lacy, 2002). Some drugs also stimulate excess water consumption and excretion. Environmental conditions, such as wet humid weather or very cold temperatures, can cause wet litter if the broiler house ventilation system is not able to eliminate moisture effectively. Waterers, foggers and evaporative cooling pads, if not managed and maintained carefully, can contribute greatly to wet litter problems.

3.5 Re-use of litter

In the USA it is a common practice to use litter for more than one batch of broilers. This is due to the scarcity and expense of pine shavings, and the difficulty of handling and disposing of used litter. They use the old litter as base and top it up with a thin fresh layer of new material. In South Africa this is not the case, because of the potential of problems such as diseases caused by ammonia and viruses such as Newcastle–disease.

4. LITTER MANAGEMENT

Lacy (2002) has the following basic checklist to be considered concerning litter management:

1. Increase ventilation immediately if you smell any ammonia.
2. Use mixing fans to move air within the house.
3. The combination of heating and ventilating will remove considerable moisture from the house.
4. Check for and repair water leaks. Do not empty waterers on the litter.
5. Make sure no moisture enters from the outside. Good drainage around the house is important.

It is very likely that cleaning out completely and spreading new litter between flocks is economically justified. At the very least, it is a sound practice to clean out and put in new bedding material in the brooding end of the house. Litter must be managed carefully and kept in good condition whether it is new or used. "Litter quality" concerns providing, maintaining and disposing of a flooring material that will enhance the production of healthy, efficient, high-grade broilers and, as a result, maximize profits for grower and integrators.

Van Middelkoop (2004) emphasizes the fact that ventilation at chicken level is very important to lower litter temperature. Good ventilation at the chicken level reduces bacterial activity in the litter contributing to a lower litter temperature of about 4°C. This resulted in better broiler performance and a better persistency in growth rate.

It is important to keep poultry litter free from foreign objects. Broiler litter can contain extraneous materials; such as rocks, pieces of mesh wire, nails, glass, wrenches, or even hammers. A method of removing these foreign materials must be in place if you plan to feed this material to livestock, because these objects are hazardous to both animals and equipment (Bagley & Evans, 1998). Accidental consumption of metal objects or glass by beef cattle can result in decreased animal performance and death (Daniel & Olson, 2001). For safety, pass the broiler litter through equipment with magnetic strips to pick out metal contaminants (such as nails and wire).

4.1 Storage of broiler litter

Broiler flock schedules determine when litter is cleaned from the houses. This does not always coincide with the best time to use litter for livestock feed or as fertilizer. Litter must then be stored under proper conditions to receive the best return and highest quality of feed possible.

The storage of broiler litter has three functions (Bucklin *et al.*, 1997):

1. To serve as a holding facility from the time the house is cleaned until feeding;

2. To increase the acceptability to ruminants;

3. To eliminate disease-causing bacteria and prevent the growth of molds.

4.2 Treatment and composting of poultry litter

The holding facility looks and acts basically the same as a silage bunker. The easiest and most cost effective way of processing broiler litter is deep stacking for 4 to 6 weeks (Bucklin *et al.*, 1997). During deep stacking, the litter undergoes a combined composting-ensiling process. According to Ayangbile *et al* (1993) ensiling or deepstacking of poultry litter reduces the pathogenic organisms, and improves the acceptability and nutritional value of the litter for ruminants. The action of bacteria generally heats the stack to a temperature of 60 to 70°C. This is sufficiently hot enough to kill any pathogens, such as *E.coli* and *Salmonella* that may be present in the raw litter. Chaudhry *et al.* (1996) stated that the majority of microorganisms are killed at temperatures between 45 and 55°C, and that the pathogenic organisms are killed when exposed to 55 to 60°C for 30 minutes (Chaudhry *et al.*, 1998). The final product is drier, but crude protein and other nutrients are retained in the litter. Composting can be described as follows: Composting is the process of decomposing organic matter, whether manure or crop residue, by a mixed microbial population in a warm, moist aerobic environment. The organic matter is decomposed by the successive action of bacteria, fungi and actinomycetes (Gill, 1992).

4.3 Pathogens

Pathogens such as bacteria and viruses can be present in chicken litter. Several affect only poultry, but some may also be harmful to humans as well as ruminants. According to Turner & Stephens (2002) the main pathogens that may be present in poultry litter and can have an effect on litter as feed, are listed below:

4.3.1 Clostridium spp:

This is a spore-forming organism with a capacity to survive for prolonged periods in the environment. *Cl. perfiringens* and *Cl. botulinium* are widely distributed in the environment. *Cl. botulinium* can cause botulism, an acute intoxication. Types C and D affects poultry and ruminants.

4.3.2 Salmonella spp:

This can be present in the gut of poultry. It can be present in large numbers without any symptoms of disease. Effective composting or deep stacking can destroy it.

4.3.3 Escherichia coli:

This pathogen is a common, normal bacterium in the gut of most mammals and birds. Most types in poultry are harmful to birds only and do not cause infections in humans.

Pathogens from animal manure can be transferred to drinking water or food supplies, if proper safe guarding procedures are not followed. Ogonowski *et al.* (1984) analyzed 813 South African fresh poultry manure and litter samples for the presence of microorganisms. The micro-organisms found included *Clostridia* Species in 0.37 percent, *E.coli* in 0.49 percent, *Staphylococcus* in 0.25 percent and *Salmonella* in 12.3 percent of the samples. The *Clostridia* species produced botulism causing toxins. Botulism is a common problem in ruminants eating unsterilised poultry litter. The source of the Clostridia species is dead rodents and chicks, partly hatched eggs, etc. found in the manure/litter. Vaccination (preferably twice) against botulism is essential, though not 100 % effective. The toxin is not destroyed by heat and will be present in dry and processed litter (Van Ryssen, 2000).

5. NUTRITIONAL CHARACTERISTICS

Several researchers have investigated the nutritional characteristics of poultry manure/litter for ruminants. The possibility of using poultry litter as a dietary ingredient for ruminants has been investigated long ago (Noland *et al.*, 1955; Bishop *et al.*, 1971; Van der Merwe *et al.*, 1975). The most current investigations was for its use in cattle (Daniel & Olson, 2001) and sheep and goats (Mavimbela & Van Ryssen, 2001; Murthy *et al*, 1996).

5.1 Variation

The nutritional value of poultry litter varies greatly across time and among sources, as stated in Table 4. Factors which can contribute to variation, are composition of the diet of birds (layer viz. broiler rations), type of bedding material (sawdust, bagasse, hay, straw, newspaper, hulls); litter processing and management; number of birds and duration of birds on bedding material. It is advisable to obtain the chemical composition, especially of crude protein, before the product is used (Van Ryssen, 2000).

Table 4 Variation and approximate composition of broiler litter on a dry basis (Van Ryssen, 2000)

Nutrient	%
Moisture	10-24
Crude protein	10-26
True protein (% of CP)	40-60
Crude fibre	22-25
Neutral detergent fibre	30-50
Acid detergent fibre	20-35
Ash	10-26
Total digestible nutrients	45-65
Metabolizable energy (MJ/kg)	6.0-7.3
Calcium	1.5-3.0
Phosphorus	1.2-1.8

5.2 Moisture content

The moisture content of litter is not as important as the profile of other nutrients, but it does influence the physical quality of feed. For ease of processing and feeding, moisture in the broiler litter should be between 12 and 25 percent (Jacob *et al* 1997). Litter with moisture levels greater than 25 percent may be gummy and hard to mix with other feeds. If the moisture content is more than 25 percent, the deep stack may generate too much heat and the excess heat may damage (denaturate) the protein in the litter. When protein becomes denatured, ruminants are not able to digest it as easily. Poultry litter with moisture levels of 10 percent or less will be excessively dusty, causing the litter to be unpalatable to ruminants. Dry litter would also not go through a proper heat cycle during deep stacking. Too much moisture due to spillage around bird watering systems is called "cake" and must be removed from the broiler house. According to Jacob *et al*., reduced spillage will:

1. Save water,
2. Improve bird quality,
3. Improve production environment by reducing humidity and ammonia levels,
4. Reduce ammonia release from litter,
5. Reduce the volume of wet manure cake, and
6. Extend the time between litter clean-out which reduces labour and other cost.

5.3 Crude protein

According to Van Ryssen (2000) crude protein (nitrogen X 6.25) concentrations of up to and over 30 percent on a dry basis (DM) are reported for poultry litter in the USA; South African samples usually contain between 18 and 22 percent crude protein. This might be due to the fact that in South Africa broiler houses are cleaned out after every batch and in the USA only once per year. Other possible reasons might be a higher proportion of bedding material and higher ammonia losses during sun drying. If crude protein values are below 18 percent, the litter should be used only as a fertilizer and not as a feed source. The crude protein consists of both true protein and non-protein nitrogen, with uric acid the main non-protein nitrogen in poultry wastes (Noland *et al.*, 1955; Ruffin & McCaskey, 1998). In manure containing 68 g/kg nitrogen, 26 to 34 g/kg units consisted of uric acid and 21 g/kg units of amino acid nitrogen (Smith *et al.,* 1978). Other non-protein nitrogen components in manure include ammonia, urea and creatinine.

5.4 Available energy

It is frequently stated that poultry litter is deficient in energy. When high levels of litter are fed, molasses is often added as a source of energy that is readily available to the rumen microbes to complement the high nitrogen (N) concentration of litter (Mavimbela *et al.,* 1997; Mavimbela & Van Ryssen, 2001). Where broiler litter was used as a survival ration under drought feeding conditions, a better response was obtained in the performance of sheep when 15 percent molasses was mixed with litter, compared to a 100 percent litter diet (Mavimbela *et al.,* 1997; Van Ryssen, 2000).

5.5 Fibre

South African poultry litter seems to contain more fibre and has on average larger particle size (higher effective fibre) than litter in the USA (Van Ryssen, 2000). The fibre in broiler litter comes mainly from chicken bedding materials such as wood shavings, sawdust, or peanut hulls. A high crude fibre content is indicative of a high proportion of bedding in the litter and thus a lower total digestible nutrient content (TDN)(Jacob *et al.,* 1997). Jacob *et al.* (1997) also stated that as more flocks of broilers are grown on the litter, total fibre in the litter decreases. This is only the case in the USA, because in South Africa bedding material are only kept for one flock.

5.6 Vitamins

Poultry litter contains very little or no levels of the fat-soluble vitamin A, so the supplement fed to ruminants containing poultry litter diets should contain vitamin A. Fresh forages are very high in vitamin A, and cattle can store relatively large quantities of vitamin A in the liver. However, vitamin A is a relatively inexpensive feed additive and a supplement containing vitamin A should be fed with litter diets.

5.7 Ash

The chemical analysis of poultry litter for ash usually provides the most information about the quality of the poultry litter. Ash in litter is made up of minerals from feed, manure, bedding material, and soil. The ash content can also be influenced by the treatment of the litter. Composting can reduce organic matter in the litter that raises the ash content. Care should be taken to keep the ash content, especially the soil percentage, as low as possible if the litter is to be used as a feedstuff for ruminants Ash levels between 15 and 25 percent are acceptable (Jacob *et al.,* 1997). Litter containing ash levels of more than 25 percent should not be fed. High ash levels indicate that large amounts of soil contaminated the litter. Ruminants do not find good quality poultry litter highly palatable, and litter with a high ash content (above 25 percent) will result in poor feed consumption and subsequent poor animal performance (Mavimbela, 2000).

5.8 Minerals

Broiler litter is an excellent source of the macro and trace minerals needed in the diet of ruminants (Jacob *et al.*, 1997). Van Ryssen *et al.* (1993) conducted a survey of the concentration of minerals in South African samples. According to Table 5 the

Table 5 Mean mineral concentration of broiler litter and pure layer manure in South Africa (DM basis) (Van Ryssen, 2000)

Element	Broiler litter	Layer manure
Calcium %	2.53	8.81
Phosphorus %	1.46	2.31
Magnesium %	0.58	0.90
Sodium %	0.56	0.47
Potassium %	1.33	2.05
Aluminum mg/kg	834	1683
Copper mg/kg	43.6	45.9
Iron mg/kg	1335	2271
Zinc mg/kg	254	372
Manganese mg/kg	317	546
Cadmium mg/kg	0.32	0.50
Cobalt mg/kg	1.08	1.39
Chromium mg/kg	11.21	9.20
Arsenic mg/kg	4.92	2.48
Lead mg/kg	0.55	1.17
Vanadium mg/kg	30.10	10.10
Molybdenum mg/kg	1.46	10.37
Mercury mg/kg	0.49	1.71
Selenium mg/kg	0.57	0.13

minerals in the litter seem to be readily available to the animal. The calcium and phosphorus concentrations in litter are well above the requirements of beef cattle and sheep (Van Ryssen, 2000).

Copper toxicity used to be a problem, as it is stored in the liver of sheep fed copper sulphate (Van Ryssen *et al.,* 1993). Van Ryssen (2000) stated in his latest survey (Table 5) that it became obvious that copper sulphate is not used in South Africa as a growth promoter in broiler diets anymore. In some literature from the USA (Daniel & Olson, 2001) it seems that copper toxicity can still be a problem. Bagley & Evans (1998) stated that many broiler houses have now changed from using copper sulphate to using propionic acid, which means high levels of copper should not be a problem in litter from those houses.

The calcium concentration of the South African broiler litter was 25.3 g/kg and in layer litter 88.1 g/kg and that of phosphorus 14.4 g/kg and 23.1 g/kg, respectively (Van Ryssen, 2000). These calcium and phosphorus concentrations are well above the requirements of beef cattle and sheep (NRC, 1985; Ruffin & McCaskey, 1998).

Arsenic containing compounds are sometimes included in the diets of young broilers (Van Ryssen, 2000). Van Ryssen *et al.* (1993) did not measure high arsenic concentrations in poultry excreta collected in South Africa. The average concentration for the South African samples was 4.9 g/kg DM.

Van Ryssen (2000) emphasized that the feeding of unsterilised poultry excreta to farm animals is potentially dangerous. If farmers want to use the product it should be stressed that they take precautions and must pay attention to the following:

1. In general, it must be accepted that poultry litter is a fairly low quality feed which will reduce production at high inclusion rates in the diet.

2. The source of the product – it is advisable not to feed just any litter available on offer. Practices on the poultry farm such as the hygienic and general management must be evaluated.

3. The drugs included in the feeds must be known, e.g. antibiotics and coccidiostats.

4. Animals must be vaccinated against botulism, even if the litter was processed.

5. The degree of processing must be ascertained. The product should at least be sifted, e.g. to remove dead birds and lumps due to moisture.

6. Proper storage of the product must be attended to, especially to avoid an increase in the moisture content and the loss of nitrogen as ammonia.

7. Special attention should be paid to the moisture level in the litter – the drier the better. The feeding of wet and damp litter must be avoided. This is especially important because of the risks of contamination with Salmonella and aflatoxins.

8. It is advisable to obtain the services of a competent advisor to assist in the planning of the feeding of the product.

9. It is advisable to have at least a crude protein analysis done on the litter.

10. If nothing is known about the product, it is recommended that a withdrawal period of 14 days be observed before animals are slaughtered for human consumption (Van Ryssen, 2000).

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CHAPTER 3

THE EFFECT OF DIFFERENT TYPES OF BEDDING MATERIAL ON THE PRODUCTION PERFORMANCE OF BROILERS

1. INTRODUCTION

The importance of good quality bedding material for the rearing of broilers on conventional floor systems has been recognized and emphasized (Anisuzzaman & Chowdhury, 1996). Broilers do not perform to their genetic potential in a poor environment. The quality of the environment is highly dependent upon bedding material. The poultry industry consumes large quantities of processed solid wood residues and other materials for litter. Although a variety of products, such as wood shavings, wheat straw and peanut- and sunflower hulls, are used as bedding for poultry, alternative litter sources are always of interest to the poultry producer (Hester *et al.*, 1997).

In South Africa different types of bedding material such as sunflower- and peanut hulls, wood shavings and wheat straw are used. In other parts of the world good quality grass (Rude & Rankins, 1993), shredded/processed paper (Howard & Heimlich, 2002; Lacy, 2002), sand (Bilgili *et al.*, 2000), rice hulls, sugarcane pomace (bagasse) and crushed corn cobs (Lacy, 2002) are used. The type of bedding material can effect the performance of the broiler to a certain extent (Lacy, 2002). Anisuzzaman & Chowdhury (1996) compared four types of litter, viz. rice husk, saw dust, paddy straw and sand, and found that rice husk was the best litter material for rearing broilers with better growth, food consumption and food conversion. Swain & Sundaram (2000) stated that there was no difference in weight gain, food consumption efficiency of food utilization or mortality, between rice husk, saw dust or choir dust as a bedding material.

Locally available materials are usually preferred as bedding material. Lacy (2002) stated that an effective litter material must be absorbent, light, inexpensive and non-toxic. Seeing that wood shavings, wheat straw, peanut- and sunflower hulls are readily available products in South Africa, the aim of the study was to look at the effect of these four waste products as a bedding material, on the production performance of commercial broilers in a conventional floor system, during two different periods.

2. MATERIALS AND METHODS

2.1 Treatments

Six hundred, day old Ross-1-broilers were randomly divided into 30 groups of 20 each. Six groups (replications) were then randomly allocated to one of the following five treatments:

1. Wood shavings and saw dust (Byproduct Development Services, 0.5 to 5 cm)
2. Peanut hulls
3. Sunflower hulls
4. Wheat straw (ground through a 30 mm sieve)
5. Control group (cement floor)

The different groups have been randomly allocated to 30 broiler cages in a closed but well ventilated building. The cages made of hard board material measured 1.2 x 1.2m, with a floor space of 1.44m² were used to accommodate 14 birds per m² as specified by Parkhurst & Mountney (1988). Ten kilograms moist free bedding materials were placed in each cage. The air-dry bedding material was spread to a depth of 10 cm according to the recommendations of Parkhurst & Mountney (1988); Ross Broiler Management manual (1996) & Lohmann Broiler Management program (1990). The litter (bedding material) was turned weekly. Each pen was equipped with an electric brooder. Maximum and minimum temperatures in the building were recorded daily. The group weight of each pen was measured weekly. The trial was conducted from March to June and consists of two six-week periods including three replications per treatment per period. The first period was from March to April and the second from April to June 2002.

2.2 Diets

Three different commercial broiler diets as indicated in Table 1 were fed *ad libitum* as mash. The chemical analysis and physical composition values were as supplied by the feed manufacturer. Water was available at all times. Commercially available plastic circular feeders and waterers were used. The day old chicks were immunized against Newcastle disease (live vaccine), infec Bronchitis (live vaccine) and Mareks disease (rispin).

Table 1 **Physical and chemical composition of broiler diets on an air-dry basis**

ITEM	Broiler Starter (Day 1-14)	Broiler Finisher (Day 15-35)	Broiler Post-Finisher (Day 36-42)
Physical composition (%)			
Prime Gluten	3.50	3.50	3.37
Soya oil cake	25.41	19.15	13.67
Sunflower oil cake			0.91
White Fishmeal	1.20	0.10	
Maize	64.56	72.66	77.75
Feedgrade Limestone	1.71	1.67	1.72
Salt (no 1 fine)	1.04	0.79	0.66
Kynofos 21 MCP [1]	2.00	1.55	1.26
Methionine	0.17	0.16	0.16
Lysine	0.20	0.23	0.30
Broiler Starter Premix [2]	0.20		
Broiler Finisher Premix [2]		0.20	
Broiler Post-Finisher Premix [2]			0.20
Chemical composition (%)[3]			
Protein (min)	22.00	18.00	18.00
Crude Fibre (max)	5.00	5.00	5.00
Moisture (max)	12.00	12.00	12.00
Fat (min)	2.50	2.50	2.50
Calcium (max)	1.20	1.20	1.20
Phosphorous (min)	0.70	0.60	0.50
Lysine (min)	1.10	0.90	0.90

[1] Mono calcium phosphate

[2] Vitamin and mineral premix for broilers

[3] Specifications of commercial diets

At the end of the trail, the birds were slaughtered, carcass weights measured and dressing percentages calculated. Weekly body weight gain, food consumption and mortality were recorded. Mass of excreta per cage and percentage of moisture in excreta were recorded as well. The efficiency of performance was evaluated in terms of production number (PN) as follows (Swain & Sundaram, 2000).

$$PN = \frac{abw \times \% \, liv.}{Days \times fc/10}$$

Where, abw = average body weight gain; liv. = percent livability; days = duration of fattening in days; fc = food conversion.

2.3 Ammonia

Ammonia production was tested with a "Dräger Multi Gas Detector" (Dräger Saftey AG Co. KgaA, 2001). On day 30 the samples were taken by stroking the pump ten times at different places in each cage (approximate one minute/cage). The Dräger tubes change from yellow to blue for a positive value for ammonia. The principle of the reaction is:

NH? + pH indicator ⟶ blue reaction product

The atmospheric pressure was collected from the Bloemfontein weather bureau and worked to a factor F.

$$F = \frac{1013}{\text{Actual atmospheric pressure (hPa)}}$$

The measured value was then multiplied with the F – factor.

2.4 Moisture absorption and release

Moisture absorption and release were calculated according to the method described by Pearson *et al.* (1999) as follows:

2.4.1 Absorption

Five 10 g samples of each type of bedding material were placed in bags measuring 150 x 80mm with a pore size of 53 ±10um. The weighed samples were submersed (in water) for 30 minutes. The samples were removed from the water bath and allowed to drain for five minutes, shaken gently three times to remove excess water and re-weighed. This soaking was repeated 10 times. For the first four hours every half-hour and then again at 24 and 48 hours. Each subsequent sample was allowed to soak in the water to determine the time of maximum absorption for that material.

Moisture holding capacity on a weight basis was calculated as:

$$\text{Moisture holding capacity (\%)} = \frac{\text{Wet weight} - \text{bag weight} - \text{sample weight} \times 100\%}{\text{Sample weight}}$$

2.4.2 Moisture release

Saturated material was spread out five cm deep at a constant temperature of 25°C. Samples were weighed every hour for six hours and at 24 and 48 hours, to determine the rate of moisture release. The moisture content remaining over time and the rate of moisture release were recorded.

2.5 Temperatures

The day's maximum and minimum temperature was recorded on a maximum-minimum thermometer. The thermometer was hanged in a central place in the experimental building and kept there for the whole period. The daily maximum- and minimum temperatures were recorded.

2.6 Statistical analysis

A one way anova with treatments in a 2 X 5 factorial were used (Proc Anova of SAS, 1994). Treatment effects were two experimental periods and five bedding materials, namely wood shavings, peanut- and sunflower hulls, wheat straw and a control group on a cement floor. An analysis of variance was performed and significant differences were identified by means of Tukey's T–test (Steele & Torrie, 1960).

3. RESULTS AND DISCUSSION

3.1 Environment

3.1.1 Temperature

The average daily temperatures recorded during Phase 1 and 2 are presented in Figure 1. It is evident that lower average temperatures prevailed during Phase 2. During Phase 1 an average minimum and maximum temperature of 18 and 28.5°C respectively were recorded. On the other hand an average minimum and maximum temperatures of 15 and 25°C respectively were observed during Phase 2. According to Lohmann, Broiler management program (1990) and Ross Breeders, Ross broiler management manual (1996) the optimum average room temperature should be 21-22°C. Compared to this optimum temperature, the broilers in Phase 1 experienced higher average temperatures for approximately the first 22 days of the growing period. In contrast the average temperature in the building during Phase 2 was lower compared to the optimum for the last 11 days of the growing period. These low temperatures were, however, counteracted by the electric brooders in the cages.

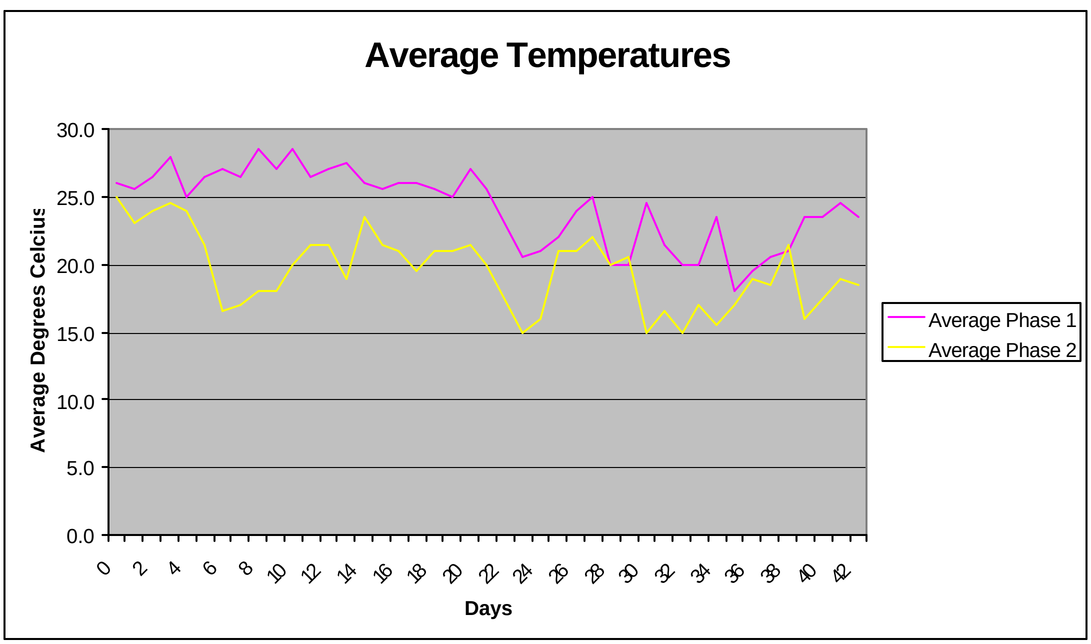
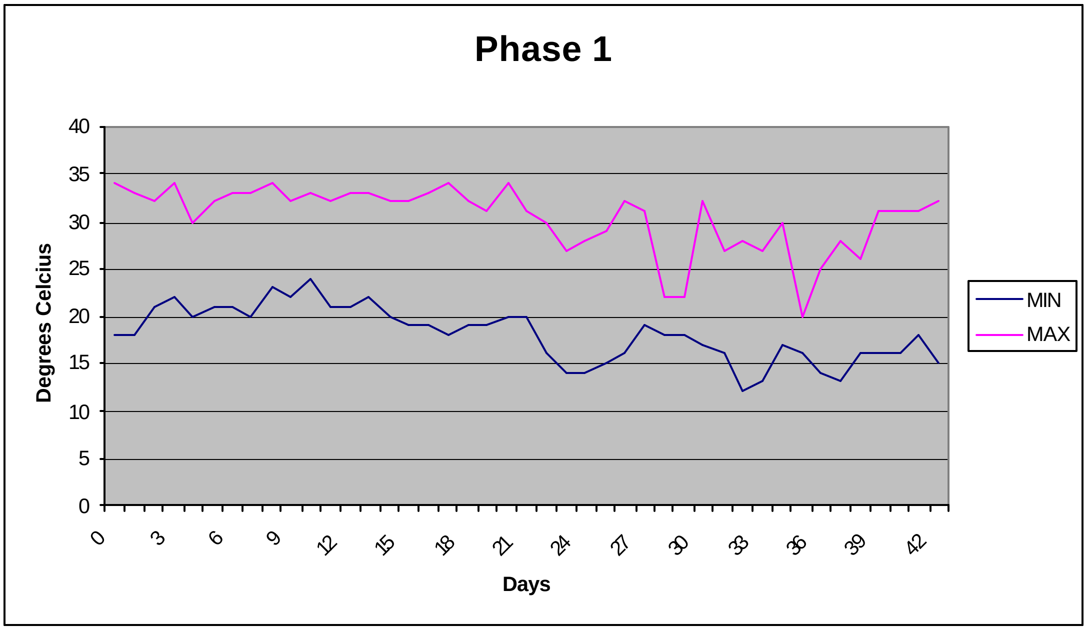


Figure 1 **Average temperatures during the growing period of broilers**

According to Sainsbury (2000) a house temperature of 25-30°C will be associated with the best results for broilers. Above or below this range, weight gains and feed conversion efficiencies will be reduced. The worst results are associated with house temperatures below 20°C. In this regard Freeman (1983) stated that within certain temperature zones, birds are capable of keeping body temperature within normal levels without having to apply mechanisms to increase heat loss to increase heat production. This is termed the thermo neutral zone and can be defined as the range where minimal energy is needed to maintain body temperature. For adult birds the neutral zone is regarded as between 18 - 24°C. The exact temperature is however difficult to define as factors such as feather cover, fat and age of the bird as well as relative humidity of the air and ventilation could play a role.

The daily minimum and maximum temperatures during Phase 1 and 2 fluctuated and were measured to compare with the recommended temperatures. According to Figure 2 the minimum temperature in the building during Phase 2 was throughout below 20°C. During Phase 1 the minimum temperature was lower than 20°C for the last 21 days of the experimental period. According to Freeman (1983) it is important to take note that the critical period of heating is during the first three to four weeks of a chick’s life. Heating is therefore essential in the first period of a chick’s life when minimum temperatures are lower than the recommended temperatures (±20°C). Because of the presence of electric brooders during the whole experimental period low temperatures probably did not play a major role in the current study. Maximum temperatures above 30°C prevailed for the first 21 days of Phase 1 and periodically for the first 18 days of Phase 2. These high temperatures could hamper feed intake and growth performance of the broilers. From Figure 1 it also seems that more extreme temperatures occurred especially during the first 20 days of Phase 2.



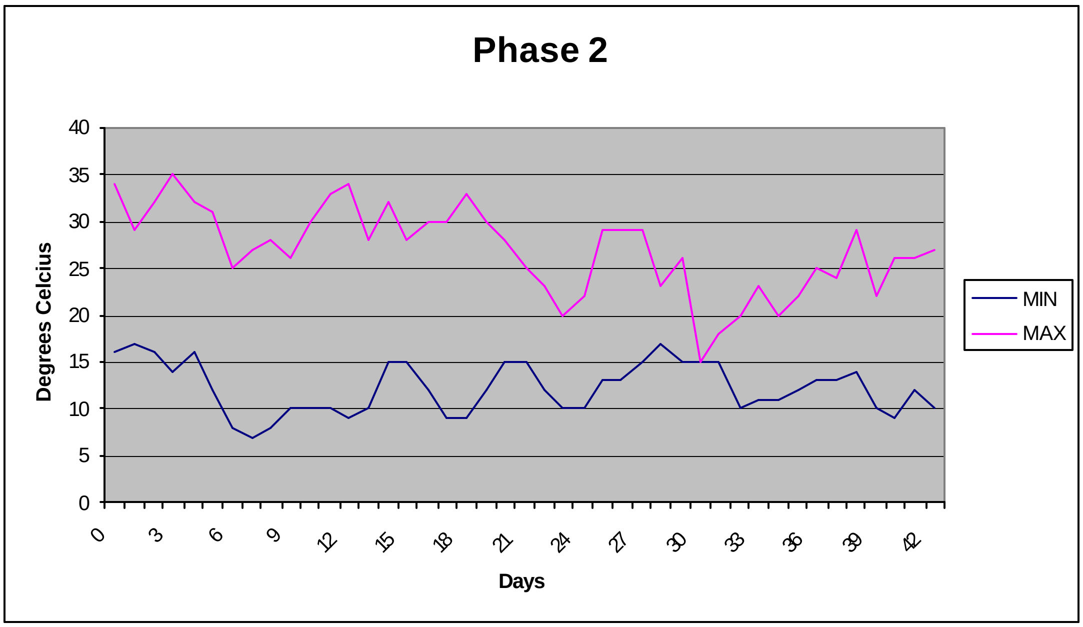


Figure 2 **Minimum and maximum temperatures during the growing period of broilers**

3.1.2 Moisture absorption

On the basis of weight of water absorbed per weight of bedding material, wheat straw absorbed significantly ($P<0.05$) more water than peanut hulls, wood shavings or sunflower hulls (Figure 3.). A number of factors determine the amount of water absorbed by a material. According to Pearson *et al.* (1999) the amount of water present in the original product will reduce the amount of additional water that can be absorbed. In the present study peanut hulls contained 10.2 % moisture, sunflower hulls 9.2 %, wood shavings 7.7 % and wheat straw 6.9 %. Therefore the higher moisture holding capacity of wheat straw coincided with lower moisture content. The same relationship was however not observed for the other bedding materials. These results must be interpreted with caution as simple and multiple linear regression and correlation's coefficients could not be calculated. From Table 2 it is clear that the moisture holding capacity of the same bedding material can vary considerably. Factors like moisture, present in the original product (humidity) and particle size could contribute to these different results of various researchers. The amount of moisture absorbed could also be influenced negatively by a higher fat content in peanut- and sunflower hulls compared to wood shavings and wheat straw. Smaller

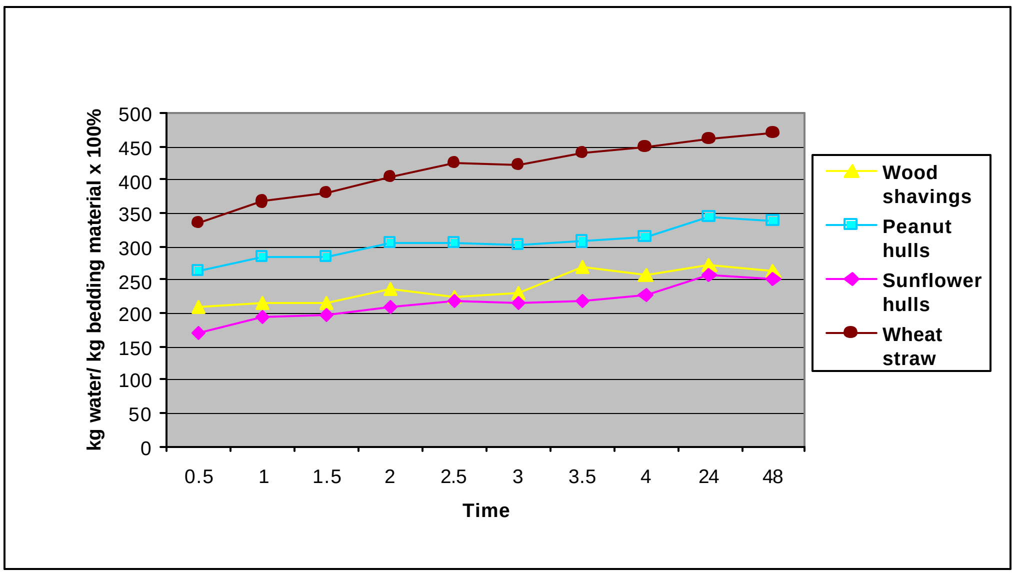


Figure 3 **Moisture holding capacity of various bedding materials**

particle size absorbs more water, but too small particles may cause a dust problem for the broilers (Pearson *et al.*, 1999). No fat analysis was however carried out on the different bedding materials compared in the present study.

Table 2 Moisture holding capacity of various bedding materials

Bedding material	Current trail kg water/ kg material	Ames[1] kg water/ kg material	Adams[2] kg water/ kg material	Antoniewicz[3] kg water/ kg material
Wood shavings	2.4	2.0	1.3-1.5	3.0
Peanut hulls	3.0			2.5
Sunflower hulls	2.2			
Wheat straw	4.2	2.1	3.0	2.95

[1] Ames I.A, Dairy housing equipment handbook, 6th edition

[2] Adams R.S, Dairy reference manual, 3rd edition (1995)

[3] Antoniewicz, R.J, Bedding for horses (2002)

3.1.3 Moisture release

No significant (P> 0.05) differences in the percentage moisture release of different bedding materials occurred. Table 3 shows the average moisture release time of all four bedding materials, with their standard deviation.

Table 3 Average moisture -releasing percentages of bedding materials over different time slots

Moisture Release time	Average %	STDV
1	0.63	0.10
2	0.96	0.16
3	1.23	0.23
4	1.52	0.26
5	1.82	0.25
6	2.14	0.26
24	6.24	0.84
48	10.82	2.00

3.1.4 Ammonia production

Ammonia production is caused by the bacterial breakdown of uric acid in the litter of poultry. According to Lacy (2002), the primary cause of high levels of ammonia is a high level of moisture in the litter. The ammonia levels of the different treatments are given in Figure 4. According to Parkhurst & Mountney (1988), an ammonia level of

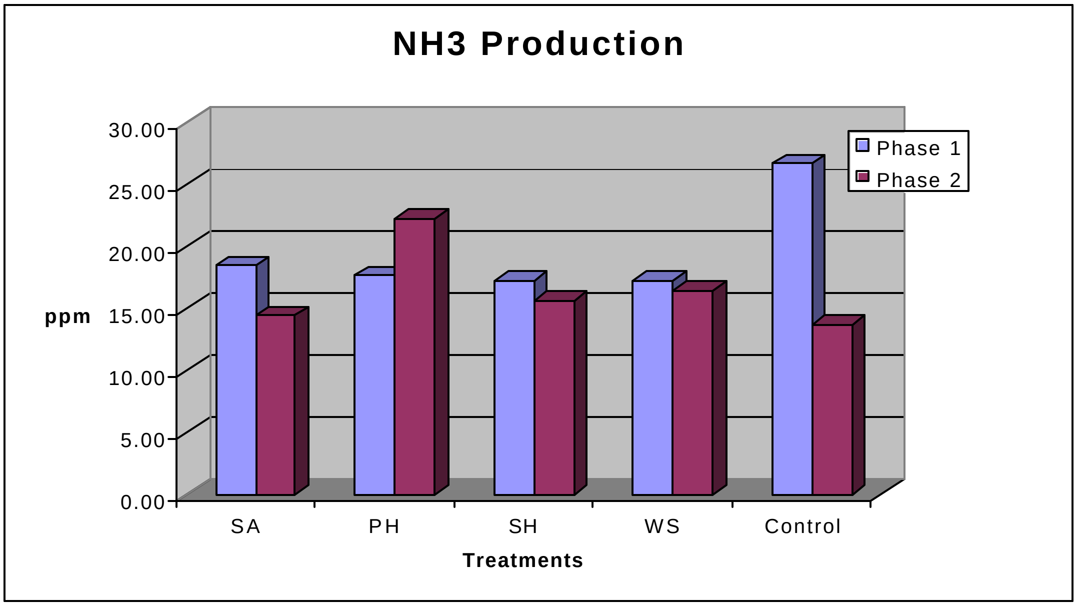


Figure 4 **The influence of bedding material on ammonia production in broiler cages**

With; SA = wood shavings, PH = peanut hulls, SH = sunflower hulls, WS = wheat straw

25-35ppm causes eyes to burn. This level only occurred in the control group during Phase 1. No significant differences ($P<0.05$) in ammonia production were however detected between the various treatments. In the current study ammonia production was measured on day 30 when relatively lower temperatures prevailed (Figures 1 & 2). These cooler environments could result in lower ammonia levels. Accordingly ammonia levels tended to be lower during Phase 2 (with the exception of the PH treatment) when cooler average temperatures prevailed (Figure 1).

3.2 Performance

The influence of bedding material on the performance of broilers is shown in Table 4. No statistically significant ($P>0.05$) differences occurred in feed intake, weight gain, efficiency of feed conversion, carcass weight and dressing percentage of broilers on the different treatments of bedding materials used. Accordingly Swain & Sundaram (2000) and Anisuzzaman and Chowdhury (1996) reported that the type of bedding material did not affect ($P>0.05$) the final mass, carcass mass and dressing percentage of broilers. Hester *et al.* (1997) reported the same results with turkeys grown on different bedding materials including fine particleboard, coarse particleboard and hardwood shavings. In the present study the broilers with even no bedding material in their cages did not perform significantly different from those with bedding material. These results are probably only valid at the temperatures experienced in the present study. The average and extreme (minimum and maximum) temperatures seem to be moderate enough for the broilers without bedding material to perform well. In accordance with the lower average and extreme temperatures during Phase 2 the broilers tend to perform poorer.

According to Swain & Sundaram (2000) production number, calculated from average body weight, livability (percentage of chicks that survived the feeding period) and feed conversion, is a reliable measurement of the efficiency and performance of broilers. This value reflects the weighted sum of average body weight, percent livability, duration of period and feed conversion. From Table 4 it is evident that the highest ($P<0.05$) production number was calculated for broilers on peanut hulls, followed by the control, wood shavings, sunflower hulls and ending with wheat straw.

4. CONCLUSION

Wheat straw showed the highest moisture holding capacity of all the bedding materials. It seems, however, from the literature that the moisture holding capacity of the same bedding material can vary considerably depending on factors like moisture present in the original material and particle size. In the present study bedding material had no influence on ammonia production. At higher temperatures that prevailed in the present study (30° C and higher) no bedding material could have resulted in the production of unacceptable high ammonia levels.

From the results in the present study it further seems that the different types of bedding materials did not influence the feed intake, weight gain, feed conversion and carcass weight of the broilers significantly ($P>0.05$). These results were obtained

Table 4 Performance of broilers raised on different kinds of bedding material

Characteristics Measured	Period	Treatments 1 (SA)[2]	2 (PH)	3 (SH)	4 (WS)	5 (Contol)	X	Significance ($P<0.05$)[1]
Intake (g air dry/bird/day)	1	94.22	94.72	92.13	92.43	93.71	93.44	NS
	2	86.89	87.61	86.55	87.87	86.92	87.17	
	X	90.55	91.16	89.34	90.15	90.31		NS
Initial weight (g/bird)	1	55.23	54.63	55.42	55.35	55.77	55.28	1>2
	2	41.37	42.50	41.23	41.60	35.63	40.47	(period)
	X	48.30	48.57	48.33	48.48	45.70		NS
Final weight (g/bird)	1	1.9918	2.0331	2.0134	1.9918	1.9777	2.0015	NS
	2	1.8749	1.8712	1.9233	1.9249	1.8961	1.8981	
	X	1.9333	1.9521	1.9683	1.9584	1.9369		NS
Average daily weight gain (g/bird)	1	46.11	47.11	46.62	46.11	45.76	46.34	NS
	2	44.56	44.70	43.20	45.02	43.67	44.23	
	X	45.33	45.90	44.91	45.56	44.71		NS
Feed conversion (g air dry feed/g gain)	1	1.92	1.85	1.87	1.86	1.93	1.89	NS
	2	1.87	1.84	1.89	1.83	1.90	1.86	
	X	1.89	1.84	1.88	1.85	1.91		NS
Production number[2]	1	4006.28	4037.50	4084.09	3909.54	4099.08	4027.30	NS
	2	3976.98	3988.94	3818.22	3622.89	3903.03	3862.01	
	X	3991.63	4013.22	3951.15	3766.22	4001.05		2>5>1>3>4
Carcass weight (kg/bird)	1	1.5560	1.5670	1.5530	1.5274	1.5429	1.5492	NS
	2	1.4500	1.4668	1.4249	1.4639	1.4182	1.4448	
	X	1.5030	1.5169	1.4890	1.4956	1.4805		NS
Dressing %	1	78.1200	77.0767	77.1333	76.6867	78.0233	77.41	NS
	2	75.8033	76.4167	76.7900	75.7533	75.8533	76.12	
	X	76.9617	76.7467	76.9617	76.2200	76.9383		NS

[1]Non-significant interaction

[2]Production number = $\frac{\text{abw x \% liv.}}{\text{Days x fc/10}}$

with abw = average body weight; liv. = percent livability; days = duration of period; fc =feed conversion.

SA = Wood shavings; PH = Peanut hulls; SH = Sunflower hulls; WS = Wheat straw.

NS = Non-significant

X = Average

despite the lower and more extreme temperatures prevailing during Phase 2. In fact the lack of any bedding materials did not result in poorer performance where room temperatures below 20°C were recorded. The electric brooders were probably adequate to prevent the low temperatures and the maximum temperature was not to extreme to result in any differences in performance. According to production number peanut hulls should be preferred as a bedding material for broilers. If not available, no bedding material would be the second best option if temperatures were not to high (more than 30°C) followed by wood shavings, sunflower hulls and lastly wheat straw. The availability of bedding material under specific circumstances could however be a defining factor in deciding which one to use.

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CHAPTER 4

THE EFFECT OF BEDDING MATERIAL IN BROILER LITTER AND COMPOSTING TIME OF LAYER HEN MANURE ON THE NUTRITIVE VALUE FOR RUMINANTS

1. INTRODUCTION

The possibility of using poultry litter as a cheap dietary ingredient for ruminants has been considered over a long period (Noland *et al.,* 1955; Van der Merwe *et al.,* 1975a and 1975b). The most current and strongest interest was in its use for cattle (Ayangbile *et al.,*1993; Brosh *et al.,* 1993; Rude & Rankins, 1993 Jacob *et al.,* 1997 and Daniel & Olson, 2001), sheep and goats (Murthy *et al.*, 1995; Chaudhry *et al.*, 1996; Murthy *et al.*, 1996; Deshck *et al.*, 1998; Mavimbela, 2000 and Mavimbela & Van Ryssen, 2001).

A major hampering factor in the utilization of poultry manure/litter as a ruminant feed is the variation in the chemical composition and nutritional value thereof. Various factors like different production systems (i.e. layers and broilers), diets, feed wastage's, bedding materials and collection periods can influence the chemical composition and nutritional value of poultry manure/litter.

In South Africa bedding materials like wood shavings, wheat straw, sunflower- and peanut hulls are used in broiler production systems. In other parts of the world good quality grass (Rude & Rankins, 1993), shredded/processed paper (Howard & Heimlich, 2002; Lacy, 2002), sand (Bilgili *et al.*, 2000), rice hulls, sugarcane pomace (bagasse) and crushed com cobs (Lacy, 2002) are used. In contrast to the United States of America, where broiler houses are cleaned once a year, in South Africa they are cleaned after every batch of broilers. These different bedding materials as well as cleaning practices could influence the nutritive value of poultry litter for ruminants and needs further investigation.

An important factor that can influence the nutritive value of layer manure for ruminants is the period that it gathers under cages (batteries). In practice the gathering period of layer manure and or composting time varies considerably and could influence ammonia losses, nutritional value and the presence of pathogens and mycotoxins. This aspect also needs further investigation. No scientific research results and guidelines about the influence of bedding materials generally used in South Africa or on the nutritive value of poultry litter (from different bedding material) for ruminants, could be found in the available literature. Accordingly no research on the influence of gathering (composting) of layer manure under cages on the nutritive value could be found. Accurate guidelines regarding both aspects can advantageously influence the nutritional value, safe use and marketing value of poultry manure/litter as a ruminant feed.

The aim of the study was firstly to investigate the influence of wood shavings, peanut hulls, sunflower hulls and wheat straw as bedding material for broilers on the nutritional value and safety of the poultry manure/litter as a feed source for ruminants. Secondly the influence of composting time of manure under layer cages, on the nutritional value for ruminants was investigated.

2. MATERIALS AND METHODS

2.1 Treatments

2.1.1 Broilers

Six hundred, day old Ross-1-broilers were randomly divided into 30 groups of 20 each, as described in Chapter 3. Six groups were then randomly allocated to one of the following five treatments:

1. Wood shavings and saw dust (0.5 to 5 cm in particle size)
2. Peanut hulls
3. Sunflower hulls
4. Wheat straw (grind through a 30 mm sieve)
5. Control group (cement floor)

The different groups have been randomly allocated to 30 broiler cages. The cages were made of hard board material. The cages were 1.2 x 1.2m, and had a floor space of $1.44m^2$ (14 birds per m^2)(Figure 1) as advised by Parkhurst & Mountney (1988). Ten kilogram moist free bedding materials was placed in each cage. The bedding material was spread to a depth of 10 cm according to Parkhurst & Mountney (1988); Ross Broiler Management manual (1996) & Lohmann Broiler Management programs (1990). The litter (bedding material) was turned weekly. Maximum and minimum temperatures were taken daily. The group weight of each pen was measured weekly. The trail was conducted from March to June and consisted of two six weeks periods including three replications per treatment. The first period was from March to April and the second from April to June 2002.

Broiler diets, as indicated in Table 1, were fed *ad libitum* as mash. Water was available at all times. Commercially available plastic circular feeders and waterers were used. The experiment was conducted from day old to 42 days of age. The day old chicks were immunized against Newcastle disease (live vaccine), infec Bronchitis (live vaccine) and Mareks disease (rispin).

2.1.2 Layer hens

Ninety 20-week old White Plymouth Rock layer hens were randomly divided into 30 groups of 3 each. The 30 groups were then randomly allocated to 5 treatments of 6 groups per treatment (Figure 2). All the layers received a commercial layer diet (Table 2) *ad libitum*.

The manure of each treatment was separately collected in a bowl, placed under each cage, after the following periods:

Group	Day collected
1	Daily
2	After 14 days
3	After 28 days
4	After 42 days
5	After 56 days
6	

The manure was dried at 100ºC after collection and moisture analysis was done.

Figure 1 **Broilers in the hard board cage's, with feeders and waterers**

Figure 2 **Layers in the batteries used in this study**

Table 1 Physical and chemical composition of the bro iler diet

ITEM	Diet		
	Broiler Starter[1]	**Broiler Finisher[2]**	**Broiler Post-Finisher[3]**
Physical composition (%)			
Prime Gluten	3.50	3.50	3.37
Soya oil cake (48%)	25.41	19.15	13.67
Sunflower oil cake (30%)			0.91
White Fishmeal	1.20	0.10	
Maize (8. 5%)	64.56	72.66	77.75
Feedgrade Limestone	1.71	1.67	1.72
Salt (no 1 fine)	1.04	0.79	0.66
Kynofos 21 MCP	2.00	1.55	1.26
Methionine	0.17	0.16	0.16
Lysine	0.20	0.23	0.30
Broiler Starter Premix	0.20		
Broiler Finisher Premix		0.20	
Broiler Post-Finishe r Premix			0.20
Chemical composition (%)			
Protein (min)	22.0	18.0	18.0
Fibre (max)	5.0	5.0	5.0
Moisture (max)	12.0	12.0	12.0
Fat (min)	2.5	2.5	2.5
Calcium (max)	1.2	1.2	1.2
Phosphorous (min)	0.7	0.6	0.5
Lysine (min)	1.1	0.9	0.9

[1] Day 1-14

[2] Day 15-35

[3] Day 36-42

Table 2 Physical composition of the layer hen basal diet on an air dry basis

ITEM	CONTENT
Physical composition (%)	
Old meal monogastric stomach	2.00
Maize 8% fine	38.15
Wheat 12.5%	10.00
Maize gluten 20-21.5%	8.00
Hominy Chop	6.00
Polar average fibre	1.85
Soybean oil cake 47%	2.20
Sunflower oil cake 36-37%	14.85
Feather meal	5.00
Bone meal	1.00
Limestone grit	5.00
Limestone gravel	3.30
Mono calcium phosphate	0.12
Salt (fine)	0.26
Molasses	1.50
Lysine	0.28
Methionine	0.09
Premix E[1]	0.40
Chemical composition (%)[2]	
Protein (min)	17.48
Fat (min)	3.84
Fibre (max)	6.70
Calcium (max)	3.60
Phosphorous (min)	0.68

[1] Vitamin and mineral premix for layers

[2] Specifications of commercial diets

2.2 Sampling

2.2.1 Broilers

At the end of the trial all the litter (bedding material and manure) of each group (replicate) were collected and weighed. Each batch's litter was mixed thoroughly. The litter was then quartered and a representative sample was taken. All the samples were dried at 100°C and milled through a 0.75mm sieve for chemical analysis. The rest was milled through a 2mm sieve (Michalet- Doreau & Ould-Bah, 1992) for *in sacco* degradability measurements.

2.2.2 Layer hens

At the end of the trail all the manure of the different treatments were thoroughly mixed separately. The litter was then quartered and representative samples were taken. All the samples were milled through a 0.75 mm sieve for chemical analysis.

2.3 Chemical Analysis

All chemical analysis was carried out in duplicate for both the broiler litter, as well as the layer hen manure samples.

2.3.1 Dry matter

At the end of the trial the litter was collected and samples were dried in an oven at 100°C to a constant weight.

2.3.2 Ash

Approximately 2 g of each poultry manure/litter sample was weighed accurately into a crucible and dried in an oven for a minimum of 16 hours (overnight) to a constant mass.

After it was dried to a constant mass, it was placed in a cool muffle furnace and ashed at 550° for a minimum of four hours (AOAC, 1984).

2.3.3 Acid detergent fibre (ADF)

ADF was determined by the method of Goering & Van Soest (1970), with the use of the Tecator Fibertec System.

2.3.4 Neutral detergent fibre (NDF)

NDF was determined by the method of Robertson & Van Soest (1981), with the use of the Tecator Fibertec System.

2.3.5 Fat

Fat was analyzed according to the AOAC official method 920.39 (AOAC, 2000) with some alterations, where hexane were used in the place of ether extract.

2.3.6 Minerals

Dry-ashing of the litter with sulfuric acid, according to Hesse (1971), was used to obtain the mineral values.

2.3.7. *In vitro* organic matter digestibility (IVOMID)

IVOMID was determined according to the two-phase technique by Tilley & Terry (1963) as modified by Engels & Van der Merwe (1967).

2.3.8 Crude protein

Crude protein (CP) was determined using a Leco Auto Analyser (model FP-528) Protein/Nitrogen determinator (©2001 LECO ® Corporation).

2.3.9 Degradability

Fifteen samples were prepared as described in par. 2.2 and subjected to *in sacco* degradability measurements.

(a) Bags

The artificial fibre bags were made according to the dimensions described by Meherez & ? rskov (1977). According to Michalet- Doreau & Ould-Bah (1992) the average pore size must be between 40 and 60 um. For this porosity, particle loss is not important and its impact on degradability of nitrogen feed is low. Nylon material (HS013 Nylon cloth: Simon-Macforman (Pty) Ltd, 2 Purlin Street, Isando, RSA), with the following specifications, was used:

Average Pore size - 53 ± 10 um
Effective size - 150 x 80 mm

Before stitching the seams (run and fell seams), the material was folded into double layers.

(b) Incubation

Broiler litter samples were milled to pass through a 2 mm sieve (sampling, paragraph 2.2.1) and of which approximately 5g moist free was accurately weighed into each bag (~ 15mg DM cm^{-2} bag surface area). In order to avoid period effects all samples were incubated simultaneously (complete exchange method: Pain *et al.,* 1981) for each of the following periods:

Day 1 – 1, 2 and 4 hours
Day 2 – 8, 12, and 24 hours

Dry matter and N disappearance were measured in duplicate with each of the three sheep allocated per sample as recommended by Mehrez & Ørskov (1977), giving a total of six estimates per sample. The experimental design is shown in Table 3. At the end of each incubation period, the bags were removed from the rumen, washed under running water until the water was clear and dried at 80°C in an oven.

After cooling in a desiccator, the bags plus their contents were weighed and the percentage *in sacco* DM disappearance was calculated. Samples were taken out of the bags and stored in polyethylene vials for later analyses of nitrogen according to the LECO procedures described in paragraph 2.3.8.

The percentage DM and N disappearance at each incubation was calculated from the proportion remaining after rumen incubation according to Ørskov & McDonald (1979).

Table 3 Experimental design for the degradability study

Animal No.	Sample No.	Period (days)					
		Day 1	Day 1	Day 1	Day 2	Day 2	Day 2
		Incubation time (h)					
		1	2	4	8	12	24
1	B1	*	*	*	*	*	*
2	B1	*	*	*	*	*	*
3	B1	*	*	*	*	*	*
4	B2	*	*	*	*	*	*
5	B2	*	*	*	*	*	*
6	B2	*	*	*	*	*	*
7	B3	*	*	*	*	*	*
8	B3	*	*	*	*	*	*
9	B3	*	*	*	*	*	*
10	B4	*	*	*	*	*	*
11	B4	*	*	*	*	*	*
12	B4	*	*	*	*	*	*

2.3.9.1 Animals

The *in sacco* technique described by Erasmus *et al.* (1988) and Erasmus *et al.* (1990), with some alterations was used. Twelve White Dorper lambs were individually housed indoors in metabolism crates.

The lambs were fitted with rumen cannula (40 mm internal diameter) which facilitate manual placement of bags in the ventral portion of the rumen. They were vaccinated against *Clostridium botulinium* three weeks before and vaccinated with Dectomax® (1% (10mg/ml) doramectin) one week before the degradability determinations were begun. Dectomax® were used for the treatment and control of internal parasites (1ml/ 50kg live weight).

2.3.9.2 Basal diet

The twelve Dorper lambs were fed a diet consisting of the following: 50% lucerne, 48.5% maize meal, 1% salt and 0.5% dicalcium phosphate on an air dry basis. This diet contained 11.62% protein, 9.76 MJ/kg ME, 0.62% Ca and 0.29% P. The diet were fed on an *ad libitum* basis. Allotments were offered twice daily at 08h00 and at 16h00.

2.4 Statistical analysis

A one way anova with treatments in a 2 X 5 factorial were used for the broiler litter and a one way anova was used for the layer manure (Proc Anova of SAS, 1994). For bedding materials the broiler treatments were wood shavings, peanut- and sunflower hulls, wheat straw and a control group on a cement floor. Treatments for the layers were daily, 14 days, 28 days, 42 days and 56 days removal respectively.

3. RESULTS AND DISCUSSION

3.1 Broiler litter

3.1.1 Broiler litter production

The dry matter intake and manure production of broilers, on different bedding materials are presented in Table 4. No significant differences in dry matter intake and

Table 4 Intake and manure production of broilers on a dry matter basis (42 days)

	Treatments				
	1 (SA)[1]	**2 (PH)**	**3 (SH)**	**4 (WS)**	**5 (Control)**
Dry matter intake/broiler (kg)	3.803	3.729	3.752	3.738	3.793
Dry matter manure/broiler (kg)	0.866	0.886	0.778	0.966	0.897
Bedding material (kg)	10.00	10.00	10.00	10.00	0.00
Apparent dry matter digestibility (%)	77.24	76.25	79.26	74.16	76.37

[1]SA – Wood shavings
PH – Peanut hulls
SH – Sunflower hulls
WS – Wheat straw
Control group

excretion of manure occurred. Consequently no significant differences in the digestibility of the same diet fed to the broilers on different bedding material was observed. These results are in accordance with the weight gain, feed conversion and carcass weight results of broilers reported in Chapter 3. Accordingly Oliveira *et al.* (1974) observed that type of litter had no significant effect on growth rate, food conversion, mortality and performance index of broilers reared on sand, wood shavings and rice husk. From Table 4 it can be calculated that a broiler excreted approximately 878g dry matter in a 42 day period.

3.1.2 Nutrient content of bedding material

The nutrient content of the bedding material is shown in Table 5. No statistical analysis could be done and therefore only the most important differences will be discussed. The highest CP–contents and *in vitro* digestibility was recorded for PH. On the other hand SA showed the lowest CP- content and *in vitro* digestibility. The CP-content of WS was the second lowest but the *in vitro* digestibility was similar than SH. The highest major- and trace mineral content was in SA and WS. These differences in nutrient content of different bedding materials could possibly be reflected in that of broiler litter.

3.1.3 Nutrient content of broiler litter

3.1.3.1 Crude protein

From Table 6 it is clear that the highest ($P<0.05$) CP content occurred in the manure of broilers raised on no bedding material followed by the PH treatment. No significant ($P>0.05$) differences occurred in the crude protein content of manure from the SA and WS treatments. Compared to the CP values in Table 6 it seems that the protein values of the different bedding materials accordingly influenced the CP content of the broiler litter. According to Jacob *et al.* (1997) more than 40 percent of the crude protein in litter can be in the form of non protein nitrogen. The non protein nitrogen is mostly in the form of uric acid excreted by poultry.

Table 5 Nutrient content of bedding material on a dry matter basis

Item	Bedding Material			
	SA[1]	PH	SH	WS
Crude protein (%)	1.30	10.85	7.79	3.88
Acid detergent fibre (%)	44.44	63.88	47.41	48.74
Neutral detergent fibre (%)	88.68	75.42	80.60	82.73
Fat (%)	1.93	1.61	1.65	0.78
Ash (%)	1.14	6.39	4.29	9.82
In vitro digestibility (%)	29.68	56.51	47.87	47.92
<u>Minerals</u>				
Sodium (%)	0.88	0.01	0.02	1.20
Calcium (%)	1.44	0.12	0.20	2.21
Potassium (%)	2.20	1.44	0.81	2.87
Magnesium (%)	0.45	0.15	0.13	0.82
Phosphorus (%)	1.20	0.05	0.10	1.95
Copper (ppm)	52	5	6	82
Iron (ppm)	1405	483	339	1800
Zinc (ppm)	365	19	26	560
Manganese (ppm)	332	56	41	393

[1]SA – Wood Shavings

PH – Peanut hulls

SH – Sunflower hulls

WS – Wheat straw

Van Ryssen (2000) mentioned that, South African samples usually contain between 18 and 22% crude protein. A similar average crude protein content of 19.67% was recorded in the current study, with the highest value in the control group (28.14%) and the lowest value (16.18%) in the wood shavings group. Bagley & Evans (1998) is of opinion that good quality broiler litter should contain 20 – 30% crude protein, and if values are below 18%, the litter should be used only as a fertilizer and not as a feed source. Compared to this guideline SA, SH and WS bedding material is not suitable when broiler litter is destined for feeding purposes. This also apply when the crude protein content of the litter in the present study is compared with the specifications published by the South African Farm Feed Act (Act 36 of 1947). According to this act all the broiler litter with bedding material was in terms of crude protein acceptable for feeding purposes.

Table 6 Nutrient content of litter from broilers raised on different bedding materials (dry matter basis)

Item	Treatments					Significance	
	1 (SA)[1]	2 (PH)	3 (SH)	4 (WS)	5 (Control)	(P<0.05)	CV
Crude Protein %	16.18	19.28	17.53	17.25	28.14	5>2>3,4,1	7.77
Acid detergent fibre (%)	33.58	29.77	29.16	26.24	12.30	1>2,3>4>5	6.55
Neutral detergent fibre (%)	64.29	60.76	60.69	59.58	42.23	1,2,3,4>5	3.42
Fat (%)	1.14	1.13	1.38	1.40	2.04	NS	47.05
Ash (%)	13.94	17.54	15.15	17.48	21.54	5>2,4,3>1	9.86
***In vitro* digestibility (%)**	54.88	59.39	59.88	65.24	76.79	5>4,3,2>1	5.58
Minerals							
Sodium (%)	0.87	0.81	0.64	0.73	0.85	NS	32.29
Calcium (%)	1.69	1.47	1.29	1.30	1.65	NS	30.89
Potassium (%)	2.02	2.38	1.73	2.11	2.24	NS	23.85
Magnesium (%)	0.49	0.49	0.37	0.36	0.49	NS	34.86
Phosphorus (%)	1.41	1.17	1.13	1.13	1.30	NS	32.46
Copper (ppm)	60.17	47.50	41.67	35.50	61.33	NS	44.56
Iron (ppm)	1189.83	1300.00	1207.00	1051.83	1290.67	NS	40.57
Zinc (ppm)	382.50	326.67	265.33	255.83	356.67	NS	34.49
Manganese (ppm)	292.83	258.33	275.17	302.17	316.33	NS	34.24

[1]SA – Wood shavings
PH – Peanut hulls
SH – Sunflower hulls
WS – Wheat straw
Control – No bedding material
CV – Coefficient of variation

The influence of bedding material on the degradability of crude protein in broiler litter is illustrated in Table 7. An absence of the rapidly soluble nitrogen fraction occurred.

Table 7 Crude protein degradability of litter from broilers raised on different bedding materials

Item	1 (SA)	2 (PH)	3 (SH)	4 (WS)	5 Control	Significance (P<0.05)	CV
a[1] (%)	-0.05	0.01	0.01	-0.08	0	NS[3]	-218.62
b[1] (%)	56.23	46.44	43.98	39.32	52.84	NS[3]	14.28
c[1] (%)	1416.6	24.76	265.3	3533.7	329.5	4,1>5,3,2	74.62
Effective degradability							
r = 0.02[2]	55.93	46.07	43.65	39.22	52.49	NS[3]	14.4
r = 0.05[2]	55.56	45.5	43.15	39.18	51.98	NS[3]	14.62
r = 0.08[2]	55.19	44.94	42.66	39.15	51.47	NS[3]	14.83

[1]) Fitted parameters a, b & c derived from *in sacco* determination of effective ruminal protein degradability where:

a = Rapidly soluble nitrogen fraction

b = Fraction which will degrade in time

c = Rate at which *b* fraction degrades

[2]) Rate of passage (McDonald et al., 2002)

[3]) NS = Non-significant (P>0.05)

SA – Wood shavings

PH – Peanut hulls

SH – Sunflower hulls

WS – Wheat straw

Control – No bedding material

CV – Coefficient of variation

According to Van Ryssen (2000) the crude protein in litter consists of both true protein nitrogen and non protein nitrogen (NPN), with uric acid the main NPN component. The proportion of true protein in litter varies between 40 and 60 percent of the crude protein. It could be expected that the uric acid is a rapidly soluble nitrogen fraction. These findings were however not supported by the absence of rapidly soluble nitrogen values in Table 7. Bacterial breakdown of uric acid to ammonia and the subsequent ammonia losses could probably have attributed to these findings. In Chapter 3 evidence of ammonia losses was found, which could contribute to an absence of the rapidly soluble nitrogen fraction.

A higher (P<0.05) rate at which fraction *b* degrades were found for the wheat straw and wood shavings containing broiler litter. It is however difficult to explain these findings.

From Table 7 it is evident that bedding material in broiler litter did not influence effective degradability of crude protein statistically significant (P>0.05). Mavimbela (2000) reported higher rumen degradability values of between 72 and 86% for the crude protein in poultry litter. Van Ryssen (2000) is of opinion that at higher litter intakes, high concentrations of ammonia are founded in the rumen and consequently high blood urea nitrogen concentrations. Silanikove & Tiomkin (1992) observed liver damage in beef cows consuming high levels of litter in an over-wintering diet. They stated that liver damage was caused by high ammonia concentrations in the rumen due to uric acid catabolism. This could not be substantiated by Mavimbela *et al*. (1997). Accordingly the rapidly soluble nitrogen fraction as well as effective degradability of crude protein in the broiler litter produced in the present study, was probably too low to cause excessive ammonia production in the rumen. Various factors could however influence degradability values of feeds. According to McDonald *et al*., (2002), a basic assumption of this method is that disappearance of nitrogen from the bag, virtually reflected solubility in rumen fluid, is synonymous with degradability. It has been known for some time that small amounts of food protein which are solubilised may leave the rumen without being degraded, and this must cast doubt on the veracity of values obtained using the technique. Even more serious in this context is the recent observation that acid-detergent insoluble nitrogen (ADIN), known to be undegradable, may disappear during incubation. A further complication is the presence of rumen bacteria in the bags, which contribute to the amount of nitrogen in the contents.

3.1.3.2 Fibre

The highest (P<0.05) ADF content was recorded for SA and the lowest for the control treatment, while the rest showed no significant differences. No significant differences however occurred in the NDF content of broiler litter gathered on the different bedding materials. The lowest (P<0.05) NDF content was again found where no bedding material was supplied. The higher fibre content of the poultry litter with bedding material could influence the digestibility detrimentally. This was confirmed by the *in vitro* digestibility results, where the highest values was recorded for the broiler litter without bedding material. According to Van Ryssen (2000) South African litter contains more fibre and has on average larger particle sizes (higher effective fibre) than litter in the USA. The reason is probably because, in the USA five to six batches of broilers are apparently kept on the same litter material before the houses are cleaned, while in South Africa the houses are cleaned after each batch of birds.

3.1.3.3 Fat

No significant differences ($P<0.05$) occurred in the fat content of broiler litter originating from the different treatments. The fat content of the broiler litter containing bedding material was however lower than the specifications laid down by the South African Farm Feed Act (Act 36 of 1947), namely a minimum of 1.5 % fat.

3.1.3.4 Ash

The highest ($P<0.05$) ash content was in the pure excretion and the lowest in broiler litter containing SA. There were no significant differences ($P<0.05$) amongst the remaining treatments. It seemed that pure poultry excreta had a high ash content which was diluted by the use of bedding material. This was also the case for PH and WS, which were collected from the ground and could have been contaminated with soil. The average ash content of five treatments was 17.13%. According to Van Ryssen (2000) the ash content of broiler litter can vary between 10 and 26% compared to the 14 and 18% found in the present study. Van Ryssen (2000) mentioned that ash concentration in the litter is relatively high and tends to dilute the concentration of other nutrients in litter. The high ash content reported by this author could probably be attributed to soil contaminating the litter, usually when handled carelessly during loading with front-end-loaders. The type and concentration of bedding material could also influence the ash content of broiler litter.

3.1.3.5 *In vitro* digestibility

The relationship between fibre content and digestibility has already been discussed. It is clear that bedding material and especially SA had a profound negative effect ($P<0.05$) on the digestibility and thus energy content of broiler litter. Although not statistical significant ($P>0.05$), WS tended to be the best bedding material in this regard. The possibility also exist that ammonia production caused by the bacterial breakdown of uric acid in poultry litter could increase the digestibility of wheat straw. The ammonia treatment of wheat straw is a common practice to enhance the rumen digestibility of low quality roughage like wheat straw. According to McDonald *et al.* (2002) alkali like ammonia, hydrolyzed the ester linkages between lignin and the sell wall polysaccharides, cellulose and hemicelluloses, thereby causing the carbohydrates to become more available to the microorganisms in the rumen.

It is frequently stated that broiler litter is deficient in energy. Van Ryssen (2000) is however of opinion that with a digestible energy value of between 8.0 and 10 MJ/kg dry matter and a total digestible nutrient content of approximately 60% its available energy value is comparable to that of a good quality hay. From Table 6 it is evident that the type of bedding material (SA) could however have resulted in a lower energy value than good quality hay.

3.1.3.6 Minerals

From Table 6 it is clear that bedding material had no significant (P>0.05) influence on the mineral content of broiler litter. The following average values for the minerals in the broiler litter were recorded namely Na (0.78%), Ca (1.48%), K (0.78%), Mg (0.44%), P (1.23%), Cu (49mg/kg), Fe (1208mg/kg), Zn (317mg.kg) and Mn (289mg/kg). With the exception of K, Cu, and Mn the concentration of all the other minerals was lower than the values reported by Van Ryssen (2000). Compared to the specifications laid down by the South African Farm Feed act (Act 36 of 1947) the Ca concentration in the broiler litter were lower (1.4 vs. 3.5%). It is however clear that an abundance of most minerals were present in the broiler litter and that it seems to be an excellent source of minerals to the animal. Van Ryssen *et al* (1977) pointed out that Copper toxicity used to be a problem when sheep consumed broiler litter from broilers receiving high levels of copper sulfate to act as a growth promoter and / or anti-fungal agent. From Tables 1 and 6 it is however clear that copper sulfate was not included in the diet of the broilers. Accordingly from a latest survey of Van Ryssen *et al.* (2000) it became obvious that copper sulfate is not used in South Africa as a growth promoter in broiler diets anymore. Although the copper concentrations in litter is still high relative to the requirements of the ruminant. Van Ryssen & Jagoe (1981) mentioned that the concentration of the minerals antagonistic to copper metabolism is also highest in litter. Copper toxicity in sheep should therefore not be a problem in South Africa (Van Ryssen *et al*., 1993)

3.2 LAYER LITTER

3.2.1 Crude Protein

From Table 8 it is clear that collection of layer manure after 56 days resulted in a significant (*P*<0.05) reduction in crude protein content. In this study a typical natural composting or fermentation of manure occurred which were probably accompanied by ammonia losses.

Accordingly Van Ryssen (2000) stated that losses of nitrogen occur during composting of poultry manure. It is clear that composting of layer manure for 56 days, significantly (*P*<0.05) reduced the crude protein degradability. According to Bucklin *et al.* (1997) and Daniel & Olson (2001) overheating of litter during fermentation causes damage to the feeding value, especially protein, of litter. This is due to the fact that a chemical process, termed the Millard reaction, involves the irreversible binding of certain amino acid residues in proteins with sugars. The result is that protein becomes impervious to attack by digestive enzymes and accordingly lower the digestibility of protein. Accordingly crude protein degradability could be reduced. Important was the absence of the rapidly soluble nitrogen fraction where layer manure was collected daily. These findings do not substantiate the argument that bacterial breakdown of uric acid to ammonia and the subsequent ammonia losses, probably attributed to the absence of the rapidly soluble nitrogen fraction in broiler litter and layer manure.

It seems that heat production and the subsequent Millard reaction could probably have reduced the crude protein degradability in broiler litter and layer manure.

Comparing the crude protein content of layer manure at 42 days (Table 8) with broiler litter without bedding material (Table 6) a higher value in favour of broiler litter occurred. The presence of spilled diet in broiler litter as well as a higher crude protein in the broiler compared to the layer diet could possibly have contributed to these findings. This advantage of broiler litter was however cancelled by the presence of

Table 8 Nutrient content of layer manure collected at different time intervals (dry matter basis)

Item	Treatments Period of collection					Tukey	
	1 (Daily)	2 (14 days)	3 (28 days)	4 (42 days)	5 (56 days)	(P<0.05)	CV
Crude protein (%)	27.85	22.42	21.50	21.88	17.34	1>5	17.68
Acid detergent fibre (%)	16.84	18.31	17.42	19.06	17.84	4>1	6.29
Neutral detergent fibre (%)	44.61	45.30	43.92	46.24	44.45	NS	3.27
Fat (%)	0.51	0.55	0.28	0.52	0.42	NS	72.61
Ash (%)	27.97	32.43	35.93	34.14	37.47	5>2,3,4>1	7.49
***In vitro* Digestibility (%)**	72.29	68.94	68.10	68.68	66.49	1>5	3.87
Minerals							
Sodium (%)	0.24	0.29	0.32	0.32	0.35	5,3,2>1	15.01
Calcium (%)	5.40	6.38	7.55	6.34	7.53	3,5>1	13.98
Potassium (%)	1.82	2.36	2.38	2.64	2.72	5>3,2>1	8.17
Magnesium (%)	0.65	0.75	0.77	0.86	0.87	5,4>3,2>1	5.32
Phosphorus (%)	1.30	1.55	1.63	1.72	1.72	5,4,3,2>1	7.99
Copper (ppm)	52.7	63.0	65.6	79.8	71.8	4>1	20.54
Iron (ppm)	2079.2	2385.0	2297.5	2517.5	2290.8	NS	22.09
Zinc (ppm)	395.8	415.0	433.3	459.2	452.5	NS	10.47
Manganese (ppm)	356.0	457.5	478.5	509.7	528.3	NS	24.99

CV – Coefficient of variance

bedding material. These results must however be interpreted with caution, as no statistical comparisons were possible. Crude protein specifications for layer manure as animal feed according to the South African Farm Feed act (Act 36 of 1947) is 22%.

According to this specification a composting time of more than 42 days will result in a lower crude protein value. The influence of composting time of layer manure on protein degradability can be observed in Table 9.

Table 9 Protein degradability of layer manure collected at different time intervals

Item	1 (Daily)	2 (56 days)	Significance (P<0.05)	CV
a[1] (%)	0.01	-0.03	NS[3]	513.16
b[1] (%)	69.04	39.15	1>2	7.94
c[1] (%)	1.25	12.07	NS[3]	178.53
Effective degradability				
r = 0.02[2]	67.94	38.87	1>2	7.84
r = 0.05[2]	66.34	38.51	1>2	7.57
r = 0.08[2]	64.82	38.15	1>2	7.30

[1]) Fitted parameters a, b & c derived from *in sacco* determination of effective ruminal protein degradability where:

a = Rapidly soluble nitrogen fraction

b = Fraction which will degrade in time

c = Rate at which *b* fraction degrades

[2]) Rate of passage (McDonald et al., 2002)

[3]) NS = Non-significant (P>0.05)

3.2.2 Fibre

No clear trend or influence of composting time on the ADF and NDF content of layer manure could be detected. Accordingly the significant difference found for ADF is difficult to explain.

It further seems from Table 6 and 8 that fibre (ADF and NDF) content of broiler excreta without bedding material was lower than that of layer manure collected at 42 days. The opposite however applied when bedding material with a high fibre content was added to broiler litter.

3.2.3 Fat

From Table 8 it is evident that composting time had no significant influence on the fat content of layer manure. In fact the fat content was throughout lower than the 1.5% set by the South African Farm Feed Act (Act 36 of 1947).

3.2.4 Ash

The ash content of layer manure seemed to increase significantly ($P<0.05$) with a delaying collecting period. Organic matter was therefore reduced by fermentation. According to the South African Farm Feed Act (Act 36 of 1947) the maximum ash content of layer manure for animal feed should be 25%. This is lower than the values found in this study. According to Ruffin and McCasey (1998) litter with an ash content above 28% should not be fed to cattle. The reason for this is that cattle do not find even good-quality broiler litter highly palatable and litter with a high ash content (above 28%) will result in poor consumption and subsequent poor animal performance. In agreement with the results of the present study Van Ryssen *et al.* (1993) recorded that from a total of 66 layer houses the average ash content of manure was 35.3 ±10.5%. In fact 80% of these layer houses were above the maximum ash levels stipulated by Act 36 of 1947.

3.2.5 *In vitro* digestibility

The *in vitro* digestibility of layer manure was significantly ($P<0.05$) decreased by a 56- day composting period. This is probably related to the increase in ash content with delaying collecting time. In accordance with a higher ash content the *in vitro* digestibility of layer manure was lower than that of broiler litter (treatment 5 in Table 6 compared with treatment 4 in Table 8). However the adding of bedding material resulted in the opposite results.

3.2.6 Minerals

From Table 8 it is clear that with an increase in the delaying of the collecting time an increase ($P<0.05$) in the percentage of Na, Ca, K, Mg, P and Cu occurred. No significant ($P>0.05$) influence of composting time on the concentrations of Fe, Zn and Mn was observed,

Comparing the Na content of broiler litter with that of layer manure revealed a higher value for broiler litter. On the other hand layer manure showed higher concentrations for Ca, K, Mg, P, Cu, Fe, Zn and Mn. This was especially noticeable where the composting time of layer manure was extended. The fermentation of organic matter in layer manure during composting and / or a higher mineral concentration in the diet of layers (e.g. Ca) could contribute to these findings.

Specifications for poultry manure as animal feed according to the South African Farm Feed act (Act 36 of 1947) are as follows: 8% Ca, 2% P, 0.5% Na and 50 mg/kg Cu. The results in Table 8 show that the layer manure in the current study contain less of these minerals.

4. CONCLUSION

It seems from the results of the present study that all the bedding materials had a pronounced negative effect on the nutritive value of broiler litter. The manure of broilers raised on no bedding material showed a higher crude protein, ash and *in vitro* digestibility and lower fibre content. Furthermore the type of bedding material influenced the nutritive value of broiler litter differently. In this regard wood shavings showed the most prominent negative effect on the nutritive value of broiler litter

Furthermore broiler litter had an abundance of most minerals and seems to be an excellent source of minerals for animals. Important is the fact that copper sulphate was not included in the diet of broilers. Although copper concentrations in the broiler litter were still high relative to the requirements of ruminants, copper toxicity should not be a problem.

The detrimental effect of composting time on the nutritive value of layer manure was clearly illustrated in the present study. It seems that layer manure under the cages should be collected on a regular basis and the composting time should not exceed 42 days.

Compared to the South African Farm Feed Act (Act 36 of 1947), broiler and layer manure with a composting time less than 42 days will be acceptable in terms of their crude protein content. Broiler litter was however not acceptable in terms of fat and calcium content. Accordingly layer manure contained less fat and minerals (Ca, P, Na, and Cu) as stipulated by the Farm Feed Act. The scientific basis for these values given by the Farm Feed Act is however unclear.

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GENERAL CONCLUSIONS

The dramatic growth in the poultry industry over the last 40 years created a need for an increased production performance and disposal of broiler and layer litter. According to the results of the present study one broiler secreted 21 g dry matter per day. Feeding poultry litter/manure to ruminants is a way of disposal of a waste product and concurrently supplying a low-cost protein feed to ruminants. In South Africa the trading of poultry litter/manure requires the registration thereof as an animal feed according to Act 36 of 1947. Further research is however needed on the factors influencing the nutritive value and safety of poultry manure/litter as an animal feed. In this regard different types of bedding material used can influence both performance of broilers and the nutritive value of broiler litter for ruminants. Accordingly composting time of especially layer manure could influence fermentation and feeding value thereof. The results of this study can serve as a guideline on these matters for both broiler producers and feeding consultants.

From the results it seems that wheat straw had the highest moisture absorption capacity. From the literature it however seems that the moisture holding capacity of the same bedding material can vary considerably. Factors like moisture present in the original material, particle size and fat content may influence the amount of water absorbed by a bedding material.

In the present study ammonia production in the broiler cages did not exceed the levels where eyes start to burn. These results were however obtained under prevailing temperatures of ± 28ºC and lower. At higher prevailing temperatures ammonia production in cages could probably cause a problem. This especially applies for cages without any bedding material. Although not statistical significant (P>0.05), undesirable high ammonia levels only occurred when no bedding materials was present in broiler cages.

The different type of bedding materials and even no bedding material in the cages did not statistical significantly influenced (P>0.05) feed intake, weight gain, efficiency of feed conversion, carcass weight and dressing percentage of broilers. Production number which reflects the weighted sum of average body weight, percent livability, duration of period and feed conversion was however the highest for peanut hulls, followed by no bedding material, wood shavings, sunflower hulls and lastly wheat straw. These results probably only apply under the temperatures that prevailed during the experimental period.

From the nutritive value of the broiler litter originating from the different bedding material treatments, it was clear that the inclusion of all the bedding materials had a detrimental effect. The manure of broilers raised on no bedding material showed a higher crude protein, ash and *in vitro* digestibility and lower fibre content. Furthermore it seems that the nutritive value of the different bedding materials was reflected in that of the broiler litter. The highest crude protein content was recorded for broiler litter with peanut hulls. It was however clear that wood shavings had the largest detrimental effect on the crude protein-, fibre-, ash- and energy content (*in vitro* digestibility) of broiler litter.

From the performance of the broilers on the different bedding materials and the nutritive value of the broiler litter it seems that peanut hulls should be preferred as bedding material for broilers. This bedding material resulted in the highest production number (best performance of broilers) and crude protein in broiler litter. The *in vitro* digestibility of peanut hull broiler litter also compared well with that of sunflower hulls and wheat straw. According to production number (performance of broilers) sunflower hulls should be the second choice followed by wheat straw. The crude protein and energy (in vitro digestibility) content of sunflower hulls and wheat straw was comparable. The availability of bedding material under specific circumstances could however be a defining factor in deciding which one to use. Although no bedding material resulted in the second best results in terms of production number and the best results from a nutritive value point of view, bedding material in cages is probably a requisite when the prevailing temperatures exceeded 30ºC.

The detrimental effect of composting time on crude protein- and ash content as well as *in vitro* digestibility was clearly illustrated in the present study. It seems that layer manure under the cages should be collected on a regular basis and that the composting time should not exceed 42 days.

Compared to the South African Farm Feed Act (Act 36 of 1947), broiler and layer manure with a composting time less than 42 days will be acceptable in terms of their crude protein content. Broiler litter was however not acceptable in terms of fat and calcium content. Accordingly layer manure contained less fat and minerals (Ca, P, Na, and Cu) as stipulated by the Farm Feed Act. The scientific basis for these values given by the Farm Feed Act is however unclear.

ABSTRACT

Guidelines for poultry production enterprises to increase the efficiency of broiler production and optimize the nutritional value of poultry litter and manure for use in ruminant nutrition is urgently needed. Therefore a study was conducted to investigate the effect of wood shaving (SA), wheat straw (WS), peanut hulls (PH) and sunflower hulls (SH) as bedding materials on the performance of broilers in conventional floor systems. In a second study the effect of different types of bedding materials and collecting periods on the feeding value of respectively broiler and layer hen manure for ruminants were investigated.

Six hundred, day old Ross-1-broilers were randomly divided into 30 groups of 20 each. Six groups (replications) were then randomly allocated to one of the following five treatments:

1. Wood shavings and saw dust (Byproduct Development Services, 0.5 to 5 cm)
2. Peanut hulls
3. Sunflower hulls
4. Wheat straw (ground through a 30 mm sieve)
5. Control group (cement floor)

Commercial broiler diets were fed *ad lib.* to all experimental groups.

On the basis of weight of water absorbed per weight of bedding material, WS absorbed significantly more water than PH, SA or SH. No significant ($P>0.05$) differences in the percentage moisture release of different bedding materials occurred. Accordingly no significant differences in ammonia production, feed intake, weight gain, efficiency of feed conversion, carcass weight and dressing percentage of broilers were detected among the various treatments. The highest production number (weighted sum of average weight, percent livability, period and feed conversion) was calculated for broilers on peanut hulls, followed by no bedding material (control), wood shavings, sunflower hulls and lastly wheat straw.

It was calculated that a broiler excreted approximately 878g dry matter in a 42 day period. The highest (*P*<0.05) crude protein content occurred in the manure of broilers raised on no bedding material followed by the peanut hulls treatment. No significant differences (*P*>0.05) occurred in the crude protein content of manure from the wood shavings and wheat straw treatments. Bedding materials in broiler litter did not influence effective degradability of crude protein statistically significant. The highest (*P*<0.05) acid detergent fibre content was recorded for wood shavings and the lowest for the control treatment, while the rest showed no significant differences. No significant differences occurred in the neutral detergent fibre (NDF) content of broiler litter gathered on the different bedding materials. The lowest (*P*<0.05) NDF content was again found where no bedding material was supplied. No significant differences occurred in the fat content of broiler litter originating from the different treatments. The highest (*P*<0.05) ash content and *in vitro* digestibility was in the pure excretion and the lowest in broiler litter containing wood shavings. There were no significant differences amongst the remaining treatments. Bedding material had no significant (*P*>0.05) influence on the mineral content of broiler litter.

In an effort to investigate the effect of composting time (collecting period) on the feeding value of layer hen manure, ninety, 20 week old White Plymouth Rock layer hens were then randomly divided into 30 groups of 3 each. The 30 groups were then randomly allocated to 5 treatments. The manure of each treatment was respectively collected daily and after 14, 28, 42 and 56 days.

All the layers received a commercial layer diet *ad lib*.

The collection of layer manure after 56 days resulted in a significant (*P*<0.05) reduction in crude protein content, degradability and *in vitro* digestibility. No clear trend or influence of composting time on the ADF and NDF content of layer manure could be detected. Composting time had no influence on the fat content of layer manure. The ash content of layer manure increased significantly (*P*<0.05) with a delaying collecting period. Delaying of collecting time resulted in an increase in the percentage of Na, Ca, K, Mg, P and Cu of layer manure. No significant (*P*>0.05) influence of composting time on the concentrations of Fe, Zn and Mn was observed.

It was concluded from the performance of the broilers on the different bedding materials and the nutritive value of the broiler litter that peanut hulls should be preferred as bedding material. SH should be the second choice followed by WS. Lastly it seems that layer manure should be collected on a regular basis and that the composting time should not exceed 42 days.

OPSOMMING

Riglyne vir puimvee-ondernemings om die doeltreffendheid van braaikuikenproduksie en die voedingswaarde van braaikuiken- en lêhenmis te verhoog word dringend benodig. Derhalwe is 'n ondersoek uitgevoer om die effek van houtskaafsels (SA), koringstrooi (WS), grondboontjie-doppe (PH) en sonneblomdoppe (SH) as skropmateriaal op die prestasies van braaikuikens na te gaan. In 'n tweede studie is die effek van verskillende skropmateriale en versamelperiodes op die voedingswaarde van onderskeidelik braaikuikenmis en lêhenmis ondersoek.

Ses honderd Ross-1-braaikuikens is ewekansig in 30 groepe van 20 elk ingedeel. Ses groepe (replikasies) is daarna ewekansig aan een van die volgende vyf behandelings toegeken:

1. Houtskaafsels
2. Grondbone-doppe
3. Sonneblomdoppe
4. Koringstrooi
5. Kontrole groep (sement vloer)

Kommersiële diete is *ad lib*. aan alle groepe verskaf.

In terme van gewig water geabsorbeer per gewig skropmateriaal, het WS betekenisvol meer water as PH, WS en SH geabsorbeer. Geen betekenisvolle (P>0.05) verskille in die persentasie vog vrygestel, het tussen die onderskeie skropmateriale voorgekom nie. Eweneens het geen betekenisvolle verskille in amoniak produksie, voerinname, massatoename, doeltreffendheid van voeromset, karkasmassa en uitslagpersentasie van braaikuikens op die verskillende behandelings voorgekom nie. Die hoogste produksie nommer (geweegde som van gemiddelde gewig, persentasie-oorlewing, periode en voeromsetting) is bereken vir braaikuikens op PH, gevolg deur geen skropmateriaal, SA, SH en laaste WS.

Dit is bereken dat 'n braaikuiken 878g droëmateriaal oor 'n periode van 42 dae uitskei. Die hoogste (P<0.05) ruproteïeninhoud is in die mis van braaikuikens

waargeneem wat op geen skropmateriaal groot gemaak is, gevolg deur die PH behandeling. Geen betekenisvolle verskille (*P*>0.05) het in die ruproteïeninhoud van mis afkomstig van die SA- en WS- behandelings voorgekom nie. Skropmateriaal in braaikuikenmis het nie effektiewe degradeerbaarheid van ruproteïen statisties betekenisvol beïnvloed nie. Die hoogste (*P*<0.05) suurbestande veselinhoud (SBV) is vir SA- en die laagste vir die kontrole behandeling gevind. Die res het geen betekenisvolle verskille getoon nie. Geen betekenisvolle verskille het in die neutraal bestande veselinhoud (NBV) van braaikuikenmis voorgekom wat op verskillende skropmateriale versamel is nie. Die laagste (*P*<0.05) NBV-inhoud is weereens waargeneem waar geen skropmateriaal verskaf is nie. Geen betekenisvolle verskille het in die vetinhoud van braaikuikenmis afkomstig van die verskillende behandelings voorgekom nie. Die hoogste (*P*<0.05) as-inhoud en *in vitro* verteerbaarheid was in die suiwer ekskresie en die laagste in die braaikuikenmis met SA. Daar was geen verskille tussen die oorblywende behandelings nie. Skropmateriaal het geen betekenisvolle (*P*>0.05) invloed op die minerale-inhoud van braaikuikenmis uitgeoefen nie.

In 'n poging om die effek van kolleksietyd op die voedingswaarde van lêhenmis na te vors is negentig, 20 weke oud "White Pymouth Rock" lêhenne ewekansig in 30 groepe van 3 elk ingedeel. Die 30 groepe is daarna ewekansig aan 5 behandelings toegeken. Die mis van elke behandeling is onderskeidelik daagliks en na 14 dae, 28, 42, en 56 dae gekollekteer.

Al die lêhenne het dieselfde kommersiële dieët *ad lib*. ontvang.

Die kolleksie van lêhenmis na 56 dae het 'n betekenisvolle (*P*<0.05) verlaging in die ruproteïeninhoud, degradeerbaarheid en *in vitro* verteerbaarheid teweeggebring. Geen duidelike tendens of invloed van kolleksietyd op die SBV- en NBV- inhoud van lêhenmis kon waargeneem word nie. Kolleksieperiode het nie die vetinhoud van lêhenmis beïnvloed nie. Die as-inhoud van lêhenmis het betekenisvol (*P*<0.05) met 'n vertraagde kolleksieperiode toegeneem. Vertraging van die kolleksieperiode het die persentasie Na, Ca, K, Mg, en Cu in die lêhenmis verhoog. Geen betekenisvolle (*P*>0.05) invloed van kolleksieperiode op die konsentrasie Fe, Zn en Mn kon waargeneem word nie.

Daar is tot die slotsom gekom vanaf die prestasie van die braaikuikens op die verskillende skropmateriale en die voedingswaarde van braaikuikenmis dat PH voorkeur as skropmateriaal moet geniet. SH behoort die tweede keuse te wees gevolg deur WS. Laastens blyk dit dat lêhenmis op ‘n gereelde basis gekollekteer moet word en dat die kolleksieperiode nie langer as 42 dae moet duur nie.