Effect of Carbohydrate Sources in Phase I and Phase II Pig Starter Diets

I. B. Kim[1] and G. L. Allee*
Department of Animal Sciences, University of Missouri-Columbia, Columbia, MO 65211, USA

ABSTRACT : Previous research in our laboratory has demonstrated the importance of lactose in phase I and II pig starter diets. Two experiments were conducted to evaluate the use of a carbohydrate by-product (food by-products) as a replacement for lactose. In Exp. 1, 120 weaned pigs (14±2 d and 5.65 kg) were allotted in a randomized complete block design (RCBD) to 10 replications with four pigs per pen. This experiment evaluated three carbohydrate sources (lactose, carbohydrate by-product, and 50-50 blend of the carbohydrate by-product and lactose). The carbohydrate sources were added at 26% in the phase I diets and 15% in the phase II diets. Phase I diets contained 7.5% spray dried plasma protein (SDP). The phase I diets were fed from d 0 to 14 and the phase II diets from d 15 to 28. There were no significant differences between carbohydrate sources on pig performance in phase I. However, during phase II pigs fed the diet with lactose had an improved gain/feed ratio (G/F) (p=0.06) compared to pigs fed the carbohydrate by-product. For the entire 28 d trial ADG, ADFI and G/F were similar for the 50-50 blend and those fed lactose. Total replacement of lactose with the carbohydrate by-product resulted in a reduced G/F (p=0.09). Exp. 2 used 100 weaned pigs (17±2 d and 4.75 kg) with five replications with five pigs per pen. This experiment evaluated four carbohydrate treatments (lactose, carbohydrate by-products, 50-50 blend, and corn). All phase I diets contained 3.5% SDP with the carbohydrate sources included at 15%, and were fed d 0 to 14. The phase II diets contained 7.5% of the carbohydrate sources and were fed d 15 to 27. A common phase III diet was fed d 28 to 42. During all phases pigs fed corn tended to have a lower ADG than pigs fed the other carbohydrate sources with the 50-50 blend resulting in the highest ADG. The results of both experiments suggest that this carbohydrate by-product can replace at least 50% of the lactose in phase I and phase II pig starter diets.
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Key Words : Carbohydrate Source, Starter Diet, Weaning Pig, By-Products

INTRODUCTION

After weaning, carbohydrates usually make up approximately 70% of the diet. The ability of young pigs to utilize carbohydrates depends on the form and source (Cunningham, 1959; Sewell and Maxwell, 1966). The diet initially provided to weaning pigs frequently contains milk products. Lactose is the major carbohydrate fraction in milk. Dried skim milk and dried whey are both high in lactose (50% and 70%, respectively). These milk products improve starter pig performance which may be due to the lactose supplied. Lactase activity is also much higher than amylase activity at three weeks of age. Thus, pigs should be able to digest lactose more easily than starch carbohydrates (Tokach et al., 1994). Turlington et al. (1989) suggested that, as a source of carbohydrate, lactose improved nutrient digestibility by slowing digesta flow rate compared to a simple sugar such as dextrose for 3- to 4-week-old pigs. In a phase I (normally after weaning d 0 to 14) diet, increasing lactose level (0-15-30-45%) increased ADFI and ADG (Touchette et al., 1995a). Also, Touchette et al. (1995b, 1996) reported increasing lactose levels (0-10-20-30-40% and 0-15-30%) improved ADG and ADFI in phase I. And Crow et al. (1995) reported that in day 7-21 postweaning period, lactose improved the ADG linearly as lactose levels were increased from 0 to 15%. The beneficial effects of lactose in phase I diet were maintained through 42 d postweaning (Touchette et al., 1996). But, Stephas et al. (1996) reported when the lactose level increased from 7.2 to 22.2%, there was no difference on pig performance in phase II.

Lactose is useful carbohydrate source for the pig starter diet (Giesting et al., 1985), but it is normally more expensive than other carbohydrate sources. If other carbohydrate sources could be used in place of lactose the cost of diets might be reduced. The objectives of these experiments were to determine the effects on growth performance of weaned pigs fed phase I and phase II starter diets with various carbohydrate sources (lactose, carbohydrate by-product, and a 50-50 blend of carbohydrate by-product and lactose).

MATERIALS AND METHODS

Experiment 1

A total of 120 crossbred weaning pigs were used in this experiment to determine the effects of three different carbohydrate sources (lactose, carbohydrate by-products, and 50-50 blend of carbohydrate by-product and lactose). Their initial average body weight (BW) was 5.65 kg and average age was 14±2 d. At weaning, pigs within each weight block were allotted randomly to one of three dietary treatments. The experiment was designed as randomized

* Address reprint request to G. L. Allee. Tel: +1-573-882-7726, Fax: +1-573-884-6093, E-mail: alleeg@missouri.edu.
[1] Campus Box 7621, Department of Animal Science, North Carolina State University, Raleigh, NC 27695-7621, USA.
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complete blocks (RCBD) with 3 treatments. Pigs were housed in an environmentally (32°C) controlled nursery with wire mesh flooring. Each pen contained a self-feeder and a nipple waterer to provide *ad libitum* access to feed and water. There were 4 pigs per pen and ten replicate pens per treatment. Weekly pig weights and feed consumption were collected to calculate ADG, ADFI and gain/feed ratio (G/F). The experimental diets in the phase I (table 2) fed from d 0 to 14 were formulated to contain three carbohydrate sources (lactose, carbohydrate by-product, and 50-50 blend) at 26% of total diet which included extruded soy-protein concentration 17.4%, spray dried plasma protein (SDP) 7.5%, and spray-dried blood meal (SDBM) 1.75%. The Phase II diets (table 2; fed from d 15 to 27) contained the carbohydrate sources at 15 % with SDBM 2.5%.

Table 1. Nutrients composition of the carbohydrate by-product[1]

Items	%
Total Carbohydrate	90.0
Sucrose	(40.0)
Lactose	(10.0)
Oligosaccharides and starch	(38.5)
Glucose	(1.5)
Crude protein	2.5
Crude fat	2.0
Crude fiber	0.5
Moisture	4.0
Crude ash	1.0
ME (calculated)	3,883 kcal/kg
Physical Properties	
Color:	Tan to light brown
Aroma:	Mild sweet
Texture:	Free flowing powder
Salmonella:	Negative

[1] International Ingredient Corporation, St. Louis, MO, USA.

Experiment 2

A total of 100 crossbred weaning pigs were used in this experiment to determine the effects of four different carbohydrate sources (lactose, carbohydrate by-products, 50-50 blend, and corn). Their initial average BW was 4.75 kg and average age was 17±2 d. At weaning, pigs within each weight block were allotted randomly to one of four dietary treatments. The experiment was a RCBD with 4 treatments. Pigs were housed in an environmentally (32°C) controlled nursery with wire mesh flooring. Each pen contained a self-feeder and a nipple waterer to provide ad libitum access to feed and water. There were 5 pigs per pen and five replicate pens per treatment. Weekly pig weights and feed consumption were collected to calculate ADG, ADFI, and G/F. The experimental diets of phase I (table 3;

Table 2. Composition of Phase I and Phase II Diets on Exp. 1 (%)[1]

Items	Phase I			Phase II		
	Lactose	50-50 Blend	Carbohydrate by-product	Lactose	50-50 Blend	Carbohydrate by-product
Corn	39.73	39.73	39.73	41.27	41.27	41.27
Lactose	26.00	13.00	-	15.00	7.50	-
Carbohydrate by-product	-	13.00	26.00	-	7.50	15.00
Extruded soy-protein	17.40	17.40	17.40	-	-	-
Soybean meal (CP 48%)	-	-	-	34.00	34.00	34.00
Spray dried plasma protein	7.50	7.50	7.50	-	-	-
Spray dried blood meal	1.75	1.75	1.75	2.50	2.50	2.50
Lard	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	2.22	2.22	2.22	2.00	2.00	2.00
Limestone	0.81	0.81	0.81	0.72	0.72	0.72
Salt	0.50	0.50	0.50	0.50	0.50	0.50
L-Lysine·HCl	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.20	0.20	0.20	0.12	0.12	0.12
Vitamin premix [2]	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix [3]	0.15	0.15	0.15	0.15	0.15	0.15
Carbadox premix [4]	0.25	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.09	0.09	0.09	0.09	0.09	0.09

[1] Diets were formulated to contain 1.56% lysine, 0.86% sulfur amino acid, 1.00% threonine, 0.85% Ca, and 0.8% total P in phase I, 1.3% lysine in phase II.

[2] Provided the following per kilogram of complete diet: vitamin A, 11,000 IU; vitamin D_3, 1,100 IU; vitamin E, 22 IU; vitamin K, 4.0 mg; riboflavin, 8.25 mg; niacin, 33 mg; *d*-pantothenic acid, 28.05 mg; and vitamin B_{12}, 30.25 μg.

[3] Provided the following per kilogram of complete diet (milligrams): Zn, 165; Fe, 165; Mn, 33; Cu, 16.5; I, 0.3; Se, 0.3.

[4] Provided 55 mg/kg of carbadox.

Table 3. Composition of Phase I and Phase II Diets on Exp. 2 (%)[1]

	Phase I				Phase II			
	Lactose	50-50 Blend	Carbohydrate by-product	Corn	Lactose	50-50 Blend	Carbohydrate by-product	Corn
Corn	39.49	39.49	39.49	54.49	54.69	54.69	54.69	57.91
Lactose	15.00	7.50	-	-	7.47	3.73	-	-
Carbohydrate by-product	-	7.50	15.00	-	-	3.73	7.47	-
Soybean meal (CP 48%)	30.50	30.50	30.50	30.50	27.73	27.73	27.73	34.48
Spray dried plasma protein	3.50	3.50	3.50	3.50	-	-	-	-
Spray dried blood meal	1.75	1.75	1.75	1.75	2.50	2.50	2.50	-
Lard	5.00	5.00	5.00	5.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	2.35	2.35	2.35	2.35	2.50	2.50	2.50	2.50
Limestone	0.65	0.65	0.65	0.65	0.70	0.70	0.70	0.70
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
L-Lysine·HCl	0.15	0.15	0.15	0.15	0.10	0.10	0.10	0.10
DL-Methionine	0.14	0.14	0.14	0.14	0.08	0.08	0.08	0.08
Vitamin premix [2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix [3]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Carbadox premix [4]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08
Zinc oxide	0.23	0.23	0.23	0.23	-	-	-	-

[1] Diets were formulated to contain 1.56% lysine, 0.86% sulfur amino acid, 1.00% threonine, 0.85% Ca, and 0.8% total P in phase I, 1.3% lysine in phase II.
[2] Provided the following per kilogram of complete diet: vitamin A, 11,000 IU; vitamin D_3, 1,100 IU; vitamin E, 22 IU; vitamin K, 4.0 mg; riboflavin, 8.25 mg; niacin, 33 mg; *d*-pantothenic acid, 28.05 mg; and vitamin B_{12}, 30.25 μg.
[3] Provided the following per kilogram of complete diet (milligrams): Zn, 165; Fe, 165; Mn, 33; Cu, 16.5; I, 0.3; Se, 0.3.
[4] Provided 55 mg/kg of carbadox.

Table 4. Effect of dietary carbohydrate source on weaned pig performance on Exp. 1

Items	Lactose	50-50 Blend	Carbohydrate by-product	SEM
Weight, kg				
Initial	5.65	5.69	5.62	0.068
14 d	9.79	10.11	9.57	0.213
28 d	17.58	17.45	16.75	0.349
Daily gain, kg				
0 to 14 d	0.295	0.316	0.282	0.013
15 to 28 d	0.557	0.525	0.513	0.015
0 to 28 d	0.426	0.420	0.398	0.011
Daily feed, kg				
0 to 14 d	0.391	0.406	0.372	0.015
15 to 28 d	0.734	0.757	0.738	0.025
0 to 28 d	0.562	0.582	0.555	0.017
G/F ratio				
0 to 14 d	0.750	0.776	0.750	0.011
15 to 28 d[1]	0.759	0.686	0.694	0.016
0 to 28 d	0.759	0.720	0.716	0.012

[1] Carbohydrate by-product vs. lactose (p=0.06).

fed from d 0 to 14) contained 15% of each carbohydrate sources (lactose, carbohydrate by-product, 50-50 blend) based on a corn-soybean meal diet. In order to compare as a negative control treatment, one diet contained only corn (54.49%) as the carbohydrate source. The phase II diets (table 3; fed from d 15 to 27) were formulated to contain 7.5% of three different carbohydrate sources. The negative control diet contained 57.91% of corn. In the phase III, all pigs were fed same corn-soybean meal based diet from d 28 to 42.

Statistical analysis

Data were analyzed using the general linear model (GLM) procedures of SAS program (SAS, 1992).

RESULTS

Experiment 1

There was no significant difference between carbohydrate sources on pig performance in phase I. However, during phase II pigs fed the diet with lactose had an improved G/F ratio (p=0.06) compared to pigs with the carbohydrate by-product (table 4). For the entire 28 d trial ADG, ADFI and G/F were similar for pigs fed the 50-50 blend and those fed lactose.

Experiment 2

In phase I, pigs fed corn (negative control) tended to

Table 5. Effect of dietary carbohydrate source on weaned pig performance on Exp. 2

Items	Lactose	50-50 Blend	Carbohydrate by-product	Corn	SEM
Weight[1], kg					
Initial	4.81	4.78	4.71	4.69	0.045
14 d	8.87	8.81	8.91	8.55	0.191
27 d	14.22	14.92	14.61	14.07	0.386
42 d	24.24	24.76	23.31	23.07	0.748
Daily gain[1], kg					
0 to 14 d	0.290	0.288	0.300	0.275	0.013
15 to 27 d	0.412	0.470	0.439	0.425	0.023
28 to 42 d	0.668	0.656	0.580	0.600	0.028
0 to 42 d	0.463	0.476	0.443	0.438	0.018
Daily feed[1], kg					
0 to 14 d	0.319	0.318	0.319	0.295	0.013
15 to 27 d	0.629	0.678	0.635	0.653	0.028
28 to 42 d	1.076	1.108	1.078	1.098	0.041
0 to 42 d	0.685	0.712	0.682	0.681	0.026
G/F ratio[1]					
0 to 14 d	0.911	0.899	0.944	0.935	0.026
15 to 27 d	0.656	0.696	0.689	0.660	0.018
28 to 42 d	0.621	0.595	0.555	0.593	0.014
0 to 42 d	0.676	0.670	0.656	0.666	0.010

[1] No significant differences (p>0.05).

consume less feed and gain less than pigs fed the other carbohydrate sources. Growth performances were similar for the other carbohydrate sources. A similar tend was also observed for phase II but not for phase III. In phase III, 50-50 blend and lactose dietary treatments were similar performance (table 5). For the overall period, pigs fed lactose and 50-50 blend were one kilogram heavier at the end of the 42 d experiment that pigs fed the negative control corn diet or total replacement of lactose with the carbohydrate by-product.

DISCUSSION

We evaluated a carbohydrate by-product (table 1) manufactured from food by-products including select candies, drink mixes, cake mixes, and starch. The carbohydrate by-product contained 40% sucrose, 10% lactose, 1.5% glucose, 38.5% oligosaccharides and starches, and was evaluated a replacement for lactose in phase I and phase II pig starter diets. These results indicate that this carbohydrate by-product can replace 50% of the lactose in phase I and Phase II pig starter diets without having a detrimental effect on pig performance.

Milk products play an important role in young animal diets. Piglets readily use lactose - milk sugar - as a primary energy source. Lactose is the predominant sugar in sow milk which appears to be hydrolyzed efficiently from birth, by means of the enzyme lactase (Low, 1980). Lactose improved pig growth performance (Jin et al., 1998; Nessmith et al., 1996; Touchette et al., 1996; Tokach et al., 1995; Mahan, 1992; Tokach et al., 1989) and nutrient digestibility (Jin et al., 1998; Tokach et al., 1989; Turlington et al., 1989), and improved digestibilities when combined with soybean meal (Sewell and West, 1965). However, Wilson and Leibholz (1979) found no differences in apparent nutrient digestiblities for young pigs fed diets containing lactose or wheat starch when casein was the primary protein source. Giesting et al. (1985) reported that lactose increases feed intake, whereas casein improved feed utilization.

Hansen et al. (1993) reported that lactose was superior to cornstarch in diets contained 10.0 and 13.4% porcine plasma. Similar results (Newton and Mahan, 1990; Mahan, 1991; Radke et al., 1991) support the hypothesis that young pigs cannot utilize dietary amylose as completely as lactose. Owen et al. (1993) reported that starter pig performance was improved linearly as lactose level increased from 7 to 23% in a nursery diet containing 7.5% spray-dried porcine plasma. Touchette et al. (1995a) reported an interactions between spray dried plasma protein and lactose in the first week for G/F ratio (p=0.05), and the lactose response is dependent on SDP in the weaning pig diet. They reported that pigs receiving SDP reached their peak performance at 15% added lactose while 30% and 45% added lactose was necessary in diets with no SDP. The result of Exp. 1 is in good agreement with the results of Touchette et al. (1995a).

In the phase I period of Exp. 1, the 50-50 blend diet was contained 14.3% lactose compared to lactose diet which contained 26% lactose. Growth performance of pigs was not different between the 50-50 blend diet and lactose diet treatment when both diet contained of 7.5% SDP. And in Exp. 2, when the lactose level was dropped to 15% (lactose diet) and 8.25% (50-50 blend diet) with 3.5% SDP, there were no differences in growth performance between these two diets. These results suggest lower levels of lactose in diets containing SDP give similar pig performance in the Phase I period.

Several studies (Aherne et al., 1969; Kidder et al., 1968; Sewell and Maxwell, 1966; Sewell and West, 1965; Cunningham, 1959; Cunningham and Brisson, 1957; Becker et al., 1954) have shown that glucose is rapidly absorbed by piglets from birth, over a wide intake range, but if it is fed at high levels diarrhea may arise (Low, 1980). Newton and Mahan (1990) reported that dextrose was as effective a carbohydrate source compared with lactose in early weaning pig diet. And Newton and Mahan (1993) reported that supplemental lactose or dextrose resulted in improved weight gains ($p<0.01$) to a total dietary level of 45% during the initial 14 d postweaning. They suggested that the performance of weaned pigs might be improved by the inclusion of less-complex carbohydrate sources (lactose or dextrose) at dietary levels from 34.5 to 45%. Richert et al. (1996) also reported that increasing simple sugar level (lactose, blend of lactose and dextrose) in the second and third weeks postweaning improved ADG ($p<0.07$). Also substituting dextrose for part of the dietary lactose increased ADG ($p<0.10$) in second and third weeks postweaning.

Sucrose requires an enzyme to break it into its constituent simple sugar. This enzyme is sucrase. At birth, pigs have low sucrase levels. Trials from the 1950s and 1960s demonstrated that pigs less than 7 days old eating diets with sucrose or fructose develop severe diarrhea, weight loss and suffer from high mortality (Becker and Terrill, 1954; Aherne et al., 1969). However, after pigs reach 7 to 10 days of age, they can use sucrose efficiently (NRC, 1998). Jin et al. (1998) fed a series of diets to evaluate the optimum lactose to sucrose ratio in the diet. Their results suggested that sucrose could effectively replace up to 50% lactose in starter diets.

In phase I of Exp. 1, the 50-50 blend and carbohydrate by-product diets were contained sucrose 5.2 and 10.4%, respectively. Pigs consumed a little more feed of the 50-50 blend diet in this period. This result indicated some benefit in having a cocktail of simple sugar in the diets along with lactose. There may be some synergy when lactose and other simple sugars are present in phase I pig diet. Therefore, in this study, the carbohydrate by-product shows potential of replacing part of the lactose in starter pig diets. The potential may be come from the containing simple sugar (sucrose, lactose, glucose), dextrose, and oligosaccahrides.

IMPLICATIONS

The results of both experiments suggest that this carbohydrate by-product can replace at least 50% of the total lactose in phase I and phase II diets without having a detrimental effect on pig performance. This by-product may be an economical alternative to lactose in starter pig diets.

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