United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-82-060 Oct. 1982

EPA

Project Summary

Evaluation of Waste Citrus Activated Sludge in Poultry Feeds

Bobby L. Damron, Douglas M. Janky, Robert H. Harms, and Mark F. Hall

Experiments were conducted on chick broilers and hens to determine the metabolizable energy of citrus sludge. A determination of metabolizable energy values showed that the values decreased as the level of citrus sludge in the diet increased. A series of protein levels were fed to day-old chicks for a three-week period in an attempt to assay the protein quality of citrus sludge. As the level of sludge in the diet increased, its utilization decreased, with an almost toxic effect being observed at higher concentrations.

Vitamin D_3 and sludge were fed to day-old chicks to determine if the minerals contained in the sludge could be causing the destruction of Vitamin D_3 in the feed. Results revealed that the addition of Vitamin D_3 did not offset the depressing effect of sludge feeding upon body weights. The conclusion reached was that citrus sludge was not related to Vitamin D_3 destruction.

Experiments were conducted on day-old chicks to evaluate the biological availability of the phosphorus contained in citrus sludge. All sludge treatments produced body weights significantly below those of a modified corn-soy basal diet containing monosodium phosphate.

Citrus sludge was also examined as a source of pigmentation in egg yolks. Hens were fed a white corn basal, xanthophyll-free diet to deplete egg yolk pigmentation. It was observed that citrus sludge produced eggs with the same hue as yellow corn containing comparable amounts of xanthophyll. The xanthophylls of yellow corn appeared to be more biologically available than those in citrus sludge.

Broilers were used to determine the effectiveness of citrus sludge as a pigmenting agent. White corn diets mixed with sludge were compared with yellow corn diets. Feeding sludge resulted in both the shanks and skin imparting the same hue and darkness as feeding yellow corn at equivalent xanthophyll levels.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Waste citrus activated sludge is the product resulting from the treatment of citrus processing plant wash water in a facility similar to a municipal treatment plant. One of the major problems associated with this process is the production of excess activated sludge. The handling and disposal of sludge amounts to one of the larger operating costs of the system. A typical analysis of the sludge is presented in Tables 1 and 2.

From previous studies with chicks (broilers) and hens (Jones et al., 1975), the recovery of activated sludge for the

Table 1. *Proximate Analysis of Citrus Sludge*

Nutrient	Percent
Moisture	11.10
Crude Protein	22.35
Fat	7.40
Fiber	11.45
Ash	12.20
NFE	35.50
Calcium	1.60
Phosphorus	0.45
Xanthophyll	28.60 mg/kg
Carotene	11.00 mg/kg

Table 2. *Trace Mineral Analysis of Citrus Sludge*

Element	Content (ppm)*
Aluminum	2,500
Cadmium	1
Chromium	100
Cobalt	3
Copper	260
Iron	4,600
Lead	120
Magnesium	2,100
Manganese	51
Mercury	0.5
Nickel	120
Potassium	7,300
Selenium	<1
Sodium	5,300
Zinc	430

* *Dry weight basis (ppm = mg/kg).*

use of animal feed material was known to be technically feasible and economically attractive. Experiments were designed to further define this product as a feed ingredient and to explore the cause of depressed performance at higher levels of supplementation.

Such experiments were designed to evaluate the biological availability of phosphorus, pigmenting value, and protein quality of citrus sludge in poultry feeds. The interaction between Vitamin D_3 and sludge was also examined as a possible explanation for the depressed performance seen at higher levels of supplementation. It has been theorized that the high mineral content in sludge catalyzed the destruction of Vitamin D_3.

These experiments were developed to demonstrate the use of citrus sludge as a feed ingredient to at least partially offset both dewatering and disposal costs. The addition of citrus sludge to the diet of broilers did not affect the palatability or texture of the meat. A significant improvement in egg yolk color was also observed when citrus sludge was fed to hens. The flavors of both the yolk and albumen were not affected.

Highlights of Project Findings

Metabolizable Energy of Citrus Sludge

Day-old chicks were fed several diets of citrus sludge substituted for an equal amount of sucrose. During the third and fourth week, representative samples of excreta were collected for analysis. Moisture (percent dry matter), gross energy (expressed as Kcal/g), and nitrogen and chromic oxide contents of the various diets and excreta were obtained to calculate the metabolizable energy of citrus sludge.

The metabolizable energy of sludge decreased numerically as the sludge substitution level in the diet was increased (Table 3). Excessive supplements of sludge (16 percent and above) were found to have a laxative effect on the birds. This may account for some of the decrease in utilization of sludge.

Citrus Sludge Protein Assay

A graded series of protein levels were fed to day-old chicks for a three-week period in an attempt to assay the protein quality of citrus sludge. The negative effect of sludge was reflected in its feed intake efficiency. In the corn-soy diets, as the protein level increased, feed intake improved significantly. Conversely, as the percentage of sludge was increased, its utilization decreased or became masked, and a depressing effect occurred at the highest level of supplementation (Table 4).

Citrus Sludge-Vitamin D_3 Interaction

In two experiments, a graded series of Vitamin D_3 and citrus sludge levels were added to a corn-soy basal diet and fed to day-old chicks for a three-week period. Tibia ash, phosphorus, and calcium values were obtained. There was no significant difference between the levels of sludge for values of calcium in the first experiment, nor for phosphorus or ash in both experiments. However, there was an unexplainable increase in calcium at the five percent sludge level in the second experiment. As the level of Vitamin D_3 was increased, ash values increased numerically.

There was significant interaction between sludge and Vitamin D_3. As the level of Vitamin D_3 was increased, feed intake increased. Sludge had no impact on feed intake. In summary, the depressing effect that citrus sludge had on body weight did not appear to improve with the addition of Vitamin D_3 to the diet of chicks. Therefore, the cause of the depression of body weight by citrus sludge was probably not due to the destruction of Vitamin D_3 by the level of iron in the sludge, as has been previously suspected. This lack of interaction was also expressed in ash values

Table 3. *Metabolizable Energy Per Kilogram of Citrus Sludge*

Dietary Sludge Level (percent)	Metabolizable Energy (Kcal/kg)
2	3,368
3	2,411
4	1,813
6	1,360
8	1,404
16	836

Phosphorus Assay of Citrus Sludge

Duplicate experiments were conducted to evaluate the biological availability of phosphorus contained in citrus sludge. A modified corn-soy basal diet was employed with variable amounts of citrus sludge in which monosodium phosphate, calcium carbonate, sucrose, and filler were added. Day-old chicks received each dietary treatment for a 3-week period. The addition of supplemental phosphorus had no significant influence in terms of body weight. However, increasing calcium levels supported some numerical improvements in body weights. All sludge treatments had weights significantly less than the modified corn-soy diet which had been supplemented with phosphorus (from monosodium phosphate). Calcium levels did not affect tibia ash values from sludge treatments. The failure of sludge treatment to produce better results may have been due to the reduced feed intake associated with those treatments. This reduction was felt to be due to the large amounts of sludge required to add phosphorus to the test.

Evaluation of Citrus Sludge as an Effective Egg Yolk Pigmenting Ingredient

The purpose of this experiment was to evaluate the egg yolk pigmenting efficiency of waste citrus activated sludge. Commercial hens were fed a

Table 4. *Protein Assay Chick Performance* (3 Weeks)*

% Crude Protein		Body Weight (g)			
Corn-Soy	Sludge	Exp. 1	Exp. 2	Feed Intake† (g)	Feed Efficiency † (g feed/g body wt)
16	0	364^{e}	404^{d}	33.6^{c}	1.80^{c}
18	0	508^{b}	485^{b}	36.4^{ab}	1.53^{e}
20	0	549^{a}	536^{a}	36.8^{ab}	1.42^{f}
22	0	538^{a}	545^{a}	35.2^{bc}	1.36^{f}
16	2	479^{c}	458^{bc}	37.3^{ab}	1.70^{d}
16	4	410^{d}	430^{cd}	38.1^{a}	1.91^{b}
16	6	302^{f}	289^{e}	30.5^{d}	2.24^{a}

**Means without common letters are significantly different according to Duncan's multiple range test (<0.05).*
†Values are a combination of two experiments.

white corn, basal, xanthophyll-free diet for 15 days to deplete the yolk of all pigment. The yellow corn diets were formulated to contain the same amount of xanthophyll as each of the citrus sludge diets. After 21 days on the experimental diet, the eggs were collected for analysis.

The data indicated that egg yolks produced by hens fed citrus sludge were the same color as those produced by hens fed yellow corn at equivalent xanthophyll levels. However, the egg yolks produced by hens fed citrus sludge did not have as much pigment as those produced by hens fed yellow corn. This was probably a result of xanthophylls in yellow corn being more biologically available. Citrus sludge would be a suitable pigmenting agent for eggs produced for home consumption. It would not be as suitable as yellow corn in eggs produced for commercial processes (e.g., mayonnaise, noodles), since there is less pigment in the yolks; this pigment would be diluted, resulting in processed egg products with less than the desirable color.

Evaluation of Citrus Sludge as an Effective Broiler Skin Pigmenting Ingredient

This experiment was designed to examine the influence of citrus sludge on broiler pigmentation. Day-old chicks were fed a white corn, xanthophyll-free diet for a period of four weeks. Beginning the fifth week, they were fed one of nine experimental diets for three weeks.

Pigmentation values of both shank and skin samples from broilers fed yellow corn were significantly higher than those fed the corresponding citrus sludge diet. The feeding of citrus sludge resulted in the same hue and darkness of both the shank and skin samples as did the feeding of yellow corn at comparable xanthophyll levels. Pigmentation values indicated that the xanthophyll in yellow corn was slightly more available than that in citrus sludge.

Conclusions and Recommendations

Satisfactory conclusions could not be reached. The chemical and physical nature of waste citrus activated sludge made it a very difficult product to evaluate in the feeding trials. Several experiments did show that: high mineral content in citrus sludge was not an inhibitor of Vitamin D_3 efficiency, and citrus sludge possessed pigmentation values approximately equal to yellow corn in broiler skin and shanks and egg yolks.

It is doubtful that a citrus sludge similar to the one employed in these experiments would be feasible in the commercial poultry industry because of poor nutrient content and as-yet-unidentified depressive agents. The identification of the agents that are reducing bird performance is necessary. Further work is also needed to improve the methods of concentrating, drying, and handling the product to improve its nutrient content.

★ U S GOVERNMENT PRINTING OFFICE: 1982 - 559-017/0842

Bobby L. Damron, Douglas M. Janky, Robert H. Harms, and Mark F. Hall are with the University of Florida, Gainesville, FL 32611.
***Kenneth A. Dostal** and **Harold W. Thompson** are the EPA Project Officers (see below).*
The complete report, entitled "Evaluation of Waste Citrus Activated Sludge in Poultry Feeds," (Order No. PB 82-259 904; Cost: $7.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officers can be contacted at:
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268