FRACTIONATION OF POULTRY LITTER FOR ENHANCED UTILIZATION

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ABSTRACT

A potential waste management system for the use of poultry litter was studied based upon the fractionation of litter. It was determined that the compositions of the litter by particle size varied both with the number of flocks that had been raised on the litter and the type of house. As the number of flocks raised on the litter increased from one to three flocks, the amount of fine material increased from 23 to 41%, while the concentration of the middle fraction decreased from 47 to 40%, and the coarse fraction decreased from 26 to 16%. The efficiency of retrieval of the fine fraction from the raw litter by either a vibrating screen separator or a rotary drum separator were found not to be significantly different.

It was determined by chemical analysis that the P and K concentrations appeared to be distributed uniformly throughout the litter in each fraction while the N was non-uniformly distributed. The concentration of N was greatest in the fine fraction. **KEYWORDS.** Waste management, Poultry, Litter, Fractionation.

INTRODUCTION

Poultry is one of the largest industries in the southeastern United States, generating more than 25% of the agricultural income of Arkansas, Mississippi, Alabama, North Carolina, Georgia, Virginia, Maryland, and Delaware. This industry has a tendency to concentrate in local areas to increase efficiency. Although concentration reduces production costs, it can generate more waste than can be safely applied to the available land without degrading the environment. In addition, several of these concentrated broiler growing areas are experiencing encroachment of suburban development. In some cases this encroachment has resulted in legal conflicts and legislation curtailing or prohibiting many waste application practices currently employed by the poultry industry.

Increasing environmental concerns may, in the near future, cause more regulatory scrutiny of poultry waste disposal. Therefore, the purpose of this research is to discuss a poultry litter management system which involves the fractionation of poultry litter into materials with improved handling qualities and/or increased nutrient density.

BACKGROUND

Of the 1.25 billion broilers grown in the state of Georgia, 60% are grown in adjoining counties in the north central region of the state. Likewise, Arkansas poultry production is geographically concentrated in the northwest portion of that state (Hamilton et al., 1988). Alabama, North Carolina, Virginia, Maryland, and Delaware all have similar regional concentrations. Such concentrated production can cause more manure to be produced than can be safely utilized by spreading on the land. Precipitation runoff from excessively loaded fields has been identified as a possible non-point source of pollution in Chesapeake Bay (Magette, 1988).

Legislation exists in some poultry growing regions for the utilization of waste products. In Rockingham County, Virginia, new poultry facilities are required to have both a site plan and a nutrient management plan. The nutrient management plan requires that the grower provide for safe disposal of 100% of the animal waste produced by each poultry facility. Such a plan is required to consider the presence of any source of water, geologic formations and land topography such that no ground or surface water is susceptible to pollution. While this legislation is aimed primarily at new facilities, all existing facilities will be required to comply with this legislation by 1994. In Europe, similar concerns for excessive nutrients has caused West Germany and the Netherlands to limit the number of animal units/ha of land (Naber, 1988). Similar legislation in other parts of the southeastern United States would have a great effect on current waste utilization practices used by the poultry industry.

Collins et al. (1988) stated that "a major challenge in recent years has been to find ways of making manure and litter an attractive substitute for commercial feeds and fertilizers". Most of the problems in doing this involves economics. Collins proposed that hauling and spreading of litter from an intensive poultry producing area (in Virginia) to a grain producing area, a distance of approximately 210 km away, would cost approximately \$18 to \$21/tonne. Litter was valued at \$17/tonne based on its nutrient value. Thus, transportation costs may exceed its nutrient value. However, if the nutrient density of poultry litter could be increased then it would be more profitable to haul.

Fractionation of litter has been successfully conducted on a laboratory scale. Koon (1987) determined that approximately 70% of a three flock litter would be retained by number 20 mesh screen (0.83 mm openings). In

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separate laboratory scale tests, Merka (1988) determined that 30% of poultry litter passed through a number 20 mesh sieve. He also determined that the nitrogen concentration increased as litter particle size decreased.

The potential use of poultry litter as a fertilizer or as animal feed is high if the form and/or condition of the litter can be improved. The major drawbacks that have been associated with poultry litter are: 1) low nutrient density, 2) low bulk density, and 3) non-uniformity.

Essentially all the broilers produced in the southeastern United States are grown on litter which absorbs moisture. Litter may be comprised of sawdust, peanut hulls, wood shavings or other suitable material. Raymond (see Wuhrmann, 1964) reported that litter has an average moisture content of 25% (w.b) and contains 1.7% nitrogen (N), 0.81% phosphorous (P), and 1.25% potassium (K) by weight. The North Georgia poultry industry produces approximately 1.8 million tonnes of manure annually. This manure contains enough nitrogen to fertilize approximately 280 000 ha of land at a rate of 168 kg/ha. Based on the organic nitrogen retail value ($24 to $39 per tonne of dry matter), this poultry waste would be worth $42 million. Therefore, it is imperative to develop techniques for efficient and economic utilization of poultry litter. Fractionation of poultry litter may improve the above mentioned drawbacks and will also allow specific uses for each fraction.

Objectives

The purpose of a study being conducted at the University of Georgia is to develop a simple, economical system for the efficient utilization of poultry manure and litter. A key factor in this study will be the materials handling of this product. Therefore, the following objectives were established:

- Identification of a simple, efficient, and economical technique for separation of litter into coarse and fine fractions.
- Investigation of variation that may exist in handling and separation of poultry litter from broilers reared under different management techniques.

The following factors were considered in the experimental design of this study: 1) number of flocks raised on the litter; 2) type of house from which the litter was obtained; 3) percent of N, P, and K as a function of the number of flocks raised on the litter; 4) percent of N, P, and K within each fraction of the litter; 5) percent of N, P, and K as a function of house type; and 6) efficiency of each type of separation system.

Procedure

A study was conducted to determine the variation that exists among poultry litter samples from birds that were raised under different management techniques. The management techniques were put into two categories: 1) the number of flocks raised on the litter before it was cleaned out; and 2) the type of house. The latter category consists of: a) the conventional house design where curtains on either side running half-way down the walls can be rolled up or down for natural ventilation; and b) the totally enclosed house design where ventilation of the house is achieved entirely by forced air. In this work, the two were designated as either open houses or dark houses.

Samples of poultry litter weighing an average of 300 kg were taken from each of the randomly selected open and dark houses located in the North Georgia area surrounding Athens, GA. The number of flocks that had been raised on the sample in question were noted. To ensure a representative sample of the litter material from the randomly selected houses, sampling sites were located along the length of each house at approximately 12-m intervals (one normal walking pace being taken as a rough measure of the meter-interval), and also along the whole cross-section of the house in question. On average, between 6 and 12 sampling sites were located within a given house depending on the depth of the litter. For shallower litters, more sites had to be sampled so that the 300 kg sample size could be obtained. At any one of these given locations, all the litter in a 1 m × 1 m floor area was collected down to the bare floor level and put in containers for later fractionation. Since variations could also arise out of such factors as watering facilities, any part of the house that appeared to have such unique problems was avoided. This was done to eliminate undesirable factors that had not been identified at the initial stages of the study.

A vibrating screen separator manufactured by Hance Corporation, Westerville, Ohio was used to fractionate the litter. A two stage separation separated the material into three fractions: 1) particles greater than a standard number six mesh screen (3.3 mm openings); 2) particles smaller than a standard number 20 mesh screen (0.83 mm openings); and 3) particle sizes between the above two. The equipment operating pitch was established as 12° for optimal fractionation.

For the screen separator, samples of litter were divided into batches and fed to the separator via a hopper. Each fraction was then collected and weighed separately. From time to time a hand brush would be used to scrape off the feathers to minimize blockage of the screen sieves. During the course of separation, samples of litter were collected at random from each of the three fractions and from the raw litter for laboratory analysis. Each of the samples were analyzed for (percentage by weight) nitrogen (N), phosphorous (P), and potassium (K).

Tests were also conducted to compare the performance of a vibrating screen separator to a rotary drum separator. The efficiency of separating the fine material (particle size <#20 mesh screen) from the raw litter was the main criterion. The rotary drum consisted of two small parallel drums, 0.23 m in diameter. The rotary drum was constructed such that over the 1.5 m length of the drum the particles would be separated according to the same three particle sizes as that associated with the vibrating screen separator. The working pitch for the rotary drum was set at approximately 11° for optimal separation. For this part of the study, litter samples were drawn from open houses in which only one flock had been raised on the litter. This approach was used so that a comparison between the separators could be made on similar litter material.

Results and Discussions

In this study, litter was sampled from a total of 38 houses. The majority of these houses had curtain side walls. This type of house was found to be predominant in the region surrounding Athens, Georgia. In many cases the litter within these houses was normally replaced after no more than three flocks had been raised on it. Some exceptions did occur, but this seemed to hold true for many of the houses sampled.

The moisture content of the litter was determined using a convection oven and ranged between 18 and 25% (w.b.). The moisture content of the whole litter did not appear to contribute significantly to the quantity of the fine material collected from the litter.

Composition of Litter by Particle Size.

The three fractions into which litter was fractionated were all distinct in physical appearances. The fine fraction, which was comprised of those materials less than #20 mesh screen (0.83 mm), was a brown-looking uniform powdery material that tended to clump together when squeezed. This material was believed to consist of manure, small amounts of spilt feeds, and very fine sawdust. The middle fraction, which was comprised of those materials with particle sizes between the #20 (0.83 mm) and the #6 (3.3 mm) mesh screens, were mostly small wood chips, sawdust and some unidentified flaky materials. The coarse fraction, which was comprised of those materials whose particles are larger than #6 mesh screen (3.3 mm), consisted mostly of larger wood shavings, wood chips, feathers, and conglomerate clods.

The percent of fine material retrieved from both one, two and three flocks' litter are shown in Table 1. For curtain-walled open houses, it was determined using an analysis of variance procedure (PC-SAS, 1987) that the number of flocks raised on the litter had a significant effect (α=0.05) on the percentage of fine material retrieved from the litter. It was determined that, as the number of flocks raised on the litter increased, the fine material content in the litter increased. In going from one to three flock litter, an increase of approximately 70% occurred in the percentage of fines retrieved.

Using the vibrating screen separator, tests were also conducted on one-flock litter obtained from both curtain-walled (open) and environmentally controlled (dark) houses to determine if the type of house had an effect on the percent fine material in the litter (See Table 1). Using an analysis of variance procedure, it was determined that the content of fine material in the litter was significantly affected (α=0.05) by the type of house in which the birds were raised. The results appeared to indicate that litter material from dark houses normally will have a larger proportion of fines than litter from open houses. An increase of approximately 26% was observed for dark houses over open houses.

It was initially believed that the amount of fine material in the litter was also related to the breakdown over time of the wood shavings caused by bird activity. However, the above observation conflicts with this point of view in that chickens are supposed to be more active in lighted environments that in poorly lit conditions.

Regardless of the origin of the litter materials, the content of fine fraction ranged from 22% to 40%, the middle fraction ranged between 40% and 48%, while the coarse fraction ranged from 15% to 25% (see fig. 1). These results are closely related to laboratory scale fractionation of litter. Koon (1987) determined that approximately 70% of a three flock litter would be retained by a #20 mesh sieve. Merka (1988), in separate laboratory scale fractionation tests, reported that approximately 30% of fine materials (particles less than #20 mesh sieve) were retrieved from three flock litter. While the proportion of the fine material in the litter increased with the number of flocks raised on the litter, the proportions of both the middle (#6>Particle size>#20) and coarse material (Particle Size>#6) decreased (see fig. 2).

N-P-K Content of Litter by Number of Chicken Flocks and Type of House

Standard laboratory tests were conducted to determine if the number of flocks raised on the litter and the type of house affected the concentrations of N-P-K in the litter. The results of the laboratory tests for the raw litter sampled from curtain-walled open houses are shown in Table 2. A

TABLE 1. Percent fine material (Particle size <20 mesh sieve) retrieved from one, two, and three flock litter using the vibrating screen separator

	Number of Flocks			
	One		Two	Three
	Open House	Dark House	Open House	Open House
	%	%	%	%
	21.4	32.4	36.6	41.0
	18.2	31.0	34.1	39.9
	20.9	14.2*	34.7	41.9
	27.2	31.6	28.9	40.0
	26.4	21.8	26.7	41.3
	23.3	34.8	29.1	
	32.0		28.9	
	22.9			
x	24.0	30.3	31.3	40.8
s	4.3	5.0	3.8	0.9

* This sample was obtained from a house with a concrete floor. This sample was not used in the statistical analysis.
x = Sample mean.
s = Standard deviation.

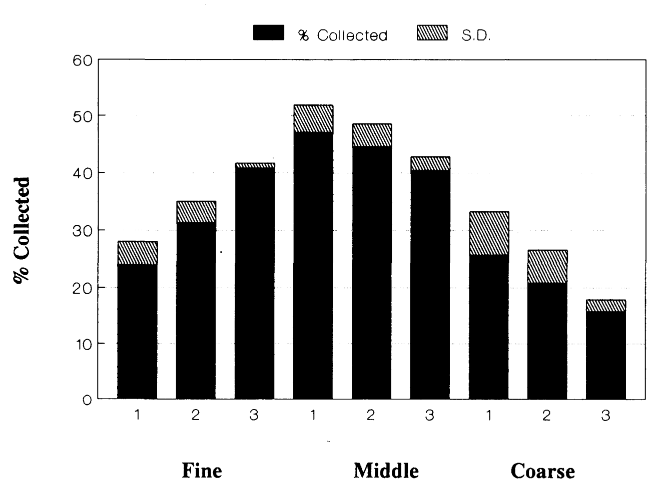

Figure 1–Proportions of each of the three fractions with respect to one, two, and three flock litter. (S. D. = standard deviation)

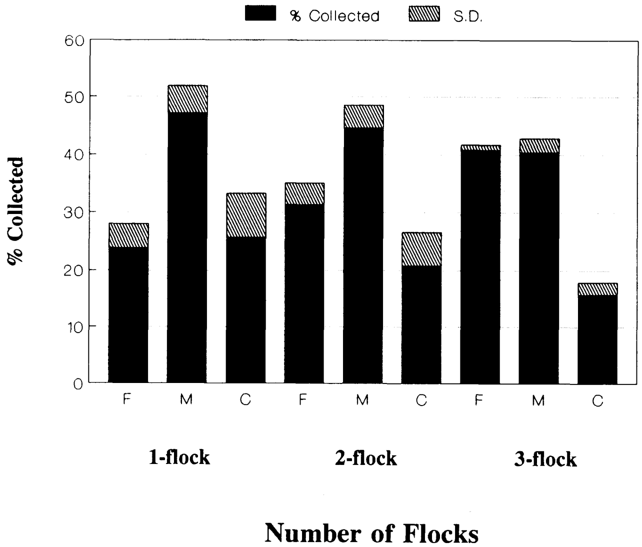

Figure 2–Fractional composition of one, two, and three flock litter. F, M, and C refer to the fine, middle, and coarse particle size. (S. D. = standard deviation)

significant variation (α=0.05) was observed in the percent N and percent K while no significant variation was observed for the percent P among the litter that had been used to raise one, two, and three flocks of chickens. Tests were also conducted on one flock litter obtained from dark houses (See Table 3). The analyses of percent N-P-K content by type of house indicated that the N-P-K content in litter drawn from either the open houses or the dark houses were not significantly different (α=0.05).

The average nitrogen content for one, two, and three flock litter was determined to be in the range of 3.2 to 4.3%, phosphorus content between 1.0 and 1.2% while potassium content was in the range 1.8 to 2.4%. These figures compare favorably with those reported by other researchers. Wuhrmann (1964) determined that chicken litter, with an average moisture content of 25%, contained 1.7% N, 0.81% P, and 1.25% K; while Carr (1988) reported that five flock broiler litter (original moisture content not reported) contained 3.9% N, 1.29% P, and 1.57% K on an oven dry basis.

TABLE 2. Percent N-P-K content of raw litter samples from curtain-walled open houses and one, two, and three flocks' litter*

Number of Flocks								
One			Two			Three		
N %	P %	K %	N %	P %	K %	N %	P %	K %
2.8	0.9	2.0	4.5	1.3	2.0	4.7	0.9	2.2
4.0	1.0	1.5	4.4	1.4	2.2	3.7	1.3	2.9
3.3	1.3	1.9	3.7	1.0	2.1	4.2	1.4	2.2
3.8	0.7	2.2	4.8	1.1	1.7	3.6	1.0	2.1
2.9	1.0	1.9	†		1.2	2.2	4.3	1.4
2.5								
2.4	0.8	1.4	4.4	1.1	2.3			
3.1	1.1	2.0	3.8	1.0	2.3			
3.2x	1.0	1.4	4.3	1.2	2.1	4.1	1.2	2.4
0.6s	0.2	0.3	0.4	0.2	0.2	0.5	0.2	0.3

* Results of the chemical analysis are reported on an oven dry basis.
† Results of laboratory analysis were not reported for this sample.
x = Sample mean.
s = Standard deviation.

TABLE 3. Percent N-P-K content of raw litter samples from environmentally controlled dark houses for one flock litter*

N (%)	P (%)	K (%)
2.7	0.6	1.3
4.5	1.3	2.0
2.9	1.2	1.9
3.1	1.3	2.2
4.2	1.3	2.5
3.5	1.0	2.2
3.5x	1.1	2.0
0.7s	0.3	0.4

* Results of the chemical analysis are reported on an oven dry basis
x = Sample mean.
s = Standard deviation.

N-P-K Distribution Within the Litter

Studies were also conducted to determine the N-P-K distribution within a given litter material, i.e., percent (N-P-K) content of each one of the four fractions of litter: whole litter, Particle Size<#20, #6>Particle Size>#20 and Particle size>#6 are designated as raw litter, fine, middle, and coarse fractions, respectively. The results of these tests are shown in Table 4.

Within any given litter material, irrespective of its origin, the distribution of N-P-K was found to be similar. The distribution of P and K appeared to be uniform within any given litter with no significant variation observed in the P and K content for the four fractions (including the raw litter) for one, two, and three flock litter. However, the distribution of N within the litter was determined to be significantly higher in the fine material than in the rest of the fractions. These results agree with similar results conducted at the laboratory level by Merka (1988) who

TABLE 4. Percent N-P-K content of litter by fractional sizes and number of flocks from curtain-walled open houses

# of Flocks	Raw Litter	Fine Fraction	Middle Fraction	Coarse Fraction
		Nitrogen (%)		
1	3.1	3.9	2.8	2.9
2	4.3	5.1	3.2	3.4
3	4.1	5.2	3.3	3.2
		Phosphorous (%)		
1	1.0	1.1	0.9	1.1
2	1.2	1.3	1.2	1.4
3	1.2	1.4	1.1	1.3
		Potassium (%)		
1	1.8	1.8	1.7	1.8
2	2.1	2.2	2.1	2.3
3	2.4	2.6	2.2	2.2

* Results of the chemical analysis are reported on an oven dry basis.

determined that as litter particle size decreased, nitrogen concentration increased.

Fractionation Equipment

Two separators were evaluated for their respective performances in fractionation of poultry litter: 1) a vibrating screen separator, and 2) a rotary drum separator. The performance of each was based on the efficiency of retrieval of the fine fraction. Only samples from one flock open houses were compared. At the $\alpha=0.05$, the two separators showed no significant difference in their ability to retrieve the fine material from the raw litter.

Litter Management System

A potential waste management system for poultry litter utilizing the fine fraction as a potential fertilizer or feed ingredient may be possible. The fine fraction which comprises 24 to 41% of the raw litter is much richer in nitrogen than either of the other two fractions and the raw litter. Moreover, this fraction has a very consistent nature (almost uniform particle sizes) compared to the raw litter. The fine fraction also displays a high potential of being pelletized.

Although poultry litter has been used as a fertilizer for a long time in the development of agriculture, it has already been very much superseded by today's synthetic fertilizers. Since the use of poultry litter has proved successful in production of agronomic crops, the potential of poultry litter has fully been realized. The only problem has been lack of efficiency in its utilization. This lack of efficiency has been attributed to the heterogeneous nature of the material which does not make it amenable for accurate application by mechanical equipment, and its low nutrient density. The latter factor results in higher transportation costs as well as higher application costs per unit of nutrient. The fine fraction has improved qualities. The material is uniform and has a higher nutrient density.

The middle fraction which comprises 40 to 47% of the raw litter is low in nutrients, it is a uniform material and is composed of small wood chips and sawdust which are still quite intact. This material could be recycled into the poultry houses as used litter. However, to prevent any transmission of diseases, this material needs to be free of any pathogens.

The coarse fraction is also lower in nutrients than the fine fraction and is the most non-uniform fraction. It makes up 16 to 26% of the raw litter material. This material could be spread on the farm to provide for mulching or as a fuel in wood heating systems.

Adoption of this simple management system has a potential for reducing the waste disposal problems and utilizing the waste more economically. The recycling of the middle fraction eliminates the need for placing totally fresh material into the poultry houses. This not only reduces the amount of waste to be dealt with by almost 50% but it also reduces the costs of providing fresh bedding materials for the chickens by almost 50%. The fine fraction provides a more economical product than the parent material for use as a fertilizer.

Summary

A potential waste management system for the use of poultry litter was studied which involved the fractionation of litter into three different fractions. The physical and chemical characteristics of raw litter and three different fractions obtained from both open and dark poultry houses which had housed one, two, and three flocks of birds was analyzed.

The three fractions into which litter was fractionated were all distinct in physical appearance. The fine fraction was powdery and tended to clump together when squeezed. The middle fraction was composed of a uniform mixture of small wood chips and sawdust. The coarse fraction was composed of larger wood shavings, large wood chips, and feathers and was the most heterogeneous. From fractionation experiments, it was determined that the relative composition of the litter by particle size varied both with the number of flocks that had been raised on the litter and the type of house. As the number of flocks raised on the litter increased from one to three flocks, the amount of fine material increased from 23 to 41%, while the concentration of the middle fraction decreased from 47 to 40% and the coarse fraction decreased from 26 to 16%. Similar variation was observed with respect to the type of house with the litter from dark houses having approximately 25% more fine material than the open houses.

In chemically analyzing the whole litter and each fraction, it was determined that the concentration of P and K was uniformly distributed throughout the litter. From these same tests, it was determined that the percent concentration of N was found to increase as the number of flocks of birds raised on the litter increased with the N non-uniformly distributed throughout the litter with the concentration of N greatest in the fine fraction.

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