

REMOVAL OF LIQUID FROM POULTRY WASTE BY ELECTRO-OSMOSIS

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ABSTRACT

REMOVAL OF LIQUID FROM POULTRY WASTE BY ELECTRO-OSMOSIS

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The removal of moisture from chicken excrement by the process of electro-osmosis was studied using four voltages 5, 10, 15 and 20 volts D.C. Electrodes of two different shapes, and three different materials were used. Current flow vs. elapsed time, temperature vs. elapsed time, liquid expelled vs. elapsed time, and moisture content reduction vs. applied voltage were studied.

The plug type electrodes gave higher current flows, temperatures and greater moisture content reduction than the rod type. Stainless steel electrodes were slightly better than steel and corroded much less than copper electrodes.

Initial moisture content of the droppings was 78 to 80% on a wet basis. The maximum reduction was 4.3% on a wet basis which is not sufficient to permit pelleting.

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INTRODUCTION

The present trend of poultrymen and other livestock producers is toward confinement housing and feed lots. The problem of waste disposal from these operations is becoming more critical with their increasing animal concentration and proximity to densely populated areas. Field spreading of the waste material is not generally possible since in most cases the feed is purchased and thus sufficient field area is not available.

The methods of composting and lagooning are objectionable for five major reasons. These are: 1. the creation of objectionable odors by their bacterial action, 2. the flies that use these areas for breeding create a public nuisance and health hazard, 3. drainage from these areas can contaminate underground water leading to public and private water supply lines, 4. plant nutrients are lost from the composte pile due to decomposition and leaching, and 5. in lagoons all the plant nutrients are lost since the material is thoroughly decomposed. Also large areas are required which makes them prohibitive for large operations. Thus some new form of waste disposal is needed.

In addition to disposing of the waste material, it would be desirable to have a saleable product. This would provide the livestock owner with additional income from materials he is presently throwing away. The product would be in the form of a dry or pelleted substance suitable for use on lawns, shrubs, gardens, etc. From reports on pelletizing feed concentrates and hay, it appears that the moisture content of the excrement

would have to be reduced to a range of 5-25% wet basis for pelleting. This is the range of moisture contents reported for feed and hay respectively.

Otis E. Cross in his thesis, "The Influence of Variable Parameters on the Electro-osmotic Hoisture Migration in Poultry Excrement" at Lichigan State University (1963), concluded that the amount of liquid expelled by electro-osmosis was a function of: 1. current flow, 2. time, 3. length of sample, and 4. moisture content of the sample.

In his investigation, Cross used a constant voltage that provided equal initial currents. These values were held to a sufficiently low level to reduce the affect of Joule heating. The samples were placed horizontally to eliminate the effect of gravitational flow. The results of that study showed that the moisture content of poultry excrement was not reduced to a pelletable level.

The purpose of this investigation was the utilization of Joule heating and gravitational flow to assist the electroosmotic process in reducing the moisture content to a suitable level. Preliminary tests indicated that if the voltage was greater than 30 volts the samples became very hot. The liquid was thus evaporated, in fact boiled, instead of being removed by the electro-osmotic process. To keep the Joule heating from going to this extreme, the voltages selected for this investigation were 5, 10, 15, and 20 volts D.C. The samples were placed in a vertical position to include the gravitational flow.

In addition to this, different electrode materials and shapes were studied. The metals chosen were: 1. copper, 2. stainless steel, and 3. steel. Each of these three was obtained in two different forms: 1. plug type 2" dia. x 1" thick and 2. rod type $\frac{1}{2}$ " dia. x 2" long.

APPARATUS

The containers used for the test samples (fig. 1) were nade from plastic tubing with 5" I.D., wall thickness of $\frac{1}{2}$ ", and a length of approximately 15". A piece of sheet aluminum was mounted on one end of the tube to form the base and serve as the cathode. The plastic tube was sealed to the base with calking compound. Holes, 1/8" dia., were drilled through the base to allow passage of the liquid. Flywood was used for a loose cover on the tube. Two holes were drilled through the cover to permit the entrance of the electrode wire and to hold the thermometer in place. The thermometers used were standard laboratory -20 to +110° C thermometers.

The sample tubes were placed on a stand over receptacles for the collection of the liquid expelled. Measurement of the liquid was achieved by pouring the contents of the receptacles into a 100 milliliter graduated cylinder.

The electrical system was composed of a D.C. power supply, electrodes, voltmeter, ammeters, and the samples (fig. 2 & 3).



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Fic. 3

PROCEDURE

Chicken excrement for the tests was obtained from the dropping board of caged laying hens. All tests were made with excrement collected from the same group of chickens. The material for a test was placed in a large container and thoroughly stirred to obtain as uniform a mixture as possible. Two samples of approximately 150 grams each were taken from this mixture, weighed, and placed in a 200° F oven to dry. From these samples the initial moisture content, % wet basis, was determined.

Each tube was then placed on a scale and four pounds of the mixed excrement placed in it. This value was chosen for two reasons: 1. uniformity, and 2. it filled the tubes approximately one-half full thus allowing room for any expansion that might take place. Each sample was tamped in an effort to remove the air pockets and to obtain constant bulk density of samples. Five samples were used for each test run: 1. two for each electrode type eg. two samples with copper plug electrodes and two samples with stainless steel plug electrodes, 2. one sample for control with no applied voltage. Thus two different electrode types and/or materials were tested during each run.

Each electrode was weighed before and after each test run to determine its change in weight. The electrodes were placed in the center of the cylinders. The plug type was submerged until the top of the electrode was even with the top of the sample (fig. 2). The rod type, however, was completely submerged to the center of the sample (fig. 3).

The data recorded was: 1. time, 2. voltage (adjusted to predetermined value), 3. anneter reading for each sample, and 4. the temperature of each sample. These readings were taken hourly until a definite downward trend became established, then periodically for the duration of the test. The liquid removed was measured whenever there had been a sufficient amount collected to cause negligible error while transferring it from the receptacle to the graduated cylinder. Thus its frequency decreased as the test run progressed.

The test run was terminated when the liquid removal rate appeared to be very low. The steps involved in the termination were as follows: 1. take final data readings; 2. shut off power supply, disconnect, clean, and weigh electrodes; 3. thorough mixing of each sample; and 4. weighing of approximately 150 gms. of the contents of each sample and placement of it in the drying oven for final moisture content determination. The remainder of the sample was discarded and the equipment made ready for the next test run. All of the drying samples were left in the oven for a minimum of 36 hours to ensure complete drying.

DATA EVALUATION

Evaluation of the data consisted of plotting the following graphs: 1. current flow vs. elapsed time; 2. temperature vs. elapsed time; 3. liquid removed vs. elapsed time; 4. moisture content reduction, % wet basis, vs. applied voltage; 5. maximum temperature deviation vs. applied voltage; and 6. average

electrode weight loss vs. applied voltage. The current flow vs. elapsed time curves were planimetered to dotermine the total ampere-hours of current used. These values were then used for electrode evaluation and electrode weight loss determination.

RESULTS

CURRENT

The general shapes of the curves for current flow vs. elapsed time were of two forms. The simplest (type 1) was monotonic decreasing from its initial value until it approached some asymptotic value. The other form (type 2) started like the first but after a few hours began to increase. This continued until an absolute maximum had been reached. Then, it usually became monotonic decreasing and continued similar to type one. Occasionally secondary local maximums occurred.

For the 5, 10, and 15 volt D.C. tests all samples with the rod type electrodes gave curves of type 1, fig. 4, 5, & 6. At the 20 volt D.C. level the rod electrodes gave results similar to type 2. However, the secondary local maximums were much less than the initial current level. The stainless steel plug type electrodes gave type 2 curves for all four voltages tested, fig. 7. The steel plug type electrodes gave type 2 curves for the 15 and 20 volt tests but type 1 curves for the 5 and 10 volt tests, fig. 8. The copper plug type gave type 2 curves for the 10, 15, and 20 volt tests and type 1 for the 5 volt tests, fig. 9.



Fig 4



F16. 5



F16. 6









The magnitude of the secondary local maximums increased with increasing voltage.

RESULTS OF PLANIMETERING

The current flow vs. elapsed time curves were planimetered to determine the total ampere-hours of current used. The following procedure was used: 1. each curve was planimetered three times and the average value taken; 2. the values for the two curves for each electrode type and material were then averaged together; 3. the results from step (2) were then divided by the total elapsed time of the test to determine the average current rate. The results of this are given in fig. 10.

The results from this procedure show that the copper electrodes permitted less current flow. The stainless steel electrodes had the largest current flow, but the results from the steel were very close to it. This was due to the corrosion rates of the respective metals. The copper electrode corroded and reacted with the adjacent material much more rapidly than the stainless steel and steel. The resulting material reduced the conductivity and thus the current flow.

The larger current flow rates for the plug type electrodes were due to the greater surface area of the plugs. They gave better sustained electrode to sample contact than the rod types.

TEMPERATURE

The temperature differential i.e. (sample temperature) - (control sample temperature), increased with increasing voltage.

ANESSAN - J'RRENT FLOW



FIG. 10

This was due to Joule heating i.e. $W=I^2R=E^2/R$. The maximum temperature differentials for the voltages tested are given in fig. 11.

The plug type had larger temperature differentials than the rod type. This was due to the higher current rates occurring with the plug type. The order of copper, steel, and stainless steel for increasingly larger temperature differences was caused, also, by the larger current flows occurring in that order.

ELECTRODE EROSION

The erosion of the electrodes is clearly visible in figs. 12 and 13, which show the electrodes as they appeared before and after the tests were conducted. In both figures the copper, steel, and stainless steel electrodes are designated A, B, and C respectively.

The average rate of the electrodes was evaluated by dividing the total weight loss of the electrode by the ampere hours of current used. The values calculated are shown graphically in fig. 14.

All of the erosion rates increased to a maximum and then decreased with increasing voltage. For the plugs this maximum was at the 15 volts D.C. level, but for the rods it was 10 volts D.C. The cause of this was not determined. In general, the rate of erosion in decreasing order was copper, steel, and stainless steel. This is the reason the current flow rates were in the opposite order, as mentioned above.



FIG. 11







FIG. 14

LIQUID EXPELLED

The quantity of liquid expelled due to electro-osmosis increased with both applied voltage and time as was discovered by Cross. The values were determined by subtracting the control sample value from the sample value and then averaging the results for like samples. The values are shown in figs. 15, 16, and 17.

To avoid excessive crowding in the liquid expelled vs. elapsed time curves, only the two extreme cases are shown, namely those of the stainless steel and copper electrodes. To facilitate comparison the same coordinate system scale was used for both the plug and the rod type electrodes. The plug type expelled between two and three times more liquid than did the corresponding rod type of the same material.

An estimate of the cost involved to remove this liquid tas made. The results for the stainless steel plug type electrodes at 20 volts D.C. and 2¢ /kwh are:

From plunimeter results (18.9 amp-hr)(20 v) = 378 watt-hrtotal liquid removed = 222.5 ml

 $Cost = \frac{(.375 \text{ kwh})(2\% / \text{kwh})}{(222.5 \text{ml})(2.64 \times 10^{-4} \text{gal/ml})} = 12.9\% / \text{gal of liquid removed}$

MCISTURE CONTENT REDUCTION

The initial moisture contents ranged from 73 to 30% wet basis. The reduction in moisture content due to electro-osmosis was determined by subtracting the reduction of the control sample from the other samples. The average value of like samples





FIG. 15





was then taken. Fig. 18 shows these results. The reductions increased with increased voltages. The maximum reduction achieved in these tests was 4.0% w.b. This was not sufficient to lower the excrement to a pelletable level of less than 25%w.b. Since the reductions were much less than anticipated, the method of determining the final moisture content proved to be insufficiently accurate. The error incurred by mixing the sample and then taking a portion of the mixture for oven drying was very significant. It was estimated to be not less than $\frac{1}{2}\%$ w.b. Thus with the values achieved, errors greater than 100% could have been caused by poor mixing.

The order of efficiency for the electrodes was the same as for the previous results reported, i.e. in decreasing order, stainless steel, steel, and copper. The deviations from this order were within the error caused by poor sample mixing, i.e. $\pm 1\%$.

A point of interest was that all samples with rod electrodes showed less reduction at the 10 volt D.C. level than at the 5 or 15 volt levels. Repetition of the 10 volt tests for rods showed the same tendency. The reason for this was not known. It could have been a coincidence since the deviations are well within the mixing error. This point should be studied further, however, and thus the key may be found to solve the problem of moisture retention.

MOISTURE GONTENT REDUCTION DUE TO ELECTRO-OSMOSIS VS. APFLIED VOLTAGE



FIG. 18

PROBLEMS FOR FUTURE INVESTIGATION

This investigation demonstrated some points that should be studied further. They were: 1. elimination of all gas from the sample prior to and during the test run. This will reduce the expansion and provide better electrode contact and sample conductivity; 2. eliminate corrosion of the electrodes; 3. removal of dried material near the electrode to improve conductivity; 4. use of multiple electrodes in a sample; and 5. study the 10 volt D.C. phenomena more fully.

SUFFARY

This investigation was undertaken to extend the study performed by Cross. Its objectives were: 1. reduce the moisture content of chicken excrement to a pelletable level of less than 25% w.b.; 2. study the effects of increased voltages; 3. evaluate the performance of two electrode types; and 4. study the performance of electrodes made from three different materials.

Appropriate data was collected, moisture contents determined, and graphs plotted. The average current flow rates were determined by planimetering the current flow vs. elapsed time curves and then dividing the result by the total elapsed time.

From the resulting curves it was found that the plug type electrodes gave larger current flows, higher temperatures, and

greater moisture content reduction than the rod types. Evaluation of the three metals tested showed that stainless steel gave higher currents, temperatures, and larger moisture content reductions than steel and copper. The steel electrodes, however, gave results very close to those of the stainless steel. Copper was the poorest because it corroded more readily than the others, thus reducing its conductivity.

The initial moisture content was 73 to 80% w.b. The maximum moisture content reduction was 4.3% w.b. which was insufficient to reach a pelletable level of less than 25% w.b.

Some points for future investigations were observed: 1. elimination of gas from the sample; 2. electrode corrosion; 3. removal of dried material next to electrode; and 4. use of multiple electrodes.

