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Elimination of Pollutants by Utilization of Egg Breaking Plant Shell-waste

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ELIMINATION OF POLLUTANTS BY UTILIZATION OF EGG BREAKING PLANT SHELL-WASTE

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FOREWORD

When energy and material resources are extracted, processed, converted, and used the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The project demonstrated technology that converts egg shell waste to a by-product and determined the benefits in utilization of the by-product in feed for poultry. The waste is now commonly disposed of on land which can cause large discharges of oxygen demanding materials into surface waters. For further information on the subject the Food and Wood Products Branch, Industrial Pollution Control Division, IERL-Ci should be contacted.

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ABSTRACT

Disposal of egg shell waste is becoming an increasingly serious problem for the egg breaking industry in the United States. There are approximately 150 egg breaking plants and they yield an estimated 50,000 tons of waste annually. At present, these wastes are disposed of in landfills or on farm land. This method of disposal is becoming more difficult because of objections due to the potential for pollution.

Laboratory studies of the material coupled with experiments to determine its nutritional value as a feedstuff when fed to laying hens showed that it had considerable potential. With this strong evidence that egg shell meal could be a valuable by-product of the egg breaking industry, plans to establish a field study in Missouri were successfully implemented. This study was partially funded by the Environmental Protection Agency beginning in March 1975. There were three significant aspects of the project: (1) dehydration of egg shell wastes to produce egg shell meal, (2) analysis of product and incorporation into layer rations, and (3) feeding trials with production flocks.

A triple pass rotary drum dehydrator was installed at an egg breaking plant. With appropriate engineering modifications a system for producing egg shell meal from the breaking plant shell waste was developed. Egg shell meal was produced from the total egg shell waste from the breaking plant. This meal was utilized as a feedstuff by a local mill and incorporated into a layer diet. This diet was fed to several commercial flocks of cage layers.

Appropriate data were collected to determine meal production costs, yield of meal, feed produced, feeding data, and layer flock performance. Five-day and 26-day BOD data were generated to determine the total pollution potential of the product were it not entering commercial channels as a useful by-product.

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ACKNOWLEDGEMENTS

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SECTION I

INTRODUCTION

The magnitude of continental United States egg industry in 1973 was 291,827,000 laying hens. They produced 3,045 million kg of egg products. In 1972, 11% of the shell eggs were broken in 152 egg breaking plants for use in further processed egg products (1). From 1950 to 1972 the number of egg breaking plants decreased from 477 to 152. During the same period the total processed liquid egg production increased. With this increased production in the egg breaking plants, there was an increase in the quantity of plant waste produced at any one site. These plants yielded some 45,454 metric tons of waste annually. The primary disposal methods were in landfills and on farm land pastures.

The egg breaking industry is faced with an increasingly serious waste disposal problem. The Egg Products Inspection Act (84 Stat. 1620 Et. seq., 21 USC 1031-1056) was enacted December 29, 1970. On July 1, 1972, phase two of this act became effective, controlling restricted shell eggs (checks, dirties, leakers, incubator rejects, inedible and loss eggs). All of these types of eggs, except checks and dirties, must be denatured or destroyed at the point of segregation to eliminate them from the consumer food channels.

The above inedible eggs can be utilized in animal foods and at large plants they are normally saved and sold to feed producers. The egg shells from the breaking machines retain some of the egg liquid. At plants where there is a market, these shells are centrifuged and the liquid portion sold for animal foods. The egg shells are typically a waste needing disposal, and in some cases both the inedible eggs and the liquid egg remaining in the shell are also wasted. Disposal of these wastes to a municipal sewer is occassionally practiced, but land disposal is usually the most economical means. Rainfall on the waste material dissolves large amounts of Biochemical Oxygen Demanding materials and the runoff can cause serious damage to the local water resources.

The analytical data on the chemical composition of egg breaking plant wastes was reported by Walton _et al._ (1). This work demonstrated that there were significant levels of calcium and protein present. The nutritional value of egg shell meal (ESM), when fed to laying hens, was comparable to the nutrients that were replaced from feedstuffs normally used in laying diets (Vandepopuliere _et al._ (2)). With the advent of larger egg breaking plants, the waste produced at a given location has increased making it economically feasible to utilize processing equipment that is currently available.

SECTION II

CONCLUSIONS

1. Centrifuged egg breaking plant wastes can be processed by a rotary drum dehydrator such as the Heil SD 45-12.

2. Non-centrifuged egg breaking plant waste can be processed if it is blended with ESM prior to introducing it into the dehydrator.

3. ESM as it is discharged from the dehydrator at 82^{o}C, has excellent handling and storing properties.

4. The performance of ESM as a feedstuff in cage layers diets is excellent.

5. The economic ratio of processing cost vs feedstuff value is highly favorable to disposing of this waste through the feed milling industry.

6. Egg shell waste from one (1) 30 dozen case, which has been centrifuged, and dried has an average BOD_5 of 42,545 mg O_2. Approximately 50% of this BOD_5 is readily soluble in water and if spread on a pasture would be dissolved by rain.

SECTION III

RECOMMENDATIONS

1. If there is a profitable market for the liquid inedible egg, install a centrifuge on stream ahead of the dehydrator.
2. Provide a bypass arrangement to collect egg shell waste in the event that a dehydrator failure occurs.
3. Provide heavy wear plates in bends and elbows which must handle ESM.
4. Install a secondary collector or wash system to eliminate fine ESM particle emission.

SECTION IV

PLAN OF RESEARCH

In the initial phase it was necessary to select the processing equipment that would dehydrate egg breaking plant wastes to produce ESM. The dehydrating equipment would be required to accept a wet abrasive product that could congeal and have the consistency of a glue when the protein was dehydrated or denatured.

Three commercial co-operators were required to conduct the experiment: (1) Kraft's egg breaking plant at Neosho, Missouri was selected in which to install the dehydrator, (2) a feed manufacture, MoArk, Neosho, Missouri, to mill the feed containing the ESM, and (3) an egg producer, MoArk, Neosho, Missouri, to conduct the feeding study. The ESM produced must be analyzed for protein, calcium, phosphorus, fat and microbial content. The nutritional value of ESM would have to be evaluated in layer diets by replacing nutrients in the control diet with the nutrients in the ESM. The BOD and COD characteristics of ESM would be needed to evaluate the environmental benefits in eliminating disposal of this waste material.

SECTION V

DEHYDRATOR CONSTRUCTION

SELECTION AND INSTALLATION OF EQUIPMENT

Processing and dehydration of egg breaking plant waste can be accomplished by heating and removing moisture. There are several types of cookers and dehydrators on the market. Some employ a batch principle while others have a continuous flow through a series of shaker screens, tubes or rotating drums. They are heated with steam, gas or oil. Dehydrators were available in various sizes, however, the smallest units have more capacity than needed at most egg breaking plants. Additional constraints on the selection of the unit were processing controls and costs. A used Heil SD 45-12, Heil Co., Milwaukee, Wisc. 53201, was purchased. The capacity of this dryer is 455 kg H_2O/hr which is 80% more than needed at the Kraft plant. The unit consisted of a triple pass rotary dehydrator with controls to automatically modulate the natural gas burner to regulate the discharge temperature of the product. The dryer is the smallest one made by Heil and sell new for approximately $45,000. A cyclone collector was included with the dehydrator.

Engineering planning and design, including the development of some special equipment, was necessary to set up operations. Since the plant was operating, it was important to have a diverter system so that wastes could go to the previous disposal carrier or to the dehydrator. This allowed modification in design and operation without disrupting the egg processing operations.

The Heil SD 45-12 was transported on a flat bed trailer to the University of Missouri, Columbia, Missouri. The unit was rewired electrically and a new control panel installed. The dehydrator was cleaned and painted.

Simultaneously with the dehydrator refurbishing, a structure was designed and built to house the raw waste or egg shell meal truck. The shelter was of concrete and steel construction with adequate strength to support the cyclone collector on the roof.

The dehydrator was unloaded on site with a crane and rolled on pipes into an existing structure. It was then mounted on appropriate piers. Steel legs to support the cyclone collector were constructed to conform to the slope of the roof. The collector was positioned to permit gravity flow of ESM to the carrier truck or to the dehydrator for recycling. The diverter pipes were installed at a minimum of 40^{o} to permit the flow of ESM. Figures 1, 2, 3 and 4 illustrate many of these features.

Special sheet metal design was necessary to connect the dehydrator to the collector. The 90^{o} turn (Figure #5) is subjected to the continuous abrasive action of ESM impinging on the curved inner surface. Plate steel, 1/4" thick, was fabricated in the wear area. This heavy elbow and related duct work were supported by an appropriate steel pipe frame. The radius of curvature for this elbow is 2 ft.

UTILITIES

The dehydrator was connected to the existing natural gas source, however, a separate gas meter was installed to provide operating data.

Electricity was provided through a new control panel (Figure #6). The panel contained the following features:

a. on-off switch
b. temperature controls - No. 522 B solid state temperature control system. Exhaust product temperature is used to control the flow of fuel to the furnace.
c. flame control - failure protection switch
d. exhaust fan draft failure shut down switch
e. furnace temperature pyrometer

A special steam line was installed to flood the dehydrating chamber in case of fire.

A 45^{o} diverter was installed above the dehydrator to direct raw wastes to the disposal truck or to the blending auger which fed the dehydrator.

OPERATIONAL EXPERIENCE

During the first few days of operation all wastes from the egg breaking plant were introduced into the dehydrator. The egg shell waste from the breaking machines contained 30 percent moisture which included considerable free albumen. In addition, the inedible whole eggs were introduced periodically into the dehydrator. Predictably, the liquid coagulated, adhered to the dehydrator flights, and clogged the unit. Three design changes were made:

1. A centrifuge was installed in line to receive the egg shell waste from the breaking machines. The centrifuge extracted the liquid egg from the egg shell waste (Figure #10).
2. Since the centrifuge that was available did not have sufficient capacity to handle both the egg breaker waste and inedible eggs, an inedible egg separator was designed and constructed so that the liquid from the inedible eggs could be salvaged separately (Figure #7). Subsequent to the initial installation a larger centrifuge

Figure 1. Dehydrator being unloaded at Kraft Plant in Neosho, Mo.

Figure 2. Dehydrator being placed in position.

Figure 3. Cyclone installation.

Figure 4. Processed egg shell meal diverter.

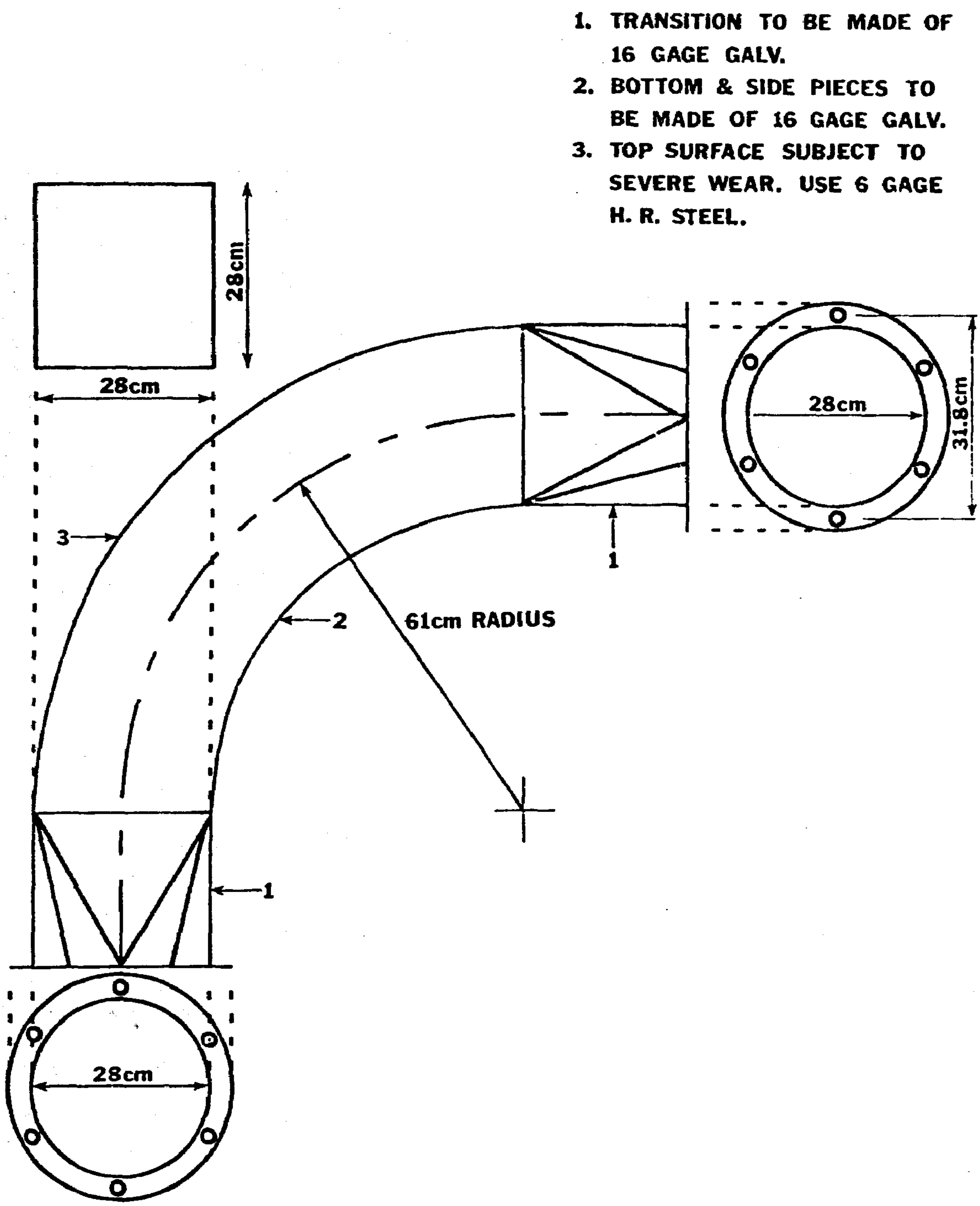

Figure 5. Special 90^{0} elbow for ESM dehydrator.

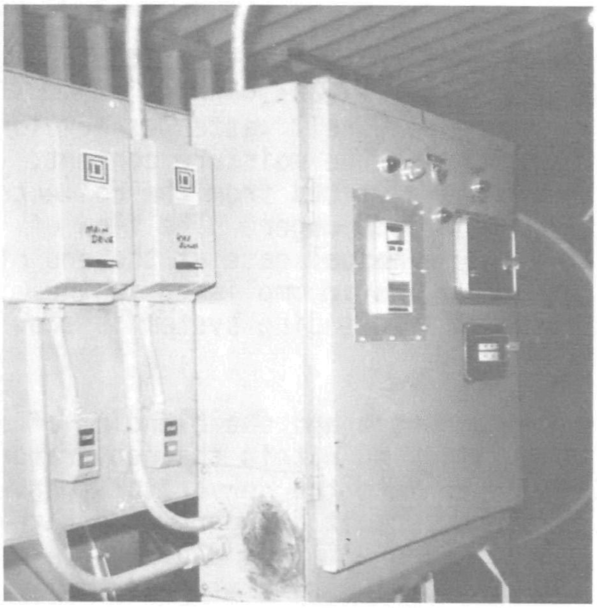

Figure 6. Control panel for Heil dehydrator.

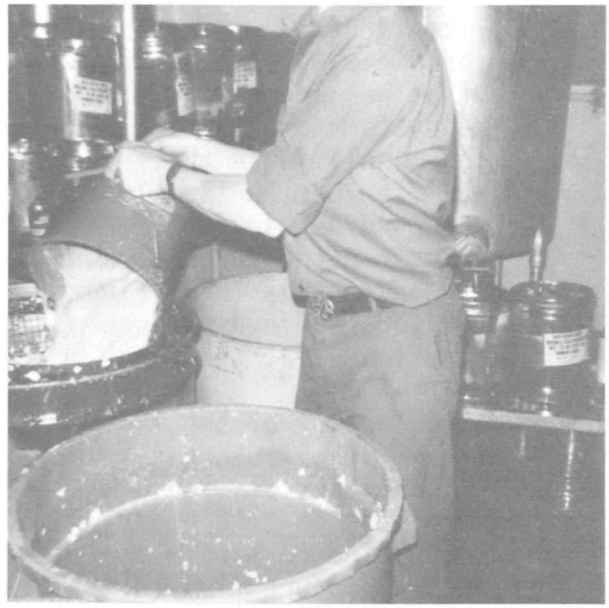

Figure 7. Inedible egg liquid separator.

Figure 8. ESM blend-back control gate.

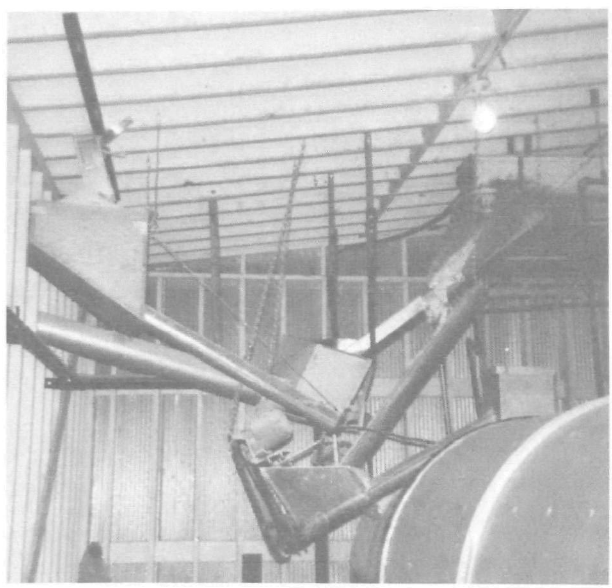

Figure 9. ESM blending-conveying system.

2. (continued)
became available which was capable of handling all of the liquid that was in the egg breaker waste and inedible eggs.
3. A system for blending dried ESM into the wet shell waste was developed to eliminate the free albumen by lowering the moisture content. ESM for use in the blending operation was diverted from the collector to a surge bin that fed by gravity to the feed auger. The flow of ESM from the surge bin was controlled by a manual gate at the end of the discharge tube (Figure #8). Blending was accomplished in the dehydrator feeding auger. The complete ESM blending system is shown in Figure #9.

This control of the liquid content of the waste and the blending of dry ESM with wet shell waste eliminated product sticking within the dehydrator. Larger quantities of liquid could be introduced into the dehydrator than were permitted in this study, however a more efficient blender would have to be installed to handle the blending load. Figure #11 is a diagram showing the product flow in the breaking plant during this study.

The ESM was a granular type of free flowing product as it came from the dehydrator. No additional grinding or processing was required before it's utilization as a feedstuff. This product is shown in Figure #12.

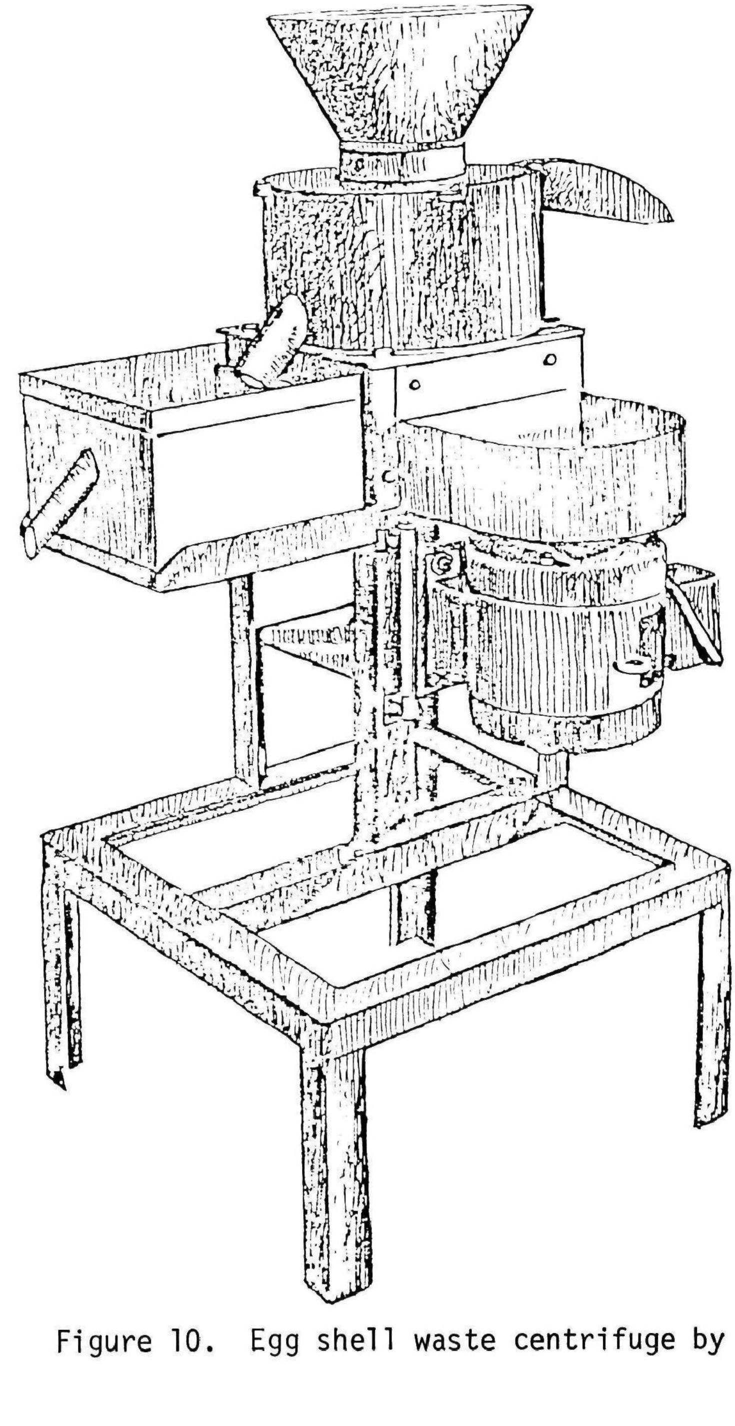

Figure 10. Egg shell waste centrifuge by Seymour.

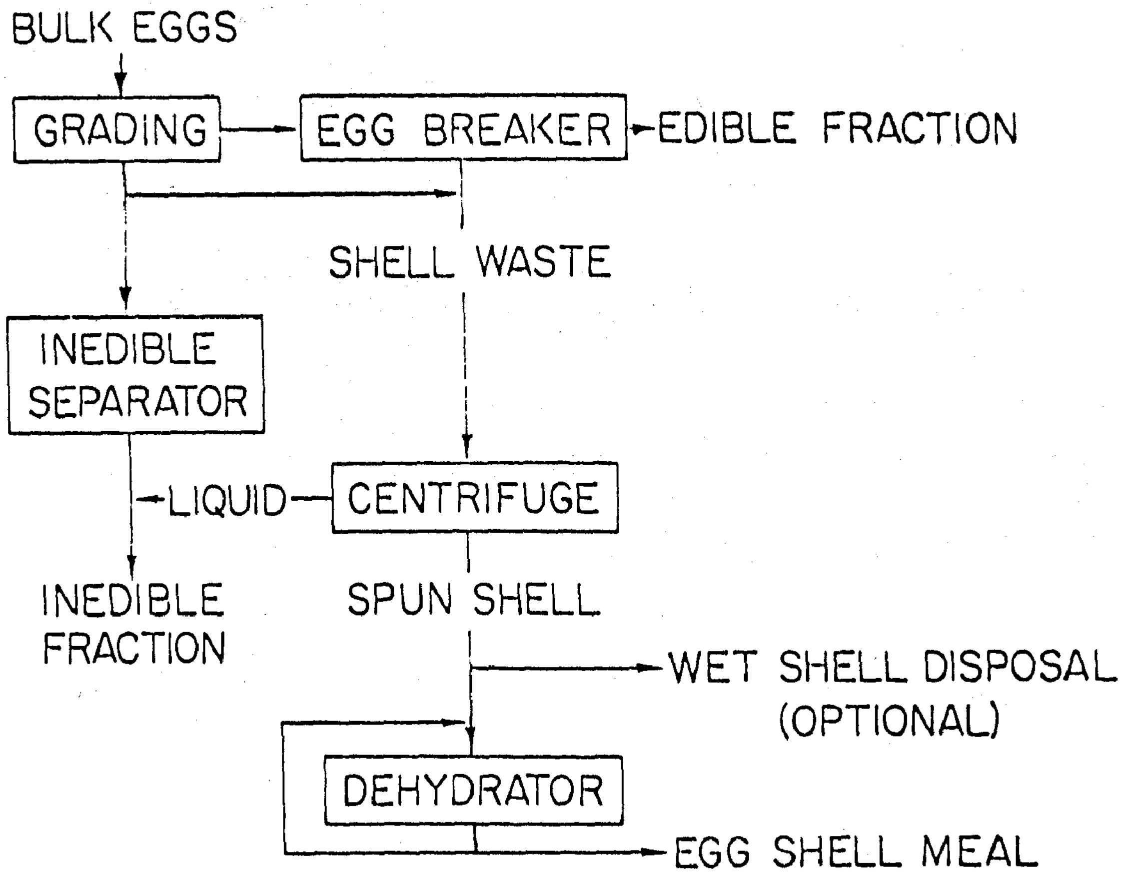

Figure 11. Flow diagram of egg breaking plant and egg shell waste processing.

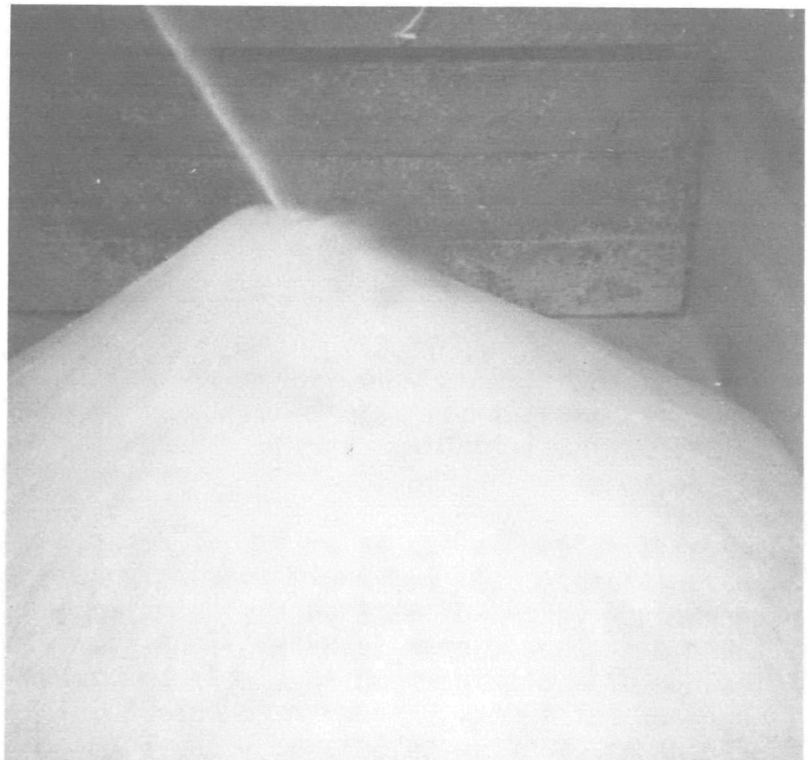

Figure 12. Granular ESM flowing from the cyclone collector.

SECTION VI

EXPERIMENTAL PROCEDURE

FEEDING STUDY

A local integrated egg producing corporation (including a feed mill) agreed to place approximately half of their laying hens on a diet formulated with ESM. The control (A) and experimental ESM diet (B) are shown in Table 1.

TABLE 1. DIETS USED IN FIELD STUDIES EVALUATING ESM

Ingredient	Cost ($/100 kg)	Composition (%) A	Composition (%) B
Corn, yellow	11.37	25.8	23.0
Milo	10.27	35.0	38.7
Soybean meal (44)*	15.16	18.8	17.6
Dehydrated alfalfa (17)*	12.76	3.2	3.2
Limestone, ground	1.65	7.2	----
Egg shell meal	3.40	----	7.5
Protein concentrate	20.68	10.0	10.0
Total		100.0	100.0
Diet Cost $/100 kg		11.97	12.06

*Figures in parenthesis represent % protein.

The ESM diet contained approximately 1% more energy than the control diet. This higher energy level was worth approximately $0.66 per metric ton. This increased value would negate the slightly higher cost of the ESM diet.

The number of hens involved in each treatment (Diet A and Diet B) ranged between 97,000 to 197,800 over a seven months period.

DATA COLLECTION

Daily processing data were recorded for gas and electricity. In addition the number of 30 dozen cases broken and plant yield of edible egg were tabulated.

Egg production and feed efficiency on the feeding trial were computed monthly.

Analytical work on ESM was conducted on a series of daily production samples taken during the early phase of the operation. Protein and calcium was determined according to the AOAC (1970) (3). Amino acid analyses were done by cation-exchange chromatography (Benson et al., 1971) (4). Salmonella and total aerobic counts were determined. Salmonella Survival Test was run according to Cotterill and Glauert (1969) (5). The total aerobic count was determined by weighing 25 g ESM aseptically and blending it with 225 ml sterile distilled water in a Waring Blendor for 2 min. at high speed. Total counts were made from Trypticase soy agar plates incubated at 37°C for 24-48 hrs.

BOD and COD

BOD and COD analyses were performed as described by Standard Methods (1971) (6). Bacterial seed from the BOD tests were cultured from activated sludge taken from Columbia's Sewage Treatment Plant. Results for the BOD and COD are reported as mg O_2 per kg of dried waste material.

Samples were assayed to determine the effect of the egg shell waste on a secondary sewage treatment plant and the potential of dissolving pollutants by rain and transferring them to nearby surface waters. Ten (10) grams of dried egg shell material were placed into one liter of distilled water and mixed slowly with a magnetic stir bar. Three mixing times were used: 15, 30 and 60 minutes. The mixing was done to simulate the mixing that may occur in a sewer line prior to reaching the treatment plant and to determine the total fraction of BOD and COD that would be dissolved by sewage or repeated rainfall.

After mixing, the solutions were placed into one liter Imhoff cones and allowed to settle. After one hour of settling, solids were measured in the cone and a sample of the supernatant was removed from mid-depth in the cone. These samples were analyzed for BOD, COD and pH.

FORMULATION AND MILLING

The cooperating mill used a protein premix which restricted the ingredient flexibility in formulating the diet. The diets employed in the field study are shown in Table 1. The grain portions, soybean meal and ground limestone were adjusted when ESM was added.

A local feed mill received all of the ESM from the beginning of the project and incorporated it into layer diets for use in feeding layer flocks which the mill operator controlled. The level of ESM in the layer diet was based on its analytical composition. It replaced all calcium normally obtained from ground limestone, and its protein component substituted for an equal amount of protein normally supplied by a combination of other feed ingredients (basically soybean meal in this instance).

The layer diet containing egg shell meal as a feedstuff was fed to several production flocks. The regular layer diet used by this producer was fed to a second group of production flocks as a control. Feed consumption and egg production records were kept. As with many field experiments, control was not easy; and there was an age difference between birds receiving the egg shell meal (ESM) diet and those receiving the control diet.

In a milling operation where there is complete ingredient flexibility, it is possible to realize additional savings by adjusting the phosphorus and amino acid levels. A suggested formula change with one group of ingredients is shown in Table 2. ESM can be used with other ingredients combinations.

TABLE 2. SUGGESTED FORMULA CHANGE FOR ONE GROUP OF INGREDIENTS

Ingredient	Formula Change (%)
Corn	-.05
Soybean meal (48)*	-.41
DL-methionine	-.01
Dicalcium phosphate	-.04
Ground limestone	-5.87
Egg shell meal	+6.38

*Figure in parenthesis represents % protein.

SECTION VII

RESULTS AND DISCUSSION

Periodic samples of ESM were collected for analyses. Nutrient analyses were made so that feed formulation information could be supplied to the feed processor.

MICROBIOLOGICAL COMPOSITION

During December, 1975 and March, 1976 six samples of ESM were collected aseptically after dehydration for microbial evaluation. It is of interest that retention time in the dehydrator is such that all microorganisms are not killed, however all samples were salmonella negative. Total Aerobic bacteria of 17.6 x 10^5 per gram in wet shell waste decreased to 5.6 x 10^5 per gram in dry product processed at 60°C exhaust temperature and to 70 microorganisms per gram in dry product processed at 127°C exhaust temperature. This decrease was logarithmic with increasing temperature (Figure #13).

MOISTURE CONTENT OF ESM

The ESM moisture content was studied at six exhaust temperatures. The data in Table 3 indicates maximum moisture removal at an exhaust temperature of 82°C. The shell particle and membrane sizes were larger at 60 and 71°C than at higher temperatures. Note the large reduction in moisture between 71 and 82°C processing.

TABLE 3. MOISTURE LEVEL OF ESM PROCESSED AT VARIOUS TEMPERATURES

Exhaust Temperature °C	Moisture %
60	4.4
71	6.1
82	1.3
93	1.6
104	1.8
115	1.6

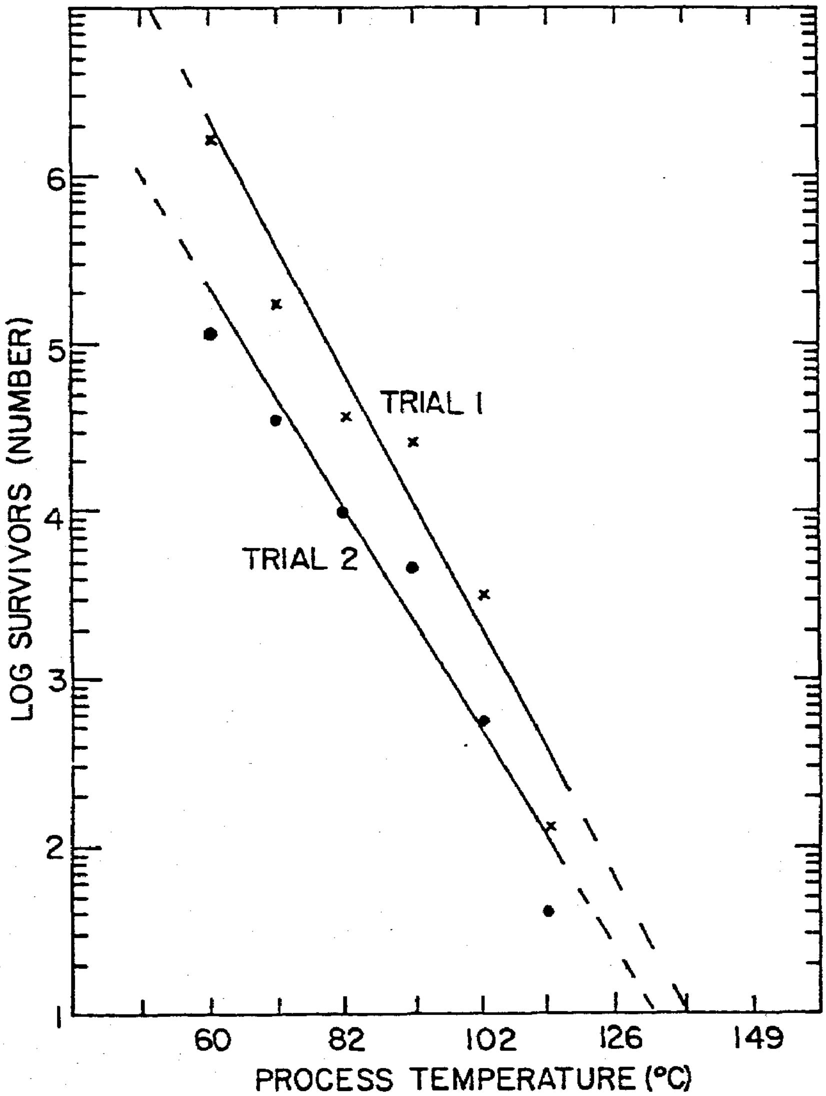

Figure 13. Destruction of microorganisms in egg breaking plant waste during dehydration at various temperatures.

RETENTION TIME IN THE DEHYDRATOR

A food dye was mixed with 6 liters of raw centrifuged shells. These dyed shells, membranes, and adhering egg white were introduced as a single marked product into the dehydrator. Discharge samples were collected every two minutes during the next 32 minutes. These ESM samples were examined for color intensity by three techniques: (1) Average visual appearance of the dry product based on 12 judges opinions on a 1-5 score basis (5 = most color). (2) Five g of shell were mixed with 10 ml of water in a test tube, shaken, let settle, and the membrane layer scored as in 1. (3) Same as 2, except scores were for shell layer. The experiment was repeated at four operating temperatures 71°, 82°, 93° and 104°C.

The slug of dyed egg shells passed through the dryer in a biphasic pattern. One fraction had a retention time of about 4-8 minutes and another was expelled in about 20-24 minutes. Since similar patterns were obtained for all four process temperatures only results of the 71°C trial are presented graphically (Figure #14). The membranes and shells appeared to pass through the dryer at the same rates. There was no readily apparent difference in particle size. The red dye was more easily viewed than the blue dye. However, the color intensity of all samples of ESM was faint. Attempts to extract the color and measure color intensity colorimetrically were unsuccessful.

CHEMICAL COMPOSITION

Samples were collected of ESM which resulted from egg shell waste which had passed through a centrifuge prior to drying. Laboratory analyses of these samples for protein, calcium and amino acids appear reasonably consistent from day to day (Table 4). A protein level of 6.5 percent and 36.3 percent calcium levels were in agreement with previous work on ESM (Walton et al., 1973) (1). The amino acid values are in Table 5 and were used in computing the cage layer diet.

TABLE 4. ANALYSES OF 15 PRODUCTION SAMPLES OF EGG SHELL MEAL (Dry Basis)

	Centrifuged %
Protein	6.46 ± 0.16*
Ether extract	0.47 ± 0.18
Calcium	36.30 ± 0.65
Phosphorus	0.11 ± 0.01

*Standard error of the mean.

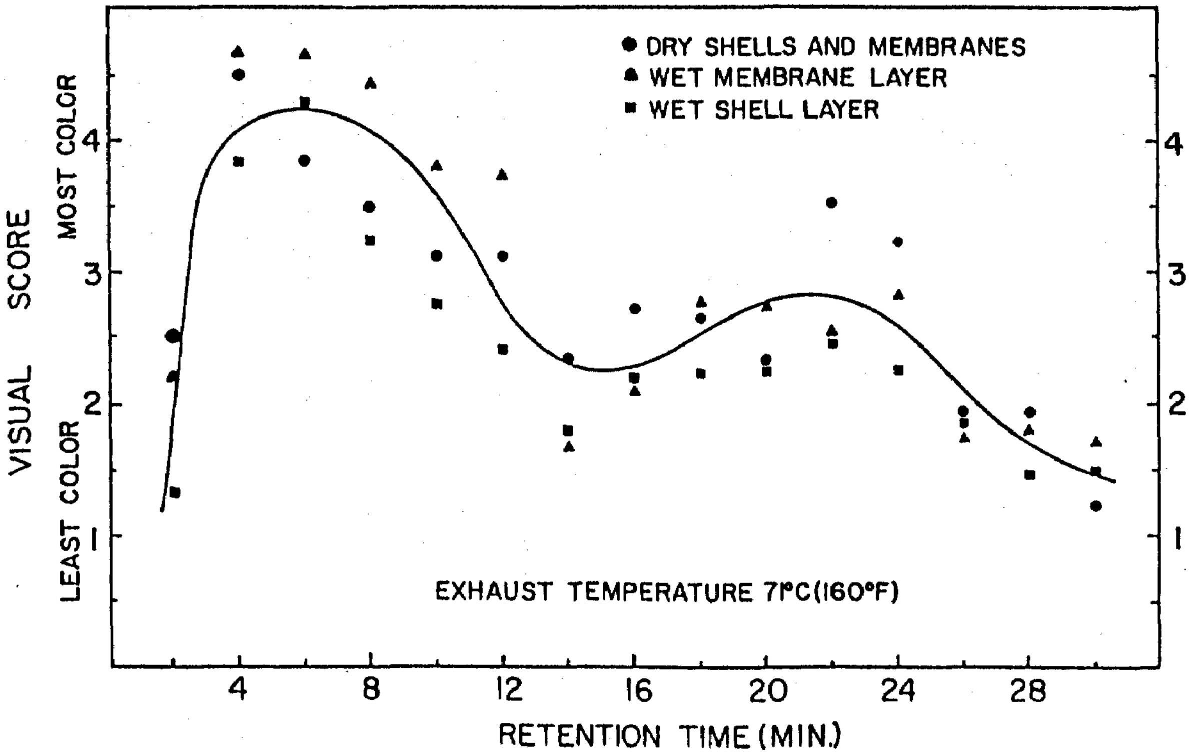

Figure 14. Visual color scores for ESM after various retention times.

TABLE 5. AVERAGE AMINO ACID COMPOSITION OF 15 SAMPLES OF ESM

	%	
Aspartic acid	.58	± 0.08*
Threonine	.32	± 0.04
Serine	.39	± 0.05
Glutamic acid	.82	± 0.11
Proline	.43	± 0.07
Glycine	.37	± 0.05
Alanine	.29	± 0.03
Cystine (includes Cysteine)	.33	± 0.08
Valine	.40	± 0.06
Methionine	.22	± 0.04
Isoleucine	.24	± 0.03
Leucine	.42	± 0.06
Tyrosine	.18	± 0.02
Phenylalanine	.21	± 0.03
Histidine	.24	± 0.03
Lysine	.30	± 0.04
Arginine	.43	± 0.06
Total	6.17	

*Standard error of the mean.

BOD AND COD OF ESM

Results of the BOD_5 and COD tests on the dried egg shell are presented in Table 6. The wet waste had been centrifuged prior to drying with the result that most of the BOD_5 observed is probably coming from the membrane attached to the shell. The average COD/BOD ratio of 1.50 suggests that the organic fraction of the waste is quite biodegradable compared to domestic sewage (average ratio of 2.0).

Figure 15 represents a 26-day BOD curve for one of the samples represented in Table 6. A value for the rate constant, k, of 0.19 day^{-1} was calculated by the Thomas Method (Metcalf and Eddy, 1972) (7) and compares favorably with a value of 0.17 commonly used as an average value for domestic sewage (Sawyer and McCarty, 1967) (8). The oxygen demand curve (Figure #15) shows 68% of the 26-day ultimate BOD was exerted in 5 days.

Results of the mixing-Imhoff cone experiments are presented in Table 7. Mixing time appeared to have a minor influence on soluble BOD_5 or COD. A 7% increase in both BOD_5 and COD was achieved by increasing the mixing time from 15 to 60 minutes. Comparing the data of Table 6 and 7, 43-50% of the BOD_5 was solubilized (61-67% of COD). Settling in the cones occurred very rapidly due to the heavy nature of the egg shells.

TABLE 6. EGG SHELL WASTE CHARACTERISTICS*

	Number Samples	Mean, $\bar{X}$	Range	Std. Dev., S
BOD_5, mg/kg	15	24,051	14,901-32,858	$\pm$5,024
COD, mg/kg	15	35,410	25,577-48,596	$\pm$5,500
COD/BOD_5	15	1.50	1.16-1.72	$\pm$ 0.17

*Material has been centrifuged in a Seymour Shell Spin and dried at 82°C in a Heil SD 45-12 dehydrator prior to analysis.

TABLE 7. CHARACTERISTICS OF IMHOFF CONE SUPERNATANT

	Mixing Time, minutes		
	15	30	60
pH	8.36	7.80	7.82
Settleable solids*, ml/l	12.8	13.9	12.5
COD, mg/kg	21,500	22,800	23,600
BOD_5, mg/kg	10,300	10,600	12,100

*10 grams of egg shell waste/liter

Egg shell waste which has been centrifuged and dried exerts an average BOD_5 of 24,000 mg O_2 per kg waste (dry wt.) which is equivalent to 42,545 mg of oxygen demand from each 30 dozen case of eggs processed. Approximately 50% of this BOD becomes soluble when the dry material is placed in water. Considering the industries potential of 45,455 metric tons per year of dry ESM, the readily soluble component could exert a BOD_5 of 545,460 kg

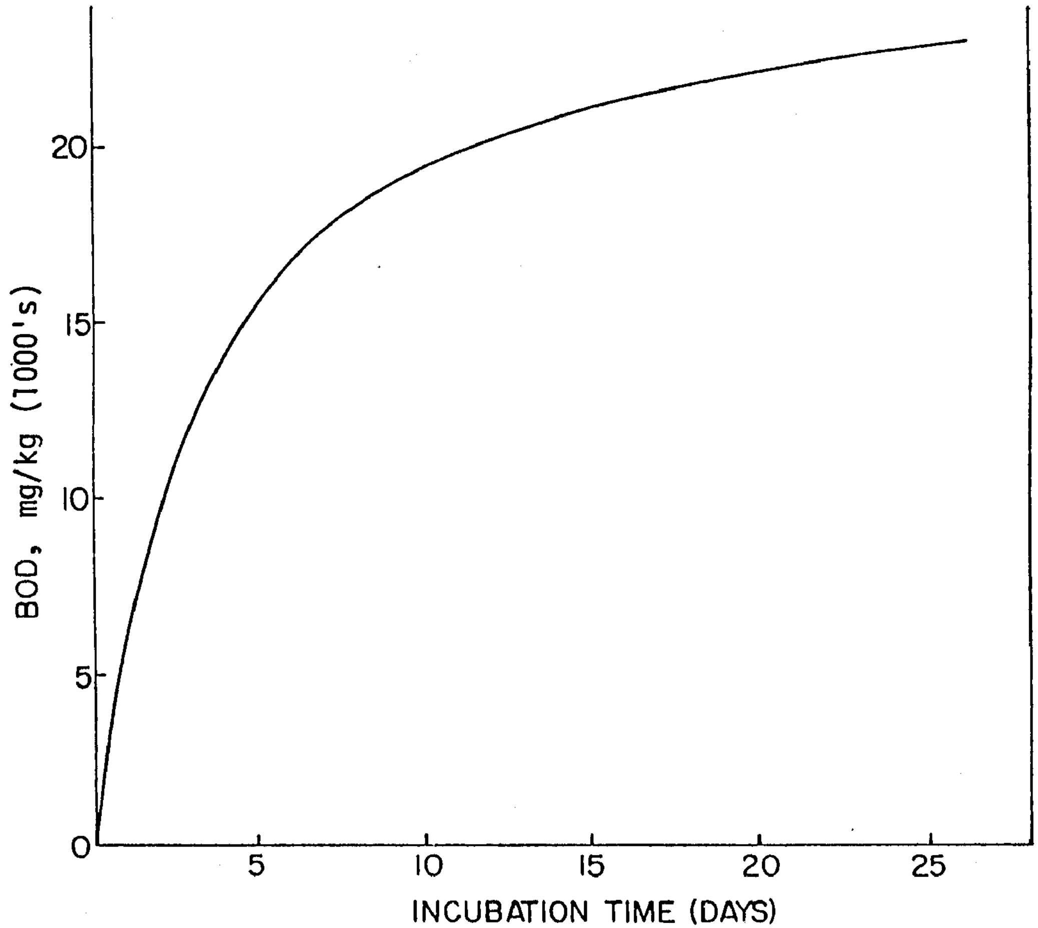

Figure 15. BOD content of one sample of ESM after various incubation times.

O_2 per year. The most likely environmental impact of present disposal practices for egg shell waste is transfer of the BOD to surface waters by rainfall runoff. This is because this waste material is presently disposed of on land rather and not converted into a by-product (ESM). However, egg shell waste discharged to a sewer would exert a significant BOD load on the receiving secondary treatment plant.

PLANT PRODUCTION

The average monthly egg breaking plant data are shown in Table 8. The average number of cases broken daily varied slightly with March being the highest with 1,395 cases and June the lowest with 1,264 cases. The average pounds of edible egg and ESM varied with the number of cases broken. From these data an egg breaker with a centrifuge could expect 1.77 kg ESM from each 30 dozen cases broken.

TABLE 8. AVERAGE DAILY PRODUCTION AT EGG BREAKING PLANT UNDER STUDY

Month	30 doz cases	Edible egg kg	ESM kg
March	1,395	25,069	2,443
April	1,370	24,649	2,606
May	1,338	23,102	2,409
June	1,264	20,970	2,100
July	1,330	23,242	2,304
August	1,363	22,153	2,384
September	1,318	22,149	2,202

CAGE LAYER PERFORMANCE

When the feeding trial was initiated the flocks were allotted to the treatments according to age. Initially the bird age was similar on both treatments however as the experiment progressed it was not possible to maintain the desired balance (Table 9).

Laying hens reach peak production at approximately 32 weeks of age. Subsequent to peak production there is a linear decrease in egg production and a corresponding increase in feed required to produce a dozen eggs.

Using the average age difference of 11.6 weeks, a change in egg production and feed conversion of 4.4% and 0.18 kg feed/doz. eggs respectively can be predicted (Scott et al., 1969) (9). This negates the

TABLE 9. PERFORMANCE DATA OF CAGE LAYERS FED ESM AND NUMBER OF LAYERS INVOLVED

	Age (weeks)		Egg Production (%)		Feed conversion (kg/doz)		Number of hens (000 omitted)	
	Control	ESM	Control	ESM	Control	ESM	Control	ESM
March	48.9	46.4	79.0	77.8	1.72	1.65	164.0	109.4
April	54.5	43.5	75.6	79.9	1.81	1.73	164.0	162.4
May	58.7	44.6	72.3	76.4	1.77	1.71	184.0	197.8
June	55.6	44.0	76.0	77.5	1.76	1.59	166.5	183.8
July	59.6	46.2	70.6	79.6	1.79	1.57	133.0	193.6
August	61.3	45.7	68.8	79.4	1.82	1.60	104.0	159.6
September	62.3	49.7	68.7	77.1	1.87	1.68	97.0	159.6
AVERAGE	57.3	45.7	73.0	78.2	1.79	1.65	144.6	166.6

observed improvement in egg production and feed conversion when ESM was fed. Performance on both diets was comparable.

Since the experiment has been terminated the processor and feed manufacturer-egg producer has signed a two year contract on ESM. The continued use of ESM attests to the satisfaction of both parties on its' economic value.

SECTION VIII

ECONOMIC CONSIDERATIONS

A series of tables were developed describing the production cost of ESM under a variety of equipment and labor cost situations (Appendix I). The calculated production cost of ESM ranges from $13.58 to $39.82 per metric ton with cost per ton decreasing with increasing size of the egg breaking operation.

BASIS FOR COOPERATORS·SHARE OF ESM VALUE

The value of ESM as a feedstuff was accepted as a basis for the economic relationship between the cooperators. ESM was assigned a value based upon the market value of the ground limestone and the protein ingredients it replaced in a ration. At the time the experiment was initiated it had a value of $34 per metric ton. Hence, this $34 was available to pay processing costs and provide payments to the cooperators. The processing plant operator delivered the dry product to the mill. The mill operator paid the processor for his out-of-pocket costs plus one-third of the remaining value of the product. The other two-thirds of the remaining value was shared equally by the miller and the egg producer (the same person in this case).

OWNERSHIP AND OPERATING COSTS

The overall economic potential for an egg shell waste processing system mainly depend on the size of equipment and plant. The minimum dehydrator installation cost would be approximately $35,000 (1977 prices). Daily ownership cost would also vary depending on depreciation, interest, maintenance, insurance and taxes. The basis for cost in this study are presented in Table 10 and ranged between $15.87 and $25.20 per day depending upon the length of depreciation.

TABLE 10. COST OF DEHYDRATOR OWNERSHIP BASED ON AN INSTALLED COST OF $35,000

	Depreciation period		
Cost item	10 year	20 year	30 year
Annual depreciation	$3,500.00	$1,750.00	$1,166.67
Annual interest (8% of avg. invested)	$1,400.00	$1,400.00	$1,400.00

Continued

TABLE 10 (continued)

Cost item	Depreciation period 10 year	20 year	30 year
Maintenance and repair (2% of cost, annually)	\$ 700.00	\$ 700.00	\$ 700.00
Insurance and taxes (2% of cost, annually)	\$ 700.00	\$ 700.00	\$ 700.00
Annual cost of ownership	\$6,300.00	\$4,550.00	\$3,966.67
Cost/day of operation (250 days/yr.)	\$ 25.20	\$ 18.20	\$ 15.87

Operating costs to produce one ton of dried egg shell meal was calculated for the Missouri field installation by using records of labor input and energy use. An average of 2.38 metric tons of dried egg shell meal was produced each day with a daily input of 57.7 KWH of electricity, 139 cubic meters gas and one hour of labor. The cost of these inputs were 2.7¢/KWH of electricity \$1.00/28 M^3 of gas, and \$6.00/hr. of labor. Hence, the cost of producing one metric ton of ESM was estimated by combining ownership and operating expenses. It ranged from \$15.82/metric ton to \$11.92/metric ton depending upon the depreciation schedule followed (Table 11).

TABLE 11. COST TO PROCESS ONE METRIC TON OF DRIED EGG SHELL MEAL BASED UPON ACTUAL OPERATING COSTS (MISSOURI FIELD INSTALLATION) COMBINED WITH DRYER OWNERSHIP COSTS

Cost item	Depreciation period 10 year	20 year	30 year
Dehydrator ownership	\$10.58	\$ 7.64	\$ 6.67
Labor (1 hr./day @ 6.00)	\$ 2.52	\$ 2.52	\$ 2.52
Electricity (57.7 KWH/day)	\$ .65	\$ .65	\$ .65
Gas (139 M^3/day)	\$ 2.07	\$ 2.07	\$ 2.07
Total cost ton (\$/metric ton)	\$15.82	\$12.88	\$11.91

VALUE OF EGG SHELL MEAN

The feedstuff value of ESM was estimated over a wide range of corn and soybean meal prices, as identified in Table 12. For example, if corn and soybean meal prices increased to $92 and $210 respectively, ESM would be worth $37.75 per ton.

TABLE 12. VALUE OF CENTRIFUGED ESM BASED ON VARIOUS CORN-SOYBEAN PRICES

SBM (48)*	Corn ($/metric ton)					
($/metric ton)	75	85	95	105	115	125
150	33.00	---	---	---	---	36.10
160	---	---	---	---	---	---
170	---	---	---	---	---	---
180	---	---	---	---	---	---
190	---	---	---	---	---	---
200	---	---	---	---	---	---
210	---	---	** ---	---	---	---
220	---	---	---	---	---	---
230	---	---	---	---	---	---
240	---	---	---	---	---	---
250	39.70	---	---	---	---	42.70

*Numbers in parenthesis represent % protein.

**ESM value of $37.75 based on prices for corn (@$92) and SBM (@$210).

Comparing this $37.50/metric ton value for the ESM with the cost figures in the Appendix (Tables A-5), it can be seen that the process is economically justified except for small operations of 1000 cases/day or less which also have a high labor cost of $5.00/hour or more. This comparison does not include elimination of the pollution control cost for disposal of this waste with its high BOD levels. Accounting for the disposal costs further increases economic feasibility of this by-product recovery system.

SECTION IX

FEED CONTROL OFFICIAL DEFINITION

In April 1975 a product description was submitted for consideration by the Board of Directors of the Feed Control Officials. This description read as follows, "Egg Shell Meal is a mixture of egg shells, shell membranes and egg content obtained by drying the residue from an egg breaking plant in a dehydrator to an end product temperature of 200°F. It must be designated according to its protein content." In order to describe and control the product, minimum protein and calcium levels for the non-centrifuged product should be 7 percent and 35.5 percent respectively. While the minimum protein and calcium on the centrifuged ESM would be 5.0 and 35.5 percent, respectively.

In June 1976, after reviewing moisture, salmonella and bacteriological data it was recommended that the end product temperature be reduced from 200°F to 180°F. With this recommended modification, ESM remained on a tentative status.

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APPENDIX A

AN ECONOMIC ANALYSIS OF THE DEHYDRATION OF EGG BREAKING PLANT WASTES (November, 1974)

TABLE A-1. DRYER COST

Cost item	Assumed First Cost ($) 25,000	30,000	35,000
Annual depreciation (30-year life)	$ 833.33	$ 1,000.00	$ 1,166.67
Annual interest (8% of avg. invested)	1,000.00	1,200.00	1,400.00
Maintenance and repair (2% of cost, annually)	500.00	600.00	700.00
Insurance and taxes (2% of cost, annually)	500.00	600.00	700.00
Annual cost of ownership	2,833.33	3,400.00	3,966.67
Cost/day of operation (250 days/hr)	11.33	13.60	15.87
Cost/day of operation (156 days/yr)	18.16	21.79	25.43

TABLE A-2. LABOR COST

	Hourly rate ($) 3	4	5
Annual cost	$6,240	$8,320	$10,400
Daily cost	24.00	32.00	40.00

TABLE A-3. DAILY MOISTURE LOAD, FUEL COST, AND DRY MATTER YIELD (EGG BREAKING PLANT WASTE)

Item	Size of operation (cases per day) 1,000	1,500	2,000	2,500
Kg wet waste	2,273	3,409	4,545	5,682
Kg water @ 30%	682	1,023	1,364	1,705
Cal required	76×10^7	113×10^7	151×10^7	189×10^7
Liter fuel	95	142	189	237
Fuel cost @ 7.9¢/L	$7.50	$11.22	$14.93	$18.72
Kg dry material	1,591	2,386	3,182	3,977
Metric tons dry mat.	1.59	2.39	3.18	3.98

Note assumptions: 8×10^6 cal/l fuel, used at 50% efficiency (i.e., 1.1×10^6 evaporates 1 kg water)

TABLE A-4. COST $ PER DAY FOR DRYING EGG BREAKING PLANT WASTES

Dryer cost $	Labor cost #/hr	Size of operation (cases per day) 1,000	1,500	2,000	2,500
25,000	3	42.83	46.58	50.33	54.08
	4	50.83	54.58	58.33	62.08
	5	58.83	62.58	66.33	70.08
30,000	3	45.10	48.85	52.60	56.35
	4	53.10	56.85	60.60	64.35
	5	61.10	64.85	68.60	72.35
35,000	3	47.37	51.11	54.87	58.62
	4	55.37	59.11	62.87	66.62
	5	63.37	67.11	70.87	74.62

TABLE A-5. COST $ PER METRIC TON FOR DRYING EGG BREAKING PLANT WASTES

Dryer cost $	Labor cost #/hr	Size of operation (cases/day) 1,000	1,500	2,000	2,500
25,000	3	26.92	19.48	15.82	13.58
	4	31.96	22.82	18.34	15.59
	5	36.97	26.17	20.84	17.60
30,000	3	28.35	20.43	16.53	14.16
	4	33.37	23.78	19.04	16.16
	5	38.40	27.13	21.56	18.17
35,000	3	29.77	21.37	17.25	14.72
	4	34.80	24.73	19.76	16.73
	5	39.83	28.07	22.28	18.74

APPENDIX B

OPERATING PROCEDURE

START UP PROCEDURE

1. Turn on automatic trunion and drive chain oiler
2. Grease trunion and other grease fittings, do not grease motors.
3. Turn main power switch on.
4. Turn control panel power switch on.
5. Set dial reading on 520 controller to get needle on positive (+) side of dial.
6. Check gas modulator valve for being closed in #1 position.
7. Turn main drive switch on.
8. Turn gas blower switch on.
9. Depress pilot light-off button after safe start buzzer (green signal light) comes on. Pilot should light, when solenoid energizes (loud snap), release light-off button. Pilot should remain lit.
10. Open main gas valve.
11. Open two gas control valves by pushing levers forward.
12. Increase reading on 520 controller dial until needle is on negative (-) side of dial (5-10^{o}). As needle moves to positive side, increase dial setting gradually (5-10^{o}), and allow burner to bring heat up. Continue raising dial setting gradually until desired reading (180^{o}) is reached.
13. Turn feeder conveyor on to allow machine to receive waste shells.

SHUT DOWN PROCEDURE

1. Clear and turn feed conveyor off
2. Turn main gas valve off.
3. Turn two lever controlled gas valves off by moving levers to the rear or off position.
4. Turn gas blower switch off.
5. Turn main drive switch off.
6. Set dial on 520 controller to zero (000) to allow gas modulator valve to close.
7. Turn control panel power off.
8. Turn main power switch off.
9. Cover solenoids and valves on east end of machine with plastic to protect from water from clean-up crew.

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

Egg breaking plants yield an estimated 50,000 tons of waste annually. These wastes are commonly disposed of on land. This method of disposal is becoming more difficult due to the potential for pollution of local water resources.

A triple pass rotary drum dehydrator was installed at an egg breaking plant. With appropriate engineering modifications a system for producing egg shell meal from the total egg shell waste from the breaking plant was developed. This meal was utilized as a feedstuff by a local mill and incorporated into a layer diet. This diet was fed to several commercial flocks of cage layers.

Appropriate data were collected to determine meal production costs, yield of meal, feed produced, feeding data, and layer flock performance. COD and BOD data were generated to determine the pollution potential of the waste were it not converted to a useful by-product.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Poultry, Pollutants, Waste Disposal, By-products	Egg Breaking Wastes, Pollution Potential, Egg Shell Meal, By-product Recovery, Feed Performance	43F 50B 91A

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