In Situ Evaluation of Hen Mortality Meal as a Protein Supplement for Dairy Cows

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ABSTRACT

A study was conducted to evaluate the nutritional composition and in situ degradation of hen mortality meals. There were four treatments: control autoclaved hen meal (C-HM), enzyme-treated, fermented, autoclaved hen meal (E-HM), NaOH-treated, fermented, autoclaved hen meal (NaOH-HM), and soybean meal (SBM). For the E-HM or NaOH-HM, hen mortality was treated with a feather digesting enzyme or NaOH to improve digestibility of feathers on the carcass. After the enzyme or NaOH treatment, treated hen mortality was preserved by a fermentation procedure. The crude protein levels of the C-HM and SBM were higher than the E-HM and NaOH-HM, and the concentration of fat in the C-HM was higher than the other treatments. Levels of Lys, Thr, Arg, Ile, Leu, Val, and Phe for the C-HM and SBM were higher than in the E-HM and NaOH-HM. The Met, Cys, and Gly levels in the C-HM were higher than the soybean meal. In situ ruminal degradation data showed that the C-HM had lower dry matter and crude protein degradation than the other treatments, whereas the E-HM or NaOH-HM was more susceptible to ruminal degradation. These results indicate that the C-HM has higher levels of crude protein, amino acids, and resistance to ruminal degradation, whereas the E-HM or NaOH-HM was more digestible to ruminal microorganisms.

(Key words: in situ degradation, hen meal, fermentation, NaOH)

Abbreviation key: C-HM = control autoclaved hen meal, E-HM = enzyme-treated, fermented, autoclaved hen meal, NaOH-HM = NaOH-treated, fermented, autoclaved hen meal, SBM = soybean meal.

INTRODUCTION

Proper disposal of poultry mortalities on commercial-scale farms is necessary to maintain biosecurity, main-

tain neighbor relations, and recycle carcass nutrients to either plants or animal production systems. A flock of 50,000 broilers grown to 49 d of age that averages 0.1% daily mortality will produce approximately 2.2 tonne/yr of carcasses (Blake et al., 1990). A flock of 100,000 hens with normal losses (0.1% per week) will produce 6.8 tonne of hen mortality annually.

Disposal of these poultry farm mortalities results in the loss of a tremendous amount of nutrients (Blake and Donald, 1992). Malone et al. (1987) determined that fresh broiler carcasses contain approximately 51.8% protein, 41.0% fat, and 6.3% ash on a DM basis. Many studies have demonstrated the techniques to recycle poultry mortalities into feed ingredients for poultry by rendering, extrusion, or fermentation (Tadtiyanant et al., 1993; Patterson et al., 1994; Barbour et al., 1995). Cai et al. (1994) reported that lactic acid fermentation successfully inactivated pathogenic organisms and preserved poultry carcasses. However, Kim and Patterson (2000b) indicated that broiler chicks fed fermented hen mortality meals treated with a feather digesting enzyme or NaOH depressed feed intake, weight gain, protein efficiency ratio, and net protein ratio compared with chicks fed nontreated hen mortality meal or a control diet. This study indicated that feather hydrolysis with enzyme or NaOH treatment followed by fermentation or autoclaving could depress nutritional quality of hen mortality meals for monogastric broiler chicks. However, heat and NaOH treatments might result in more resistance ruminant feed ingredients to microbial rumen degradation. Nishino and Uchida (1995) indicated that NaOH treatment has the potential to reduce ruminal degradation of feed-stuffs. Thus, utilization of fermented hen mortalities as a feed ingredient for ruminants might be a better nutritional recycling niche than feeding to monogastric broiler chickens.

Whereas previous studies have demonstrated a recycling niche for poultry byproducts as feed ingredients for ruminants (Waltz et al., 1989; Blasi et al., 1991; Cunningham et al., 1994), there is no information on the effects of feather-digesting treatments or fermentation on the nutrient composition and rumen degrada-

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tion of hen mortality meals. Thus, it was hypothesized that hen carcass feather hydrolysis with enzyme or NaOH and fermentation would change the nutrient values and rumen degradation of hen mortality meals. Therefore, the objective of this study was to evaluate the nutritional composition and in situ ruminal degradation of such treated hen mortality meals.

MATERIALS AND METHODS

Treatment and Sample Preparation

Sixty-five week-old Shaver 2000 spent hens were used in the preparation of hen meal supplements. There were four treatments: control autoclaved hen meal (**C-HM**), enzyme-treated, fermented, autoclaved hen meal (**E-HM**), NaOH-treated, fermented, autoclaved hen meal (**NaOH-HM**), and soybean meal (**SBM**). Each treatment was replicated three times. Birds were killed by cervical dislocation and stored at 25°C for 5 h. For the C-HM, 10 dead whole birds were ground and autoclaved at 124 kPa, 127°C for 90 min without fermentation, enzyme, or NaOH treatment. For the E-HM or NaOH-HM, 10 dead whole birds were placed in a mixer (99.1 L) (Monarch Industries, Winnipeg, Manitoba, Canada) with rubber picking fingers. For the E-HM, the birds were treated with 25.6 mg of Insta-pro feather-digesting enzyme (INSTA-PRO International, Des Moines, IA) per 1 g of feathers and 2.5 L of water for 12 h at 25°C. Feather weight was determined to be 4% of fresh weight of dead birds (Webster et al., 1996). For the NaOH-HM, the birds were incubated with 2.5 L of 0.4 N NaOH for 2 h at 25°C for feather hydrolysis. During incubation, the mixer agitated the birds vigorously. After incubation, treated feathers and carcasses were collected and ground. Sucrose (10%, wt/wt) was added to all ground bird treatments (E-HM and NaOH-HM) and blended thoroughly with an electric paddle. Fifteen kilograms of ground birds was placed in 19-L plastic buckets with lids and fermented for 21 d at 25°C. After fermentation, the E-HM and NaOH-HM were autoclaved at 124 kPa, 127°C for 90 min. Autoclaved samples were dried in a forced-air oven (Precision Scientific Inc., Chicago, IL) at 60°C to a constant weight, ground through a 2-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA), and stored at -20°C until further analysis. Commercial SBM (48% CP) was similarly ground and used as a standard protein supplement for comparison purposes. The dried samples were analyzed for CP, ether extract, AA composition (AOAC, 1990). Soybean meal, C-HM, E-HM, and NaOH-HM were evaluated for DM and CP degradations by in situ nylon bag incubation.

Table 1. The composition of diet fed to cannulated cows (DM basis).

Ingredient	%
Ryelage	31.35
Corn silage	17.98
Roasted soybeans, cracked	5.40
Shelled corn	25.42
Ren Plus ¹	1.55
Soybean meal (48%)	6.19
Wheat middlings	6.42
Animal-vegetable fat ²	1.33
Molasses	1.33
Limestone	0.90
Monosodium phosphate	0.35
Trace mineral salt	0.57
Magnesium oxide	0.15
Selenium premix (0.06%)	0.04
Vitamin mix ³	0.96

¹Ren Plus (Agway, Inc., Syracuse, NY) composition (percentage of DM): 69.1% CP, 1.6% ADF, 7% fat, 5.4% Ca, 2.77% P, 0.53% Mg, 0.59% K, and 0.64% S. Ingredients: pork meat meal, flash-dried blood meal, hydrolyzed poultry feathers, poultry by-product meal, fish meal, deflourinated phosphate, and calcium carbonate.

²Ratio of animal to vegetable fat. 1:1.

³Vitamins supplemented per cow, 100,000 IU/d of vitamin A, 35,000 IU/d of vitamin D, and 500 IU/d of vitamin E.

In Situ Nylon Bag Incubation

In situ incubation was conducted using the method described by Lykos and Varga (1995). Two ruminally cannulated Holstein cows (7 and 9 yr of age; average 530 kg of BW) were used for this experiment. They were in tie stalls for the entire 72-h period and fed a TMR once daily. The composition of the ration fed to these cannulated cows is presented in Table 1. The four protein treatments were SBM, C-HM, E-HM, and NaOH-HM. Nylon cloth (Marvelier White Strauss Co., New York, NY) with a mean pore size of 52 μ m and dimensions of 21 $\times$ 26 cm were folded and heat-sealed into bags. Each nylon bag contained 5 g (DM basis) of sample, and two replicate treatment bags were used for each time point. The bags were tied with plastic ties 2 cm below the top. Before placing them in the rumen, all bags including blanks were soaked in 39°C distilled water for 15 min to prevent sudden temperature change in the rumen. Duplicate bags were tied to the end of a 100-cm fishing line and incubated in the rumen of each cow. A blank was included at each time point to correct for rumen material entering the bags. After 1, 2, 4, 8, 12, 24, 36, and 72 h of incubation, bags were removed. Sample bags were rinsed with cold water using a hand-washing method until the rinse water was clear and then dried in a forced-air oven at 60°C until a constant weight was reached. The CP and DM content were determined before and after incubation to estimate the ruminal digestibility of hen meal treatments and the SBM standard (AOAC, 1990). The disappearances of DM and CP were expressed as a percentage of total

Table 2. The nutritional composition of control, enzyme, and NaOH treated hen meals, and soybean meal (DM basis).

	C-HM ¹	E-HM	NaOH-HM	SBM	Pooled SEM
	(%)				
CP	49.4 ^a	39.1 ^b	40.7 ^b	48.8 ^a	0.9
Ether extract	36.4 ^a	30.5 ^b	28.1 ^b	1.5 ^c	1.2
	(AA, g/100 g CP)				
Methionine	2.06 ^a	1.56 ^b	1.36 ^c	1.50 ^{bc}	0.05
Cystine	2.20 ^a	2.01 ^{ab}	1.77 ^b	1.67 ^b	0.07
Methionine +Cystine	4.26 ^a	3.57 ^b	3.13 ^c	3.18 ^{bc}	0.06
Lysine	5.78 ^a	4.78 ^b	3.92 ^c	6.29 ^a	0.14
Threonine	3.95 ^a	3.63 ^b	3.57 ^b	3.93 ^a	0.05
Arginine	6.37 ^a	4.67 ^b	4.45 ^b	7.56 ^a	0.11
Isoleucine	4.41 ^a	3.87 ^b	3.77 ^b	4.89 ^a	0.06
Leucine	7.39 ^a	6.33 ^b	6.14 ^b	7.92 ^a	0.07
Valine	5.82 ^a	5.07 ^b	5.15 ^b	5.67 ^a	0.09
Histidine	2.16 ^a	2.26 ^a	1.83 ^b	2.68 ^a	0.05
Phenylalanine	3.89 ^b	3.32 ^b	3.12 ^c	5.20 ^a	0.03
Glycine	8.65 ^a	7.87 ^b	7.62 ^b	4.40 ^c	0.16
Serine	4.92	4.94	4.65	4.59	0.11

^{a-c}Means within a row with different superscripts differ significantly ($P < 0.05$).

¹Control autoclaved hen meal (C-HM); enzyme-treated, fermented, autoclaved hen meal (E-HM); NaOH-treated, fermented, autoclaved hen meal (NaOH-HM); soybean meal (SBM); $n = 3$ per mean.

DM and CP, respectively. All animal care procedures were carried out as described in the protocol approved by The Pennsylvania State University Institutional Animal Care and Use Committee (95R027A0; 98R123-0).

Statistical Analysis

The data were subjected to one-way ANOVA in a completely random design using the general linear models procedure of SAS (SAS Institute, 1994). Significant differences in the nutritional composition and DM and CP degradations at 1, 2, 4, 8, 12, 24, 36, and 72 h of incubation among the means were determined by using Duncan's new multiple range test. All statements of significance are based on the probability level of 0.05.

RESULTS AND DISCUSSION

Chemical Composition of Test Diets

The CP levels of the C-HM and SBM were significantly higher than the E-HM and NaOH-HM, whereas the ether extract level of the C-HM was higher ($P < 0.05$) than all others, and SBM was the lowest among the ingredients (Table 2). There were no significant differences in CP or ether extract between the E-HM and NaOH-HM. These results indicate that although the enzyme and NaOH treatments with fermentation would enhance storage time and preservation, there were negative effects on CP and ether extract concentrations compared with the C-HM. The nutritional composition of these hen meals was somewhat different

from commercial hen meals. Kersey et al. (1997) indicated that the CP and fat levels of commercial rendered spent hen meals could vary from 65 to 71% and from 8 to 11%, respectively. The hen meals from this study (C-HM, E-HM, and NaOH-HM) contained lower CP and higher fat levels than other commercial rendered hen meals because commercial meals usually remove some level of fat. The different nutritional concentrations are due to different processing conditions, and marketing strategies. Commercial rendering plants extract the fat from hens because it makes processing easier and increases meal protein levels. The extracted fat is marketed as a highly digestible energy feed supplement.

In the present study, the E-HM and NaOH-HM had lower CP concentrations than the C-HM, indicating the enzyme or NaOH treatment reduced the CP levels. Papadopoulos (1985) findings are in agreement with this result. They treated feather meals with NaOH (0.2 to 0.6%) for various lengths of time (30 to 70 min). As processing time with NaOH increased, CP levels were also reduced.

The AA levels of SBM, C-HM, E-HM, and NaOH-HM are also shown in Table 2. The Lys, Thr, Arg, Ile, Leu, and Val levels of the C-HM and SBM were higher ($P < 0.05$) than the E-HM and NaOH-HM. The Met, Cys, and Gly levels of the C-HM were higher ($P < 0.05$) than the SBM. The NaOH-HM was lower ($P < 0.05$) in Met, Lys, His, and Phe than in the E-HM. These results indicate that the C-HM has similar or higher AA levels compared with SBM, whereas enzyme or NaOH treatment reduced AA levels. Furthermore, the NaOH treat-

Figure 1. The ruminal DM degradation of control, enzyme, and NaOH-treated hen meals, and soybean meal. Control, autoclaved hen meal (C-HM); enzyme-treated, fermented, autoclaved hen meal (E-HM); NaOH-treated, fermented, autoclaved hen meal (NaOH-HM); soybean meal (SBM). ^{a-d}Means within a row with different superscripts differ significantly ($P < 0.05$).

ment depressed AA quality more than the enzyme treatment. Papadopoulos et al. (1985) realized similar findings. They found that the Cys, Lys, and Met levels in feather meals were reduced as NaOH concentrations increased.

Figure 1 shows the ruminal DM degradation of the C-HM, E-HM, NaOH-HM, and SBM. At 1, 2, and 4 h of incubation, the DM degradation of the SBM (11.7, 15.6, and 31.1%, respectively) was less ($P < 0.05$) than for the E-HM (25, 35.4, and 37.5%) and NaOH-HM (42.5, 42.2, and 55.17%) because the feather-digesting enzyme and NaOH treatment hydrolyzed feathers and carcass tissue. However, after 8 h, the DM degradation of the SBM (67.7%) was increased considerably and was higher ($P < 0.05$) than the other treatments at 12, 24, 48, and 72 h. Autoclaving and NaOH treatment during hen meal preparation may decrease DM degradability of the E-HM and NaOH-HM from 8 h on. Nishino and Uchida (1995) suggested that NaOH treatment would give feedstuffs more resistance to microbial degradation in the rumen. Lykos and Varga (1995) indicated that heat treatment decreased ruminal degradability of soybean. During the entire experimental period, the C-HM showed the lowest DM degradation among the treatments. Especially at 8, 12, and 24 h, the degradation rates of the C-HM (21, 25.3, and 37.3%) were one half to one third the degradation of the other ingredients. There might be some possibility of losses of treatment particles from in situ bags because small particles could escape from in situ bags during incubation periods. Michalet-Doreau and Cerneau (1991) reported that the losses of corn particles through the bag pores were higher when feed particle size was reduced. However,

Figure 2. The ruminal CP degradation of control, enzyme, and NaOH-treated hen meals, and soybean meal. Control, autoclaved hen meal (C-HM); enzyme-treated, fermented, autoclaved hen meal (E-HM); or NaOH-treated, fermented, autoclaved hen meal (NaOH-HM); soybean meal (SBM). ^{a-d}Means within a row with different superscripts differ significantly ($P < 0.05$).

they also indicated that these losses were not significant.

Figure 2 shows the ruminal protein degradation among treatments. The trends for protein degradation were similar to that for DM degradation. Although DM degradation was corrected for DM remaining in the blanks, microbial N contamination was not corrected because the level was negligible. Studies showed that microbial N contamination was not significant for high protein feedstuffs (Varviko, 1986; Erasmus et al., 1994). The SBM at 1, 2, and 4 h (11, 14.8, and 29.6%) also had lower protein degradation than the E-HM (25.4, 35.9, and 37.9%) and NaOH-HM (47.6, 43.9, and 57.2%). After 4 h, the protein degradation of SBM was increased yet not significantly different from the E-HM or the NaOH-HM from 24 to 72 h. The CP degradation of the C-HM was less ($P < 0.05$) than the E-HM and NaOH-HM during the entire experimental period and lower ($P < 0.05$) than the SBM from 2 to 72 h, except for 4 h.

After 8 h, the E-HM and NaOH-HM had similar or lower DM and CP degradation rates compared with the SBM; however, they had much less resistance to ruminal degradation than the C-HM. These results indicated that the C-HM was more resistant to ruminal degradation, suggesting more protein could reach the small intestine compared with the other treatments, whereas the E-HM or NaOH-HM was more digestible for ruminal microorganisms.

The higher resistance to ruminal degradation of the C-HM may be due to the feathers remaining with the hen carcass. Feathers constitute approximately 10% of the BW of hens on a dry weight basis (Webster et al., 1996). Approximately 90% of feather protein has a high degree of crosslinking with cystine disulfide bonds, hy-

drogen bonds, and hydrophobic interactions. (Harrap and Woods, 1964). This crosslinking results in greater resistance to gastrointestinal digestion (Parry et al., 1977). However, the enzyme- or NaOH-treated hen meals were more susceptible to ruminal degradation because these treatments might have hydrolyzed the crosslinking of feathers and other tissues during pretreatment. Kim and Patterson (2000a) determined that NaOH and the feather-digesting enzyme treatments improved feather solubility.

The present study suggests that hen mortalities have potential as an alternative protein source for ruminants. Laying hens at the end of their productive life (spent hens), in addition to poultry mortalities, could also be a good protein source for a ruminant ration supplement. In recent years, egg producers have had difficulty disposing of spent hens because consumer demand for chicken pot pies and chicken soup has utilized readily available broiler and roaster meat in place of poor yielding spent hens (Christmas et al., 1996; Lyons and Vandepopuliere, 1996). Selection for high rates of egg production and feed conversion has resulted in smaller body weights with less edible meat from the carcass. In addition, mechanical deboning of spent hen carcasses has resulted in residual bone fragments in the meat as a result of brittle bones among older hens, and reduced their value (Kersey et al., 1997). Thus, the utilization of spent hens as an ingredient in ruminant feeds could reduce a potential disposal problem and provide a positive economic return for producers (Haque et al., 1991). Utilizing these poultry byproducts as feed ingredients for ruminants could be an alternative nutritional recycling strategy for poultry industry.

CONCLUSIONS

The present study indicated that fermentation and feather hydrolysis with enzyme and NaOH treatments reduced CP and AA values of hen mortality meals and increased rumen degradation. The C-HM has some resistance to ruminal degradation, whereas the E-HM or NaOH-HM was more available for ruminal microorganisms. In the future, feeding trials are necessary to ensure the benefits of hen mortality meals for ruminants. The present study showed another possibility of recycling hen mortalities into a feed ingredient for ruminants.

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