Evaluating dietary inclusion of Missouri high oleic soybean oil and meal on broiler performance and lipid quality

Abstract

The banning of partially hydrogenated oils in food processing by the FDA has led to a search for alternative oil sources with a decreased potential for oxidation. High oleic soybean oil has the ability to serve as an oil source for both livestock feed and in human food production. The objective of this experiment was to evaluate the effect of dietary inclusion of high oleic soybean meal and oil on broiler performance and lipid quality of broiler meat. Male Ross 308 broiler chicks (n=160) were sorted by weight and randomly assigned to one of two treatments containing 10 replicate pens with 8 broilers each. Treatment groups consisted of a control corn-soy diet that included commodity soybean meal and oil (CON) and a corn-soy diet containing high oleic soybean meal and oil (MOS). Broilers received, ad libitum, a two-phase diet consisting of starter (d0-21) containing 5% oil and grower (d21-42) containing 3% oil. Pen weight (PW) and feed intake (FI) were recorded on days 0, 21, and 42 and used to calculate feed to gain ratio (F:G). Broilers were slaughtered on d42, after which carcasses were weighed and fabricated. Weights of fabricated parts were recorded for carcass yield. Samples of breast and thigh meat were taken for fatty acid profile analysis, which was conducted using a modified version of methods by Folch *et al*. (1957) and Morrison and Smith (1964). To measure lipid oxidation, boneless, skinless breast halves chosen randomly from each pen were placed on Styrofoam trays and overwrapped with oxygen permeable, polyvinyl chloride and placed in retail storage (4°C) and used for collection of thiobarbituric acid reactive substances (TBARS) on day 1, 3, and 5 of storage. Data was analyzed using PROC GLM procedure in SAS, with level of significance set at $P < 0.05$. CON pens had a greater ($P < 0.002$) change in weight (23480.61 g.

vs 21829.39 g.), however, the CON treatment had an increase in FI ($P < 0.001$) compared to the MOS treatment (29841.74 g. vs. 27405.68 g). Thus, there was no difference in F:G between treatments. While there was no difference in percent carcass yield or breast yield, the CON treatment had a higher ($P = 0.01$) percent thigh yield compared to the MOS treatment (16.36% vs 15.86%). Results of lipid oxidation showed there was an effect of day ($P <0.001$), but no treatment or interaction effects were observed. Diet changed ($P < 0.001$) the proportion of SFA, MUFA, and PUFA in breast and thigh meat. MOS treatment increased the proportion of MUFA and decreased the proportion of PUFA and SFA in both breast and thigh meat. Both breast and thigh samples from the MOS treatment had increased ($P < 0.001$) proportions of C18:1n9 and decreased proportions of C18:2n6 compared to the control. Inclusion of MOS soybean meal and oil in broiler diets resulted in increased uptake of MUFA (C18:1) and decreased PUFA (C18:2) in both breast and thigh meat, while having no impact on broiler feed efficiency. Pull through effect of MOS acid seen in fatty acid analysis of broiler meat, shows the ability to serve as a mechanism to increase oleic acid inclusion in human diets.
Keywords: high oleic, fatty acid, broilers, lipid oxidation

Introduction

Poultry meat is known to have a fatty acid profile weighted heavier with PUFAs compared to pork, beef, and lamb, resulting in an increased rate of lipid oxidation in fresh poultry (Aberle et al., 2012). This causes fresh poultry products to have a shorter shelf-life and decreases margins for retailers due to having to mark down the prices of these products sooner or through a shorter time spent in the retail case. The fatty acid profile of poultry can be manipulated by feed ingredients added to the diet, however any changes made to the diet can

yield unexpected outcomes on growth and efficiency. The recent FDA ban on partially hydrogenated oils has driven entities to produce high oleic soybean oil alternatives. The potential exists for these new oil sources to enter the feed supply chain (FDA, 2015). Currently little is known regarding the effect of this oil source on broiler performance, as well as its ability to assimilate into broiler muscle and adipose tissues. We predict that feed efficiency and growth of broilers fed Missouri high oleic soybean oil and meal will be similar that of broilers fed a diet containing conventional soybean oil and meal. We expect to see a lower rate of lipid oxidation in breast and thigh meat from the broilers fed Missouri high oleic soybean oil and meal, due to these broilers having a fatty acid profile higher in monounsaturated fatty acids, more specifically oleic acid (C18:1).

Objectives

1. Evaluate the effect of Missouri high oleic soybean oil and meal the growth performance and efficiency of broilers.
2. Determine the impact of Missouri high oleic soybean oil and meal on broiler carcass yield.
3. Evaluate changes in fatty acid profile and fat quality of broilers fed a diet containing Missouri high oleic soybean oil and meal.

Experimental Design

The University of Missouri Animal Care and Use Committee approved animal care and experimental protocols prior to initiation of this experiment. Male Ross 308 broiler chicks (n=160) were sorted by weight and then randomly assigned to one of two treatment groups, that contained 10 replicate pens with 8 broilers each. Broilers were housed in a climate-controlled

facility, that allowed for the temperature to be adjusted to meet the birds' requirements throughout the growing period.

The two treatment groups consisted of a control diet corn-soy diet that included conventional soybean meal and oil (CON) and a corn-soy diet containing Missouri high oleic soybean meal and oil (MOS). Broilers received a two-stage diet consisting of a starter diet (d0-21) and a grower diet (d21-42). All diets (Table 1) were formulated and balanced to meet energy requirements using the Brill diet formulation software. All animals were provided water and feed *ad libitum*. Feed was added to pens as needed, with the total weight of feed added recorded to use to calculate the total feed consumption of each pen.

Broilers were humanely slaughtered at 7 weeks of age (42 days) following standard and sanitary U.S. poultry industry practices and USDA/FSIS inspection criteria, at the University of Missouri Poultry Processing Facility. The abdominal fat pad was collected from each bird during the evisceration process and then weighed. Abdominal fat pads were then placed in labeled Whirlpack bags and frozen until analysis. A boneless, skinless breast portion and a boneless, skinless thigh were collected from each chilled carcass to be used for further analysis. Samples were sealed in Whirlpack bags, labeled and frozen until sample analysis.

Methodology

Growth Performance

The body weight and feed consumption of all pens was recorded from the start of the study to the final day before the all broilers were processed. Pen weights were recorded on days 0, 21, and 42. All pens started with a known amount of feed and any additional feed needed per pen was weighed and recorded before being added. Feeder weights were recorded on days 21

and 42 to measure the residual feed at the end of the starter and grower periods. Measurements recorded were used to calculate changes in pen body weight (BW) average daily gain (ADG), feed intake (FI), and feed to gain ratio (F:G) for each treatment.

Carcass Weight and Breakdown

Broilers were weighed individual prior to slaughter, thus allowing for the dressing percentage of each bird to be calculated. The hot carcass and chilled carcass weight of each bird was recorded. Dressing percentage was calculated by dividing the hot carcass weight by the live weight and multiplying the value by 100. Carcasses were then chilled in an ice water bath for 1 hour, after which a chilled carcass weight was recorded for each carcass. One half of each carcass was fabricated in a major, minor, wing, thigh, and leg. The weight of each piece was recorded and used to calculate the percent carcass yield.

Fatty Acid Analysis

Fatty acid profiles were determined according to modified methodologies by Folch *et al*. (1957) and Morrison and Smith (1964). Approximately 100 mg of adipose tissue was homogenized in chloroform:methanol ($CHCl_3$:CH_3OH, 2:1, v/v) in a glass tube to extract lipids. Dehydrated samples were filtered through a sintered glass funnel fitted with a Whatman 2.4 cm GF/C filter.

A volume of 8 ml of 0.74% KCl was added to each sample and after two hours, two distinct layers formed. The upper phase was removed and discarded while the lower phase was evaporated to dryness with nitrogen in a water bath. At the point of dryness, 1 ml of 0.5 N KOH was added to each tube and heated for 10 min. in a 70°C water bath. The addition of KOH initiates the saponification reaction, which hydrolyzes fatty acids from a triglyceride molecule. Following this, 1 ml of 14% BF_3 in MeOH was added, samples were flushed with nitrogen and

heated in the water bath for 30 min. Boron trifluoride is highly volatile and acts as an acid catalyst in the transesterification reaction that methylates the acid group on free fatty acids removing the net negative charge. The remaining molecule is known as a fatty acid methyl ester (FAME).

FAMEs are liquefied by adding 2 ml of HPLC grade hexane and 2 ml of NaCl. Two distinct layers are formed; the upper layer is removed and added to ~800 mg of Na_2SO_4 to remove any moisture in the sample. At this point, 2 more ml of hexane was added to the tube containing NaCl and once more, the upper layer was removed and added to the tube containing Na_2SO_4. The hexane portion was removed from the salt and added to a labeled scintillation vial. The salt was rinsed once more with 1 ml of hexane and the liquid was added to the vial. Samples were evaporated to dryness in a water bath at 70°C under nitrogen flow. Lastly, samples were reconstituted with 1 ml HPLC grade hexane and transferred to gas chromatograph vials.

The stable FAMEs were loaded into a Varian 3,800 gas chromatographer (Varion, Pala Alto, CA) to determine fatty acid profiles. The column utilized was a fused silica capillary column (SPTM – 2,560; 100 m x 0.25 mm x 0.2 μm film thickness; Supelco, Bellefonte, PA). Temperature of the injector was held constant at 240°C and temperature of the flame-ionizer detector was held at 260°C. The oven operated at 140°C for 5 min (temperature programmed 2.5°C/min to 240°C and held for 16 min). Helium, the carrier gas, was maintained at a constant pressure of 37 psi. Individual fatty acids were expressed as a percentage of the total area under the peaks.

Total saturated fatty acid (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acid (PUFA) contents were calculated according to the following equations: SFA = (C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0 +

C23:0); MUFA = (C14:1 + C15:1 + C16:1 + C17:1 + C18:1n9t + C18:1n9c + C18:1n7 + C20:1 + C22:1n9 + C24:1); PUFA = (C18:2n6t + C18:2n6c + C18:3n6 + C18:3n3 + C18:9c11t + C18:10t12c + C18:9c11c + C18:9t11t + C20:2 + C20:3n6 + C20:3n3 + C20:4n6 + C22:5n3 + C22:6n3). The ratio between PUFAs and SFAs was calculated using the equation: [(C18:2n6c) + (C18:3n3)]/[(C14:0 + C16:0 + C18:0)]. The following equations were used to calculated total omega 3 and omega 6 fatty acid content: total omega 3 = C18:3n3 + C20:3n3 + C22:5n3 + C22:6n3); total omega 6 = (C18:3n6 + C20:3n6 + C20:4n6). Finally, IV from fatty acid profiles were determined according to the equation described by AOCS (1998): IV = (0.95 x C16:1) + [0.86 x (C18:1n9t + C18:1n9c)] + [1.732 x (C18:2n6t + C18:2n6c)] + (2.616 x C18:3n3) + (0.785 x C20:1).

Lipid Oxidation (TBARS)

Lipid oxidation of boneless breast, thigh meat, and fresh pork sausage will be measured using the method described by Tarladgis et al. (1960) with modifications from Fernando et al. (2003). Malonaldehyde, a by-product of oxidation, was measured to indicate the rate of oxidation that had occurred in each sample over a specified time period. Four boneless, skinless chicken breast samples from each pen were placed on Styrofoam trays and overwrapped with polyvinyl chloride (PVC), then randomly and stored to one of two retail display cases for 7 days. The conditions within each retail display case were as follows, temperature of 4C and high florescent light source. One sample breast for each pen was removed to be measured on day 1, 3, 5, and 7 of the shelf-life study. Duplicate 5-gram samples of each hanging tender were blended for 2 minutes with 25 ml of distilled water using a Hamilton Beach hand blender. Following homogenization, the cup containing the sample was rinsed with an additional 25 ml of distilled water and transferred into a Kjeldahl flask. 2.5 ml of HCl was added to the flask to balance the

pH between 1.5 – 1.6 along with two drops of antifoam solution. 25 ml of each sample was distilled through a water-cooled distillation apparatus. Following distillation, 5 ml of each sample was pipetted into a glass tube followed by 5 ml of TBA (0.02 M thiobarbituric acid in 90% acetic acid) reagent. Samples were then placed in a boiling water bath for 35 minutes and then immediately transferred to an ice bath for 10 minutes to stop the chemical reaction. Color absorbance was measured at 538 nm using a Spectronic 20 (Bausch & Lomb, Rochester, NY) spectrophotometer. Values of each reading were recorded and averaged for further calculation. Lipid oxidation was expressed in mg/kg of malonaldehyde recovered and calculated using the recorded spectrophotometer averages and the give equation below.

mg/kg of malonaldehyde = 7.8 * spectrophotometer reading

Fat and Moisture Content Analysis

Fat and moisture content analysis was performed according to Keeton et al. (2003). A CEM Moisture/Solids Analyzer and Smart Trac Rapid Fat Analysis system (CEM Corp., Matthews, NC, U.S.A.) was used to analyze the samples. Briefly, the moisture percentage was determined by weight using the CEM moisture/solids analyzer and the fat percentage was determined on dry basis using nuclear magnetic resonance and converted to wet basis. Each sample for analysis was performed in triplicate as described by Dow et al. (2011).

Statistical Analysis

Data for growth performance and carcass yield was analyzed using the PROC GLM procedure of SAS (SAS Inst., Cary, NC) with pen serving as the experimental unit. The statistical model included the fixed effects of dietary treatment (control corn-soy diet using conventional soybean oil and meal or corn-soy diet using Missouri high oleic soybean oil and

meal). The least squares means and standard errors were estimated. Level of significance was set at $P<0.05$.

Results

Growth Performance

Pens receiving the CON diet showed a significantly greater ($P < 0.002$) change in weight compared to the pens fed the MOS diet (23480.61 g. vs 21829.39 g.). However, the pens fed the CON treatment diet had an increase in FI ($P < 0.001$) compared to the MOS treatment (29841.74 g. vs. 27405.68 g). Therefore, no significant difference in F:G between treatments was found.

Carcass Weight and Breakdown

Results for carcass weight and yield can be found in Table 3. Pens fed the CON diet produced significantly heavier HCW ($P = 0.002$; 2.13 kg vs 2.01 kg) and CCW ($P = 0.007$; 2.23 kg vs 2.19 kg) compared to the pens receiving the MOS diet. However, there was no difference found for dressing percentage and percent carcass yield between treatments. A significant difference between treatments for weight of individual parts and corresponding percent of carcass weight was only seen for liver weight ($P = 0.049$), leg weight ($P < 0.001$), thigh weight ($P < 0.001$), and thigh % ($P = 0.011$). Compared to the pens receiving the MOS diet, pens fed the CON diet had heavier livers (45.17 g vs. 42.50 g), leg portions (156.16 g vs 145.50 g), and thighs (182.20 g vs 166.39 g) Moreover, pens fed the CON treatment had a higher percent thigh yield compared to the MOS treatment (16.36% vs 15.86%).

Fatty Acid Analysis

The fatty acid profile of breast meat samples can be found in Table 6. Diet had a significant impact ($P < 0.001$) on the proportion of saturated fatty acids (SFA), monounsaturated

fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) in broiler breast meat. Breast samples from pens fed the MOS treatment diet had an increase in the proportion of MUFA, with a decrease in the proportion of PUFA and SFA compared to their counterparts receiving the CON diet. Results for the impact of diet on the level of C18:n9 in breast meat, show a significantly higher amount ($P < 0.001$) of C18:1n9, combined with a lower ($P < 0.001$) amount of C18:2n6, in breast meat from pens receiving the MOS treatment compared to CON. However, breast meat from pens fed the MOS treatment had significantly lower levels ($P < 0.001$) of n-6 fatty acids compared to the CON pens.

Results for the fatty acid profile of broiler thigh meat (Table 7) indicate that diet had a significant impact ($P < 0.0001$) on the proportion of SFA, MUFA, and PUFA in broiler thigh meat. Similar to the results for the breast samples, pens fed the MOS diet had an increase in the proportion of MUFA, combined with decreased levels of PUFA and SFA in thigh meat. Thigh samples from pens fed the MOS treatment had increased ($P < 0.001$) levels of C18:1n9, as well as decreased ($P < 0.001$) amounts of C18:2n6 and n-6 fatty acids compared to the control.

Lipid Oxidation (TBARS)

Table 5 outlines the lipid oxidation results from the stimulated retail storage of boneless, skinless breast meat. There was no interaction effect found between treatment and day. Further analysis indicated that while there was also no significant treatment effect on the rate of lipid oxidation of breast meat, breast meat from MOS pens showed a tendency ($P = 0.074$) for a lower average amount of malonaldehyde (0.217 vs. 0.313) . Results did show a significant effect of day ($P <0.0001$) on the rate of lipid oxidation, with the amount of malonaldehyde remaining similar from day 1 to 3 (0.138 mg/kg and 0.113 mg/kg) and drastically increasing on day 5 (0.546 mg/kg).

Fat and Moisture Content Analysis

Results for the moisture and fat percentage of broiler breast and thigh meat can be found in Table 4. The effect of dietary treatment showed no significant differences for the moisture or fat percentage found in broiler breast meat. The results for the moisture and fat percentage of broiler thigh meat were similar to that of the breast meat, as no significant difference existed.

Discussion

While pens fed the CON diet showed a significantly greater amount of weight change compared to the MOS pens, this came at the cost of increased feed intake to acquire this added body weight. Thus, pen growth performance, as measured by F:G, shows no benefit due to one treatment effect versus another.

The improvements shown by the CON pens in live weight carried through to improve overall HCW and CCW compared to that of pens fed MOS, which is to be expected. The increase in weight found in CON pens, compared to MOS pens, appears to be the result of added weight found in the leg and thigh portions from carcass breakdown. What is unknown is if the increase in the weight of the leg and thigh portion of birds fed CON diet is the result of an increase in muscle tissue or bone. However, when combined with the lack of difference in the moisture and fat content of the thighs, it can be suggested that the increase in leg and thigh weights of CON treatment birds may be the result of added bone mass. An increase in lean muscle mass can be potentially ruled out, as thighs of both treatments had similar moisture contents. As the greatest portion of muscle is water, then it can be suggested that if there was an increase in the muscle mass of thighs from the CON treatment, there would be a corresponding increase in the moisture content of CON thighs.

Fatty acid analysis of breast and thigh meat revealed that birds from the MOS treatment showed greater inclusion of dietary MUFA (C18:1) in muscle tissues. This increase in the proportion of MUFA came with a corresponding decrease in the amount of PUFA and SFA, specifically C18:2 and C16:0, in breast and thigh meat. These results add further confirmation to the ability of monogastric species to assimilate dietary fatty acids into tissues and the potential to use this ability to customize the supply of fatty acids that are deposited into broiler muscle and adipose tissue. While not statistically significant, boneless, skinless breasts from MOS fed pens had a tendency for decreased lipid oxidation after 5 days of storage in a retail display, compared to breast fillets from CON fed pens. This tendency may be the result of the increase in the proportion of C18:1 in breast meat of MOS fed birds.

Overall, the inclusion of Missouri high oleic soybean oil and meal in the diets of broilers had no impact on broiler feed efficiency compared to broilers fed a diet containing traditional commodity soybean oil and meal that contains a greater proportion of C18:2. Furthermore, results from this pilot experiment show that the increased supply of C18:1 via Missouri high oleic soybean meal and oil in broiler diets resulted in a shift in the fatty acid profile in both breast and thigh meat to contain a greater portion of MUFA. Thus, offering the potential to create a broiler meat product containing high levels of MUFA.

References

Dow D. L., Wiegand, B. R., Ellersieck, M. R., and Lorenzen, C. L. 2011. Prediction of fat percentage within marbling score on beef longissimus muscle using 3 different fat determination methods. *J. Anim. Sci.* 89, 1173-1179.

Fernando, L. N., Berg, E. P., and Gruen, I. U. (2003). Quantitation of hexanal by automated SPME for studying dietary influences on the oxidation of pork. *Journal of Food Composition and Analysis*, 16, 179-188.

FDA. (2015). Final Determination Regarding Partially Hydrogenated Oils. 80 FR 34650, 2015-14883, 34650-34670.

Folch, J., M. Lees, and S. G. H. Stanley. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem*, 226, 497-509.

Keeton , J. T., Hafley, B. S., Eddy, S. M., Moser, C. R., McManus, B. J., and Leffler, T. P. 2003. Rapid determination of moisture and fat in meats by microwave and nuclear magnetic resonance analysis. *J. of AOAC Int.*, 86, 1193-1202.

Morrison, W. R., and Smith, L. M. (1964). Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. *J. Lipid Res*, 5, 600-608.

Tarladgis, B. G. (1960). A distillation method for the quantitative determination of malonaldehyde in rancid foods.

Table 1. Composition of treatment diets comparing commodity and Missouri high oleic soybean oil and meal.

	Treatment Diets[1]			
	Starter		Grower	
	CON	MOS	CON	MOS
Corn	1062.70	1135.96	1258.20	1335.32
SBM 48	757.68	-	602.38	-
MO High Oleic SBM	-	682.06	-	531.22
Commodity Soybean Oil	100.92	-	73.26	-
MO High Oleic Soybean Oil	-	100.92	-	64.90
Dical Phosphate	34.30	35.30	24.70	25.2
Limestone	24.96	25.28	26.78	26.92
Salt	9.24	9.32	6.66	6.66
NB 3000 Vitamin Premix	5.00	5.00	5.00	5.00
Methionine	3.72	4.58	1.52	2.26
Coban 60	1.50	1.50	1.50	1.50
Lysine	-	-	-	1.02
	2000.00	2000.00	2000.00	2000.00
Crude Protein, %	23.99	23.65	18.15	16.96
Crude Fat, %	4.80	7.25	3.73	5.12
Crude Fiber, %	2.22	2.08	2.39	3.11
Moisture, %	11.54	10.11	12.04	11.12
Ash, %	5.20	5.96	5.15	4.06

[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Table 2. Growth Performance least squares means of broilers fed commodity and Missouri high oleic soybean oil and meal.

	Treatments[1]			
Item[A]	CON	MOS	SEM	P-value
Pen Weight Change, g.	23480.61[b]	21829.40[a]	325.60	0.002
Feed Consumption, g.	29841.74[b]	27405.70[a]	390.39	<0.001
F:G	1.27	1.25	0.01	0.220

[A] LS means within a row with similar superscripts do not differ at P<0.05.
[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Table 3. Carcass yield least squares means of broilers fed commodity and Missouri high oleic soybean oil and meal.

	Treatments[1]			
Item[A]	CON	MOS	SEM	P-value
HCW, kg.	2.13[b]	2.01[a]	325.60	0.002
CCW, kg.	2.23[b]	2.10[a]	0.03	0.007
Dressing Percent, %	76.87	77.10	0.16	0.299
Carcass Yield, %	72.05	73.09	0.84	0.387
Fat Pad, g.	42.00	39.13	1.35	0.133
Fat Pad, %	1.87	1.88	0.06	0.975
Liver, g.	45.17[b]	42.50[a]	0.95	0.049
Liver, %.	2.12	2.12	0.03	0.911
Major, g.	296.72	283.02	6.41	0.133
Major, %	26.48	26.62	0.27	0.708
Minor, g.	52.97	51.44	1.06	0.309
Minor, %	4.76	4.89	0.07	0.202
Leg, g.	156.16[b]	145.50[a]	2.00	<0.001
Leg, %	14.05	13.94	0.12	0.484
Thigh, g.	182.20[b]	166.39[a]	2.78	<0.001
Thigh, %	16.36[b]	15.86[a]	0.14	0.011
Wing, g.	115.56	125.70	10.78	0.507
Wing, %	10.41	11.78	0.83	0.242

[A] LS means within a row with similar superscripts do not differ at P<0.05.
[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Table 4. CEM moisture and fat percentages of breast and thigh meat.

	Treatments[1]			
Item[A]	CON	MOS	SEM	P-value
Breast Moisture, %	74.53	74.95	0.17	0.093
Breast Fat, %	3.25	2.93	0.17	0.200
Thigh Moisture, %	74.50	74.30	0.17	0.419
Thigh Fat, %	5.77	6.05	0.19	0.310

[A] LS means within a row with similar superscripts do not differ at P<0.05.
[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Table 5. Influence of High Oleic Soybean Oil and Meal on Lipid Oxidation of Chicken Breast

	Treatments[1]		
Item[A]	Malonaldehyde, mg./kg.	SEM	P-value
Treatment			
CON	0.313	0.17	0.074
MOS	0.217		
Day			
1	0.138[a]		
3	0.113[a]	0.05	<.001
5	0.546[b]		

[A] LS means within a column with similar superscripts do not differ at P<0.05.
[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Table 6. Fatty acid profile of broiler breast meat.

	Treatments[1]			
Fatty Acid [A]	CON	MOS	SEM	P-value
C16:0	20.64[b]	18.95[a]	0.16	<.001
C16:1	3.31[a]	3.91[b]	0.06	<.001
C18:0	7.05[b]	6.03[a]	0.09	<.001
C18:1n9c	34.07[a]	54.30[b]	0.25	<.001
C18:2n6c	28.97[b]	11.90[a]	0.20	<.001
C20:3n6 (20:4)	2.18[b]	0.73[a]	0.03	<.001
SFA	28.92[b]	26.05[a]	0.25	<.001
MUFA	39.27[a]	60.52[b]	0.20	<.001
PUFA	31.44[b]	12.87[a]	0.23	<.001
n-6	31.15[b]	12.56[a]	0.22	<.001
n-3	0.24	0.28	0.05	0.594

[A] LS means within a row with similar superscripts do not differ at P<0.05.
[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Table 7. Fatty acid profile of broiler thigh meat.

	Treatments[1]			
Item[A]	CON	MOS	SEM	P-value
C16:0	19.78[b]	18.01[a]	0.17	<.001
C16:1	3.57[a]	4.14[b]	0.10	<.001
C18:0	6.54[b]	5.43[a]	0.08	<.001
C18:1n9c	33.68[a]	55.02[b]	0.13	<.001
C18:2n6c	29.42[b]	11.97[a]	0.13	<.001
C20:3n6 (20:4)	2.24[b]	0.75[a]	0.02	<.001
SFA	27.60[b]	24.22[a]	0.28	<.001
MUFA	38.95[a]	60.31[b]	0.58	<.001
PUFA	32.84[b]	13.46[a]	0.19	<.001
n-6	31.67[b]	12.56[a]	0.16	<.001
n-3	1.11[b]	0.85[a]	0.05	0.004

[A] LS means within a row with similar superscripts do not differ at P<0.05.
[1]CON = Control, MOS = Missouri high oleic soybean oil and meal

Determining the effect of traditional and novel dietary oils on performance and quality of finishing pigs.

Introduction

The source and quality of lipids added to diets fed to livestock play a major role in the production performance. Changes in lipids, or more specifically fatty acids, can cause positive and negative outcomes for the many facets of livestock production, influencing growth, milk production, reproductive efficiency, and the quality and shelf-life of the meat products produced. Novel feed ingredients and different feed ingredient processing methods produce a varying fatty acid profile in diets, which must be considered by nutritionists when formulating diets and food processors when producing final food products.

On June 17, 2015, the Food and Drug Administration (FDA) announced that it was removing the Generally Recognized as Safe (GRAS) status from partially hydrogenated oils (FDA, 2015). The FDA declared these oils to be the primary source of dietary trans-fats for humans (FDA, 2015). Trans-fats have been shown to increase LDL cholesterol, or "bad" cholesterol, levels, thus promoting concern over their negative effects on human health. The FDA listed a final compliance date of June 18, 2018 for trans-fats to be removed from human food products (FDA, 2015). According to the United Soybean Board, this decision by the FDA could lead to a loss of 1.5 billion pounds of soybean oil demand from U.S. food companies on top of the 4 billion pounds of annual soybean demand due to previous trans-fat labeling requirements by the FDA (United Soybean Board, 2017). To fill this void, entities have both created high oleic (C18:1) oil soybean varieties to source a more stable, heart healthier oil product, compared to bio-hydrogenated soybean oil.

Monounsaturated fatty acids have gained recognition from their prevalence in Mediterranean diets (Yang et al., 2017; Delgado et al., 2017). These diets traditionally contain greater amounts of olive oil, which is rich in MUFAs, primarily in the form of oleic acid (C18:1) (Yang et al., 2017; Delgado et al., 2017). Schwingshackl and Hoffmann (2014) reported that the consumption of diets rich in MUFAs have been linked to lower cardiovascular events and mortality, compared to diets rich in SFAs. Fat sources containing a greater proportion of MUFAs, primarily oleic acid, may yield a cooperative "middle ground". Studies have shown that dietary MUFA increase HDL cholesterol, decrease LDL cholesterol, and may even improve insulin sensitivity (FAO-WHO, 2008; Gillingham, Harris-Janz, & Jones, 2011). On top of their health benefits, MUFAs have a lower oxidative potential compared to PUFAs due to only having one double bond. Meat scientists and food processors have long sought the ideal fatty acid profile of a raw meat product, which yields both an extended shelf life and human health benefits. High oleic soybean oil offers the potential of yielding that ideal fatty acid profile. While research has been conducted over the use of other feed ingredients that contain high levels of oleic acid, limited research has been done to understand how livestock models utilize this new source of high oleic acid and how it affects the quality of the final products from these livestock.

Other feed sources that contain increased levels of oleic acid have shown the ability to improve quality traits of pork products by altering the fatty acid profile. MUFAs not only can increase the firmness of pork fat when compared to PUFAs, but at the same time, oleic acid (C18:1) content has been positively correlated with organoleptic properties such as flavor, tenderness, juiciness, pork flavor, flavor liking and overall acceptability (Cameron & Enser, 1991; Cameron et al., 2000; Tikk et al., 2007). With the emergence of this new soybean source of high oleic acid, little is known on its effect on the meat and lipid quality of pork and the

retention rate of oleic acid within that final product. This experiment evaluated the effect of traditional and novel dietary oil sources on the growth performance and meat/lipid quality traits of finisher pigs. We hypothesis that feed efficiency and growth of finisher pigs fed novel high oleic oil will remain unaffected compared to the performance of pigs fed traditional oil sources. Furthermore, we predict that fat and muscle samples from these animals fed novel high oleic oil will yield a fatty acid profile higher in oleic acid and consequently producing firmer pork with a decreased potential for lipid oxidation.

Design

In this ACUC (Animal Care and Use Committee) approved experiment, finisher pigs (n=80) were weighed and blocked by weight and age into two groups. The groups were assigned the names of early start-finishing group (early) and late start-finishing group (late). Within group, pigs were randomly sorted into 8 treatment groups containing 5 individually housed pigs per treatment. Pigs were be housed in the Double L Building at the MU Swine Teaching Farm and under the same environmental conditions. Both groups were placed on treatment at approximately 150 lbs. (68 kg.). The treatment diets contained a variety of dietary oil sources at an inclusion rate of 3%, unless otherwise stated. All diets (Table 1) were formulated based on the nutrition requirements of finishing pigs set forth in the Swine NRC. Treatment diets included the follow oil sources, control - choice white grease (CON), commodity soybean oil (CS), coconut oil (CO), control+Missouri high oleic soybean oil (C+MOS), Missouri High Oleic Soybean Oil (MOS), 4% Missouri high oleic soybean oil (MOS4), Plenish (P), and 4% Plenish. All pigs were provided ad libitum access to feed and water until the time of slaughter. Pig weights and quantity of feed consumed by each animal were recorded on days 0, 14, and 28.

Recorded weights were used to determine average daily gain, feed intake, and feed to gain ratio. On day 28, pigs were slaughtered under USDA inspection at a target finished weight of 280 lbs. (127 kg.). The late-start finishing group were slaughtered 14 days following the early-start finishing group. Carcasses were weighed, then chilled for 24 hours. After 24 hours, carcass measurements were recorded per the methods described below. After 48 hours, carcasses were fabricated to obtain the samples needed to analyze pork and fat quality using the methods outlined below.

Methodology

Growth Performance

The body weight and feed consumption of all pigs were recorded on days 0, 14, and 28, with feed consumption calculated from recorded weights of feed in and residual feed. These measurements were then used to calculate average daily gain, total feed intake, and feed to gain.

Carcass Measurements

Hot carcass weights (HCW) were recorded immediately after slaughter and used with the final live weight to calculate a dressing percentage for each animal. Loin eye area, backfat thickness at the tenth rib, and fat thickness at the last rib will be taken 24 hours postmortem from the right side of each carcass between the 10^{th} and 11^{th} ribs. Loin eye area was measured in square inches using a grid with which 20 dots equals 1 square inch. 10^{th} rib fat thickness was measured in tenths of an inch using a ruler probe at ¾ around the loin eye from the backbone on the ribbed surface. Last rib fat thickness was measured in tenths of an inch using a ruler probe and taken adjacent to the split surface of the backbone, next to the last rib.

Loin and Ham pH

A portable pH probe was utilized to collect pH readings from the loin and ham of the right side of each carcass. Measurements were taken at the same location and depth of the loin and ham. Ham pH readings were taken from the semimembranosus just above the aitch bone. Readings for loin pH were taken from the longissimus dorsi between the 9^{th} and 10^{th} vertebrae. A pH reading was recorded once the pH value reached a settling point.

Subjective Marbling and Color Score

A subjective marbling score and color score will be determined for each animal by visual evaluation of marbling and color in the loin eye at the ribbed surface between the 10^{th} and 11^{th} ribs. Amounts of marbling and color observed within each loin eye (longissimus dorsi) were compared to marbling and color scorecards from the National Pork Board. This yielded a numerical score for marbling and color within the loin of each carcass.

Moisture and Fat Content

A loin chop sample taken from the 1oth rib of the longissimus dorsi of the right side of each carcass. Loin chop samples were analyzed for moisture and fat content, using CEM and Rapid Fat Analyzer. Samples were analyzed in triplicate. Results were expressed as content percentage.

Fatty Acid Analysis

Fatty acid profiles of fat depot (jowl, subcutaneous, intermuscular, and intramuscular) samples were determined according to an adaptation of the methodologies described by Folch et al. (1957) and Morrison and Smith (1964). At the moment of analysis, approximately 1 g of sample is homogenized in 5 mL of chloroform:methanol ($CHCl_3$:CH_3OH, 2:1, v/v) in a glass tube to extract lipids and samples are filtered through a sintered glass funnel fitted with a Whatman 2.4 cm GF/C filter. A volume of 8 mL of 0.74% KCl is added to each sample and

after two hours of rest, two distinct phases formed. The upper phase is carefully removed and discarded while the lower phase was evaporated to dryness with nitrogen gas in a heated water bath at 70°C. At the point of dryness, 1 mL of 0.5 N KOH in MeOH is added to each tube and heated for 10 minutes in a 70°C water bath. Following this, 1 mL of 14% boron trifluoride (BF_3) in MeOH is added and samples are flushed with nitrogen and heated in the 70°C water bath for an additional 30 minutes in order to form fatty acid methyl esters (FAME). After cooling to room temperature, FAMEs are extracted by adding 2 mL of HPLC grade hexane and 2 mL of saturated NaCl. Two distinct layers formed; the upper layer is removed and added to approximately 800 mg of Na_2SO_4. At this point, an additional 2 mL of hexane are added to the tube containing NaCl and once more, the upper layer is removed and added to the tube containing Na_2SO_4. The hexane portion is removed from the salt and added to a labeled scintillation vial. The salt is rinsed a final time with 1 mL of hexane and the liquid was added to the vial. Samples are evaporated to dryness in a water bath at 70°C under nitrogen flow. Lastly, samples are reconstituted with 1 ml HPLC grade hexane and transferred to gas chromatograph vials.

The stable FAMEs are loaded into a Varian 3800 gas chromatograph (Varian, Palo Alto, CA) to determine fatty acid profiles. The GC column utilized id a fused silica capillary column (SPTM – 2560; 100 m x 0.25 mm x 0.2 μm film thickness; Supelco, Bellefonte, PA). Temperature of the injector is held constant at 240°C and temperature of the flame-ionization detector is held at 260°C. The oven operates at 140°C for 5 min, then temperature programmed at 2.5°C/min to 240°C and held for 16 min. Helium, the carrier gas, is maintained at a constant pressure of 255.11 kPa. Individual fatty acid areas are normalized and so that the area under each peak represents a percentage of the total area. Total saturated fatty acid (SFA),

monounsaturated fatty acids (MUFA) and polyunsaturated fatty acid (PUFA) contents are calculated according to the following equations: SFA = (C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0 + C23:0); MUFA = (C14:1 + C15:1 + C16:1 + C17:1 + C18:1n9t + C18:1n9c + C18:1n7 + C20:1 + C22:1n9 + C24:1); PUFA = (C18:2n6t + C18:2n6c + C18:3n6 + C18:3n3 + C18:9c11t + C18:10t12c + C18:9c11c + C18:9t11t + C20:2 + C20:3n6 + C20:3n3 + C20:4n6 + C22:5n3 + C22:6n3). The ratio between PUFAs and SFAs is calculated using the equation: [(C18:2n6c) + (C18:3n3)]/[(C14:0 + C16:0 + C18:0)]. The following equations are used to calculated total omega 3 and omega 6 fatty acid content: total omega 3 = C18:3n3 + C20:3n3 + C22:5n3 + C22:6n3); total omega 6 = (C18:3n6 + C20:3n6 + C20:4n6).

Bacon Slice Yield and Quality

Green bellies that were vaccum sealed and frozen during fabrication were processed into slab bacon and sliced under commercial settings. Prior to analyzing each slab, 10 slices were removed from the shoulder and flank ends to account for end damage to slices from processing. Each slab of bacon was analyzed for the number of total slices, number one slices, number two slices, shattered slices, irregular slices, fish hook slices, and evidence of bone in slices.

Statistical Analysis

Collected data was analyzed using SAS 9.4. The least squares mean and standard error were determined for variable according to treatment. An analysis of variance of least squares means of treatments for pre-established variable was conducted using PROC GLM to determine if there was an effect of treatment, within each group. Level of significance was set at $P < 0.05$.

Results

Growth Performance

A detailed list of data for growth performance of both groups can be found in Table 3. Animal growth performance, as described by ADG and F:G, was not significantly affected by the source of dietary oil in either group of pigs. Furthermore, no differences were observed for final body weight and feed consumption between treatments, within either group. Thus treatment had no statistically significant effect on ADG and F:G for either group.

Carcass Yield and Quality Measurements

A complete listing of carcass measurements of composition and quality for both groups of finishing pigs are outlined in Table 4. Results for of carcass measurements for the early group were not significantly difference. Source of dietary oil included in the treatment diets showed no impact on carcass yield when it comes to HCW, dressing percent, LEA, last rib and 10^{th} rib fat thickness. Furthermore, no treatment effect was detected when looking at the quality indicators of marbling score, color score, loin pH, and ham pH.

Treatment effect was observed at both a significant and trend level for variables of carcass composition and quality within the late group. A significant difference ($P = 0.031$) in loin eye area was detected between the treatments of CO and MOS4 (8.88 $in.^2$ vs 7.26 $in.^2$). The remain treatments were statistically similar in measurable loin eye area. Results from the late group also indicated a tendency ($P = 0.069$) for differences in ham pH. Dietary oil source showed no effect on the variables of HCW, dressing percentage, last rib fat thickness, 10^{th} rib fat thickness, marbling score, color score, and loin pH.

Fat and Moisture Content

The results for the moisture and fat content of loin chops for both groups, can be found in Table 5. Analysis indicated no significant differences across treatments. This outcome was shared by both groups of finishing pigs.

Bacon Slice Yield and Quality

Bacon slice yield and quality measurements for both groups are outlined in Table 6. No detectable differences were found amongst the treatments for bacon slice yield and quality, within the early-start finishing group. Analysis of the bacon slice yield and quality data from the late group only showed a tendency ($P = 0.051$) for treatment effect in the yield of Number 1 slices. No other effect of treatment was found within the late-start finishing group for the remaining variables of bacon slice yield and quality.

Fatty Acid Profile Analysis

Results of fatty acid profile of fat depots are pending further analysis.

Discussion

The outcome of growth performance results proved to match our hypothesis. As treatment diets were balanced for energy requirements, it can be expected that little to no difference would be seen in the resulting growth performance data, as all treatment received adequate energy supply regardless of source. As a result of no evidence of reduced feed intake, combined with similar growth performance, provides support to the idea that finisher pig diets can be reformulated to include novel high oleic soybean oil, regardless of source.

While results from the carcass analysis of the early-start finishing group showed no significant effect of dietary oil treatment, the same cannot be said for the late-start finishing

group. The size differences detected in loin eye area between the CO and MOS4 treatments, is most likely the result of the proportional increase in carcass of the CO treatment compared to the MOS4 treatment. It should be noted however, that no significant difference was observed for HCW among treatments. Results from the carcass analysis of both groups further support the case that traditionally dietary oil sources can be replaced successfully with novel high oleic soybean oils, without resulting in deleterious effects on carcass weights and lean meat yields. Furthermore, the resulting lack of detectable differences in the analyzed variables of fresh meat quality, is evidence of little impact that dietary inclusion of novel high oleic soybean oil would have on the fresh pork supply chain.

While the majority of parameters of bacon slice yield and quality showed little difference as a result of dietary treatment across both groups, the late-start finishing group did show a tendency for treatment effect on the yield of number 1 slices. The increase in the number of number 1 slices from CO slabs is evidence of the potential for fatty acid profile of monogastrics to mirror that found in the diet, which has been supported by previous research from our lab. The greater proportion of saturated fatty acids found in the diet containing coconut oil, most likely increased the quantity of number one slices by altering the fatty acid profile of the CO treatment bellies to include a greater proportion of saturated fatty acids. This would result in firmer bellies that allow for easier fabrication, yielding a thicker and more uniform belly for bacon processing. Pending analysis of samples for fatty acid profile will provide further insight into potential uptake and resulting effects of fatty acids.

References

Aberle, E. D., Forrest, J. C., Gerrard, D. E., and Mills, E. W. (2012). *Principles of Meat Science*, 5th Edition. Kendall Hunt, Dubuque, IA.

Cameron, N.D., and Enser, M.B. (1991). Fatty acid composition of lipid in Longissimus dorsi muscle of Duroc and British Landrace pigs and its relationship with eating quality. *Meat Science*, 29(4), 295–307.

Cameron, N.D., Enser, M., Nute, G.R., Whittington, F.M., Penman, J.C., Fisken, A.C., Perry, A.M., and Wood, J.D. (2000). Genotype with nutrition interaction on fatty acid composition of intramuscular fat and the relationship with flavour of pig meat. *Meat Science*, 55(2), 187–195.

Delgado, G. E., Kramer, B. K., Lorkowski, S., Marz, W., Schacky, C. V., and Kleber, M. E. (2017). Individual omega-9 monounsaturated fatty acids and mortality-The Ludwigshafen Risk and Cardiovascular Health Study. *Journal of Clinical Lipidology*, 11, 126-135.

FAO-WHO (2008). Interim summary of conclusions and dietary recommendations on total fat & fatty acids. Retrieved from http://www.fao.org/ag/agn/nutrition/docs/Fats%20and%20Fatty%20Acids%20Summary.pdf

FDA. (2015). Final Determination Regarding Partially Hydrogenated Oils. 80 FR 34650, 2015-14883, 34650-34670.

Fernando, L. N., Berg, E. P., and Gruen, I. U. (2003). Quantitation of hexanal by automated SPME for studying dietary influences on the oxidation of pork. *Journal of Food Composition and Analysis*, 16, 179-188.

Folch, J., M. Lees, and S. G. H. Stanley. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem*, 226, 497-509.

Gillingham, L.G., Harris-Janz, S., & Jones, P.J.H. (2011). Dietary monounsaturated fatty acids are protective against metabolic syndrome and cardiovascular disease risk factors. *Lipids*, 46(3), 209–228.

Morrison, W. R., and Smith, L. M. (1964). Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. *J. Lipid Res*, 5, 600-608.

NAMI. 2014. *The Meat Buyer's Guide*, 8th Edition. North American Meat Institute, Washington, DC.

Rentfrow, G. T., Sauber, T. E., Allee, G. L., and Berg, E. P. (2003). The influence of diets containing either conventional corn, conventional corn with choice white grease, high corn oil, or high oil high oleic corn on belly/bacon quality. *Meat Science*, 64, 459-466.

Schwingshackl, L., and Hoffmann, G. (2014). Monounsaturated fatty acids, olive oil and health status: a systematic review and meta-analysis of cohort studies. *Lipids Health Dis*. 13, 154.

Tarladgis, B. G. (1960). A distillation method for the quantitative determination of malonaldehyde in rancid foods.

Tikk, K., Tikk,M., Aaslyng, M.D., Karlsson, A.H., Lindahl, G., and Andersen, H.J. (2007). Significance of fat supplemented diets on pork quality — Connections between specific fatty acids and sensory attributes of pork. *Meat Science*, 77(2), 275–286.

United Soybean Board. (2017). High Oleic Soybeans. Retrieved from http://unitedsoybean.org/media-center/issue-briefs/high-oleic-soybeans/. Accessed July 24, 2017.

Yang, Z. H., Gordon, S. M., Sviridov, D., Wang, S., Danner, R. L., Pryor, M., Vaisman, B., Shichijo, Y., Doisaki, N., and Remaley, A. T. (2017). Dietary supplementation with long-chain monounsaturated fatty acid isomers decreases atherosclerosis and alters lipoprotein proteomes in LDLr-/- mice. *Atherosclerosis*, 262, 31-38.

Table 1. Composition of swine finisher treatment diets containing various dietary oils.

	Treatment Diets							
Ingredient, lbs.	CON	CS	CO	C+MOS	MOS	MOS4	P	P4
Corn	1504.70	1504.70	1504.7	1504.70	1504.70	1484.70	1504.70	1484.70
SBM 48	380.0	380.00	380.00	380.00	380.00	380.00	380.00	380.00
CWG	60.00	-	-	30.00	-	-	-	-
Commodity Soy Oil	-	60.00	-	-	-	-	-	-
Coconut Oil	-	-	60.00	-	-	-	-	-
MO High Oleic Soy Oil	-	-	-	30.00	60.00	80.00	-	-
Plenish	-	-	-	-	-	-	60.00	60.00
Dical	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
Limestone	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50
Salt	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
L-Lysine	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Methionine	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
L-Threonine	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
Vitamin Premix	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Trace Mineral Premix	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00

[1]CON = Control, CS = Commodity Soybean Oil, CO = Coconut Oil, C+MOS = Control + Missouri High Oleic Soybean Oil, MOS = Missouri High Oleic Soybean Oil, MOS4 = 4% Missouri High Oleic Soybean Oil, P = Plenish, P4 = 4% Plenish

Table 2. Feed Analysis of swine finisher treatment diets containing various dietary oils.

	Treatment Diets							
Item	CON	CS	CO	C+MOS	MOS	MOS4	P	P4
Crude Protein, %	15.96	14.34	15.59	16.62	17.72	15.36	17.27	17.87
Crude Fat, %	4.70	4.70	4.19	5.94	4.90	6.04	5.15	6.20
Crude Fiber, %	2.38	2.38	2.27	3.21	2.29	2.35	2.70	2.85
Moisture, %	11.98	11.81	11.87	11.41	11.43	11.64	11.70	11.55
Ash, %	4.35	4.17	3.89	4.57	4.39	4.15	4.70	4.32
Lysine, %	1.04	1.11	1.00	1.09	1.08	1.07	1.03	1.04
Methionine, %	0.33	0.33	0.33	0.30	0.27	0.32	0.38	0.30
Tryptophan, %	0.18	0.20	0.18	0.18	0.19	0.18	0.17	0.17

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Table 3. Growth Performance least squares means of early- and late-start finishing pigs fed various dietary oils.

		Treatments[1]									
Group	Item[A]	CON	CS	CO	C+MOS	MOS	MOS4	P	P4	SEM	P-value
Early	Final BW, kg.	133.91	132.27	127.73	125.09	133.09	126.36	128.46	124.09	4.20	0.587
	Feed Consumption, kg.	85.54	91.08	82.36	87.10	89.95	88.22	88.62	83.58	4.99	0.912
	ADG, kg.	0.92	1.01	0.85	0.87	1.01	0.88	1.04	0.89	0.08	0.601
	F:G	3.32	3.24	3.62	3.61	3.20	3.75	3.15	3.39	0.25	0.604
Late	Final BW, kg.	118.46	117.73	124.27	120.91	123.36	114.46	118.98	116.55	3.12	0.232
	Feed Consumption, kg.	82.36	77.62	79.97	76.78	77.98	76.38	80.44	66.11	4.93	0.318
	ADG, kg.	0.90	0.79	0.89	0.72	0.95	0.82	0.94	0.76	0.10	0.463
	F:G	3.36	3.55	3.37	3.84	2.94	3.37	3.16	3.79	0.35	0.537

[A] LS means with in a row with similar superscripts do not differ at P<0.05.

[1]CON = Control, CS = Commodity Soybean Oil, CO = Coconut Oil, C+MOS = Control + Missouri High Oleic Soybean Oil, MOS = Missouri High Oleic Soybean Oil, MOS4 = 4% Missouri High Oleic Soybean Oil, P = Plenish, P4 = 4% Plenish

Table 4. Carcass composition and quality of early- and late-start finishing pigs fed various dietary oils.

		Treatments[1]									
Group	Item[A]	CON	CS	CO	C+MOS	MOS	MOS4	P	P4	SEM	P-value
Early	HCW, kg.	105.73	104.77	100.32	98.64	105.09	99.64	100.91	97.64	3.59	0.615
	Dressing Percent	78.92	79.20	78.52	78.84	78.94	78.82	78.54	78.70	0.73	0.998
	LEA, in.^{2}	8.95	8.84	8.22	7.49	8.70	8.42	8.52	8.04	0.43	0.311
	Last Rib Fat, in.	1.25	1.26	1.18	1.22	1.31	1.30	1.27	1.24	0.08	0.952
	10th Rib Fat, in.	0.88	1.01	0.95	1.02	1.10	1.05	0.99	0.96	0.10	0.836
	Marbling Score	3.00	3.60	3.80	3.40	2.80	3.00	3.40	2.80	0.62	0.915
	Color Score	3.20	2.80	3.00	2.80	3.00	2.20	2.60	2.80	0.33	0.555
	Loin pH	5.61	5.63	5.61	5.62	5.57	5.65	5.63	5.63	0.02	0.436
	Ham pH	5.69	5.66	5.68	5.69	5.66	5.71	5.67	5.68	0.03	0.826
Late	HCW, kg.	92.64	93.27	97.73	95.80	96.55	89.00	93.64	90.91	2.15	0.056
	Dressing Percent	78.24	79.28	78.70	79.30	78.28	77.72	78.75	78.04	0.88	0.830
	LEA, in.^{2}	7.47^{ab}	8.02^{ab}	8.88^{a}	7.65^{ab}	8.30^{ab}	7.26^{b}	8.23^{ab}	8.19^{ab}	0.43	0.031
	Last Rib Fat, in.	1.27	1.42	1.34	1.39	1.41	1.31	1.39	1.18	0.10	0.542
	10th Rib Fat, in.	0.86	0.95	0.85	1.09	0.91	0.82	0.86	0.75	0.09	0.269
	Marbling Score	3.20	3.20	1.80	2.75	2.80	2.40	3.00	4.20	0.79	0.468
	Color Score	3.00	2.80	2.60	2.75	3.20	3.20	3.00	3.60	0.38	0.566
	Loin pH	5.62	5.61	5.58	5.59	5.58	5.58	5.65	5.59	0.03	0.587
	Ham pH	5.73	5.66	5.64	5.70	5.65	5.65	5.77	5.66	0.03	0.069

[A] LS means with in a row with similar superscripts do not differ at P<0.05.

[1]CON = Control, CS = Commodity Soybean Oil, CO = Coconut Oil, C+MOS = Control + Missouri High Oleic Soybean Oil, MOS = Missouri High Oleic Soybean Oil, MOS4 = 4% Missouri High Oleic Soybean Oil, P = Plenish, P4 = 4% Plenish

Table 5. CEM Moisture and fat percentages of loin chops from early- and late-start finishing pigs fed various dietary oils.

		Treatments[1]									
Group	Item[A]	CON	CS	CO	C+MOS	MOS	MOS4	P	P4	SEM	P-value
Early	Moisture, %	73.48	72.91	72.66	71.96	73.81	72.97	72.57	73.00	0.51	0.331
	Fat, %	1.76	2.27	2.50	2.74	1.86	2.03	2.50	2.16	0.51	0.805
Late	Moisture, %	73.39	72.47	74.49	72.42	73.88	73.07	73.20	73.55	0.59	0.201
	Fat, %	2.00	2.59	1.43	2.42	1.83	2.40	2.31	2.39	0.52	0.743

[A] LS means with in a row with similar superscripts do not differ at P<0.05.

[1]CON = Control, CS = Commodity Soybean Oil, CO = Coconut Oil, C+MOS = Control + Missouri High Oleic Soybean Oil, MOS = Missouri High Oleic Soybean Oil, MOS4 = 4% Missouri High Oleic Soybean Oil, P = Plenish, P4 = 4% Plenish

Table 6. Bacon slice yield and quality of early- and late-start finishing pigs fed various dietary oils.

		Treatments[1]									
Group	Item[A]	CON	CS	CO	C+MOS	MOS	MOS4	P	P4	SEM	P-value
Early	Total Slices	65.00	60.00	60.00	62.20	64.40	62.20	60.20	57.80	2.65	0.560
	Number 1 Slices	22.40	18.40	26.20	19.60	17.40	16.75	23.40	19.20	3.32	0.345
	Number 2 Slices	22.80	18.00	16.40	15.40	18.80	22.60	16.20	16.40	3.27	0.603
	Shattered Slices	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
	Irregular Slices	24.75	23.60	17.40	24.00	28.20	26.20	20.60	22.20	5.34	0.836
	Evidence of Bone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
	Fish Hook Slices	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Late	Total Slices	65.00	58.40	61.20	61.25	60.80	60.80	61.50	58.80	2.50	0.595
	Number 1 Slices	22.75	14.8	24.40	17.25	22.33	14.00	19.00	18.20	2.87	0.051
	Number 2 Slices	25.20	18.20	17.40	25.50	22.80	24.25	19.50	18.60	3.99	0.579
	Shattered Slices	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
	Irregular Slices	21.60	25.25	19.40	18.50	24.60	33.00	23.00	22.00	6.49	0.767
	Evidence of Bone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-
	Fish Hook Slices	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	-	-

[A] LS means with in a row with similar superscripts do not differ at P<0.05.

[1]CON = Control, CS = Commodity Soybean Oil, CO = Coconut Oil, C+MOS = Control + Missouri High Oleic Soybean Oil, MOS = Missouri High Oleic Soybean Oil, MOS4 = 4% Missouri High Oleic Soybean Oil, P = Plenish, P4 = 4% Plenish