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Evaluation of Spray-Dried Animal Plasma and Select Menhaden Fish Meal in Transition Diets of Pigs Weaned at 12 to 14 Days of Age and Reared in Different Production Systems^{1,2}

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ABSTRACT: We conducted two experiments with pigs weaned at 12 to 14 d of age to evaluate the effects of adding spray-dried animal plasma (SDAP) and select menhaden fish meal (SMFM) to the diets fed from 5 to 19 (Exp. 1) and 7 to 21 d (Exp. 2) after weaning. This 14-d period represents the transition from the nutrient-dense diet fed to all pigs after weaning to the simpler corn-soybean meal-based diet fed to all pigs for an additional 14 (Exp. 1) or 7 d (Exp. 2) after the experimental period. Pigs averaged 5 kg at the start of the experimental period. In Exp. 1, pigs had a high health status and were weaned to an off-site nursery (SEW) and fed 12 experimental diets in a 3 (0, 2.5, or 5% SDAP) × 4 (0, 2.5, 5, or 7.5% SMFM) factorial arrangement. Diets were formulated to contain 1.6% lysine and contained 20% dried whey, 5% soybean oil, and 2.5% spray-dried blood meal. The SDAP and(or) SMFM replaced corn and soybean meal on an equal lysine basis. Average daily gain and ADFI were not affected by treatment during any period of the experiment. Gain:feed was improved by the

addition of SDAP (linear, $P < .05$) and SMFM (linear, $P < .07$) during the period from 5 to 19 d. Over the 33-d experiment, SDAP and SMFM improved (linear, $P < .05$) gain:feed. In Exp. 2, pigs were weaned on-site to an all-in/all-out by room nursery and fed diets identical to those fed in Exp. 1, with 0 or 2.5% SDAP and 0, 2.5, or 5% SMFM in a 2 × 3 factorial arrangement. The addition of 2.5% SDAP improved ADG and gain:feed during the period from 7 to 14 d ($P < .05$) and 0 to 28 d ($P < .10$), but not over the period from 7 to 21 d. The addition of SMFM did not affect ADG during any period, but it resulted in a quadratic improvement in gain:feed during the periods from 7 to 14 ($P < .05$) and 7 to 21 ($P < .10$) d. These results suggest that high-health SEW pigs respond less to SDAP and SMFM in the transition diet than pigs with a lower health status reared in an on-site nursery. The data further suggest that formulation of transition diets should consider the type of production system if pig performance and diet cost are to be optimized.

Key Words: Pigs, Spray Drying, Blood Plasma, Menhaden Fish Products, Blood Protein

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Introduction

In formulations of nutrient-dense diets for early-weaned pigs, selected ingredients should stimulate feed intake and provide highly digestible amino acids

in the proper proportions. Several studies have demonstrated that spray-dried animal plasma is an effective protein source when used in diets for pigs from d 0 to 14 after weaning (Gatnau and Zimmerman, 1990, 1992; Sohn et al., 1991; Kats et al., 1994). Hansen et al. (1993) and de Rodas et al. (1995) reported that pigs fed spray-dried porcine plasma had increased ADG as a result of increased feed intake.

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Select menhaden fish meal has an excellent amino acid profile and is used extensively as a component of early-weaning diets. Stoner et al. (1990) reported that replacing a portion of the soybean meal in a starter diet with select menhaden fish meal resulted in improved ADG, ADFI, and gain:feed.

Use of these ingredients that stimulate feed intake of weanling pigs has allowed many swine producers in the United States to implement segregated early-weaning (SEW) as a means to improve herd health

Table 1. Composition of experimental diets, as-fed basis^a

Ingredient	Plasma, %:				0				2.5				5			
	Fish meal, %:	0	2.5	5	7.5	0	2.5	5	7.5	0	2.5	5	7.5			
Corn		34.67	36.70	38.73	40.76	37.35	39.38	41.41	43.44	40.03	42.06	44.09	46.12			
Soybean meal (46.5% CP)		33.44	29.34	25.23	21.13	28.16	24.05	19.95	15.83	22.87	18.77	14.66	10.55			
Dried whey		20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00			
Soy oil		5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00			
Select menhaden fish meal		—	2.50	5.00	7.50	—	2.50	5.00	7.50	—	2.50	5.00	7.50			
Spray-dried animal plasma		—	—	—	—	2.50	2.50	2.50	2.50	5.00	5.00	5.00	5.00			
Spray-dried blood meal		2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50			
Monocalcium phosphate		1.55	1.31	1.07	0.82	1.66	1.42	1.17	0.94	1.78	1.53	1.29	1.05			
Antibiotic ^b		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
Limestone		.67	.49	.32	.15	.67	.50	.33	.16	.67	.50	.33	.16			
Zinc oxide (72% Zn)		.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38			
Premix ^c		.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40			
L-Lysine HCl		.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15			
DL-Methionine		.14	.13	.12	.11	.13	.12	.11	.10	.12	.11	.10	.09			
Salt		.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10			
Chemical Analysis, %																
CP																
Calculated		23.52	23.31	23.09	22.88	23.04	22.82	22.61	22.39	22.55	22.34	22.12	21.91			
Analyzed		22.46	23.72	23.21	22.44	23.29	23.51	23.56	23.52	22.99	22.37	22.59	22.97			

^aDiets were formulated to contain 1.60% lysine, .9% Ca, .8% P, and at least .44% methionine.

^bProvided 55 µg/kg carbadox.

^cPremix provided per kilogram of complete diet: Mn, 12 mg; Fe, 165 mg; Zn, 165 mg; Cu, 16 mg; I, .3 mg; Se, .3 mg; vitamin A, 11,025 IU; vitamin D₃, 1,103 IU; vitamin E, 44 IU; menadione (menadione sodium bisulfate complex), 4.4 mg; riboflavin, 8.3 mg; d-pantothenic acid, 29 mg; niacin, 50 mg; choline, 166 mg; and vitamin B₁₂, 33 µg.

and performance (Dritz et al., 1994; Tokach et al., 1994). However, spray-dried animal plasma and select menhaden fish meal are relatively expensive protein sources, and nutritionists are challenged to make practical recommendations that will result in optimal growth at a reasonable cost. Dritz et al. (1993) observed similar growth performance of early-weaned pigs fed a nutrient-dense diet from d 0 to 7 postweaning, followed by a less complex transition diet from d 7 to 14 and pigs fed the nutrient-dense diet from d 0 to 14 after weaning. Therefore, our objective was to determine the effects of combinations of soybean meal, select menhaden fish meal, and spray-dried animal plasma on growth performance of the early-weaned pig (12 to 14 d of age) during the transition from a nutrient-dense postweaning diet to a simpler corn-soybean-based diet.

Materials and Methods

Experiment 1. Three hundred pigs (PIC, C15 × 326) were weaned at 14 ± 2 d of age and transported by truck and trailer for approximately 8 h to the SEW facilities at Kansas State University. The herd of origin was classified as high-health status according to the procedures of Madec et al. (1993). Neither injectable antibiotics nor vaccines were administered to the pigs at weaning or during the experiment. The pigs were allotted by weight (initially 4.0 ± .9 kg BW) in a randomized complete block design, with five pigs

per pen and five replicate pens per treatment. The initial temperature (34°C) of the environmentally regulated nursery was reduced by approximately 1.5°C each week to maintain pig comfort. Each pen (1.2 × 1.2 m with slatted metal flooring) contained a four-hole self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Each pen provided .29 m² of space per pig. From d 0 to 5 after weaning, all pigs were fed a common, early-weaning diet containing 31% corn, 25% dried whey, 14.15% soybean meal (46.5% CP), 7.5% spray-dried animal plasma, 6% select menhaden fish meal, and 5% lactose (Goodband et al., 1994). This diet was formulated to contain 1.70% lysine, .49% methionine, .9% Ca, and .8% P.

From d 5 to 19 after weaning, the pigs (initially 4.9 kg BW) were fed 12 previously assigned dietary treatments containing spray-dried animal plasma (MP-722, Merrick's, Union Center, WI; 0, 2.5, or 5%) and select menhaden fish meal (Zapata Proteins, Mandeville, LA; 0, 2.5, 5, or 7.5%) in a 3 × 4 factorial arrangement (Table 1). Select menhaden fish meal and/or spray-dried animal plasma replaced soybean meal in the basal diet on an equal lysine basis. The amino acid estimates used in diet formulation for corn, dried whey, and select menhaden fish meal were obtained from NRC (1988). Amino acid values for soybean meal (46.5% CP) were derived from published values (NCR-42, 1992). The amino acid profile of spray-dried animal plasma was provided by the supplier (6.10% lysine and .70% methionine). The early-weaning and experimental transition diets were

pelleted through a mill equipped with a die 4.0 mm in diameter. On d 5 and 19 when diets were changed, all feeders were weighed then emptied before the next diet was added. Feed samples were collected and analyzed for CP (AOAC, 1984). Analyzed concentrations were similar to calculated values (Table 1).

From d 19 to 33 after weaning, all pigs were fed a common diet in meal form. This corn-soybean meal-based diet contained 10% dried whey and 2.5% spray-dried blood meal and was formulated to contain 1.35% lysine, .37% methionine, .9% Ca, and .8% P. Pigs and feeders were weighed on d 5, 12, 19, 26, and 33 postweaning to determine ADG, ADFI, and gain:feed ratio.

Experiment 2. An experiment was conducted to evaluate SDAP and SMFM in the transition diet of pigs weaned on-site and reared in an all-in/all-out by room system. In this experiment, 324 pigs (PIC, C15 × 326) at a commercial farm in Kansas were weaned at 12 ± 2 d of age. To provide for the daily care of the pigs, farm personnel moved freely between the breeding, farrowing, and nursery facilities. A foot bath containing disinfectant (Tektrol, Bio-Tek Industries, Atlanta, GA) was used by farm personnel before they entered the nursery. The pigs were allotted to the pens and dietary treatments based on their initial weight (initially 3.9 ± 1.0 kg BW) in a randomized complete block design, with one block of seven pigs per pen, four blocks of nine pigs per pen, and one block of 11 pigs per pen to provide six replicate pens per treatment. Pigs were weaned into a room containing 12 pens (two blocks) each week for a 3-wk period. The initial temperature (34°C) of the environmentally regulated nursery was reduced by approximately 1.5°C each week to maintain pig comfort. Each pen (1.5 × 1.5 m with wire mesh flooring) contained a six-hole self-feeder and two nipple waterers to allow ad libitum consumption of feed and water. Each pen provided approximately .21 to .32 m² of space per pig. From d 0 to 7 after weaning, all pigs were fed the same common, pelleted, early-weaning diet used in Exp. 1.

From d 7 to 21 after weaning, the pigs (initially 4.8 kg BW) were fed six previously assigned dietary treatments containing spray-dried animal plasma (MP-722; 0 or 2.5%) and select menhaden fish meal (0, 2.5, or 5%) in a 2 × 3 factorial arrangement. These six pelleted diets were identical to that used in Exp. 1 (Table 1). On d 7 and 21 when diets were changed, all feeders were weighed then emptied before the next diet was added.

From d 21 to 28 after weaning, all pigs were fed a common meal diet identical to that in Exp. 1. Pigs and feeders were weighed on d 7, 14, 21, and 28 postweaning to determine ADG, ADFI, and gain:feed ratio.

Statistical Analysis. Data in both trials were analyzed as a randomized complete block design with a factorial (3 × 4 in Exp. 1; 2 × 3 in Exp. 2) arrangement of treatments. The main effects of spray-

dried animal plasma and select menhaden fish meal, as well as the interactions, were evaluated. Pigs were blocked on the basis of initial weight, with pen as the experimental unit. Analysis of variance was performed using the GLM procedure of SAS (1988). In Exp. 1, pig weight on d 5 was used as a covariate, and the linear and quadratic effects (Peterson, 1985) were evaluated for the levels of spray-dried animal plasma and select menhaden fish meal. In Exp. 2, pig weight on d 7 was used as a covariate, and the linear and quadratic effects were evaluated for the level of select menhaden fish meal.

Results

Experiment 1. From d 0 to 5 after weaning, when the pigs were fed a common diet, ADG, ADFI, and gain:feed ratio were 187 g, 153 g, and 1.21, respectively. Throughout the study, ADG was not affected ($P > .10$) by the addition of spray-dried animal plasma or select menhaden fish meal to the transition diet (Table 2). From d 5 to 12 after weaning, gain:feed increased (linear, $P < .05$) as the level of spray-dried animal plasma increased. However, a spray-dried animal plasma × select menhaden fish meal interaction occurred for gain:feed ratio from d 12 to 19. Increasing select menhaden fish meal in the diet without spray-dried animal plasma seemed to decrease then increase gain:feed during this period, whereas pigs fed 2.5% spray-dried animal plasma and 7.5% select menhaden fish meal or 5% spray-dried animal plasma and 2.5 or 5% select menhaden fish meal had gain:feed similar to that of pigs fed the basal diet. For the entire period from d 5 to 19, gain:feed increased (linear, $P < .05$) as the level of spray-dried animal plasma increased and tended (linear, $P < .07$) to increase as the level of select menhaden fish meal increased. When all pigs were fed a common diet from d 19 to 33, performance was not affected by prior dietary treatment.

For the overall trial (d 0 to 33), ADG and ADFI were not different among treatments. However, gain:feed was improved (linear, $P < .05$) by including spray-dried animal plasma and select menhaden fish meal in the transition diet from d 5 to 19.

Experiment 2. From d 0 to 7 after weaning, when the pigs were fed a common diet, ADG, ADFI, and gain:feed ratio were 142 g, 175 g, and .82, respectively. No spray-dried animal plasma × select menhaden fish meal interactions occurred ($P > .10$) during the trial for any of the response criteria (Table 3). From d 7 to 14 after weaning, ADG and gain:feed increased ($P < .05$) when pigs were fed 2.5% spray-dried animal plasma. Additionally, gain:feed increased (quadratic, $P < .05$) when pigs were fed increasing amounts of select menhaden fish meal. Average daily gain and gain:feed were not affected ($P > .10$) by the addition of spray-dried animal plasma or select menhaden fish

Table 2. Influence of spray-dried animal plasma and select menhaden fish meal in the transition diet on growth performance of the segregated early-weaned pig (Exp. 1)^a

Item	Plasma, %:		0				2.5				5				SEM
	Fish meal, %:		0	2.5	5	7.5	0	2.5	5	7.5	0	2.5	5	7.5	
Day 5 to 12															
ADG, g			253	260	265	240	270	280	265	294	301	251	267	278	18.5
ADFI, g			299	292	288	291	291	317	270	303	299	279	273	290	11.6
Gain:feed ^b			.85	.89	.91	.83	.92	.88	.98	.96	1.00	.91	.98	.97	.05
Day 12 to 19															
ADG, g			429	405	409	436	407	426	405	431	399	417	398	404	16.5
ADFI, g			505	527	527	523	526	558	506	516	520	502	481	500	17.1
Gain:feed ^c			.85	.77	.78	.83	.77	.76	.80	.84	.77	.83	.83	.81	.02
Day 5 to 19															
ADG, g			341	333	337	338	339	353	335	363	350	334	333	341	10.9
ADFI, g			402	409	408	407	409	438	388	410	409	391	377	395	11.6
Gain:feed ^{bd}			.85	.81	.82	.83	.83	.81	.86	.89	.86	.86	.88	.87	.02
Day 19 to 33															
ADG, g			510	528	510	527	486	525	530	519	533	520	505	511	17.3
ADFI, g			800	788	786	813	800	784	789	776	815	768	770	763	18.1
Gain:feed			.64	.67	.65	.65	.62	.67	.67	.67	.65	.68	.66	.67	.02
Day 0 to 33															
ADG, g			395	400	393	404	385	407	401	408	411	395	390	396	9.5
ADFI, g			545	543	541	553	542	553	533	536	557	526	521	526	9.7
Gain:feed ^{be}			.73	.74	.73	.73	.71	.74	.75	.76	.74	.75	.75	.75	.01

^aThree hundred weanling pigs (initially 4.0 kg and 14 d of age) were used, with five pigs/pen and five pens/treatment.

^bEffect of increasing spray-dried animal plasma (linear, $P < .05$).

^cSpray-dried animal plasma \times select menhaden fish meal interaction ($P < .05$).

^dEffect of increasing select menhaden fish meal (linear, $P < .07$).

^eEffect of increasing select menhaden fish meal (linear, $P < .05$).

Table 3. Influence of spray-dried animal plasma and select menhaden fish meal in the transition diet on growth performance of the early-weaned pig (Exp. 2)^a

Item	Plasma, %:		0			2.5			SEM
	Fish meal, %:		0	2.5	5	0	2.5	5	
Day 7 to 14									
ADG, g ^b			246	235	218	255	274	257	10.6
ADFI, g			333	309	301	333	309	324	10.3
Gain:feed ^{bc}			.74	.76	.72	.77	.88	.80	.03
Day 14 to 21									
ADG, g			338	355	359	359	342	328	16.1
ADFI, g ^d			432	439	463	436	429	459	12.1
Gain:feed			.79	.81	.78	.83	.79	.73	.04
Day 7 to 21									
ADG, g			294	297	291	311	310	294	9.7
ADFI, g ^e			385	377	385	387	372	394	7.8
Gain:feed ^e			.77	.79	.76	.81	.83	.76	.02
Day 21 to 28									
ADG, g			421	401	409	410	435	411	17.1
ADFI, g			681	665	680	633	663	688	18.0
Gain:feed			.62	.61	.60	.67	.65	.60	.03
Day 0 to 28									
ADG, g ^f			292	285	283	295	305	291	6.5
ADFI, g			414	402	407	400	401	419	7.1
Gain:feed ^b			.71	.71	.70	.74	.76	.70	.02

^aThree hundred twenty-four weanling pigs (initially 3.9 kg and 12 d of age) were used, with 7 to 11 pigs/pen (depending on the block) and six pens/treatment.

^bEffect of spray-dried animal plasma ($P < .05$).

^{c,d,e}Effect of increasing select menhaden fish meal (quadratic, $P < .05$; linear, $P < .06$; and quadratic, $P < .10$; respectively).

^fEffect of spray-dried animal plasma ($P < .08$).

meal to the diet from d 14 to 21. However, ADFI increased (linear, $P < .06$) for pigs fed increasing select menhaden fish meal during this period. During the entire period from d 7 to 21, ADG was not affected ($P > .10$) by the addition of spray-dried animal plasma or select menhaden fish meal to the diet, but ADFI tended (quadratic, $P < .10$) to decrease then increase and gain:feed tended (quadratic, $P < .10$) to increase then decrease with increasing select menhaden fish meal.

No differences ($P > .10$) in growth performance were observed when all pigs were fed a common diet from d 21 to 28. However, for the overall trial (d 0 to 28), pigs fed a transition diet containing 2.5% spray-dried animal plasma from d 7 to 21 tended ($P < .08$) to have increased ADG and increased ($P < .05$) gain:feed.

Discussion

Segregated early weaning has become a standard management practice on many swine farms as a means of disease control. Benefits of early weaning (< 20 d of age) and rearing pigs in off-site facilities include improved health status and growth performance (Williams et al., 1994; Dritz et al., 1995). Implementation of segregated early weaning has been facilitated by the use of nutrient-dense diets containing specialty protein (i.e., spray-dried animal plasma and select menhaden fish meal) and lactose sources. However, because of the excellent health status of segregated early-weaned pigs and high feed intake, the duration for which these nutrient-dense diets must be fed may be decreased relative to pigs weaned into on-site facilities (Tokach et al., 1994). Dritz et al. (1993) observed that high-health status pigs could be switched from a nutrient-dense diet to a less complex diet at approximately 5 kg BW without affecting growth performance. Furthermore, they observed that pigs fed this transition diet had improved growth performance compared with pigs switched from a nutrient-dense diet to a simple corn-soybean meal-dried whey diet. Formulation of a diet to move the pig from nutrient-dense diets to simple corn-soybean meal diets offers an economic opportunity to reduce feed costs associated with early weaning (< 20 d of age).

Spray-dried animal plasma is a superior protein source compared to dried skim milk in early-weaned pig diets containing dried whey and lactose (Hansen et al., 1993). Kats et al. (1994) reported that nursery pig performance was improved with up to 10% spray-dried animal plasma in the diet when dietary methionine is maintained at or above requirements. Studies by Gatnau and Zimmerman (1990, 1992), Sohn et al. (1991), Hansen et al. (1993), Rojas et al. (1994), and de Rodas et al. (1995) have demonstrated that the improvements in ADG associated with spray-dried animal plasma result from increased ADFI. Addition-

ally, Ermer et al. (1994) reported that pigs preferred a diet containing spray-dried animal plasma over a diet containing dried skim milk.

The studies cited above were conducted under conditions similar to those in Exp. 2, in which the addition of 2.5% spray-dried animal plasma improved ADG and gain:feed. In Exp. 1, however, ADG and ADFI of segregated early-weaned pigs were not improved by including spray-dried animal plasma in the transition diet. This suggests that the response to spray-dried animal plasma is dependent on the health status of the pigs. Coffey and Cromwell (1995) reported similar growth performance of pigs fed starter diets containing dried skim milk or spray-dried animal plasma when pigs were reared in an off-site, experimental nursery, but ADG and ADFI of pigs reared in a conventional, on-farm nursery was improved by feeding spray-dried animal plasma rather than dried skim milk. Stahly et al. (1994) reported that ADG and ADFI were improved when spray-dried animal plasma was included in the diet of pigs reared in an environment with high exposure to antigens. The addition of spray-dried animal plasma to the diet did not improve performance of pigs reared in an environment with low exposure to antigens.

In contrast to our results, Dritz et al. (1996), using lipopolysaccharide-induced immune challenge as an immune system modulator, reported that the improved growth resulting from increased dietary spray-dried animal plasma and other specialty protein sources was independent of immune challenge. The different responses to spray-dried animal plasma and select menhaden fish meal observed between Exp. 1 and 2 in our study may suggest that the lipopolysaccharide-induced immune challenge model may not be entirely representative of herd health dynamics observed under commercial conditions.

Stoner et al. (1990) observed improvements in ADG, ADFI, and gain:feed when select menhaden fish meal was substituted for soybean meal in the starter diet. The addition of 4 or 8% select menhaden fish meal to a diet containing 10% dried whey resulted in the greatest improvements in that study. They also reported that select menhaden fish meal could replace all of the soybean meal in the diet. In both of our experiments, ADG was not affected by replacing soybean meal with select menhaden fish meal in the transition diet. However, feeding pigs 2.5% select menhaden fish meal from d 7 to 14 in Exp. 2 resulted in improved gain:feed, and there was also a slight improvement in gain:feed associated with increasing select menhaden fish meal in Exp. 1.

Based on the different magnitude of response to spray-dried animal plasma and select menhaden fish meal observed in our studies, their dietary inclusion may be dependent on the health status of the pigs. Replacing soybean meal with spray-dried animal plasma or select menhaden fish meal improved gain:feed regardless of production system. This is likely a

result of lower dietary fiber and increased digestibility of these protein sources relative to soybean meal. However, pigs reared in an on-site nursery had an increase in ADG as a result of added spray-dried animal plasma. Hansen et al. (1993) suggested that the improved performance observed when pigs are fed spray-dried animal plasma may be due to the presence of biologically active plasma proteins that contribute to the health of starter pigs. However, Rojas et al. (1994), Stahly et al. (1994), and Coffey and Cromwell (1995) suggest that the growth-enhancing effects of spray-dried animal plasma are independent of antimicrobial agents added to the diets. Even though the response to spray-dried animal plasma is likely not mediated via the same mechanisms as antimicrobial agents, our results agree with those of Stahly et al. (1994) and Coffey and Cromwell (1995) that the response to spray-dried animal plasma varies based on health status. Therefore, health status and economics should be considered when determining whether and how much spray-dried animal plasma and select menhaden fish meal should be included in the transition diet.

Implications

In transition diets fed to shift pigs from a nutrient-dense diet to a simple corn-soybean meal-dried whey diet, spray-dried animal plasma and select menhaden fish meal increased gain:feed regardless of health status (segregated vs on-site production system). However, average daily gain of early-weaned pigs reared in an all-in/all-out, on-site nursery was improved by spray-dried animal plasma. Health status and economics will ultimately determine the optimal combination of protein sources to include in the transition diet for the early-weaned pig.

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