Evaluation of Essential Fatty Acids in Lactating Sow Diets on Sow Reproductive Performance, Colostrum and Milk Composition, and Piglet Survivability[1]

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Summary

A total of 3,451 mixed parity sows and their litters were used to evaluate the effects of essential fatty acid intake on sow reproductive performance, piglet growth and survivability, and colostrum and milk composition. At approximately d 112 of gestation, sows were blocked by parity within farrowing room and randomly assigned to 1 of 4 experimental treatments. Lactation diets were corn-soybean meal-wheat-based and included 0.5 (Control) or 3% choice white grease (CWG), 3% soybean oil (SO), or a combination of 3% soybean oil and 2% choice white grease (Combination). Thus, sows were provided diets with low essential fatty acid (EFA; as linoleic [LA] and α-linolenic acid [ALA]) in diets with choice white grease or high EFA in diets with soybean oil. Prior to farrowing, sows were provided 4 lb/d of their assigned lactation diet and then allowed *ad libitum* access after parturition. Overall lactation ADFI increased ($P < 0.001$) when sows were fed the Combination and CWG treatments compared to sows fed the Control or diet with 3% SO. Regardless of differences among ADFI, daily LA and ALA intake of sows assigned to the Combination and SO treatments were greater ($P < 0.001$) than sows fed diets with lower EFA provided as CWG. There was no effect of sow EFA intake on piglet survivability from birth to 24 h or from 24 h to weaning ($P > 0.10$). Overall, sows consuming high EFA provided in the Combination and SO diets produced litters with greater ($P < 0.05$) litter gain and litter ADG during the lactation period and heavier ($P < 0.001$) piglet weaning weights when compared to litters from sows fed diets with low EFA provided through CWG. Lactation diet EFA composition did not influence colostrum or milk dry matter, crude protein, or crude fat content ($P > 0.10$). However, LA and ALA content in both colostrum and milk at weaning increased ($P < 0.05$) in response to increased EFA levels in diets that contained SO. There was no evidence for differences ($P > 0.10$) in wean-to-estrus

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interval, percentage of sows bred by d 7, percentage of sows bred by d 12, farrowing rate, or subsequent farrowing performance due to sow lactation EFA intake. In conclusion, increased LA and ALA intake during the lactation period from soybean oil addition increased overall litter growth and average weaning weights of pigs but did not affect piglet survivability or subsequent reproductive performance of sows.

Introduction

Supplemental fat sources are effective and widely accepted methods to increase energy density of sow diets. Some sources of fat can provide essential fatty acids (EFA), such as linoleic acid (LA) and alpha-linolenic acid (ALA), that support neonatal brain, vision, and immune system development and function. Previously, researchers have observed changes in milk fat or fatty acid composition as a reflection of dietary fatty acid composition when supplemented in mid- to late-gestation[5,6] which may improve pre-weaning piglet survival.[7] However, the influence of supplemental fat source and EFA concentration on colostrum and milk composition provided shortly prior to farrowing are not fully understood. Furthermore, Rosero et al.[8] concluded that sows remaining in a negative EFA balance may enter a state of deficiency that impairs subsequent reproductive function and later suggested that dietary EFA intake should exceed 125 g/d LA and 10 g/d ALA to maximize reproductive performance.[9] Additionally, Australian Pork Ltd[10] observed a reduction in piglets born dead when sows were fed diets containing 120 g/d LA compared to 70 g/d of LA beginning at entry to the farrowing room. Therefore, the objective of this study was to determine the influence of fat source providing low and high EFA intake on sow performance, litter growth and livability, colostrum and milk composition, and subsequent reproductive performance.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This trial was conducted between August 2020 and July 2021 at a Smithfield commercial research farm in Milford, UT. All diets were manufactured by a Smithfield-owned feed mill located near Milford, UT.

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Animals and diets

A total of 3,451 mixed-parity sows were used in this experiment (Smithfield Premium Genetics; parity = 4.8 ± 1.8; initial BW = 551.9 ± 58.7 lb). On approximately d 112 of gestation, sows were blocked by parity within farrowing room and randomly assigned to 1 of 4 dietary treatments. Experimental lactation diets were pelleted corn-soybean meal-wheat-based and included supplemental fat as either 0.5 (Control) or 3% (CWG) choice white grease, 3% soybean oil (SO), or a combination of 3% soybean oil and 2% choice white grease (Combination). Thus, sows were provided diets with low and high EFA and were projected to have daily EFA intakes as follows: Control: 89 g/d LA and 5 g/d ALA; SO: 189 g/d LA and 19 g/d ALA; CWG: 109 g/d LA and 6 g/d ALA; and Combination: 205 g/d LA and 20 g/d ALA (assumed 14 lb ADFI). The treatment structure also allowed comparison of increasing fat levels at 0, 3, and 5% and direct comparison of 3% CWG and 3% SO.

All diets were formulated to meet or exceed NRC[11] requirement estimates with a constant SID Lys:ME ratio for all diets, with SID Lys increasing from 1.07 to 1.14% with the fat additions (Table 1). Prior to farrowing, sows were provided 4 lb/d of their assigned lactation treatment and then allowed *ad libitum* access after parturition. Sow feed intake was monitored by daily recording of feed additions and weighing remaining feed at weaning.

Sow body weight, backfat depth at the P2 position, and body condition caliper scores were recorded at entry to the farrowing rooms and again at weaning. Within 24 h of parturition, litter sizes were standardized through cross-fostering of pigs within treatment. During parturition, pigs born alive, stillborn, and mummified were weighed and recorded. Litters were then weighed after cross-fostering at 24 h and on the day prior to weaning to evaluate litter growth performance. All instances and reason for piglet mortalities were recorded within 24 h of parturition and then through the remaining lactation period.

Within 3 h of the onset of parturition, colostrum was collected from a subset of 40 sows (n = 10 sows/treatment) by hand stripping all functional teats, with an attempt to collect equal samples from all teats for one representative sample. Milk samples were also collected as previously described one day prior to weaning. To initiate milk letdown at weaning, 10 IU of oxytocin was administered via IM injection. All samples were immediately frozen and stored at -20°F until analysis.

Any sow that did not complete a full lactation period was removed from the final dataset prior to analysis (n = 344 sows). Reasons for early lactation removal included sow prolapses, early weaning, and mortalities. Additionally, nurse sows and sows with mixed litters after cross-fostering were removed from the final dataset (n = 241 sows).

On the day of weaning, sows were moved to individual gestation stalls and checked daily for signs of estrus. Wean to first service interval and the percentage of sows bred by d 7 and 12 were recorded on a total of 2,938 sows that remained after culling. Farrowing rate and subsequent farrowing performance including total born, born alive,

[11] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

stillborn, and mummifies were also evaluated. During this subsequent performance period, all sows consumed a common gestation and lactation diet.

Chemical analysis

Feed samples were collected once weekly and pooled by month from August 2020 to February 2021. One sample per month (n = 6/treatment) were then sent for proximate and fatty acid profile analysis (Midwest Labs, Omaha, NE; and the University of Missouri, ESCL, Columbia, MO, respectively; Table 2). Colostrum and milk samples were analyzed for dry matter, crude protein, crude fat, and fatty acid profile analysis (University of Missouri ESCL, Columbia, MO).

Statistical analysis

Data were analyzed using the GLIMMIX procedure in SAS (v. 9.4, SAS Institute, Inc., Cary, NC) and considered sow (litter) as the experimental unit. The statistical model considered fixed effects of dietary treatment and random effects of farrowing turn and room. The statistical model also evaluated linear and quadratic contrasts of dietary fat inclusion. The following data responses were fitted by a Poisson distribution in the statistical model: parity, functional teats, and litter size at farrowing, start, and weaning. Additionally, the following data responses were fitted by a binomial distribution in the statistical model: percentage of pigs born alive, stillborn, mummified, survival of pigs from birth to 24 h and from 24 h to wean, percentage of sows bred by d 7 and d 12, and farrowing rate. All data are reported as least square means and considered statistically significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Sow performance

Average parity, pre-farrow days of lactation diet consumption, overall lactation length, and the number of functional teats per sow were consistent across experimental treatments ($P > 0.10$; Table 3). Although there was no evidence for differences among sow body weights at entry or weaning ($P > 0.10$), sows that consumed the Combination diet with 5% added fat tended ($P = 0.090$) to lose less BW during the lactation period compared to sows consuming diets with either 0.5 or 3% CWG, with the SO treatment intermediate. However, backfat depth of sows fed the Combination fat diet was lower at weaning compared to all other treatments ($P = 0.046$) even though backfat loss was not different among treatments.

During lactation, feed intake was greater when sows were fed the Combination and CWG diets compared to sows consuming the Control and SO diets. Sows assigned to the Combination fat diet had greater ($P < 0.001$) LA and ALA daily intakes compared with all other treatments. Despite lower lactation feed intake, sows that consumed diets that contained 3% SO still consumed greater ($P < 0.001$) LA and ALA intakes compared with sows fed the Control and 3% CWG diets. Most importantly, these responses confirm that sows assigned to the SO and Combination treatments exceeded the recommended LA and ALA intakes suggested by Rosero et al.[9] while diets only containing CWG did not.

Total pigs born and born alive were not influenced ($P > 0.10$) by dietary treatments, which were provided approximately 5 d prior to farrowing. However, the average count of stillborn pigs per litter was greater ($P = 0.034$) for sows fed the Combination 5% fat diet compared to sows fed diets with either 0.5 or 3% CWG, while sows fed SO were intermediate. Overall, there was no influence ($P > 0.10$) of lactation treatments on piglet survivability from birth to 24 h or from 24 h to weaning.

Litter performance

There was no evidence for differences among piglet survivability, and litter sizes at birth, 24 h, and weaning were similar across treatments ($P > 0.10$; Table 4). Furthermore, there was no evidence for difference ($P > 0.10$) in litter or average piglet weights at birth or 24 h after birth. However, sows fed diets with high EFA provided in the Combination and SO diets produced litters with greater ($P < 0.05$) total litter gain and litter ADG, resulting in higher litter weaning weights than litters from sows provided low EFA from diets containing CWG at 0.5 or 3%. These litter growth responses mirrored heavier piglet weaning weights and piglet ADG ($P < 0.001$) for litters from sows fed the Combination and SO diets when compared to litters from sows fed diets with low EFA provided through CWG.

Colostrum and milk composition

Supplemental fat source and EFA composition did not influence ($P > 0.10$) average dry matter, crude protein, and crude fat composition of colostrum or milk at weaning (Table 5). Although crude fat percentage was not influenced by supplemental fat source in lactation diets consumed prior to farrowing, EFA composition of colostrum increased ($P < 0.05$) in response to the increased EFA composition of diets that contained SO. These modifications in colostrum composition appear to be maintained throughout lactation where sow milk at weaning contained increased ($P < 0.001$) concentrations of both LA and ALA when supplemental fat was provided by SO rather than CWG.

Subsequent reproductive performance

There was no evidence for differences in wean-to-estrus interval, percentage of sows bred by d 7, percentage of sows bred by d 12, or farrowing rate among treatments ($P > 0.10$; Table 6). Additionally, there was no influence of lactation diet supplemental fat source and EFA intake on subsequent farrowing performance.

In summary, sows that consumed diets with greater EFA composition produced litters with greater lactation ADG and heavier weaning weights when compared to sows with lower daily EFA intakes provided through CWG. Although dry matter, crude protein, and crude fat composition of colostrum and milk were not influenced by supplemental fat sources and EFA composition of lactation diets, EFA composition of colostrum and milk at weaning were greater for sows that consumed diets with higher EFA which may have supported litter performance. However, sow EFA intake did not influence piglet survivability in the first 24 h or through the remainder of lactation. Lactation EFA intake did not influence subsequent reproductive or farrowing performance of sows.

Table 1. Diet composition (as-fed basis)

Item	Control	SO	CWG	Combination
Ingredient, %				
Corn	42.69	37.67	37.87	33.98
Soybean meal, 47% CP	27.45	29.85	29.50	31.50
Wheat, soft white	25.00	25.00	25.00	25.00
Choice white grease	0.50	---	3.00	2.00
Soybean oil	---	3.00	---	3.00
Calcium carbonate	1.10	1.10	1.10	1.10
Monocalcium P, 21% P	1.15	1.25	1.25	1.30
Salt	0.50	0.55	0.55	0.55
Liquid Lys, 50%	0.38	0.36	0.36	0.34
Liquid Met, 88%	0.05	0.05	0.05	0.05
L-Thr	0.07	0.07	0.07	0.07
Choline chloride, 60%	0.05	0.05	0.05	0.05
Trace mineral premix	0.12	0.12	0.12	0.12
Vitamin premix	0.06	0.06	0.06	0.06
Miscellaneous[1]	0.88	0.87	1.02	0.88
Total	100.00	100.00	100.00	100.00
Calculated analysis				
SID AA, %				
Lys	1.03	1.07	1.07	1.10
Ile:Lys	68	72	71	74
Met:Lys	29	30	30	30
Met and Cys:Lys	56	57	57	58
Thr:Lys	66	69	68	70
Trp:Lys	20	21	21	22
Val:Lys	77	81	80	83
ME, kcal/lb	1,450	1,509	1,495	1,548
SID Lys:ME, g/Mcal	3.22	3.22	3.22	3.22
CP, %	19.2	19.9	19.8	20.4
Crude fat, %	2.58	4.91	4.92	6.79
Ca, %	0.70	0.73	0.73	0.74
Available P, %	0.41	0.43	0.43	0.44
Linoleic acid, %	1.29	2.79	1.38	2.87
α-Linolenic acid, %	0.07	0.38	0.08	0.39

[1]Includes laxative product, flow agent, and dye coloring for treatment identification.
SO = soybean oil. CWG = choice white grease.

Table 2. Chemical analysis of diets (as-fed basis)[1,2]

Item, %	Control	SO	CWG	Combination
DM	87.28	87.88	87.26	87.77
CP	19.6	20.0	19.8	20.6
Crude fat	2.53	4.84	4.76	6.52
Acid detergent fiber	3.09	3.00	3.11	3.14
Ash	5.42	5.57	5.59	5.65
Linoleic acid[3]	1.25	2.64	1.54	2.88
α-Linolenic acid[3]	0.09	0.35	0.12	0.39

[1]Experimental treatments contained supplemental fat at 0.5% (Control), 3% (soybean oil, SO; or choice white grease, CWG), or 5% (Combination). Diet samples were collected once weekly and pooled by month prior to analysis. Values represent the average analyzed composition from 6 samples collected between August 2020 to February 2021.
[2]Proximate analysis was completed by Midwest Laboratories (Omaha, NE).
[3]Fatty acid profile analysis was completed by the University of Missouri Experiment Station Chemical Laboratories (Columbia, MO).

Table 3. Effects of dietary fat source and essential fatty acid intake on lactating sow performance[1]

Trait	Control	SO	CWG	Combination	SEM	Treatment *P* =
Sows, n	850	874	865	862	---	---
Parity	4.7	4.7	4.7	4.7	0.11	0.858
Pre-farrow days	4.6	4.6	4.6	4.6	0.12	0.528
Lactation length, d	24.1	24.0	24.1	24.1	0.11	0.733
Functional teats	14.9	14.9	14.9	14.9	0.13	0.999
Sow BW, lb						
d 112 gestation	548.0	548.9	550.5	549.2	2.85	0.832
Wean	535.5	539.0	537.7	539.7	3.12	0.478
Change[2]	-12.6[b]	-9.9[ab]	-12.6[b]	-9.1[a]	1.84	0.090
Sow backfat, mm						
d 112 gestation	12.2	12.3	12.3	12.0	0.13	0.219
Wean[2]	12.1[a]	12.0[a]	12.1[a]	11.7[b]	0.12	0.046
Change	-0.20	-0.25	-0.17	-0.22	0.085	0.857
Caliper score[4]						
d 112 gestation	1.8	1.8	1.8	1.8	0.02	0.496
Wean	2.1	2.1	2.1	2.1	0.03	0.807
Sow ADFI, lb						
Pre-farrow	4.00	4.00	4.00	4.00	0.003	0.546
Lactation[2,3]	14.64[b]	14.49[b]	15.05[a]	15.17[a]	0.086	< 0.001
Linoleic acid intake, g/d[2,5]	83.0[d]	173.6[b]	105.1[c]	198.4[a]	0.83	< 0.001
α-linolenic acid intake, g/d[2,3,5]	6.0[d]	23.0[b]	8.2[c]	26.9[a]	0.10	< 0.001
Total EFA intake, g/d[2,3,5]	88.9[d]	196.6[b]	112.6[c]	225.3[a]	0.93	< 0.001

continued

Table 3. Effects of dietary fat source and essential fatty acid intake on lactating sow performance[1]

Trait	Control	SO	CWG	Combination	SEM	Treatment $P =$
Farrowing performance						
Total pigs born, n	15.6	15.7	15.5	15.8	0.14	0.481
Pigs born alive, n	13.7	13.7	13.7	13.8	0.13	0.983
Stillborn, n[2]	1.39[b]	1.49[ab]	1.46[b]	1.62[a]	0.052	0.001
Mummy, n	0.40	0.42	0.36	0.39	0.024	0.263
Pigs born alive, %[2]	88.4[a]	87.9[ab]	88.3[ab]	87.4[b]	0.34	0.033
Stillborn, %[2]	8.9[b]	9.4[ab]	9.4[ab]	10.2[a]	0.30	0.003
Mummy, %	2.6	2.7	2.3	2.4	0.15	0.276
Piglet survivability, %						
Birth to 24 h[3,6]	89.9	89.3	89.1	89.6	0.33	0.167
24 h to wean[7]	89.7	90.0	90.0	89.6	0.33	0.751

[a-d]Means within row with different superscripts differ ($P < 0.05$).

[1]A total of 3,451 sows and their litters were used over 28-d experimental periods with 850 to 874 sows per treatment. Experimental treatments contained supplemental fat at 0.5% (Control), 3% (soybean oil, SO; or choice white grease, CWG), or 5% (Combination).

[2]Supplemental fat level effect, linear $P < 0.05$. EFA = essential fatty acid.

[3]Supplemental fat level effect, quadratic $P < 0.05$.

[4]A body condition caliper was placed at the last rib of the sow and recorded according to the following scale: 1 = thin, 2 = ideal, and 3 = fat.

[5]Calculated using analyzed LA and ALA values and overall lactation ADFI.

[6]Survival from birth to 24 h = [(Pigs born alive – count of mortality within 24 h)/Pigs born alive].

[7]Survival from 24 h to wean = count of pigs at weaning/count of pigs alive at 24 h.

Table 4. Effects of dietary fat source and essential fatty acid intake on litter performance[1]

Trait	Control	SO	CWG	Combination	SEM	$P =$
Sows, n	850	874	865	862	---	---
Litter size, n						
Start[2]	12.5	12.4	12.5	12.4	0.12	0.996
Wean	11.2	11.2	11.2	11.2	0.11	0.995
Litter weight, lb						
Total born	45.0	44.9	44.7	45.2	0.37	0.677
Born alive	41.2	40.9	40.9	40.9	0.36	0.881
Start[2]	39.1	39.0	39.1	38.7	0.30	0.528
Wean[6]	166.5[b]	170.0[a]	168.7[ab]	170.5[a]	1.37	0.028
Litter gain, lb[3,6]	127.4[b]	131.0[a]	129.5[ab]	131.7[a]	1.23	0.006
Litter ADG, lb[4,6]	5.43[b]	5.59[a]	5.53[ab]	5.62[a]	0.045	0.003
Piglet body weight, lb						
Total born	2.96	2.93	2.94	2.92	0.021	0.606
Born alive	3.05	3.03	3.03	3.02	0.021	0.689
Start[2]	3.14	3.15	3.14	3.12	0.019	0.620
Wean[6]	14.82[b]	15.17[a]	14.98[b]	15.21[a]	0.099	< 0.001
Piglet ADG, lb[5,6]	0.48[c]	0.50[a]	0.49[b]	0.50[a]	0.003	< 0.001

[a-c]Means within row with different superscripts differ ($P < 0.05$).

[1]A total of 3,451 sows and their litters were used over 28-d experimental periods with 850 to 874 sows per treatment. Experimental treatments contained supplemental fat at 0.5% (Control), 3% (soybean oil, SO; or choice white grease, CWG), or 5% (Combination).

[2]Start litter size represents litter size within 24 h of farrowing after cross-fostering within treatment.

[3]Litter gain = litter weight at wean – litter weight at start.

[4]Litter ADG = litter gain ÷ lactation length.

[5]Piglet ADG = Litter ADG ÷ count of pigs at wean.

[6]Supplemental fat level effect, linear $P < 0.05$.

Table 5. Effects of dietary fat source and essential fatty acid intake on colostrum and milk composition[1]

Trait	Control	SO	CWG	Combination	SEM	*P* =
Colostrum						
Dry matter, %	23.9	25.2	23.3	23.4	1.78	0.663
Crude protein, %	16.8	17.1	16.6	18.2	0.95	0.584
Crude fat, %	4.2	4.5	4.4	3.9	0.46	0.697
Linoleic acid, %[2]	22.6[b]	24.8[b]	23.0[b]	28.1[a]	1.34	0.012
α-Linolenic acid, %[2]	1.2[b]	1.9[a]	1.3[b]	2.1[a]	0.20	< 0.001
Milk, weaning						
Dry matter, %[2]	17.3	15.5	13.8	12.3	1.84	0.159
Crude protein, %	6.2	5.9	5.9	6.0	0.21	0.670
Crude fat, %	6.2	6.4	6.2	6.7	0.37	0.693
Linoleic acid, %[2,3]	12.7[b]	21.5[a]	14.0[b]	19.8[a]	0.61	< 0.001
α-Linolenic acid, %[2,3]	0.9[b]	2.8[a]	1.1[b]	2.6[a]	0.13	< 0.001

[ab]Means within row with different superscripts differ ($P < 0.05$).
[1]A total of 3,451 sows and their litters were used over 28-d experimental periods with 850 to 874 sows per treatment. Experimental treatments contained supplemental fat at 0.5% (Control), 3% (soybean oil, SO; or choice white grease, CWG), or 5% (Combination). A subset of 10 sows per treatment were randomly selected for analysis of colostrum and milk composition at weaning.
[2]Supplemental fat level effect, linear $P < 0.05$.
[3]Supplemental fat level effect, quadratic $P < 0.05$.

Table 6. Effects of dietary fat source and essential fatty acid intake on subsequent reproductive performance of sows[1]

Trait	Control	SO	CWG	Combination	SEM	*P* =
Wean to estrus interval, d	4.7	4.6	4.5	4.7	0.14	0.790
Bred by d 7, %	94.8	95.1	95.9	95.5	0.81	0.749
Bred by d 12, %	95.6	95.8	96.4	96.0	0.74	0.838
Farrowing rate, %	87.9	88.9	87.2	86.8	1.25	0.564
Farrowing performance						
Subsequent litters, n	648	655	637	637	---	---
Total born, n	14.6	14.4	14.6	14.4	0.15	0.563
Born alive, n	13.2	13.1	13.4	13.1	0.15	0.378
Stillborn, n[2]	1.0[a]	0.9[ab]	0.8[b]	1.0[a]	0.05	0.003
Mummy, n[3]	0.3	0.2	0.3	0.2	0.03	0.116

[ab]Means within row with different superscripts differ ($P < 0.05$).
[1]A total of 3,451 sows and their litters were used over 28-d experimental periods with 850 to 874 sows per treatment. Experimental treatments contained supplemental fat at 0.5% (Control), 3% (soybean oil, SO; or choice white grease, CWG), or 5% (Combination).
[2]Supplemental fat level effect, quadratic $P < 0.05$.
[3]Supplemental fat level effect, linear $P < 0.05$.