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# Effects of Spray-Dried Whole Egg and Biotin in Calf Milk Replacer

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## ABSTRACT

Holstein bull calves (n = 120) were fed milk replacers containing 0, 10, or 20% of the formulation (0, 22, or 44% of crude protein) as spray-dried whole egg powder in a 56-d feeding trial. Milk replacer was medicated with oxytetracycline and neomycin and was fed from d 1 to 42 of the study in a phase-fed program. All experimental milk replacers were supplemented with B vitamins, except biotin. One half of all calves were supplemented with 1 mg/kg of supplemental biotin to determine whether avidin in the egg protein product inhibited growth. Increasing spray-dried whole egg caused a linear reduction in body weight, body weight gain at 28 and 56 d of the study, calf starter intake, and feed efficiency. Calves fed milk replacers containing 0, 10, and 20% spray-dried whole egg gained an average of 486, 369, and 302 g/d, respectively, during the 56-d trial. Efficiency of feed utilization was 446, 318, and 231 g of body weight gain per kilogram of dry matter intake. Improvement in body weight and feed efficiency occurred when calves began consuming calf starter on d 29. Digestibility of protein or fat from egg may have been reduced during the trial; however, the addition of biotin to the milk replacer did not influence animal performance, suggesting that avidin in spray-dried whole egg was not responsible for impaired performance. The spray-dried whole egg product used in this study did not provide nutrients to support adequate growth of milk-fed calves.
(**Key words:** calves, egg, milk replacers, biotin)

**Abbreviation key:** **CMR** = calf milk replacer, **CS** = calf starter, **SDWE** = spray-dried whole egg.

## INTRODUCTION

Spray-dried whole egg (**SDWE**) is a high quality alternative feed ingredient that contains significant CP and crude fat. The AA profile and biological value of the protein are excellent (Yamamoto et al., 1997), and the fat contains significant lecithin, which can provide emulsifying properties to calf milk replacer (**CMR**) formulas. Egg byproducts have been used successfully as alternative ingredients for many animal feed applications. Nonedible SDWE is produced in significant quantities by the egg processing industry. One potential limitation to the use of SDWE is the presence of antinutritional proteins, including protease inhibitors and avidin, which nonreversibly binds biotin. Inadequate heat processing of SDWE may not completely inactivate avidin, which reduced growth of pigs, chicks, and mink (Hamilton et al., 1983; Kratzer et al., 1988; Wehr et al., 1980). The objectives of this study were to determine the value of SDWE on the performance of calves fed CMR containing varying amounts of SDWE and to determine whether supplemental biotin was effective in reducing potential effects of avidin in SDWE.

## MATERIALS AND METHODS

Holstein bull calves (n = 120) were purchased from area dairies and shipped (maximum 300 km) to the APC Calf Research Unit in Ames, Iowa. Calves averaged 5.4 d of age (SD = 1.2) on arrival. Calves were received in two groups on March 3, 2000, and March 10, 2000, and began the study on the next day. Blood was collected by jugular venipuncture into evacuated tubes from each calf upon arrival and a subsample collected for measurement of hematocrit. Tubes were then centrifuged and plasma was separated. A subsample was used to measure total protein using a refractometer, and remaining plasma was frozen (–20°C) until analyzed for IgG by turbidimetric immunoassay (Etzel et al., 1997). Calves were weighed on arrival, fed 1 dose (454 g) of a colostrum supplement product (Lifeline Calf Nutritional Colostrum Supplement, APC, Inc.) and then were assigned randomly to receive one experimental CMR with 0, 10, or 20% of the CMR formula (0, 22, or 44% of CP) as SDWE (Table 1) provided by the manufacturer (Rose Acre Farms, Winterset, IN). All CMR were formulated to contain 22% CP, 20% fat, 0.8% Ca, 0.7% P (air-dry basis), and to meet or exceed NRC requirements (NRC, 1989) for vitamins and minerals. All CMR were formulated to contain a minimum of 1.85% Lys, 0.65%

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**Table 1**. Formulation of experimental calf milk replacer (CMR).

| | SDWE in CMR[1] | | |
|---|---|---|---|
| Ingredient, % | 0% | 10% | 20% |
| Whey protein concentrate, 34% CP | 32.5 | 17.5 | 1.9 |
| Dry fat-protein blend, 20% CP, 40% fat | 49.7 | 41.8 | 35.0 |
| Spray-dried whole egg | 0.0 | 10.0 | 20.0 |
| Dried whey | 7.0 | 21.0 | 34.0 |
| Vitamin/mineral premix | 2.5 | 2.5 | 2.5 |
| Dicalcium phosphate, 18.5% | 2.8 | 2.1 | 1.5 |
| Antibiotic premix | 5.0 | 5.0 | 5.0 |
| DL-Methionine | 0.1 | 0.0 | 0.0 |
| L-Lysine HCl | 0.0 | 0.1 | 0.1 |
| Salt | 0.4 | 0.1 | 0.0 |

[1]Percentages are on an air-dry basis.

Met, 1.2% Thr, and 2.0% Leu on an air-dry basis to meet predicted AA requirements of milk fed calves (Williams, 1984); however, AA composition of final diets was not measured. Experimental CMR were manufactured at a commercial blending facility (Animix, Juneau, WI), weighed into 22.7-kg bags and transported to the experimental facility. In addition, calves were assigned to receive 0 or 1 mg/kg of added biotin (Roche Vitamins, Inc., Parsippany, NJ), which was added to the CMR twice daily at time of feeding.

Calves were housed in individual fiberglass hutches and fed CMR twice daily at approximately 0700 and 1600 h in amounts shown in Table 2. Experimental CMR was mixed in hot water (approximately 50°C) to disperse fat. Cool water was then added to bring temperature to approximately 39°C. Reconstituted CMR was fed in individual nipple bottles. The amount of CMR offered and refused was measured at each feeding.

Commercial textured calf starter (**CS**; Cargill Herd Builder, Cargill, Inc., Minnetonka, MN) was offered once daily ad libitum beginning on d 29, and feed refusals were measured daily. No hay was fed during the study. The amount of water offered and refused was determined volumetrically, and daily intake was calculated as offered minus refused. Hutches were bedded with straw throughout the study. Samples of CMR and CS were collected weekly and stored (–20°C) before analysis for CP, ether extract, ash (AOAC, 1990), and minerals (ICP emission spectroscopy) by a commercial laboratory (Silliker Laboratories of Iowa, Cedar Rapids, IA).

**Table 2**. Amount and concentration of calf milk replacer fed to calves.

| Week | L liquid/d | DM, g/L |
|---|---|---|
| 1 | 3.78 | 120 |
| 2 | 4.54 | 123 |
| 3 | 5.24 | 123 |
| 4 | 5.64 | 130 |
| 5 | 4.54 | 123 |
| 6 | 2.27 | 123 |

Calves were weighed once weekly. Fecal consistency was subjectively scored once daily using a scale of 1 = normal fecal consistency, 2 = slightly liquid consistency, 3 = moderately liquid consistency, and 4 = primarily liquid consistency (severe scours). When fecal material was unavailable for scoring, calves were assigned a missing value. A scour day was defined when calves had a fecal score of 3 or 4. Calves with scours were treated using intramuscular injections of antibiotics for 3 d and electrolyte therapy until signs of disease abated.

Weather data (daily low and high temperatures, mean relative humidity and mean solar radiation) were obtained from the Iowa State University Campbell Network; data were collected at a weather station within 1 km of the research facility.

Daily intake of CS, CMR, and water, fecal scores, application of veterinary treatments were pooled by week, and weekly BW and feed efficiency were analyzed as repeated measures ANOVA using the mixed procedure of SAS (1989). Body weights at 0, 28, and 56 d, BW gain from 0 to 28, 29 to 56, and 0 to 56 d, and initial BW and blood measurements were analyzed as a completely randomized experimental design using the GLM procedure of SAS (SAS, 1989). Initial BW and plasma IgG at 1 d were evaluated as covariates, but neither explained a significant ($P > 0.05$) amount of variation in the model. Therefore, unadjusted least squares means are reported. Single degree of freedom contrasts were used to compare linear and quadratic effects of SDWE protein and effects of addition of biotin. Data from calves that died were included in the dataset until time of death. Significance was declared at $P < 0.05$ unless otherwise noted.

## RESULTS

The composition of SDWE (Table 3) was slightly higher in CP and lower in fat than published values

**Table 3**. Chemical composition of experimental spray-dried whole egg.

| Nutrient | Amount |
|---|---|
| DM, % | 95.54 |
| CP, % | 54.21 |
| Fat, % | 37.51 |
| Calcium, % | 0.37 |
| Phosphorus, % | 0.71 |

[1]Data from Silliker Labs. All analyses are on a 100% DM basis, except DM.

(Yamamoto et al., 1997). The chemical compositions of experimental CMR (Table 4) were similar to values formulated, except that protein in CMR was higher than expected. Calcium and P were higher in SDWE than formulated, and the concentration of both minerals declined with increasing SDWE. Conversely, increasing SDWE increased the amount of K in the diets. Calf starter was markedly higher in CP than indicated by the guaranteed analysis, although other components were similar to formulated values.

Calves were generally healthy throughout the trial, and two calves died (1.7% mortality). These calves were not replaced; therefore, least squares means are presented. On arrival at the facility, mean blood hematocrit, total plasma protein, and plasma IgG were 34.4%, 5.61 g/dl, and 8.6 g/L, respectively (Table 5). The initial hematocrit was higher in calves fed 20% SDWE, and plasma IgG was highest in calves fed 0% SDWE. However, when evaluated as covariates in several statistical models, neither variable contributed significantly to any model, therefore, they were excluded and nonadjusted least squares means are presented.

The addition of biotin to CMR had no effect on any parameter measured, nor were biotin × SDWE interactions significant. Therefore, no data regarding these effects are presented.

Mean BW of calves at the start of the trial (d 0) was 45.6 kg and did not vary by treatment. However, by 28 d, the linear effect of SDWE in CMR was highly significant ($P < 0.001$), and calves on 10 and 20% SDWE were 4.5 and 7.1 kg lighter, respectively. Differences in BW were maintained to 56 d. By 56 d, calves on 20% SDWE were 11 kg lighter than calves fed 0% SDWE. Weekly mean BW (Figure 1) indicated that differences in BW began in the first week and increased throughout the study. Body weight gains from 0 to 28 d, 29 to 56 d, and over the entire 56-d study were reduced ($P < 0.001$) with increasing amounts of SDWE in CMR.

Intake of CMR was unaffected by treatment and averaged 403 g of DM/d throughout the 8-wk study; mean intake for the 6 wk that calves were fed CMR was 538 g/d. Starter intake declined ($P < 0.001$) with increasing SDWE in CMR and ranged from 588 g of DM/d to 452 g of DM/d (Table 5). Weekly total DMI (Figure 2) increased during the first 4 wk of the study according to the CMR feeding schedule; thereafter, intake of total DM reflected intake of CS, which was greatest in calves fed 0% SDWE.

Intake of water increased with increasing starter intake, and water intake was lower when calves were fed 10 and 20% SDWE. The efficiency of feed utilization was linearly depressed ($P < 0.001$) with increasing SDWE during the 56-d trial. Weekly means of feed efficiency (Figure 3) indicate that efficiency of DM utilization increased with week, but were consistently lower for calves fed 10 or 20% SDWE until approximately 6 wk of the study, at which time calves were weaned. Incidence of scours was affected by a quadratic effect of treatment; calves fed 10% SDWE had greater incidence of scours than other calves (Table 5). Weekly incidence of scours (Figure 4) indicated that calves on 0% SDWE had fewer days with scours until the fifth week, when incidence of enteric disease approached zero for all calves.

Mean daily high temperatures ranged from 1.4 to 28.8°C and overall mean was 16.2°C. Mean low ambient temperatures ranged from –8.3 to 13.5°C and overall

**Table 4**. Chemical composition of experimental diets.

| | Milk replacer | | | |
|---|---|---|---|---|
| Nutrient[1] | 0% SDWE | 10% SDWE | 20% SDWE | Calf starter |
| DM, % | 97.6 | 97.9 | 98.1 | 85.8 |
| CP, % | 23.8 | 24.1 | 24.5 | 25.4 |
| Ash, % | 8.9 | 8.2 | 8.0 | 5.3 |
| Fat, % | 22.2 | 21.8 | 22.6 | 4.9 |
| Calcium, % | 1.4 | 1.1 | 1.0 | 0.7 |
| Phosphorus, % | 1.0 | 0.9 | 0.9 | 0.6 |
| Potassium, % | 1.3 | 1.4 | 1.4 | 1.0 |
| Magnesium, % | 0.1 | 0.1 | 0.1 | 0.2 |
| ADF, % | . . . | . . . | . . . | 6.1 |

[1]Data from Silliker Labs. All analyses are on a 100% DM basis, except DM.

**Table 5**. Least squares means of animal performance.

| | % SDWE in CMR | | | | | | Contrasts[1] | |
|---|---|---|---|---|---|---|---|---|
| | 0 | SE | 10 | SE | 20 | SE | L | Q |
| n | | | | | | | | |
| Begin | 30 | . . . | 30 | . . . | 30 | . . . | . . . | . . . |
| End | 30 | . . . | 28 | . . . | 30 | . . . | . . . | . . . |
| Initial IgG, g/L | 10.4 | 0.9 | 7.5 | 0.9 | 7.9 | 0.9 | 0.06 | NS |
| Hematocrit, % | 33.3 | 1.1 | 33.0 | 1.1 | 36.8 | 1.1 | 0.03 | NS |
| Total protein, % | 5.76 | 0.11 | 5.51 | 0.11 | 5.55 | 0.11 | NS | NS |
| Age, d | 5.3 | 0.2 | 5.3 | 0.2 | 5.6 | 0.2 | NS | NS |
| BW, kg | | | | | | | | |
| d 0 | 45.8 | 0.7 | 45.7 | 0.7 | 45.2 | 0.7 | NS | NS |
| d 28 | 52.3 | 0.3 | 47.8 | 0.3 | 45.2 | 0.3 | 0.001 | NS |
| d 56 | 73.1 | 1.5 | 66.5 | 1.6 | 62.1 | 1.5 | 0.001 | NS |
| ADG, g/d | | | | | | | | |
| d 0–28 | 231 | 17 | 70 | 18 | 0 | 17 | 0.001 | 0.04 |
| d 29–56 | 741 | 35 | 668 | 36 | 605 | 35 | 0.007 | NS |
| d 0–56[2] | 486 | 23 | 369 | 23 | 302 | 23 | 0.001 | NS |
| DMI, g/d | | | | | | | | |
| CMR[2,3] | 403 | 3 | 402 | 3 | 404 | 3 | NS | NS |
| Starter[2,3,4] | 588 | 21 | 482 | 21 | 452 | 21 | 0.001 | NS |
| Total[2,3,4] | 992 | 21 | 884 | 21 | 856 | 21 | 0.001 | NS |
| Protein intake, g/d[2,3,4] | 245 | 5 | 219 | 5 | 214 | 5 | 0.001 | NS |
| Fat intake, g/d[2,3,4] | 118 | 1 | 111 | 1 | 113 | 1 | 0.005 | 0.003 |
| Water intake, L/d[2,3,4] | 1.8 | 0.1 | 1.6 | 0.1 | 1.4 | 0.1 | 0.002 | NS |
| ADG:DMI, g/kg[3,4] | 446 | 21 | 318 | 21 | 231 | 21 | 0.001 | NS |
| Fecal scores | 1.61 | 0.03 | 1.72 | 0.03 | 1.67 | 0.03 | 0.07 | 0.01 |
| Scours, days[3,4] | 5.7 | 0.7 | 8.2 | 0.7 | 6.9 | 0.7 | NS | 0.04 |
| Treated, days[3] | 0.7 | 0.2 | 0.8 | 0.2 | 0.3 | 0.2 | NS | NS |

[1]Contrasts: L = linear effect of SDWE in CMR; Q = quadratic effect of SDWE; NS = $P > 0.10$.

[2]Mean intake for d 1 to 56.

[3]Significant effect of week ($P < 0.001$).

[4]Significant week × treatment interaction ($P < 0.001$).

mean was 2.1°C. Therefore, environmental temperatures were often outside the typical thermoneutral range for calves (NRC, 1981), and at least some metabolizable energy would have been directed toward thermoregulation. Mean relative humidity ranged from 29.8 to 98.7% and overall mean was 60.4%. Mean solar radiation ranged from 72.9 to 654.1 kcal/cm$^2$, and overall mean was 385.6 kcal/cm$^2$.

## DISCUSSION

Eggs have traditionally been considered an excellent source of nutrients for many classes of animals. Spray-dried whole egg is typically high in CP and fat and low in carbohydrate and many minerals. Therefore, the potential replacement of expensive milk protein and fat (tallow, grease, and coconut oil) with inedible SDWE could provide nutrients to calves, while providing an environmentally sound alternative to disposal of the SDWE.

Reduced BW at 28 and 56 d and BW gain throughout the trial indicated the dramatic response to the inclusion of SDWE. Because diets were similar in nutrient content (Table 4), we conclude that some factor(s) present in the SDWE was responsible for the reduced performance. Body weight gains (d 0 to 56) of calves fed 10 and 20% SDWE were reduced by 24 and 38%, respec-

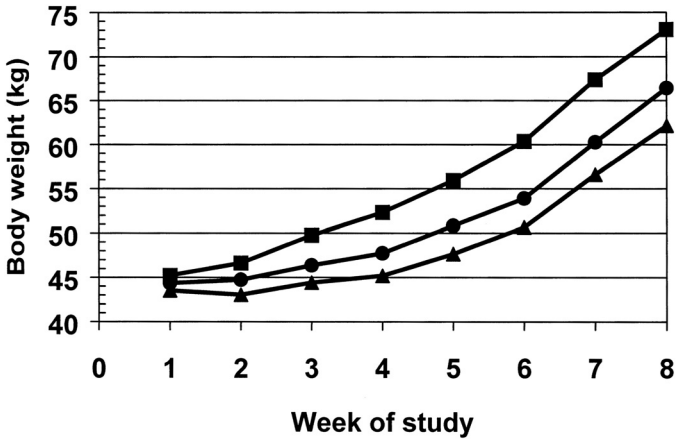


**Figure 1**. Least squares means of weekly BW in calves fed 0 (■), 10 (●), or 20% (▲) of the milk replacer formula as spray-dried whole egg. Standard error of the weekly means = 1 kg.

tively. The magnitude of the reduced performance is consistent with the presence of antinutritional factors, nutrient imbalance, or disease state. That BW gain and efficiency of feed utilization were reduced most dramatically during the first 28 d suggests that the reduced growth was caused by the composition of the CMR. Although BW gain may be reduced in calves during the first month of life due to enteric infections and diarrhea, the calves in this study suffered a relatively low incidence of diarrhea compared with other published studies at the same location (Quigley et al., 2000). Therefore, the most likely cause of reduced performance was the SDWE.

Avidin in eggs impaired growth of pigs, chicks, and mink (Hamilton et al., 1983; Kratzer et al., 1988; Wehr et al., 1980) due to nonreversible binding of biotin, although some researchers consider the amount of avidin too low to induce a biotin deficiency in human diets (Yamamoto et al., 1997). Although heat treatment associated with spray-drying is usually sufficient to denature antinutritional proteins in SDWE, it is possible that the method of processing used for the production of the SDWE may not completely inactivate antinutritional proteins. We attempted to maximize the opportunity to observe a response to avidin in the SDWE by minimizing the amount of dietary biotin, thereby inducing impaired growth consistent with a biotin deficiency. To minimize endogenous biotin, we included antibiotics in the CMR to reduce microbial growth and biotin production, excluded supplemental biotin in all CMR formulas, and fed CS only after d 28 to minimize biotin production from rumen microbial protein synthesis. It is possible that, in spite of these factors, sufficient dietary biotin was provided in CMR. However, the lack of response to the addition of 1 mg/kg of supplemental

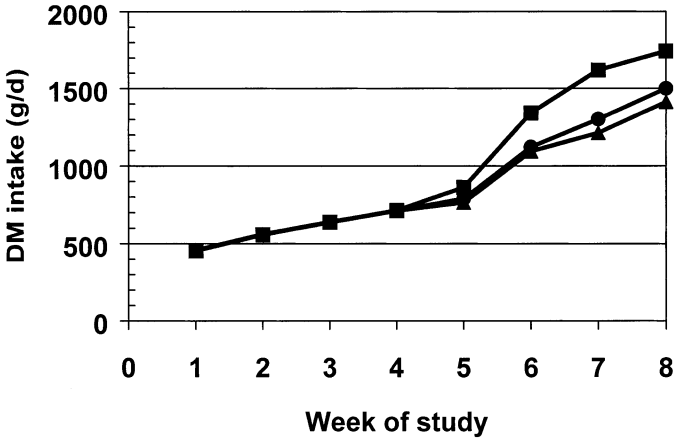


**Figure 2**. Least squares means of weekly intake of DM in calves fed 0 (■), 10 (●), or 20% (▲) of the milk replacer formula as spray-dried whole egg. Standard error of the weekly means = 35 g.

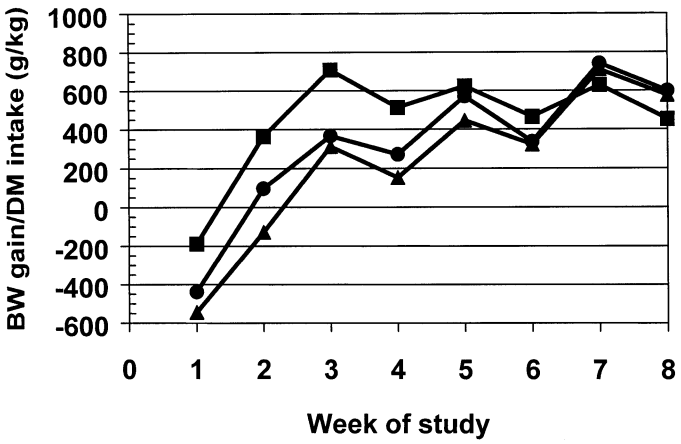


**Figure 3**. Least squares means of weekly efficiency of feed utilization in calves fed 0% (■), 10 (●), or 20% (▲) of the milk replacer formula as spray-dried whole egg. Standard error of the weekly means = 51 g/kg.

biotin indicates that a biotin deficiency due to avidin in the CMR was not the cause of impaired performance in this study. Alternatively, the amount of avidin in the CMR might have bound all of the added dietary and endogenous biotin, thereby resulting in a biotin deficiency; however, calves did not show signs of biotin deficiency. Therefore, we conclude that avidin did not influence the responses observed in this study.

Comparisons of the results of the present study with others in the literature are limited. Scott et al. (1999) fed 173 calves CMR containing 0, 25, or 50% of protein as SDWE for a 56-d trial. Calves gained 0.13, 0.01, or –0.06 kg of BW/d, respectively, for the first 14 d of the study, and 0.32, 0.22, and 0.19 kg/d, respectively, during the entire 56-d trial. In addition, the efficiency of feed utilization was reduced by 29 and 38% when CMR contained 25 and 50% of protein as SDWE, respectively. These data are consistent with the dramatic reduction in performance observed in this study. Conversely Kellogg et al. (2000) reported acceptable intake and BW gain when calves were fed 0 or 30% egg protein were included in CMR. Hill et al. (2001) fed calves diets containing 0 to 30% of CP in CMR from egg protein obtained from two sources. The authors reported reduced growth and intake when calves were fed 30% of CP from egg protein. However, 15% of CP from egg protein did not affect animal performance compared with calves fed CMR containing whey protein (Hill et al., 2001). Differences in animal performance among studies may reflect differences in source of SDWE and (or) methods of processing.

Whole dried egg contains lipid, derived primarily from egg yolk. According to Stadelman and Cotterill (1986), the composition of yolk lipid is approximately

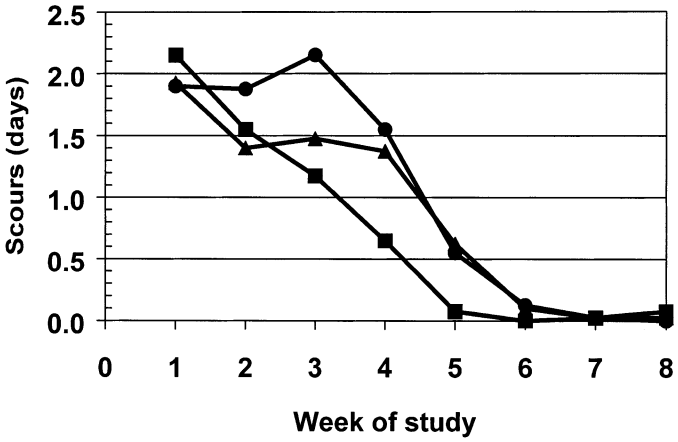


**Figure 4**. Least squares means of weekly incidence of scours in calves fed 0 (■), 10 (●), or 20% (▲) of the milk replacer formula as spray-dried whole egg. Standard error of the weekly means = 1.0.

66% triglycerides, 5% cholesterol, and 29% phospholipids. The triglycerides in egg lipid are primarily of palmitic (27% of total fatty acids), oleic (42%), and lineolic (14%; USDA, 1999). Most egg yolk phospholipid is phosphatidylcholine and phosphatidylethanolamine. To our knowledge, the digestibility of lipid in SDWE has not been determined. It is possible that the processing or availability of egg lipid is poor, and this resulted in reduced animal growth and efficiency. However, this could not be determined using our experimental design.

The biological availability and safety of byproducts of animal origin have received increased scrutiny. Animal byproducts must be collected, handled, processed, stored, and fed in a way that minimizes the risk of transmission of pathogens, unwanted biologically active peptides, and antinutritional factors. Clearly, the SDWE used in the current study contained factors that reduced animal performance. Future research is needed to determine the nature of this depressed performance. Although SDWE did not promote acceptable animal performance in this study, the opportunity to utilize SDWE in environmentally and nutritionally sound means remains attractive.

## CONCLUSIONS

The incremental addition of SDWE reduced performance of bull calves fed CMR. Although the avidin content of CMR was not determined, the addition of 1 mg/kg of supplemental biotin had no effect on animal performance. Additional research is needed to identify methods to reduce the activity of factors inhibiting animal performance to allow use of SDWE in CMR formulations.

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