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Effects of Dietary Astaxanthin on the Growth Performance and Carcass Characteristics of Finishing Pigs[1]

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Summary

A total of 48 barrows (initially 215 lb) were used to evaluate the effects of increasing dietary astaxanthin (0, 5, 10, and 20 ppm) on late-finishing pig performance and carcass characteristics. Pigs were blocked by weight and randomly allotted to 1 of 4 dietary treatments in a 26-d experiment. Pigs were fed simple corn-soybean meal-based diets. Treatments consisted of a control diet and the control diet with 5, 10, or 20 ppm added astaxanthin. For overall growth performance (d 0 to 26), ADG and F/G of pigs fed astaxanthin was not different from that of the control pigs. However, ADFI tended (linear; $P < 0.10$) to decrease with increasing astaxanthin. For the comparison of carcass characteristics, pigs fed increasing astaxanthin had decreased average ($P < 0.03$) and 10th rib ($P < 0.06$) backfat depth compared with control pigs. Pigs fed 5 or 10 ppm astaxanthin tended to have the lowest (quadratic; $P < 0.10$) 10th rib fat depth. Pigs fed increasing astaxanthin tended to have increased (quadratic; $P < 0.10$) standardized fat-free lean and percentage of fat-free lean, and pigs fed 5 or 10 ppm were the leanest. The loin muscle of pigs fed astaxanthin tended to have lower L* and b* ($P < 0.06$ and $P < 0.08$, respectively), indicating a darker color. The improved carcass characteristics of pigs fed astaxanthin resulted in a numeric increase in the net profit per pig for those fed 5 and 10 ppm astaxanthin. In conclusion, growth performance of pigs fed 5, 10, or 20 ppm astaxanthin was not different from that of pigs fed the control diet. However, the improved carcass characteristics could be economically beneficial to pork producers. Additionally, the improvements observed in loin color could result in improved consumer acceptance of fresh pork. These results warrant further research.

Key words: astaxanthin, carcass characteristics, pork color

Introduction

Astaxanthin is a carotenoid that has potent antioxidant properties and exists naturally in various plants, algae, and seafood. Astaxanthin is used extensively in the aquaculture feed industry for its pigmentation characteristics, but it is not currently approved for use in feed for food animals (other than farmed aquatic species) in the United States. Although it is used primarily for pigmentation, astaxanthin also has been found to be essential for the proper growth and survival of certain aquatic species.

Inclusion of astaxanthin in poultry diets has been reported to improve egg production and the general health of laying hens. It has also been found to improve hatching percentage and the shelf life of eggs. In addition, improvements in chick growth and

[1] Appreciation is expressed to IGENE – Astaxanthin Partners, Ltd. for providing the Aquasta astaxanthin and for partial funding of the trial.

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feed utilization during the first 3 wk of life and resistance to *Salmonella* infection have also been observed with astaxanthin supplementation. Furthermore, chick mortality associated with yolk sac inflammation has been reduced. Other studies have reported changes in egg yolk color and poultry muscle color that could improve consumer acceptance.

Few studies have been performed to evaluate feeding astaxanthin to pigs. Researchers in Scandinavia (Smits et al., 2000[3]) reported increased semen volume and sperm count for boars fed 3 g/d astaxanthin, which resulted in an increased number of pigs born alive. In another experiment (Inborr et al., 1997[4]) using sows over 2 consecutive parities, mean litter weight at 21 d of age was increased for sows fed 5 ppm astaxanthin for 35 d pre-farrowing through lactation and 21 d after weaning. During the second parity, the wean-to-service interval was reduced for sows fed astaxanthin.

In a study performed in Korea by Yang et al. (2006[5]), feeding 1.5 and 3 ppm astaxanthin to finishing pigs for 14 d prior to slaughter linearly improved dressing percentage and loin muscle area and decreased backfat thickness. There were no differences in meat color score. However, few animals were used in this study, and the linear responses observed in carcass characteristics suggest that higher levels of astaxanthin need to be evaluated.

Therefore, our objective was to evaluate the effects of feeding astaxanthin to finishing pigs for 26 d prior to slaughter on growth performance, carcass characteristics, and loin color.

Procedures

Procedures used in this experiment were approved by the Kansas State University (K-State) Institutional Animal Care and Use Committee. The project was conducted at the K-State Swine Teaching and Research Farm. Pigs were housed in an environmentally regulated finishing building with pens over a totally slatted floor that provided approximately 8 ft^2/pig. Each pen was equipped with a dry self-feeder and a nipple waterer to provide ad libitum access to feed and water. The facility was a mechanically ventilated room with a pull-plug manure storage pit.

Forty-eight barrows (PIC TR4 × C22) averaging 215 lb were used in this study. Pigs were blocked by weight and randomly allotted to 1 of the 4 dietary treatments; there were 2 pigs per pen and 6 pens per treatment. Experimental diets were fed in meal form, and astaxanthin (0, 5, 10, and 20 ppm) was added to the control diet at the expense of cornstarch to achieve the dietary treatments (Table 1). Pigs and feeders were weighed on d 0, 7, 14, 21, and 26 to determine ADG, ADFI, and F/G.

[3] Smits, R. J., P. R. Smith, and J. Inborr. 2000. Nutritional supplementation of astaxanthin to breeding boars affects semen characteristics and increases litter size. 14th Intl. Congress on Anim. Reprod. Stockholm, July 2-6. Poster abstract 10:35.
[4] Inborr, J., R. Campbell, B. Luxford, D. Harrison, and Å. Lignell. 1997. Improving sow and litter performance by feeding astaxanthin-rich algae meal. Proceedings of the VII International Symposium on Digestive Physiology in Pigs. Saint Malo, France. EAAP No. 88:479-482.
[5] Yang, Y. X., Y. J. Kim, Z. Jin, J. D. Lohakare, C. H. Kim, S. H. Ohh, S. H. Lee, J. Y. Choi, and B. J. Chae. 2006. Effects of dietary supplementation of astaxanthin on production performance, egg quality in layers and meat quality in finishing pigs. Asian-Aust. J. Anim. Sci. 19(7):1019-1025.

On d 27, one pig per pen was transported to the K-State meats lab for humane slaughter and collection of carcass data. Hot carcass weights were collected immediately after evisceration. First-rib, 10th rib, last-rib, and last-lumbar backfat depth as well as loin eye area at the 10th rib were collected from the right half of each carcass 24 h postmortem. Additionally, each carcass was evaluated for loin muscle color at the 10th rib with a HunterLab Miniscan XE Plus spectrophotometer (Model 45/0 LAV, 2.54-cm-diameter aperture, 10° standard observer, Illuminant D65, Hunter Associates Laboratory, Inc., Reston, VA) to measure CIE L*, a*, and b*. This was performed after 30 min of bloom time for each loin muscle surface.

Data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with pen as the experimental unit. Linear and quadratic polynomial contrasts were used to determine the effects of increasing astaxanthin.

Results and Discussion

The analyzed astaxanthin levels for the experimental diets were 0.8, 4.8, 9.5, and 19.8 ppm, similar to the targeted values of 0, 5, 10, and 20 ppm used in diet formulation.

For overall growth performance (d 0 to 26), ADG and F/G of pigs fed astaxanthin were not different than those of control pigs (Table 2). However, ADFI tended (linear; $P < 0.10$) to decrease with increasing astaxanthin.

Increasing astaxanthin decreased average ($P < 0.03$) and 10th rib ($P < 0.06$) fat depth. The reduction in 10th rib fat depth tended to be greatest (quadratic; $P < 0.10$) at the 5 or 10 ppm level of astaxanthin.

The amount of standardized fat-free lean in the carcasses tended (quadratic; $P < 0.09$) to be improved with increasing astaxanthin, and this resulted in a trend ($P < 0.09$) for an increased percentage of fat-free lean for pigs fed astaxanthin. Pigs fed 5 or 10 ppm astaxanthin tended (quadratic; $P < 0.10$) to have the greatest percentage of fat-free lean.

Loin color measurements of CIE L* and b* tended ($P < 0.06$ and $P < 0.08$, respectively) to be lower for pigs fed astaxanthin. The L* measurement indicates the degree of lightness (0 = black, 100 = white). The b* is a measure of yellowness (positive value) vs. blueness (negative value). The CIE a* and b* measurements were lowest (quadratic; $P < 0.02$ and $P < 0.06$, respectively) at the 10 ppm level of astaxanthin; however, the CIE a* of pigs fed 5 and 20 ppm astaxanthin was numerically greater than that of the controls. The a* is a measure of redness (positive value) vs. greenness (negative value).

In this study, the improved carcass characteristics associated with feeding astaxanthin resulted in numeric improvements in the net profit per pig for those fed 5 and 10 ppm. However, because there was not any further improvement in carcass characteristics for pigs fed 20 ppm astaxanthin, feeding this level was of no economic benefit (based on a price of $9.07/lb for the 10,000 ppm astaxanthin product). The improvements in carcass characteristics are similar to those observed by Yang et al. (2006), who evaluated feeding 1.5 and 3 ppm astaxanthin for 14 d preslaughter. However, Yang et al. (2006) did not observe differences in loin muscle color at the 10th rib.

Although packers do not generally provide producers with premiums or discounts based on muscle color characteristics, consumer acceptance studies for pork have determined that lower CIE L* values are more desirable. Results of the current study indicate that feeding higher concentrations of astaxanthin over a longer period may improve pork color characteristics.

In conclusion, growth performance of pigs receiving 5, 10, or 20 ppm astaxanthin was not different from that of pigs fed the control diet. However, the improvements in carcass characteristics could be economically beneficial to pork producers. Additionally, the improvements in loin color could result in improved consumer acceptance of fresh pork. However, astaxanthin is not yet approved for food animals other than farmed aquatic species in the United States. These results warrant further research.

Table 1. Composition of the experimental control diet[1, 2]

Ingredient	%
Corn	85.40
Soybean meal (46.5% CP)	12.44
Monocalcium P (21% P)	0.45
Limestone	0.85
Salt	0.35
L-lysine HCl	0.15
Vitamin premix	0.08
Trace mineral premix	0.08
Cornstarch[3]	0.20
Total	100.00
Calculated analysis	
Total lysine, %	0.72
SID[4] amino acids	
Lysine, %	0.63
Isoleucine:lysine ratio, %	71
Leucine:lysine ratio, %	188
Methionine:lysine ratio, %	33
Met & Cys:lysine ratio, %	68
Threonine:lysine ratio, %	64
Tryptophan:lysine ratio, %	18
Valine:lysine ratio, %	85
Protein, %	13.2
ME, kcal/lb	1,522
SID lysine:ME ratio, g/Mcal	1.88
Ca, %	0.47
P, %	0.42
Available P, %	0.15

[1] Experimental diets were fed for 26 d before slaughter.
[2] Ingredient prices used to determine the diet cost were: corn, $118/ton; soybean meal, $207/ton; Monocalcium P, $332/ton; Limestone, $30/ton; Salt, $53/ton; L-lysine HCl, $1,800/ton; Processing and delivery, $12/ton; and Astaxanthin (10,000 ppm), $9.07/lb.
[3] Astaxanthin replaced cornstarch in the control diet to achieve the 5, 10, and 20 ppm astaxanthin treatments.
[4] Standardized ileal digestible.

Table 2. Growth performance and carcass characteristics of pigs fed increasing astaxanthin[1]

	Astaxanthin, ppm					Probability, $P <$		
Item	0	5	10	20	SEM	Control vs. Astaxanthin	Linear	Quadratic
Growth performance, d 0 to 26								
Initial wt, lb	215	215	215	215	2.90	---[2]	---	---
ADG, lb	2.11	2.23	2.03	1.99	0.12	---	---	---
ADFI, lb	6.67	6.76	6.24	6.20	0.24	---	0.10	---
F/G	3.22	3.05	3.08	3.16	0.15	---	---	---
Final wt, lb	270	273	268	267	3.81	---	---	---
Feed, $/lb gain	0.23	0.23	0.25	0.29	0.01	---	0.01	---
Feed, $/pig	12.57	13.55	13.23	14.59	0.51	0.06	0.02	---
Carcass characteristics								
Live wt, lb	271	273	271	270	3.95	---	---	---
HCW, lb	192	192	191	189	3.38	---	---	---
Yield, %	71.0	70.6	70.6	70.3	0.64	---	---	---
Average backfat thickness, in.	1.00	0.89	0.85	0.87	0.05	0.03	---	---
10th rib fat depth, in.	0.82	0.65	0.65	0.70	0.07	0.06	---	0.10
Loin eye area, sq. in.	7.33	7.72	7.58	7.28	0.30	---	---	---
Loin eye color[3]								
CIE L*	60.3	55.3	58.9	56.2	1.42	0.06	---	---
CIE a*	9.4	10.1	8.2	10.3	0.31	---	---	0.02
CIE b*	15.8	14.8	14.4	15.1	0.47	0.08	---	0.06
Standardized fat-free lean, lb	102	107	106	103	2.37	---	---	0.09
Fat-free lean, %	53.2	55.6	55.5	54.5	1.04	0.09	---	0.10
Economic implications								
Estimated carcass value, $/100 lb[4]	68.76	70.13	70.08	69.41	0.65	---	---	---
Estimated total carcass value, $	128.37	131.79	130.98	130.41	2.40	---	---	---
Estimated net profit/loss per pig relative to control, $	-	2.44	1.95	0.02	3.31	---	---	---

[1] A total of 48 barrows (PIC TR4 × C22) were used with 2 pigs per pen and 6 pens per treatment. Data were obtained from 1 pig per pen for the determination of carcass characteristics.
[2] Probability, $P > 0.10$.
[3] The range for CIE L* is 0 to 100 (0 = black, 100 = white). A positive CIE a* indicates the degree of redness. A positive CIE b* indicates the degree of yellowness.
[4] From the Sept. 13, 2007, USDA National Daily Direct Negotiated Hog Purchase Matrix with adjustments for carcass weight differentials.