Effects of a nursery feed regimen with spray-dried bovine plasma on performance and mortality of weaned pigs positive for porcine reproductive and respiratory syndrome virus

Joe D. Crenshaw, PhD; Joy M. Campbell, PhD; Javier Polo, PhD; Dan Bussières, BSc

Summary

Objective: To compare performance and mortality of weaned pigs positive for porcine reproductive and respiratory syndrome virus (PRRSV) provided either a feed regimen with spray-dried bovine plasma (SDBP) or a feed regimen with a combination of alternative proteins and additives (ALT).

Materials and methods: Pigs (n = 960) weaned at 21 days of age were allotted by sex and initial body weight (BW) into four nursery rooms, each with 10 pens and 24 pigs per pen. Pigs were provided either the SDBP or ALT regimen, each with three phases (phase 1, days 1-14; phase 2, days 15-21; phase 3, days 22-48 post weaning). Phase 1 and 2 diets for the SDBP regimen contained 5.0% and 2.5% SDBP, respectively, and phase 1 and 2 diets for the ALT regimen contained combinations of specialty proteins and additives as alternatives to SDBP. All pigs were fed a common phase 3 diet.

Results: Pigs fed the SDBP regimen had higher ($P < .05$) average BW at days 14, 21, 28, 35, 42, and 48 post weaning. Cumulative average daily weight gain and average daily feed intake were higher ($P < .05$) for pigs fed the SDBP regimen. There was a tendency ($P = .07$) for pigs fed the SDBP regimen to have lower mortality (21 of 480 pigs) compared to the ALT regimen (35 of 480 pigs).

Implications: Under these conditions, PRRSV-positive pigs fed the SDBP regimen have greater final BW and tend to have lower mortality compared to pigs fed the ALT regimen.

Keywords: swine, specialty proteins, spray-dried bovine plasma, porcine reproductive and respiratory syndrome virus, mortality

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Resumen - Efecto de un régimen alimenticio en destete con plasma bovino secado por aspersión en el desempeño y mortalidad de cerdos destetados positivos al virus del síndrome reproductivo y respiratorio porcino

Objetivo: Comparar el desempeño y mortalidad de cerdos destetados positivos al virus del síndrome reproductivo y respiratorio porcino (PRRSV por sus siglas en inglés) provistos con un régimen alimenticio con plasma bovino secado por aspersión (SDBP por sus siglas en inglés) o un régimen alimenticio con una combinación de proteínas alternativas y aditivos (ALT por sus siglas en inglés).

Materiales y métodos: Se distribuyeron cerdos (n = 960) destetados a los 21 días de edad, por sexo y peso corporal inicial (BW por sus siglas en inglés) en cuatro salas de destete, cada uno con 10 corrales y 24 cerdos por corral. A los cerdos, se les ofreció con un régimen ALT o SDBP, cada uno con tres fases (fase 1, días 1-14; fase 2, días 15-21; fase 3, días 22-48 post destete). Las dietas fase 1 y fase 2 del régimen SDBP tuvieron un contenido de 5.0% y 2.5% SDBP, respectivamente, y las dietas fase 1 y fase 2 del régimen ALT tuvieron un contenido de combinaciones de aditivos y proteínas especializadas como alternativas para el SDBP. Todos los cerdos fueron alimentados con una dieta común fase 3.

Resultados: Los cerdos alimentados con el régimen SDBP tuvieron un peso corporal promedio más alto ($P < .05$) en los días 14, 21, 28, 35, 42, y 48 post destete. La ganancia de peso diaria promedio acumulada y el consumo de alimento diario promedio fueron más alto ($P < .05$) en los cerdos alimentados con el régimen SDBP. Hubo una tendencia ($P = .07$) en los cerdos alimentados con el régimen SDBP a tener una mortalidad más baja (21 de 480 cerdos), comparado con el régimen ALT (35 de 480 cerdos).

Implicaciones: Bajo estas condiciones, los cerdos positivos al PRRSV alimentados con el régimen SDBP tienen un peso final mayor y tienden a tener una mortalidad más baja, comparado con los cerdos alimentados con el régimen ALT.

Résumé - Effet d'un régime alimentaire en pouponnière avec du plasma bovin déshydraté vaporisé sur les performances et la mortalité de porcelets sevrés positifs pour le virus du syndrome reproducteur et respiratoire porcin

Objectif: Comparer les performances et la mortalité de porcelets sevrés positifs pour le virus du syndrome reproducteur et respiratoire porcin (VSRRP) nourris avec un régime alimentaire avec du plasma bovin déshydraté vaporisé (PBDV) ou un régime alimentaire avec une combinaison de protéines alternatives et d'additifs (ALT).

Matériels et méthodes: Des porcs (n = 960) sevrés à 21 jours d'âge ont été répartis par sexe et poids corporel initial (PC) dans quatre

JDC, JMC, JP: Research Department, APC Inc, Ankeny, Iowa.

DB: Demeter Veterinary Services Inc / Groupe Cérès Inc, St-Nicolas, Quebec, Canada.

Corresponding author: Dr Joe Crenshaw, Research Department, APC Inc, 2425 SE Oak Tree Court, Ankeny, IA 50021; Tel: 1-515-289-7603; Fax: 1-515-289-4362; E-mail: joe.crenshaw@functionalproteins.com.

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chambres de pouponnière, chacune avec 10 enclos et 24 porcs par enclos. Les porcs ont reçu soit le régime PBDV ou ALT, chacun réparti en trois phases (phase 1, 1-14 jours; phase 2, 15-21 jours; phase 3, 22-48 jours post-sevrage). Les diètes des phases 1 et 2 du régime PBDV contenaient 5,0% et 2,5% de PBDV, respectivement, et les phases 1 et 2 du régime ALT contenaient des combinaisons de protéines de spécialité et des additifs en tant qu'alternatives au PBDV. Tous les porcs ont été nourris avec un aliment commun pour la phase 3 de la diète.

Résultats: Les porcs nourris avec le régime PBDV avaient un PC moyen plus élevé ($P < 0,05$) aux jours 14, 21, 28, 35, 42, et 48 post-sevrage. Le gain de poids quotidien cumulatif et la consommation journalière moyenne étaient supérieurs pour les porcs nourris avec le régime PBDV ($P < 0,05$). Il y avait une tendance ($P = 0,07$) pour les porcs nourris avec le régime PBDV d'avoir une plus faible mortalité (21 des 480 porcs) comparativement au régime ALT (35 des 480 porcs).

Implications: Dans les conditions de la présente étude, les porcs positifs pour VSRRP et nourris avec le régime PBDV avaient un PC final plus élevé et avaient tendance à avoir une plus faible mortalité comparativement aux porcs nourris avec le régime ALT.

Porcine reproductive and respiratory syndrome (PRRS) has a large impact on annual production losses, with estimates at $45 million for the Quebec swine industry[1] and about $664 million estimated annual losses in the United States.[2] Vaccines have been used with variable success to control PRRS.[3] However, PRRS has persisted in several swine-producing countries globally since its emergence more than 25 years ago. Pigs of all ages can be affected by PRRS, and this disease can modulate the immune response to facilitate its own persistence and transmission and increase risk of co-infection.[4]

Pigs weaned from a sow herd during an outbreak of PRRS may be lethargic, with a compromised immune system that can make it more difficult to manage pig health during the weaning process.[5] In addition, multiple stressors associated with weaning contribute to post-weaning growth lag.[6] Spray-dried animal plasma (SDAP) of porcine (SDPP) or bovine (SDBP) origin is used as a protein ingredient in diets for weaned pigs during the critical post-weaning stress period due to the well-known beneficial effects such diets have on post-weaning growth rate, feed intake, and survival.[7] Pigs experimentally challenged with PRRS virus (PRRSV) and fed a diet with SDPP had a more rapid rate of viral clearance with less interstitial pneumonia, which may have been enhanced by modulation of IL-1 and IFN-γ in lung tissue.[8,9]

Spray-dried animal plasma of either bovine or porcine origin is available for commercial use in various countries globally, depending upon governmental regulations associated with country and species origin of SDAP. In addition, some customers may have a preference for bovine or porcine origin products. A recent study[10] reported similar performance of pigs fed either bovine or porcine spray-dried plasma at 6% of the diet for the initial 14 days post weaning, suggesting that species origin of SDAP could be used interchangeably in formulations at the same concentration in the diet. However, published information regarding use of SDBP in nursery diets, and specifically fed to pigs positive for PRRSV, has not been reported. Therefore, the objective for this study was to determine the effects of a nursery-feed regimen with SDBP on performance and mortality of PRRSV-positive pigs, compared to a feed regimen used as an alternative to SDBP (ALT).

Materials and methods

Animal care and welfare

This field study was conducted under commercial conditions in a facility that provided recommended stocking density, ventilation, animal care, and welfare according to the code of practice for the care and handling of pigs developed by the National Farm Animal Care Council of Canada in 2014. During the experiment, animal health was monitored by licensed veterinarians, and animals were not manipulated beyond what would be required for diagnostic purposes.

Animals and housing. The experiment was conducted at a commercial research nursery facility by staff from Demeter Services Vétérinaires Inc, Lévis, Quebec, and Groupe Cérès Inc, St-Nicholas, Quebec. Four mechanically ventilated nursery rooms, each with 10 pens (1.8 × 3.78 m) housing 24 pigs per pen at a stocking density of 0.28 m^2 per pig, were used for the experiment. All pens had fully slatted plastic flooring with a four-space, single-sided dry feeder, one adjustable-height nipple drinker, and one water-bowl drinker. All pigs were weaned from a sow farm in Québec that had been confirmed positive for PRRSV within the previous month. All pigs were transported from the sow farm and placed in the nursery on the same day. Pigs (Fast F1 females × Fast Duroc sires; Fast Genetics, Saskatoon, Saskatchewan) were weaned at 20 to 21 days of age and allotted to pens according to body weight (BW) and sex. Pigs were visually sorted into three BW groups (small, average, and large) by sex such that each pen of 24 pigs included eight pigs representing each BW group. After the initial visual allocation to pens, individual pigs were weighed and ear-tagged. Additional pig movements were made to assure that there was less than 2.5 kg total pen weight variance within each pen in a block. Blocks consisted of two pens of each sex, with equal assignment of feed regimen within block and within room. Thus, there were five blocks per room for a total of 20 pens (10 pens, castrates; 10 pens, females) per feed regimen. The average initial BW was 6.0 ± 0.01 kg for the 960 pigs used in the experiment.

Feed regimen. Two different nursery-feed regimens were provided to pigs used in this experiment (Table 1). Both feed regimens included a phase 1 diet fed from day 1 to 14, a phase 2 diet fed from day 15 to 21, and a common phase 3 diet fed from day 22 to 48, post weaning. One feeding regimen (ALT) had a highly complex phase 1 diet that consisted of a combination of alternative specialty proteins, including dried yeast culture (PFS; Probiotech International, Saint-Hyacinthe, Quebec, Canada), enzymatically hydrolyzed egg and fish protein concentrate (PiggyMax; Premier Ag Resources, Ltd, London, Ontario, Canada), highly digestible poultry protein (Stim-A-tein; XFE Products, Des Moines, Iowa), and other feed additives, including acidifiers, betaine, enzymes, flavors, organic acids, plant extracts, prebiotics, probiotics, sodium butyrate, and sweeteners. The SDBP regimen had a less complex phase 1 diet containing 5% SDBP (AP920; APC Nutrition Ltd, Calgary, Alberta, Canada), and 10 of the dietary feed additives used in the ALT phase 1 diet were excluded from the SDBP phase 1 diet. The feed additives excluded from the SDBP phase 1 diet were betaine, calcium formate, ortho-phosphoric acid, plant extract, prebiotics, probiotics, protease, sodium butyrate, and two sweetener products.

The ALT phase 2 diet contained a combination of PiggyMax, sodium butyrate, and soy protein concentrate, while the SDBP phase 2 diet contained 2.5% AP920. The phase 3 diet was common to both feed regimens.

Both phase 1 diets contained 440 mg per kg chlortetracycline, 125 mg per kg copper, 31.8 mg per kg tiamulin, and 2500 mg per kg zinc oxide. Both phase 2 diets contained 440 mg per kg chlortetracycline, 125 mg per kg copper, and 2000 mg per kg zinc oxide. The phase 3 common diet did not contain antibiotics, but included 125 mg per kg copper and 250 mg per kg zinc oxide. The vitamin-trace mineral premix used in all diets for each phase contained copper and zinc. In addition, phase 1 and 2 diets were provided supplemental zinc oxide as shown in Table 1.

The experimental diets were formulated to contain very similar nutrient content by phase (Table 2) and met or exceeded the National Research Council nutrient guidelines for swine.[11] The sources of ingredient nutrient values used for formulation of the diets included a combination of internal feed-mill analytical results of major ingredients, such as grain and soybean meal, values from the National Research Council guidelines for swine,[11] net energy values from the National Institute of Agricultural Research,[12] and supplier specifications for specialty products and additives. The diets were manufactured at Meunerie Soucy, St-Edouard, Quebec, Canada. Diet mixing and processing was supervised by Groupe Cérès staff to ensure that each diet formulation was mixed and processed correctly. The phase 1 and 2 diets were pelleted and granulated with a #3 and #4 granulated setting, respectively. The common phase 3 diet was pelleted. The pelleting temperature for all experimental diets ranged between 68°C and 74°C. All feeds were offered ad libitum. The cost of each diet was calculated using current ingredient price at the start of the trial and using a common margin for manufacturing, transport, and sales.

Samples of each batch of the diets were sent to a certified laboratory (Central Testing Laboratory Ltd, Winnipeg, Manitoba, Canada) for standard proximate analysis to confirm that analyzed nutrient composition was within formulation specifications (Table 3). Variances of analyzed versus calculated values adjusted to a 100% dry matter basis for each diet by phase were within normal analytical variation, and these minor variances were not expected to have any specific impact on performance results. Also, the SDBP used in the

Table 1: Composition of diets for three-phase nursery feed regimens with either spray-dried bovine plasma (SDBP) or a combination of alternative specialty proteins fed to weaned pigs positive for PRRSV*

Ingredient (%)	Phase 1 (days 1-14)		Phase 2 (days 15-21)		Phase 3 (days 22-48)
	ALT	SDBP	ALT	SDBP	Common
Corn	21.06	25.57	36.08	38.11	47.34
Wheat	20.00	20.00	20.00	20.00	15.00
Corn DDGS	0.00	0.00	0.00	0.00	7.50
Soybean meal	14.00	14.00	27.50	26.33	24.49
Whey permeate	18.64	18.64	6.21	6.21	0.00
Soy/corn oil blend	4.01	4.36	2.87	2.91	2.15
SDBP†	0.00	5.00	0.00	2.50	0.00
Poultry protein†	3.52	0.00	0.00	0.00	0.00
Soy protein concentrate	9.67	8.62	1.90	0.00	0.00
Egg-fish protein†	3.50	0.00	1.25	0.00	0.00
Dried yeast culture†	1.02	0.00	0.00	0.00	0.00
L-lysine†	0.69	0.60	0.65	0.63	0.72
L-threonine	0.16	0.13	0.15	0.15	0.15
DL-methionine	0.20	0.21	0.17	0.17	0.14
L-tryptophan	0.05	0.03	0.02	0.02	0.03
Limestone	0.39	0.87	0.84	0.90	1.03
Monocalcium phosphate	0.27	0.48	0.85	0.77	0.70
Salt	0.34	0.22	0.42	0.28	0.45
Choline chloride 60%	0.08	0.08	0.05	0.05	0.05
Vitamin-trace mineral premix†	0.25	0.25	0.25	0.25	0.25
Chlortetracycline	0.20	0.20	0.20	0.20	0.00
Tiamulin	0.18	0.18	0.00	0.00	0.00
Zinc oxide (72%)	0.31	0.31	0.25	0.25	0.00

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Table 1 continued

Ingredient (%)	Phase 1 (days 1-14)		Phase 2 (days 15-21)		Phase 3 (days 22-48)
	ALT	SDBP	ALT	SDBP	Common
Acidifier†	0.10	0.10	0.10	0.10	0.00
Phytase†	0.03	0.03	0.03	0.03	0.03
Red iron oxide	0.15	0.00	0.15	0.00	0.00
Yellow iron oxide	0.00	0.15	0.00	0.15	0.00
Protease†	0.05	0.00	0.00	0.00	0.00
Calcium formate	0.30	0.00	0.00	0.00	0.00
Ortho-phosphoric acid	0.20	0.00	0.00	0.00	0.00
Sodium butyrate†	0.12	0.00	0.08	0.00	0.00
Betaine†	0.20	0.00	0.00	0.00	0.00
Brewer's yeast prebiotic†	0.20	0.00	0.00	0.00	0.00
Probiotic†	0.05	0.00	0.00	0.00	0.00
Plant extract†	0.03	0.00	0.00	0.00	0.00
Sweetener†	0.08	0.00	0.00	0.00	0.00
Sucram 3D†	0.01	0.00	0.00	0.00	0.00
Cost per kg (Ca$)	1.11	1.10	0.56	0.62	0.38

* Performance and mortality were compared in pigs provided a feed regimen with either spray-dried bovine plasma (SDBP) or a combination of alternative specialty proteins and feed additives (ALT) to replace SDBP: three dietary phases per regimen. Phase 1 and 2 diets for the SDBP regimen contained 5.0% and 2.5% SDBP, respectively; phase 1 and 2 diets for the ALT regimen contained combinations of specialty proteins and additives as alternatives to SDBP. All pigs were fed a common phase 3 diet. Weaned pigs (n = 960; 21 days old; 6.0 kg body weight [BW]) allotted by sex and initial BW into each of four nursery rooms (10 pens, 24 pigs/pen). Pen weights recorded at allotment and study days 7, 14, 21, 28, 35, 42, and 48. Individual pig BW recorded at allotment and study days 21 and 48. Individual pig medications and room water medications recorded. Data analyzed as a randomized complete block design using pen as the experimental unit. Weekly and cumulative performance data analyzed using an analysis of variance (ANOVA) model that included feed regimen, block, and the covariance of initial BW. Pen means for mortality percentage and final BW distribution percentile data analyzed using an ANOVA model that included feed regimen and block. Least squares means of all data reported for feed regimen. Probability of the F-test considered nonsignificant at $P \geq .05$ and a trend at $P < .10$.

† Spray-dried bovine plasma (AP920; APC Nutrition Ltd, Calgary, Alberta, Canada); poultry protein (Stim-A-tein; XFE Ingredients, Des Moines, Iowa); egg-fish protein (PiggyMax; Premeire Ag Resources, London, Ontario, Canada); dried yeast culture (Probiotech International, Saint-Hyacinth, Quebec, Canada); L-lysine (Bio-Lys 70; 54.6% lysine); vitamin trace-mineral premix (Starter Micro BNA3500; Meunerie Soucy, St-Edouard, Quebec, Canada); chlortetracycline; tiamulin; acidifier (Porcinat+; JEFO Nutrition Inc, St-Hyacinth, Quebec, Canada); phytase (Phyzyme XP; Danisco Animal Nutrition, St Louis, Missouri); protease (JEFO Nutrition Inc); sodium butyrate (Proformix 650; ProAg Products, Winnipeg, Manitoba); betaine (Betafin; Danisco Animal Nutrition); brewer's yeast prebiotic (IMW50; Quality Technology International, Inc, Elgin, Illinois); probiotic (BioPlus 2B; Chr Hansen, Hoersholm, Denmark); plant extract (X-Tract; Pancosma, Drummondville, Quebec, Canada); sweetener (Crystal Feed Fruity, Laboratoires Phodé Z.I. Albipôle – 81150 Terssac, France); Sucram 3D (Pancosma, Drummondville, Quebec, Canada).

PRRSV = porcine reproductive and respiratory syndrome virus; ALT = feed regimen with alternative proteins and additives; SDBP = feed regimen with spray-dried bovine plasma; corn DDGS = dried distillers grain with solubles, with corn as the grain source; Ca$ = currency in Canadian dollars.

experimental diets was confirmed as 100% bovine origin by DNA analysis (Laboratoire Demeter, Lèvis, Quebec, Canada).

Animal health management: Under attending veterinarian supervision, all pigs received medications in their drinking water as follows: penicillin V (400 g per 20 L water) days 1 to 5; gentamycin sulfate (200 g per 20 L water) days 6 to 7; apramycin sulfate (210 g per 20 L water; Elanco Animal Health, Greenfield, Indiana) plus Vitoselen (vitamin E and Se supplement, 400 g per 20 L water; JEFO Nutrition Inc, Saint-Hyacinth, Quebec, Canada) days 8 to 10; and amoxicillin trihydrate (1 kg per 30 L water) days 22 to 27 and days 29 to 35 post entry. Depending upon clinical signs, individual pigs received an injection of 0.5 mL enrofloxacin (Baytril 100; Bayer Corp, Mississauga, Ontario) or 0.5 mL ceftiofur hydrochloride (Excenel RTU; Zoetis Inc, Kirkland, Quebec), and individual pig medications were recorded. All pigs were vaccinated at entry and during week 4 of the experiment with a 3-mL injection of a combination of vaccines administered in an extra-label manner against *Mycoplasma hyopneumoniae*, porcine circovirus type 2, swine influenza virus, and *Hemophilus parasuis*. Also during week 4 of the experiment, all pigs were provided Enterisol ileitis vaccine (Boehringer Ingelheim Vetmedica, Inc, St Joseph, Missouri) in drinking water (500 doses per 2000 pigs) for 6 hours as an extra-label dose recommendation by Demeter Services Vétérinaires Inc, Lévis, Quebec.

Table 2: Calculated nutrient composition of experimental diets by feed regimen phase*

	Phase 1 (days 1-14)		Phase 2 (days 15-21)		Phase 3 (days 22-48)
Nutrients†	**ALT**	**SDBP**	**ALT**	**SDBP**	**Common**
Dry matter (%)	89.75	89.40	88.20	88.06	87.95
Crude protein (%)	22.30	21.65	20.92	20.56	19.71
Fat (%)	6.83	5.68	5.00	4.72	4.82
Net energy (kcal/kg)	2630	2630	2500	2500	2475
Total lysine (%)	1.57	1.58	1.43	1.44	1.32
SID lysine (%)	1.45	1.45	1.31	1.31	1.20
SID methionine (%)	0.51	0.48	0.45	0.44	0.41
SID methionine + cysteine (%)	0.84	0.84	0.76	0.76	0.70
SID threonine (%)	0.90	0.90	0.81	0.81	0.75
SID tryptophan (%)	0.28	0.28	0.24	0.24	0.21
SID valine (%)	0.94	0.96	0.85	0.85	0.79
SID isoleucine (%)	0.86	0.80	0.78	0.74	0.70
SID lysine:net energy‡	5.53	5.53	5.25	5.25	4.85
Calcium (%)	0.70	0.70	0.70	0.70	0.68
Phosphorus (%)	0.60	0.59	0.59	0.58	0.54
Available phosphorus (%)	0.50	0.50	0.45	0.45	0.40
Sodium (%)	0.40	0.40	0.25	0.25	0.20
Added zinc (mg/kg)	2500	2500	2000	2000	250
Added copper (mg/kg)	125	125	125	125	125
Added selenium (mg/kg)	0.30	0.30	0.30	0.30	0.30
Vitamin A (IU/kg)	12,000	12,000	12,000	12,000	12,000
Vitamin D (IU/kg)	1500	1500	1500	1500	1500
Vitamin E (IU/kg)	85	85	85	85	85
Lactose (%)	15.0	15.0	5.0	5.0	0.0
Phytase (FTU/kg)	750	750	750	750	750

* Study described in Table 1. Diets were formulated to meet the nutrient requirements by phase.[11]
† Nutrient values reported on an as-fed basis.
‡ SID lysine:net energy ratio = SID lysine (g/kg) ÷ net energy (Mcal/kg).
ALT = feed regimen with alternative proteins and additives; SDBP = feed regimen with spray-dried bovine plasma; SID = standardized ileal digestible amino acid; FTU = phytase units per kg of feed.

Evaluation of PRRSV status. Within 1 day after allotment, blood samples were collected from 40 pigs (one pig per pen in each room) and submitted to Laboratoire Demeter, Lèvis, Quebec, Canada, to assess PRRSV status using an ELISA (Idexx PRRS X3 AB; Idexx Laboratories, Westbrook, Maine) for detection of antibodies. The sample-to-positive (S:P) control ratio for the ELISA was consider negative if 0.000 to 0.199, suspect if 0.200 to 0.399, and positive if ≥ 0.400. Also, real-time quantitative reverse transcription-polymerase chain reaction (qrt-PCR) analysis for the PRRSV genome (EZ-PRRSV MPX 4.0; Tetracore Veterinary Products, Rockville, Maryland) and PRRSV sequencing were performed on four pooled samples representing 10 pigs per pool according to procedures recommended by the University of Minnesota Veterinary Diagnostic Laboratory for North American and European PRRSV open reading frame 5 sequencing. A cycle to threshold (Ct) value of < 37 for qrt analysis for PRRSV was considered positive.

Production measures. Pen weights of pigs were recorded at allotment and days 7, 14, 21, 28, 35, 42, and 48 of the experiment. Individual pig weights were also recorded at allotment and days 21 and 48 of the experiment. During the course of the experiment, the weight, date, and tag number of each dead or removed pig were also recorded. Average daily weight gain (ADG) was calculated by the weekly and cumulative weigh periods from pen weights adjusted for pig days that included weights of dead or removed pigs during a particular week. The appropriate feed treatment assigned to each pen was distributed using a feed cart equipped with a scale that allowed for accurate measurement

Table 3: Analyzed composition of experimental diets by feed regimen phase*

	Phase 1 (days 1-14)		Phase 2 (days 15-21)		Phase 3 (days 22-48)
	ALT	SDBP	ALT	SDBP	Common
Samples analyzed	**4**	**4**	**2**	**2**	**8**
Crude protein (%)					
Calculated†	24.85	24.22	23.72	23.35	22.41
Analyzed‡	24.45 ± 0.81	23.40 ± 0.35	22.84 ± 0.58	22.93 ± 0.97	22.06 ± 0.76
Crude fat (%)					
Calculated	7.61	6.35	5.67	5.36	5.48
Analyzed	7.32 ± 0.51	6.37 ± 0.39	6.06 ± 0.43	5.15 ± 0.02	5.50 ± 0.17
Calcium (%)					
Calculated	0.78	0.78	0.79	0.79	0.77
Analyzed	0.83 ± 0.04	0.79 ± 0.01	0.76 ± 0.06	0.79 ± 0.01	0.77 ± 0.03
Phosphorus (%)					
Calculated	0.67	0.66	0.67	0.66	0.61
Analyzed	0.75 ± 0.01	0.73 ± 0.01	0.71 ± 0.00	0.74 ± 0.01	0.67 ± 0.02
Sodium (%)					
Calculated	0.45	0.45	0.28	0.28	0.23
Analyzed	0.42 ± 0.02	0.44 ± 0.02	0.26 ± 0.01	0.27 ± 0.01	0.25 ± 0.03

* Study described in Table 1.
† Calculated nutrient value for diet by phase adjusted to 100% dry matter basis.
‡ Mean ± standard deviation of samples analyzed for each batch of diet used in the experiment with values adjusted to 100% dry matter basis.
ALT = feed regimen with alternative proteins and additives; SDBP = feed regimen with spray-dried bovine plasma.

of the feed added to a feeder. The feed-cart scale was calibrated on a regular basis with a standardized weight. Each time pigs were weighed, feeders were individually vacuumed and the quantity of unused feed was weighed. The phase 1 and 2 ALT diets had added red color, while the phase 1 and 2 SDBP diets had added yellow color (Table 1) to assure that animal caretakers could distinguish a visual color difference between the experimental diets. Average daily feed intake (ADFI) was calculated per pen by the weekly and cumulative weigh periods. Feed efficiency (gain-to-feed; GF) per pen was calculated as ADG per ADFI by weekly and cumulative weigh periods.

Statistical analysis. The data were analyzed as a randomized complete block design using pen (40 pens, 24 pigs per pen) as the experimental unit. Weekly and cumulative performance data were analyzed using an analysis of variance (ANOVA) model that included feed regimen, block, and the covariance of initial BW. Pen means for mortality percentage and final BW distribution percentile data were analyzed using an ANOVA model that included feed regimen and block. Least squares means of all data are reported for feed regimen, and the probability of the F-test was considered nonsignificant at $P \geq .05$ and a trend at $P < .10$.

Results

Serological testing indicated 31 of 40 pigs sampled at entry were seropositive (S:P ≥ 0.4) for antibodies against PRRSV. Results of qrt-PCR for the PRRSV genome of four pooled serum samples (10 samples per pool) were strongly positive (Ct value < 29.9, range 22.2 to 28.7). The PRRSV strain was 99.34% homologous with the strain at the sow farm.

Of the pigs fed the SDBP and ALT regimens, 459 of 480 and 445 of 480, respectively, survived to the end of the experiment (Table 4). Mortality over the entire study (days 1 to 48) tended ($P = .07$) to be lower for pigs fed the SDBP regimen than for those fed the ALT regimen.

PRRS virus-positive pigs fed the SDBP regimen had greater ($P < .05$) average BW by 14 days post weaning than did pigs fed the ALT regimen, and this greater average BW for pigs fed the SDBP regimen was maintained through the end of the study at day 48 (Table 4). A higher ($P < .05$) percentage of pigs fed the ALT regimen were in the lower 25th percentile of final BW (< 23.6 kg BW) at day 48, compared to the percentage of pigs fed the SDBP regimen. Cumulative ADG and ADFI were higher ($P < .05$) during days 1 to 14, days 1 to 21, and days 1 to 48 of the experiment for pigs fed the SDBP regimen than for those fed the ALT regimen. Feed efficiency (GF) was higher ($P < .05$) for pigs fed the SDBP regimen than for pigs fed the ALT regimen during days 1 to 21, when the feed contained SDBP; however, cumulative feed efficiency (days 1 to 48) did not differ between feed regimens by the end of the study.

On the basis of Canadian currency (Ca$) and an assumed value for a feeder pig of $2.20 per kg BW, there was a $1.06 advantage in margin over feed and medication costs for pigs fed the SDBP regimen (Table 5). Medication cost was slightly higher for pigs fed the SDBP regimen due to more individual injectable medications given to the SDBP group (264)

Table 4: Cumulative performance and mortality by feed regimen and phase of experiment*

	Feed regimen		SEM†	*P*‡
	ALT	SDBP		
Phase 1 (days 1-14)				
Initial BW (kg)	6.00	5.98	0.01	.19
BW day 14 (kg)	9.81	10.06	0.05	< .01
ADG (g)	265	280	4.2	.03
ADFI (g)	255	272	3.7	< .01
GF	1.04	1.03	0.01	.44
Mortality (%)§	3.33	2.50	0.59	.33
Phase 1-2 (days 1-21)				
BW day 21 (kg)	12.34	12.95	0.09	< .01
ADG (g)	295	321	4.7	< .01
ADFI (g)	355	378	4.4	< .01
GF	0.83	0.85	0.01	< .01
Mortality (%)§	5.00	3.75	0.86	.32
Phase 1-3 (days 1-48)				
Final BW day 48 (kg)	27.67	28.58	0.19	< .01
Lower 25th BW (< 23.6 kg) (%)§	19.48	13.51	1.36	< .01
Mid 50th BW (23.6-33.6 kg) (%)§	67.39	70.51	1.92	.26
Upper 25th BW (> 33.6) (%)§	13.13	15.97	1.65	.24
ADG (g)	435	454	3.9	< .01
ADFI (g)	631	655	5.9	< .01
GF	0.69	0.69	0.00	.32
Mortality (%)§	7.29	4.39	1.07	.07

* Study described in Table 1. Values are least squares means for 20 pens (24 pigs/pen) per feed regimen by phase of experiment, analyzed as a randomized complete block design with feed regimen, block, and covariance of initial BW in the model.
† Standard error of the least squares mean.
‡ Probability of F-test for feed regimen, considered nonsignificant at $P \geq .05$ and a trend at $P < .10$.
§ Values are least squares means of 20 pens per feed regimen by phase of experiment for percentage mortality or percentage of pigs by lower, mid, or upper final BW percentiles analyzed as a randomized complete block design with feed regimen and block in the model.
ALT = feed regimen with alternative proteins and additives; SDBP = feed regimen with spray-dried bovine plasma; BW = average body weight; ADG = average daily weight gain; ADFI = average daily feed intake; GF = gain-to-feed ratio.

versus the ALT group (215). The phase 1 SDBP diet was less complex and expensive than the phase 1 ALT diet; however, the phase 2 SDBP diet was more expensive than the phase 2 ALT diet (Table 1). Pigs fed the SDBP regimen consumed more feed, and feed cost was $0.62 more per pig completing the study.

Discussion

The economic impact of PRRS can result in large reductions in revenue due to mortality and morbidity.[1,2] Severity of PRRS on productivity may vary considerably depending upon viral strain and the adaptive immune status of the afflicted pigs. In the current study, serum samples subjected to ELISA and qrt-PCR confirmed that sampled pigs were considered PRRSV-positive at placement, and this was consistent with the stated objective for the study.

Water medications for all rooms and individual pig medications were given primarily during the initial 3 weeks of the study to treat diarrhea and respiratory signs commonly associated with PRRSV-positive pigs. In addition, all experimental diets fed during the initial 21 days of the study contained antibiotics and supplemental zinc and copper in anticipation of higher morbidity and mortality associated with PRRSV-positive pigs. The potential impact of antibiotics in the water and feed on intestinal microflora and performance results of the PRRSV-positive pigs fed the different feed regimens is unknown. Antibiotic therapy may have influenced the ability of some ingredients, such as acidifiers, prebiotics, or probiotics used in the ALT regimen, to enhance gut microflora for the benefit of animal health and performance. However, it may also have influenced the pig performance response to the SDBP regimen as well. Past research has reported increased lactobacilli in ileal and cecal digesta of pigs fed diets with spray-dried animal plasma (SDAP).[13] In addition, a review of studies comparing ADG of pigs provided diets with or

Table 5: Margin over feed and medication cost per pig completing experiment*

	Feed regimen		Variance
	SDBP	ALT	
Pigs started experiment	480	480	0.00
Pigs completed experiment	459	445	14
Average BW day 48 (kg)†	28.96	28.19	0.77
Feeder pig value (Ca$)‡	63.71	62.02	1.69
Feed/pig (kg)§	32.53	31.86	0.67
Feed cost/pig (Ca$)¶	16.35	15.73	0.62
Medication cost/pig (Ca$)**	1.61	1.60	0.01
MOFMC (Ca$)††	45.75	44.69	1.06

* Study described in Table 1.
† Sum of individual BW of pigs at day 48 divided by number of pigs completing experiment.
‡ Assumed $2.20 (Ca$) per kg BW value if sold as a feeder pig.
§ Sum of total feed per regimen divided by pigs completing experiment.
¶ Sum of cost of feed (Ca$) per phase divided by pigs completing experiment.
** Sum of cost (Ca$) of individual pig medications and water medications divided by number of pigs completing experiment.
†† MOFMC (margin over feed and medication cost) = feeder pig value (Ca$) minus feed and medication costs (Ca$) per pig completing experiment.
SDBP = feed regimen with spray-dried bovine plasma; ALT = feed regimen with alternative proteins and additives; BW = body weight; Ca$ = currency in Canadian dollars.

without SDAP and with or without antimicrobials reported higher ADG for pigs provided feed containing SDAP compared to feed containing no SDAP, regardless of presence or absence of antimicrobials in the feed.[7] However, in this review, only some of the studies reported a significant interaction of SDAP and antimicrobials in feed.

PRRS virus-positive pigs fed less complex diets with SDBP had higher final BW, ADG, ADFI, and a tendency for improved survival compared to pigs on the ALT feed regimen, even though diets within phase were formulated to have equal energy and lysine content. These results are consistent with an extensive review[7] of 143 experiments comparing performance of pigs provided diets with SDAP to performance of pigs provided diets with other specialty proteins, including blood protein, casein, dried skim milk, fish meal, meat extract, pea protein isolate, potato protein, soybean meal, soy protein concentrate, wheat gluten, or whey protein, which showed that pigs fed diets with SDAP had higher ADG and ADFI, compared to pigs fed diets with all of the other protein sources during the initial 2 weeks after weaning. In the current study, 5% SDBP in the phase 1 diet was replaced by a combination of dried yeast culture, enzymatically hydrolyzed egg and fish protein (PiggyMax; Premier Ag Resources), highly digestible protein from the proprietary transformation of poultry (Stim-A-tein; XFE Ingredients), and 10 other feed additives that included betaine, calcium formate, ortho-phosphoric acid, plant extracts, prebiotics, probiotics, proteases, sodium butyrate, and sweeteners. In the phase 2 diets, 2.5% SDBP was replaced by a combination of PiggyMax, sodium butyrate, and soy protein concentrate. Although these specialty proteins and additives in general may improve digestibility of diets and potentially support a more favorable gastrointestinal microflora, they were not as cost effective as using the SDBP regimen, under the conditions of this study. Furthermore, the administrative costs for procurement, labeling, inventory, and maintenance of all of these specialty proteins and additives to replace SDBP were not disclosed and could not be considered in the economic analyses.

Concentration of SDAP in the diet and feeding duration of the diet are important factors for minimizing inflammation-associated gut-barrier dysfunction during the critical 2 weeks after weaning.[14] For these reasons, it is recommended to use 4% to 6% SDAP in starter diets fed for at least the initial 2 weeks after weaning to support pig performance during weaning stress and minimize adverse effects of stress-related events later in life. In addition, other research has demonstrated better survival and performance of nursery pigs afflicted with porcine circovirus type 2-associated disease when spray-dried porcine plasma was included in a three-phase feeding regimen at 6%, 3%, and 1.5% of the respective diets by phase, compared to a three-phase feed regimen using fish meal to replace spray-dried porcine plasma.[15] The extended duration of feeding diets with SDBP planned for the PRRSV-positive pigs in the current study was based on the results of past research.

Multiple functional components contained in plasma have been associated with the well-known beneficial effects on performance of pigs fed starter diets containing SDAP.[7] Some authors have suggested the globulin portion of plasma, which contains antibodies, is responsible for most of the beneficial effects associated with animals fed diets with SDAP.[16,17] Antibodies against various pathogens are found in plasma, and their neutralizing capacity is maintained after spray drying.[18] Past studies[8,9] have shown that pigs fed diets with SDPP and experimentally challenged with PRRSV had a greater rate of viral clearance post infection, with less interstitial pneumonia, which was associated with modulation of TH1 cytokines in lung tissue, compared to

PRRSV-challenged pigs fed a diet without SDPP. Rodent species used in inflammatory models and fed diets containing SDAP had beneficial modulation of cytokines in enteric, respiratory, and reproductive mucosal tissues.[19-22] Collectively, these studies suggest that multiple functional components in plasma elicit the beneficial effects associated with animals fed diets containing SDAP.

Spray-dried bovine plasma has been shown to be just as effective as SDPP for improving growth of pigs when used at the same concentration in the diet.[7,10] In the current study, the higher performance values and survival of PRRSV-positive pigs fed the SDBP regimen were maintained to the end of the study, even when pigs were no longer fed SDBP. The BW advantage for the SDBP regimen resulted in a $1.06 advantage in margin over medication and feed cost, assuming pigs were sold as feeder pigs.

Implications

- Under the conditions of this study, the use of spray-dried bovine plasma in a nursery-feed regimen for PRRSV-positive pigs is more cost effective than an alternative regimen.
- Under the conditions of this study, pigs PRRSV-positive at weaning and fed nursery diets with alternative specialty proteins and other feed additives may not perform or tend to survive as well as pigs fed nursery diets with SDBP.

Conflict of interest

Drs Joe Crenshaw, Joy Campbell, and Javier Polo are employed by APC Inc, that manufactures and sells SDAP.

Dan Bussières has no conflict of interest.

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