THE INFLUENCE OF FEED MILLING, ENZYME SUPPLEMENTATION, AND NUTRIENT REGIMEN ON BROILER CHICK PERFORMANCE

TOM A. SCOTT
Agriculture and Agri-Food Canada, P.O. Box 1000, Agassiz, BC V0M 1A0, Canada
Phone: (604) 796-2221, Ext. 254
FAX: (604) 796-0359

MARY LOU SWIFT
Pro Form Feeds Inc., P.O. Box 1000, Chilliwack, BC V2P 6J6, Canada

MICHAEL R. BEDFORD
Finnfeeds Int'l., Market House, Ailesbury Court, High Street, Marlborough - Wiltshire, UK SN8 1AA

Primary Audience: Nutritionists, Feed Mills, Enzyme Supplement Suppliers, Broiler Producers

SUMMARY

The present study was designed to compare the effects of feed form (pelleted vs. expanded) of wheat-barley-based diets, and the interaction between feed form and enzyme supplementation and nutrient level of the diets. Male broiler chicks were fed 1 of the 12 diet combinations differing in feed form (expanded vs. pelleted), enzyme supplementation, and nutrient level.

Initial analysis clearly demonstrated that performance of broilers fed the wheat-barley-based diets benefitted from enzyme supplementation. Expanded diets supplemented with enzymes resulted in an overall improvement in feed:gain ratio (1.66) compared to pelleted (1.71) diets. This study indicates that feed mills with the capacity to either expand or pellet diets should consider a combination, using pelleted/crumbled feed for the starter period followed by expanded feed for the grower and finisher diets. Our results also indicate the advisability of supplementing all wheat-barley-based diets with enzymes.

Key words: Broilers, enzymes, expanded feed, feed milling, nutrient regimen

1997 J. Appl. Poultry Res. 6:391–398

DESCRIPTION OF PROBLEM

Use of commercial feed expanders, while relatively new in North America, is gaining acceptance for the manufacturing of poultry feeds. The expansion process uses heat (up to 120°C) and pressure in conditioning and extrusion of feed. Expansion in comparison to

1 PARC (Agassiz) contribution No. 572
2 To whom correspondence should be addressed
the pelleting process has been reported to increase starch gelatinization, improve pellet durability, destroy anti-nutritional factors, destroy pathogens, and improve incorporation of added fat [1]. The expansion of whole soybeans has been reported to destroy trypsin and other digestive enzyme inhibitors without any appreciable destruction of heat labile amino acids [2, 3, 4]. Furthermore, Williams [3] credits expanded feed with having improved flavor, aroma, and “mouth-feel.”

Designing studies to evaluate feed processing technology is difficult, as the results can be confounded by feed granulation, preparation methods, pellet hardness and size, and feedstuff combinations [5]. Nir et al. ascertained that improvements in metabolizable energy (ME) content of processed (pelleted) feeds did not wholly explain improved performance, as there was no difference in ME content of the processed and control diets. They did, however, observe that pelleting improved amylase hydrolysis of starch to glucose (4.5-fold greater in pelleted vs. mash corn-based diets), thereby reducing the bird’s need to produce amylase. Similarly, Prasad and Kar [6] found no improvement in ME of pelleted feeds, but did observe that bird performance was best with pelleting when diets contained low levels of added fat. Liebert et al. [7] found that expanded and pelleted diets offered significantly improved fat and organic matter digestibility compared to mash diets. Processing did not improve the digestibility of starch (digestibility of unprocessed feed was 98%) or nitrogen.

Nissinen et al. [8] compared the effect of feed expansion and pelleting to pelleting alone with and without a supplemental enzyme. These authors did not find significant differences in bird growth, although body weight was numerically highest for birds consuming the expanded/pelleted feed supplemented with enzyme. Feeding expanded/pelleted vs. pelleted feed without supplemental enzyme yielded approximately three-fold greater fecal viscosity. No significant difference in fecal viscosity between treatments was noted if enzyme supplementation was present. Vranjes et al. [9] reported a decrease in the soluble fiber content of expanded feed that resulted in a higher viscosity reading of the feed extract. This increase was more dramatic in barley- vs. wheat-based diets and was appreciably decreased in both diets when the diet formulation included supplemental enzymes.

More information is needed to understand the significance of interactions between feed form, enzyme supplementation, and feed ingredients in broiler chicken diets. The present study sought to measure the impact of feed form (expanded/pelleted vs. pelleted diets) with and without enzyme supplementation on wheat-barley-based diets formulated to contain different levels of nutrients (energy and/or amino acid).

**MATERIALS AND METHODS**

The present study was designed to measure the impact of feed form (pelleted or expanded/pelleted) of wheat-barley-based diets (differing in energy and/or amino acid levels) with or without a supplemental enzyme on broiler performance and nutrient digestibility. Feed form and enzyme supplementation treatments were applied to each of three broiler starter (0 to 21 days) and finisher (21 to 42 days) diets differing in energy and/or amino acid levels. The three dietary nutrient levels tested were formulated to meet broiler requirements published by Leeson and Summers [10]: a) 100% energy and amino acid (EAA); b) 95% energy and 100% of amino acids (95EAA); or c) 95% of energy and amino acids (95E95AA).

The ingredient profile and calculated nutrient levels of the diets are presented in Table 1. To measure digestibility, 0.5% acid insoluble ash marker (0.5% Celite [11]) was added to all diets. Diets to be supplemented with enzyme were sprayed with a liquid enzyme [12] (at 0.075% wt/wt) following cooling of the crumbles or pellets.

Diets were manufactured by Pro Form Feeds Inc. in two-ton mixes. All diets were mixed and subjected to processing treatments with or without enzyme at one time period to minimize ingredient variation between mixes. Expanded diets were manufactured using a Kahl [13] expander. Expander barrel exit temperature was 90°C and pressure was 700 PSI. Expanded mash diets were then pelleted [14]. The temperature of the feed after pelleting was 70-80°C. Those diets to be pelleted directly were pelleted with the same equipment as the expanded mash, resulting in a similar final product temperature. Starters
were crumbled and finisher diets were pelleted (4-mm size).

The protocols for bird care and sampling were pre-approved by the PARC (Agassiz) Animal Care Committee in accordance with the Canadian Council of Animal Care. Day-old male broiler chicks (Arbor Acre × Petersen male) were randomly assigned to 36 floor pens (65 birds/pen) or 36 battery cages (10 birds/cage) and provided ad libitum access to starter diets from 0 to 21 days and finisher diets from 21 to 42 days of age. Broilers reared in floor pens (2.8 x 5.1 m, with shavings litter) were reared under standard lighting (0–3 days, 23 hr light:1 hr dark, 20 lux; 4–42 days, 16 hr light:8 hr dark, 5 lux) and temperatures (33°C, 0–7 days, reduced by 3°C/wk to 21°C) with free access to water (nipple drinkers). Body weights of birds and feed consumed were determined at 21 and 42 days of age.

### TABLE 1. Ingredient and calculated nutrient profile of broiler starter and grower/finisher diets

<table>
<thead>
<tr>
<th>DIET PROFILE MAJOR INGREDIENTS</th>
<th>STARTER DIETS FED 0–21 DAYS</th>
<th>GROWER/FINISHER DIETS FED 21–42 DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EAA</td>
<td>95EAA</td>
</tr>
<tr>
<td>Wheat (g/kg)</td>
<td>493.3</td>
<td>563.0</td>
</tr>
<tr>
<td>Soybean meal (g/kg)</td>
<td>170.0</td>
<td>150.0</td>
</tr>
<tr>
<td>Barley (g/kg)</td>
<td>150.0</td>
<td>130.0</td>
</tr>
<tr>
<td>Poultry by-product (g/kg)</td>
<td>50.0</td>
<td>76.0</td>
</tr>
<tr>
<td>Meat meal (g/kg)</td>
<td>50.0</td>
<td>36.1</td>
</tr>
<tr>
<td>Tallow (g/kg)</td>
<td>63.0</td>
<td>21.0</td>
</tr>
<tr>
<td>L-Lysine (45%) (g/kg)</td>
<td>2.01</td>
<td>2.23</td>
</tr>
<tr>
<td>DL-Methionine (g/kg) Alimet</td>
<td>2.27</td>
<td>2.12</td>
</tr>
<tr>
<td>Dicalc Phosphate (g/kg)</td>
<td>3.61</td>
<td>4.12</td>
</tr>
<tr>
<td>Limestone (g/kg)</td>
<td>4.26</td>
<td>3.85</td>
</tr>
<tr>
<td>Salt (g/kg)</td>
<td>2.00</td>
<td>2.00</td>
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<tr>
<td>Liquid Choline 70% (g/kg)</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>Stereol (g/kg)</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Stafac–44 (g/kg)</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Vitamin/Mineral Premix (g/kg)</td>
<td>2.90</td>
<td>2.90</td>
</tr>
<tr>
<td>Celite (g/kg)</td>
<td>5.00</td>
<td>5.00</td>
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</table>

<table>
<thead>
<tr>
<th>CALCULATED NUTRIENT PROFILE OF DIETS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CP (g/kg)</td>
<td>218.80</td>
</tr>
<tr>
<td>AME (kcal/kg)</td>
<td>3077</td>
</tr>
<tr>
<td>Lysine (g/kg)</td>
<td>11.30</td>
</tr>
<tr>
<td>Methionine (g/kg)</td>
<td>5.10</td>
</tr>
<tr>
<td>Cystine (g/kg)</td>
<td>2.37</td>
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<tr>
<td>Threonine (g/kg)</td>
<td>7.67</td>
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<tr>
<td>Arginine (g/kg)</td>
<td>13.20</td>
</tr>
<tr>
<td>Tryptophan (g/kg)</td>
<td>2.31</td>
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<td>Fat (g/kg)</td>
<td>81.60</td>
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<tr>
<td>Calcium (g/kg)</td>
<td>10.00</td>
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<tr>
<td>Available P (g/kg)</td>
<td>4.50</td>
</tr>
</tbody>
</table>

*A Vitamin premixes provide per kg of diet: vitamin A, 12,000 IU; vitamin D₃, 3600 IU; vitamin E, 50 IU; vitamin K₂, 2.25 mg; vitamin B₁₂, 0.0225 mg; niacin, 40 mg; pyridoxine, 7.5 mg; riboflavin, 7.5 mg; thiamin, 1.5 mg; pantothenic acid, 12 mg; folic acid, 0.75 mg; biotin, 0.12 mg; choline, 900 mg. Mineral premix provides per kg of diet: magnesium, 40 mg; manganese, 90 mg; iron, 80 mg; copper, 125 mg; zinc, 80 mg; iodine, 0.4 mg; selenium, 0.3 mg.
Feeds Processing and Enzymes

Battery-reared broilers were used to measure the AME and nitrogen retention of the diets. Ten male broilers were started at Day 0 in battery brooders (Petersime, 0.8 x 1.3 m) and received the same lighting and temperature regimens as described for the floor pens. At 21 days, five birds were moved to grower cages (Petersime, 0.8 x 0.8 m) and maintained there to 42 days of age. Excreta from each pen of birds was allowed to accumulate for 24 hr on clean collection trays at three ages (14, 28, and 42 days). A 250-mL specimen jar was used to collect approximately 150 mL of wet excreta. Samples were weighed, frozen, and later dried at 60°C for 48 hr. Diet and excreta samples were finely ground (0.2 mm screen) and analyzed for acid insoluble ash [19], gross energy [16], and nitrogen [17].

At 21 and 42 days of age, four and two broilers, respectively, from each battery brooder were humanely killed (cervical dislocation) and the upper small intestinal tract (distal duodenal loop to vitelline diverticulum) were excised and contents collected. Digesta from individual birds was centrifuged [18] at 12,500 x g for 3 min, and 0.5 mL of supernatant was used to measure digesta viscosity [19]. Values are reported in centipoises (cps).

Data on growth and feed conversion were based on broilers reared in floor pens; data on digesta viscosity, AME (kcal/kg diet, on dry matter basis), and nitrogen retention were determined from battery-caged broilers. All data were analyzed [20] for main effects of feed form (expanded vs. pelleted), enzyme supplementation (with or without), nutrient level of diet (EAAs, 95EAA, 95E95AA), and two- and three-way interactions between main effects (Table 2). Results of this analysis indicated that all parameters were significantly different for diets with and without enzymes. This indicates that wheat-barley-based diets, regardless of feed form, should be treated with enzyme. Taking this into account, the data from diets with enzymes was reanalyzed for main effects of feed form, nutrient level, and two-way interaction (Table 2). Only data that is significant (P < .05) will be reported in the text.

RESULTS AND DISCUSSION

The significance of the statistical model, main effects, and interactions between main effects are presented in Table 2. The mean values for the all measurements (total) and main effects (feed form, enzyme supplementation, and nutrient level) are presented in Table 3. Values for broiler performance (body weight at 21 and 42 days of age and feed:gain ratios from 0 to 21 and 0 to 42 days) were determined from broilers reared in floor pens; data on viscosity and digestibility were determined from broilers reared in battery cages. The average body weight of broilers from all treatments was 780.9 and 2449 g at 21 and 42 days, respectively. Feed:gain ratios for the same birds were 1.28 and 1.75 g:g for the periods 0 to 21 and 0 to 42 days. Digesta viscosity of the wheat-barley-based diets averaged 7.0 cps. AME values of the starter and finisher diets were 2898 and 3074 kcal ME/kg diet (dry matter basis), respectively. Nitrogen retention rates for the same diets were 54.8 and 50.4%, respectively.

Enzyme Supplementation Effects

There were significant differences between all measurements for the main effect of enzyme supplementation (Table 2). The enzyme response, expressed as the percent change in diets with enzyme over those for diets without enzyme, was calculated from measurements in Table 3. For body weights at 21 and 42 days of age, the enzyme response was 6.2 and 7.5%; for feed:gain there was a 5.3 and 7.1% reduction in feed required for each unit of gain, between 0 to 21 and 0 to 42 days of age, respectively. Digesta viscosity of all diets with enzymes was reduced by 44% compared to those without enzymes. Enzymes supplementation increased AME of starter and finisher diets by 23.3 and 11.1%, respectively, and nitrogen retention of starter (0 to 21 days) and finisher (21 to 42 days) diets by 18.1 and 8.7%, respectively. From a practical standpoint, wheat-barley-based diets benefit from enzyme supplementation; in order to determine the effects of feed form and nutrient level effects, only data on enzyme-supplemented diets will be discussed. For wheat-barley-based diets with enzymes, the significance of main effects (feed form and nutrient level) and the two-way interaction are presented in Table 2. The mean values for main effects and two-way interaction are presented in Table 3.
FEED FORM EFFECTS (DIETS WITH ENZYMES)

For those diets supplemented with enzymes (Table 2) there were significant (P < .05) differences between feed forms for feed:gain ratio from 0 to 42 days, AME of starter diets, and nitrogen retention of starter and finisher diets. For all enzyme-supplemented diets, the feed:gain ratio from 0 to 42 days of age was 1.66 and 1.71 (g:g), for the expanded and pelleted diets, respectively. Minimal (nonsignificant) difference in feed:gain ratio was recorded between different feed forms in the starter (0 to 21 day) period.

Digestibility estimates for AME of starter and nitrogen retention of the starter and finisher were all greater (P < .05) for expanded than for pelleted diets. Expanded diets yielded 9.8, 17.4, and 9.2% increases in AME of starter and nitrogen retention of starter and finisher diets, respectively, compared to pelleted diets. For finisher diets, the AME of expanded diets was less than 1% greater than that of pelleted diets.

NUTRIENT LEVEL EFFECTS (DIETS WITH ENZYMES)

Significant effects for nutrient level of diets with enzymes were determined for body weight at 42 days, feed:gain ratio of diets fed from 0 to 42 days, and nitrogen retention of the starter and finisher diets. Broiler body weight at 42 days of age was significantly different between birds fed the EAA and the 95E95AA diets; neither was significantly different from...
the intermediate body weight for the 95EAA diets. Feedgain values of birds fed the EAA diet were significantly lower (better) than for the energy and energy and amino acid reduced diets (95EAA and 95E95AA); these latter two diets, however, were not significantly different from each other. For the starter diets, the 95E95AA diets yielded nitrogen retention significantly better than the 95EAA diets, but not significantly different from the EAA diets. The EAA, 95EAA, and 95E95AA finisher diets had nitrogen retention values of 48.9, 50.7, and 57.9%, respectively. Finisher diets containing EAA and 95EAA nutrient levels had significantly (P < .05) lower nitrogen retention than the 95E95AA diets.

**SIGNIFICANT INTERACTIONS BETWEEN MAIN EFFECTS (DIETS WITH ENZYMES)**

There was a significant two-way interaction between diet form and nutrient level only for the AME level of the starter diets. The expanded diets, with enzyme, had an equal
not significant) level of the AME regardless of nutrient level of the diet. However, the pelleted diets showed significant differences between nutrient levels. The EAA diet was significantly higher (3271 kcal ME/kg diet) than either the 95EAA (2892) or the 95E95AA (2985) diets. There were no significant differences in AME of finisher diets due to feed form or nutrient level.

Enzyme supplementation of diets significantly improved broiler performance and digestibility estimates and reduced digesta viscosity. We thus recommend that broiler diets, particularly wheat-barley-based diets, be supplemented with commercial feed enzymes to improve broiler performance, regardless of feed form. Further discussion of the effects of feed form will therefore deal only with diets of whatever nutrient level that have been supplemented with enzymes.

The present study substantiates observations that expansion of feed results in increased digesta viscosity [8, 9]. However, enzyme supplementation will counteract the increased viscosity associated with expanded feed. This still leaves open the question of whether enzyme supplementation of expanded vs. pelleted feed provides an improvement in bird performance, i.e., nutrient value of the diet.

Two factors important in ascertaining the economic advantage of any feeding program for broilers are market weight and feed conversion. Although effects of feed form on body weight were not significant, it is of interest that the differences in body weight due to feed form changed from 21 to 42 days of age. That is, broilers fed expanded diets had lower body weight than broilers fed pelleted diets at 21 days, but higher at 42 days of age. It is well documented that younger birds have more difficulty digesting most feed ingredients [21, 22] and that this is compounded by inclusion of ingredients that contain non-starch polysaccharides (NSP), such as wheat-barley [23, 24]. Feed processing methods resulting in greater solubility of NSP as described by Vranjes et al. [9] presumably would increase feed digestibility for younger birds. These authors also demonstrated that enzymes reduced the viscosity associated with expanding wheat- and barley-based diets.

Higher temperatures experienced during expansion [1], however, may result in denaturation of proteins and reduce their digestibility.

If a broiler is having difficulty digesting a feedstuff because of higher levels of NSP or a direct reduction in digestibility of amino acid, it would either exhibit reduced growth or require more feed to attain an equal growth rate, hence the importance of feed conversion comparisons. Data on feed:gain ratios indicate that younger birds required equal amounts of feed to attain nonsignificantly different body weights in the starter period. However, over the entire growing period, broilers fed expanded diets had significantly lower feed:gain ratios than birds fed the pelleted diets. Expanded diets yielded a five-point feed conversion advantage, presumably due to improved growth and reduced feed required per unit of gain during the finisher period (21 to 42 days). Based on this information, feed mills with capacity to expand or pellet diets are advised to consider using pelleted feed for the starter period and expanded feed during the finisher period when birds are capable of utilizing this feed.

With regard to digestibility estimates, expanding feed resulted in significantly improved values for AME of starter diets and nitrogen retention of both the starter and finisher diets. These differences in digestibility were near to or greater than 10%, yet, there were no corresponding 10% or greater increases in growth or decreases in feed:gain with expanded vs. pelleted feed. In this case, where do the energy and nitrogen retention differences between diets go, if not to growth or to reduced feed conversion ratios? Data on ileal digestibility (gross energy and nitrogen), although different from excreta values numerically, showed the same differences between treatments. Since the higher measurements of AME and nitrogen retention due to expanding the diet are not lost in a comparison of excreta or ileal digesta sources, it would negate our suspicion that lower gut microbial fermentation was higher for expanded than for pelleted feeds. Other explanations can only be speculative, as we unfortunately did not analyze carcass composition or perform estimation of intestinal integrity (e.g., villi health) on birds fed the expanded or pelleted diets.
CONCLUSIONS AND APPLICATIONS

1. Feed mills with capacity to either expand or pellet diets should consider a combination, using pelleted/crumbled feed for the starter diet followed by expanded feed for the grower and finisher diets.

2. It is advisable to supplement wheat-barley-based diets with a commercial enzyme source.

REFERENCES AND NOTES


12. Avizyme, Finnfeeds Intl., Market House, Ailesbury Court, High Street Marlborough - Wiltshire, UK SN8 1AA.


16. Leco Bomb Calorimeter, AC-300, Model 789-400. Leco Corporation, St. Joseph, MI 49085-2396. (Benzoic acid used as a standard, 630.8 cal/g).


18. Eppendorf Centrifuge, Model 5415C. Brinkmann Instruments, Inc., Cantigue Road, Westbury, NY 11590.


ACKNOWLEDGEMENTS

Research funding support from Pro Form Feeds Ltd, the British Columbia Broiler Chicken Marketing Board, FinnFeeds International, and Agriculture and Agri-Food Canada is gratefully acknowledged. We would also thank the AAFC staff who provided animal care of floor- and battery-reared birds, and collected data and samples for laboratory analysis.