EFFICACY OF ROVIMIX ® STAY-C® 25 AS A VITAMIN C SOURCE FOR SEGREGATED AND CONVENTIONALLY WEANED PIGS

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Story in Brief

Two experiments were conducted to evaluate the efficacy of a stable source of vitamin C for improving performance and iron status in early weaned pigs. Rovimix® Stay-C® 25 served as the vitamin C source and was incorporated at dietary vitamin C levels of 0, 75, or 150 ppm. In Exp. 1, 72 pigs (14 ± 2 d of age) were blocked based on initial body weight and penned in groups of three (8 pens/treatment) in an off-site nursery facility for 42 d. Blood samples were taken on d 14 postweaning. During d 0 to 14, 28 to 42 and for the overall 42-day postweaning period, daily gain and gain:feed were improved by the addition of vitamin C in the diet. Plasma vitamin C increased as dietary vitamin C level increased, but plasma iron, hemoglobin and hematocrit were not influenced by dietary vitamin C. In Exp. 2, 120 pigs (20 ± 3 d of age) were blocked based on initial body weight and penned in groups of five (8 pens/treatment) in a conventional nursery system for 31 d. Blood samples were taken on d 17 postweaning. During d 0 to 17 postweaning, daily gains and gain:feed were improved by the addition of vitamin C in the diet. Plasma vitamin C and serum iron increased, but unbound iron binding capacity decreased as dietary vitamin C level increased. These results suggest an inadequate dietary vitamin C level in the control diet used in this study during the first 42 d postweaning in pigs weaned as early as 12 d of age and reared in an off-site nursery facility and during the first 17 d postweaning in pigs weaned as early as 17 d of age and reared in a conventional nursery system. Rovimix® Stay-C® 25 supplemented to provide 75 ppm dietary vitamin C was adequate to meet the dietary vitamin C requirement of the early-weaned pig.

(Key Words: Vitamin C, Weanling Pigs, Performance)

Introduction

Although the neonatal pig can synthesize vitamin C by 1 week of age (Braude et al., 1950), there is evidence that the rate of synthesis during stress may be inadequate (Warriss, 1984). Upon weaning, there is a decrease in plasma ascorbic acid concentration (Mahan and Saif, 1983) which may be an indication of inadequate tissue synthesis of the vitamin or stress associated with weaning. Previous studies evaluating efficacy of relatively high levels of vitamin C (> 300 ppm) have been inconsistent in producing a growth or feed efficiency response (Yen and Pond, 1981,1987; Mahan and Saif, 1983; Kornegay et al., 1986; NCR-89 Committee, 1989). The lack of consistent findings may be due, in large part, to the innate instability of vitamin C. L- ascorbic acid is unstable when exposed to either oxygen or certain minerals which can result in a rapid oxidation to the dehydroascorbic acid derivative. Even when vitamin C is supplied as protected beadlets, it has been shown to lose potency rapidly in complete feeds (NCR-89 Committee, 1989) and no attempts have been made to estimate potency delivered to the absorption site.

Mahan et al. (1994) observed improved performance in weanling pigs (23 ± 2 d of age) fed a stable source of vitamin C (Magnesium-L-Ascorbyl-2-Phosphate) during the first 2 weeks postweaning. Rovimix® Stay-C® 25 (L-Ascorbyl-2-Polyphosphate) is another stable source of vitamin C which contains at least 25% ascorbic acid activity. Studies utilizing new methodology in recent years have produced results which make it evident that vitamin C is a strong promoter of iron absorption (Hallberg et al., 1987; Monsen, 1988). Their findings confirm previous studies where vitamin C enhancement of iron absorption has been observed (Moore and Dubach, 1951). The objective of this study was to determine the efficacy of Rovimix® Stay-C® 25 as a vitamin C source in improving performance and iron status in pigs weaned as early as 12 d of age and reared in an offsite nursery as well as in pigs weaned as early as 17 d of age and reared in a conventional nursery system.

Materials and Methods

Experiment 1. The first study evaluated the efficacy of three vitamin C levels (0, 75, or 150 ppm) in diets of segregated early weaned pigs over a 42-d postweaning period. Three diet sequences were provided during the postweaning period within each treatment group (Table 1). The first diet was fed from d 0 to 14 postweaning and formulated to contain 1.6% lysine, .96% methionine plus cystine, and 24% lactose. The second diet was fed from d 14 to 28 postweaning and formulated to contain 1.4% lysine, .84% methionine plus cystine, and 13.4% lactose. The third diet was fed from d 28 to 42 and formulated to contain 1.35% lysine, .79% methionine plus cystine, and 9.9% lactose. Rovimix® Stay-C® 25 was used as the vitamin C source and was premixed in corn and added at the appropriate level at the expense of corn. All diets were pelleted using a California spray dry 100 horsepower pellet mill equipped with a 3.97-mm die. A total of 72 pigs (14± 2 d of age) were sorted by weight, and divided into four groups (blocks). Pigs within each weight group were allotted into six equal subgroups (three pigs per pen) with stratification based on sex and litter. Dietary treatments were then randomly assigned to pens within each of the four weight groups (8 pens/treatment). Pigs were housed in an off-site nursery in pens with woven wire flooring. The initial temperature of 31°C was subsequently decreased 1°C per week. Pigs in each pen had ad libitum access to one nipple waterer and a three-hole feeder. Pig body weight and feed intake (per pen) were determined weekly to evaluate average daily gain (ADG), average daily feed intake (ADFI), and gain:feed. Two blood samples from each pig were taken via a single anterior vena cava puncture on d 14 postweaning. Samples were analyzed for hematocrit, hemoglobin (Sigma Chemical Co., 1996), plasma Fe (atomic absorption spectrophotometry) and plasma vitamin C (US Interdepartmental Committee on Nutrition for National Defense, 1963).

Experiment 2. The second study evaluated the efficacy of three dietary vitamin C levels (0, 75, or 150 ppm) in diets of pigs weaned at 20 ± 3 d of age and reared in a conventional nursery facility. Three diet sequences were provided during the postweaning period within each treatment group (Table 2). The first diet fed from d 0 to 7 postweaning was formulated to contain 1.5% lysine, .90% methionine plus cystine, and 13.4% lactose. The second diet fed from d 7 to 17 postweaning was formulated to contain 1.35% lysine, .73% methionine plus cystine, and 9.9% lactose. The third diet fed from d 17 to 31 was formulated to contain 1.15% lysine, and

.65% methionine plus cystine. All diets were pelleted using a California spray dry 100 horsepower pellet mill equipped with a 3.97-mm die. A total of 120 pigs (20± 3 d of age) were sorted by weight, and divided into four groups (blocks). Pigs within each weight group were allotted into six equal subgroups (five pigs per pen) with stratification based on sex and litter. Dietary treatments were then randomly assigned to pens within each weight group (8 pens/treatment). Pigs were housed in a conventional nursery in pens with woven wire flooring. The initial temperature of 30°C was subsequently decreased 1°C per week. Pigs in each pen had ad libitum access to one nipple waterer and a four-hole feeder. Pig body weight and feed intake were determined during each phase to evaluate ADG, ADFI, and gain:feed. Three separate blood samples from each pig were taken via a single anterior vena cava puncture on d 17 postweaning. Samples were assayed for hematocrit, hemoglobin, plasma vitamin C (as described in Exp. 1), total serum iron and unbound iron binding capacity.

Data from both experiments were analyzed according to a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was performed using the GLM procedures of SAS (1988), and orthogonal polynomials were used to test for linear and quadratic effects of dietary vitamin C levels on performance, plasma vitamin C and iron status.

Results and Discussion

In Experiment 1 from d 0 to 14 postweaning, ADG and gain:feed were improved (quadratic, $P<.1$ and $P<.05$, respectively) with increasing vitamin C in the diet (Table 3). Feed intake, however, was not affected by dietary vitamin C. From d 28 to 42 postweaning, ADG and gain:feed increased linearly ($P<.1$ and $P<.01$, respectively) as dietary vitamin C level increased. During the overall 42-d experimental period, ADG and gain:feed increased (linear, $P<.05$ and $P<.11$, respectively) with increasing vitamin C, but ADFI was not affected. Plasma vitamin C increased (linear, $P<.05$) as dietary vitamin C level increased, but plasma iron, hemoglobin and hematocrit were not influenced by dietary vitamin C (Table 4).

In Experiment 2 from day 0 to 17 postweaning, ADG and gain:feed increased (linear $P<.1$) as dietary vitamin C level increased (Table 5). Daily gain, feed intake, and gain:feed ratio were not influenced by dietary vitamin C during d 17 to 31 postweaning. Plasma vitamin C and serum iron increased (linear, $P<.05$), but unbound iron binding capacity, and total iron binding capacity decreased (linear, $P<.05$ and $P<.1$, respectively) as dietary vitamin C level increased (Table 6). Hemoglobin and hematocrit were not affected.

In general, these results suggest an inadequate dietary vitamin C level in control diets used in this study during the first 42 d postweaning in pigs weaned as early as 12 d of age and reared in an off-site nursery facility and during the first 17 d postweaning in pigs weaned as early as 17 d of age and reared in a conventional nursery system. Rovimix® Stay-C® 25 supplemented to provide 75 ppm dietary vitamin C was adequate to meet the dietary vitamin C requirement of the early-weaned pig. Vitamin C supplementation with a stable product will improve performance in young pigs during the high stress postweaning period, and may be particularly beneficial to pigs weaned at a very early age. Improved performance may be related to improvement in serum iron status resulting in an increase in serum iron and a decrease in unbound iron binding capacity.

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Table 1. Composition of experimental diets (Experiment 1)[a].			
	Diets		
Ingredient, %	d 0 to 14	d 14 to 28	d 28 to 42
Yellow corn	29.549	48.79	55.075
Lactose	4.75	-	10.00
Dehydrated whey	25.00	20.00	-
Soybean meal, 48% CP	-	12.75	22.25
Steam-rolled oats	10.00	-	-
Select menhaden fish meal	8.00	8.00	5.00
Dried skim milk	5.00	-	-
Egg protein	4.00	-	-
Biotin, 1%	.001	-	-
AP-301[b]	-	1.50	2.00
AP-920[b]	5.00	2.50	-
Soybean oil	3.00	4.00	2.50
Calcium carbonate	-	.15	.27
Dicalcium phosphate	.60	.60	1.43
Soy protein concentrate	3.00	-	-
Lysine.HCl	.14	-	.15
DL-Methionine	.15	.10	.12
Threonine	-	-	.05

Neoterramycin[c]	1.00	1.00	-
Ethoxyquin	.03	.03	.03
Berry flavor	.10	-	-
Sodium chloride	-	.20	.30
Tylan 40-sulfa[d]	-	-	.125
Copper sulfate.5H_2O	-	-	.05
Zinc oxide	.30	-	.30
Micro curb	-	-	.10
Vitamin-mineral premix[e]	.38	.38	.25
Vitamin C premix[f]	+	+	+

a As fed basis.

b AP-920: plasma protein source, AP-301: blood meal source, American Protein Corp., Ames, IA.

c Contained 22.04 g of Neomycin and 11.02 g of Oxytetracycline per kg.

d Contained 88.18 g of Tylosin and 88.18 g of Sulfamethazine per kg.

e Vitamins and minerals met or exceeded the NRC (1988) requirements.

f Ascorbic acid as Rovimix® Stay-C® 25 was premixed with corn and added to provide 75 or 150 ppm vitamin C (272.16 and 544.32 g/ton, respectively) at the expense of corn.

Table 2. Composition of experimental diets (Experiment 2)[a].	
	Diets

Ingredient, %	d 0 to 7	d 7 to 17	d 17 to 31
Yellow corn	45.77	55.465	66.545
Lactose	-	10.00	-
Dehydrated whey	20.00	-	-
Soybean meal, 48% CP	-	22.00	27.25
Steam-rolled oats	10.00	-	-
Select menhaden fish meal	8.00	5.00	-
AP-301[b]	1.50	2.00	-
AP-920[b]	3.50	-	-
Soybean oil	4.00	2.50	2.50
Calcium carbonate	.10	.35	.60
Dicalcium phosphate	.88	1.30	1.90
Soy protein concentrate	4.00	-	-
Lysine.HCl	.25	.20	.20
DL-Methionine	.22	-	-
Neoterramycin[c]	1.00	-	-
Ethoxyquin	.03	.03	.03
Berry flavor	.10	-	-
Sodium chloride	.10	.30	.42
Tylan 40-sulfa[d]	-	.125	.125
Copper sulfate.5H_2O	.07	.08	.08
Zinc oxide	-	.30	-
Micro curb	.10	.10	.10

Vitamin-mineral premix[e]	.38	.25	.25
Vitamin C premix[f]	+	+	+

a As fed basis.

b AP-920: plasma protein source, AP-301: blood meal source, American Protein Corp., Ames, IA.

c Contained 22.04 g of Neomycin and 11.02 g of Oxytetracycline per kg.

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e Vitamins and minerals met or exceeded the NRC (1988) requirements.

f Ascorbic acid as Rovimix® Stay-C® 25 was premixed with corn and added to provide 75 or 150 ppm vitamin C (272.16 and 544.32 g/ton, respectively) at the expense of corn.

Table 3. Effect of dietary vitamin C on performance of segregated early-weaned pigs (14 ± 2 d of age)a.

	Vitamin C, ppm					
Item	0	75	150	SEM		
d 0 to 14						
ADG, g[b]	223.56	245.17	233.55	8.58		
ADFI, g	272.72	282.18	281.38	8.08		
Gain:feed[c]	.81	.87	.84	.01		
d 14 to 28						

ADG, g	464.13	497.33	476.15	14.46		
ADFI, g	583.31	629.28	613.07	17.29		
Gain:feed	.79	.79	.78	.01		
d 28 to 42						
ADG, g[d]	631.40	648.57	670.44	18.40		
ADFI, g	928.45	934.45	915.52	23.29		
Gain:feed[f]	.68	.70	.73	.01		
d 0 to 42						
ADG, g[e]	439.70	463.68	460.04	7.19		
ADFI, g	594.82	615.30	603.32	13.92		
Gain:feed	.76	.79	.78	.009		

a Data are means of 8 pens of 3 pigs each. Average initial and final weights were 4.98 and 24.1 kg, respectively.

b Quadratic effect of increasing vitamin C in the diet (P<.1).

c Quadratic effect of increasing vitamin C in the diet (P<.05).

d Linear effect of increasing vitamin C in the diet (P<.1).

e Linear effect of increasing vitamin C in the diet (P<.05).

f Linear effect of increasing vitamin C in the diet (P<.01).

Table 4. Effect of dietary vitamin C level on plasma vitamin C and iron status of segregated early-weaned pig (14 ± 2 d of age)[a].

	Vitamin C, ppm					
Item	0	75	150	SEM		

Plasma vitamin C, mg/dl[b]	1.26	1.41	1.45	.03		
Plasma Fe, mg/L	2.07	2.29	1.82	.17		
Hemoglobin, g/dl	12.34	12.28	12.46	.43		
Hematocrit, %	34.44	34.11	35.99	.90		

a Data are means of 8 pens of 3 pigs each.

b Linear effect of increasing vitamin C in the diet (P<.05).

Table 5. Effect of dietary vitamin C on performance of conventional weaned pigs (20± 3 d of age)[a].

	Vitamin C, ppm					
Item	0	75	150	SEM		
d 0 to 17						
ADG, g[b]	270.63	294.57	292.91	10.61		
ADFI, g	355.01	370.28	370.95	10.63		
Gain:feed[b]	.76	.80	.79	.01		
d 17 to 31						
ADG, g	492.36	502.23	491.33	14.63		
ADFI, g	831.74	857.13	816.78	19.19		
Gain:feed	.59	.59	.60	.009		
d 0 to 31						
ADG, g	381.49	398.40	392.12	8.54		

ADFI, g	593.37	613.71	593.86	14.19		
Gain:feed	.68	.69	.70	.01		

a Data are means of 8 pens of 5 pigs each. Average initial and final weights were 7.19 and 18.97 kg, respectively.

b Linear effect of increasing vitamin C in the diet (P< .1).

Table 6. Effect of dietary vitamin C level on plasma vitamin C and iron status of conventional weaned pigs (20± 3 d of age)[a].

	Vitamin C, ppm					
Item	0	75	150	SEM		
Plasma vitamin C, mg/dl[b]	1.21	1.43	1.65	.08		
Serum Fe, μ g/dl[b]	145.30	148.15	172.18	7.36		
Serum UIBC, μ g/dl[bd]	352.98	332.45	295.46	15.01		
Serum TIBC, μ g/dl[ce]	498.28	480.60	467.64	11.01		
Hemoglobin, g/dl	11.19	11.16	11.33	.25		
Hematocrit, %	32.59	32.25	33.22	.53		

a Data are means of 8 pens of 5 pigs each.

b Linear effect of increasing vitamin C in the diet (P<.05).

c Linear effect of increasing vitamin C in the diet (P<.1)

d UIBC: unbound iron binding capacity.

e TIBC: Total iron binding capacity; TIBC=serum iron + UIBC.

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