Effects of Various Carbohydrate Sources on the Growth Performance and Nutrient Utilization in Pigs Weaned at 21 Days of Age

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ABSTRACT : A total of 125 pigs (5.8 kg BW, 21 d of age) were allotted in a completely randomized block design experiment. Dietary treatment added carbohydrate sources : corn starch, lactose, glucose, sucrose or dried whey in corn-soybean meal based diet. Each treatment has 5 replicates with 5 pigs per replicate. Lactose, sucrose and dried whey supported a better growth performance than starch and glucose ($p < 0.05$) during the first and second week postweaning. However, in the third week postweaning no difference was found in ADG and ADFI among treatment. For overall period, pigs fed lactose, sucrose and dried whey diets showed similar growth performance and were superior to starch and glucose. The gross energy digestibility in pigs fed lactose, sucrose and dried whey diets were similar and significantly higher than those fed glucose and starch diets ($p < 0.05$). DM digestibility was not significantly affected by other carbohydrate sources except starch. Pigs fed lactose, sucrose and dried whey showed the best nitrogen digestibility. In all nutrients digestibility, there was no significant difference among treatment except starch and glucose diet. DM excretion was lower in pigs fed lactose, sucrose and dried whey than pigs fed starch and glucose. In conclusion, it appeared that sucrose could be effectively incorporated in baby pig diet without sacrificing growth performance.
(**Key Words:** Pigs, Lactose, Sucrose, Carbohydrate, Growth Performance)

INTRODUCTION

During the past few years, there has been an increasing interest in weaning pigs at ages of 2 or 3 weeks. When pigs are weaned at such the early age, palatability of the starter diet is important to insure adequate consumption of required nutrients. Smith and Lucas (1956, 1957) and Leibbarandt and Ewan (1972) have reported average daily feed intake was low during the first week post-weaning for early weaned pigs. Generally, carbohydrates make up approximately 70% of the weanling diet. The ability of young pigs to utilize carbohydrates depends on the form and source (Cunningham, 1959; Sewell and Maxwell, 1966). Young pigs have shown a preference for diets containing sugar or other sweeteners (Lewis et al., 1955; Diaz et al., 1956; Aldinger et al., 1959, 1961; Aldinger and Fitzgerald, 1966).

The importance of lactose as the primary carbohydrate in the diet of sucking animals has been recognized for many years. The nutritional and physiological roles of lactose seem to diminish with time because (1) the specific activity of lactase in the digestive tract decreases with age (Simoons, 1969; Ekstrom et al., 1975), and (2) the animal no longer receives lactose from milk because milk is replaced with diets made up largely of plant feedstuffs.

Early work with sucrose indicated that newborn pigs developed severe diarrhea when fed sucrose because of their inability to hydrolyze the glucosidic bond of sucrose (Johnson, 1949; Becker et al., 1954b). Aherne et al. (1969) also found the growth rate of baby pigs fed a diet containing sucrose to be lower than that of baby pigs fed diets containing glucose or lactose. Mateo and Veum (1980) demonstrated that baby pigs could utilize sucrose at 15 days of age without mortality and attain performance similar to that of pigs fed a diet containing glucose.

Several experiments have shown that including dried whey in a starter diet generally improved daily gain and feed efficiency of piglets weaned at 2 to 4 wk of age (Kornegay et al., 1974; Miller et al., 1971; Pals and Ewan, 1978; Graham et al., 1981; Cera and Mahan, 1985; Goodband and Hines, 1987). Additional studies with dried whey have been conducted to investigate the optimum inclusion level (Mahan et al., 1981; Clarkson and Allee, 1982; Fralick and Cline, 1983), appropriate weaning age and feeding length (Pope and Allee, 1982;

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Pollmann et al., 1983). The improvement, however, was not always statistically significant (Meade et al., 1969; Wahlstrom et al., 1974)

Practically, lactose and dried whey are the most common carbohydrate sources for baby pigs. However, these milk based carbohydrate sources are usually much costly than other carbohydrate sources. Since, modem baby pig diets contains highly digestible ingredients, such as plasma protein, the role of carbohydrate sources can be diminished. Regarding this point, the value of carbohydrate sources should be re-evaluated. Thus this experiment was conducted to compare the utilization of starch, lactose, glucose, sucrose and dried whey by 21 day weaned pigs. Criteria investigated were growth performance, nutrients digestibility and nutrients excretion.

MATERIALS AND METHODS

Three way crossbreed (Landrace × Large White × Duroc) barrows weaned at 21 days of age were used as an experimental subjects. At 21 days of age, a total of 125 pigs averaged 5.8 kg of body weight were chosen and allotted in a completely randomized block design. Treatments included in growth trials were com starch, lactose, glucose, sucrose and dried whey. Each treatment has 5 replicates with 5 pigs per replicate.

During phase Ⅰ (0 to 7 d postweaning), all pigs were fed a common high nutrient density diet (table 1). he

Table 1. Formula and chemical composition of experimental diets (%)

Item	Starch	Lactose	Glucose	Sucrose	Dried whey
Ingredient (%)					
Corn	35.58	36.52	36.52	36.52	40.40
SBM	24.50	24.50	24.50	24.50	19.00
SDPP	6.00	6.00	6.00	6.00	6.00
FM	5.00	5.00	5.00	5.00	5.00
Blood meal	2.00	2.00	2.00	2.00	2.00
Corn oil	3.00	3.00	3.00	3.00	5.00
Starch	20.00	–	–	–	–
Lactose	–	20.00	–	–	–
Glucose	–	–	20.00	–	–
Sucrose	–	–	–	20.00	–
Dried whey	–	–	–	–	20.00
Limestone	0.35	0.35	0.35	0.35	0.20
MCP	1.80	1.80	1.80	1.80	1.60
Salt	0.20	0.20	0.20	0.20	0.20
Vit. min[1]	0.25	0.25	0.25	0.25	0.25
Antibiotic	0.20	0.20	0.20	0.20	0.20
Methionine	0.14	0.14	0.14	0.14	0.13
Threonine	0.02	0.02	0.02	0.02	0.02
Tryptophan	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]					
ME (kcal/kg)	3.45	3.41	3.41	3.42	3.40
CP (%)	23.21	23.21	23.21	23.21	23.21
	(23.10)[3]	(23.03)	(23.06)	(23.05)	(23.10)
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.80	0.80	0.80	0.80	0.80
	(0.76)	(0.75)	(0.74)	(0.76)	(0.75)
Lysine (%)	1.55	1.55	1.55	1.55	1.55
	(1.52)	(1.53)	(1.54)	(1.53)	(1.54)
Methionine (%)	0.47	0.47	0.47	0.47	0.47
	(0.45)	(0.46)	(0.46)	(0.45)	(0.46)
Threonine (%)	1.01	1.01	1.01	1.01	1.01
	(0.99)	(0.98)	(0.98)	(0.97)	(0.98)
Tryptophan (%)	0.28	0.28	0.28	0.28	0.28

[1] Vit.- min, mixture contains per kg : vitamin A, 2,000,000 IU; Vitamin D_3, 400,000 IU; Vitamin E, 250 IU; Vitamin K_3, 200 mg; Vitamin B_1, 20 mg; Vitamin B_2, 700 mg; Riboflavin, 10,000 mg; Pantothenic calcium, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 mg; Folacin, 200 mg; Vitamin B_{12}, 13 mg; Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; Co, 100 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Calculated value. [3] Analyzed value.

phase Ⅰ diet was formulated to 3,420 kcal ME/kg, 1.55% lysine (Jin et al., 1998), phase Ⅱ diet (table 2) were formulated to contain 1.35% total lysine with fortified methionine, threonine, tryptophan to get optimum inter-amino acids ratio suggested by Chung and Baker (1992), 0.9% Ca, and 0.8% P.

The pigs were kept in concrete-floored pens, and feed and water were provided *ad libitum* during the entire experimental period of 3 weeks. The temperature was maintained at the range of 26 to 30℃ through the experimental period. Body weight and feed intake were recorded weekly.

Table 2. Formula and chemical composition of experimental diets (%)

Item	Starch	Lactose	Glucose	Sucrose	Dried whey
Ingredient (%)					
Corn	39.18	39.19	39.18	39.18	43.16
SBM	25.80	25.80	25.80	25.80	20.20
SDPP	2.00	2.00	2.00	2.00	2.00
FM	5.00	5.00	5.00	5.00	5.00
Blood meal	2.00	2.00	2.00	2.00	2.00
Corn oil	3.00	3.00	3.00	3.00	5.00
Starch	20.00	–	–	–	–
Lactose	–	20.00	–	–	–
Glucose	–	–	20.00	–	–
Sucrose	–	–	–	20.00	–
Dried whey	–	–	–	–	20.00
Limestone	0.30	0.30	0.30	0.30	0.15
MCP	1.95	1.95	1.95	1.95	1.75
Salt	0.20	0.20	0.20	0.20	0.20
Vit. min[1]	0.25	0.25	0.25	0.25	0.25
Antibiotic	0.20	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10	0.09
Threonine	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]					
ME (kcal/kg)	3.44	3.40	3.40	3.41	3.39
CP (%)	21.00	21.00	21.00	21.00	21.00
	(20.89)[3]	(20.91)	(20.91	(20.88)	(20.89)
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.80	0.80	0.80	0.80	0.80
	(0.76)	(0.75)	(0.75)	(0.76)	(0.77)
Lysine (%)	1.35	1.35	1.35	1.35	1.35
	(1.33)	(1.35)	(1.34)	(1.33)	(1.33)
Methionine (%)	0.41	0.41	0.41	0.41	0.41
	(0.40)	(0.40)	(0.42)	(0.41)	(0.41)
Threonine (%)	0.88	0.88	0.88	0.88	0.88
	(0.87)	(0.86)	(0.87)	(0.86)	(0.87)
Tryptophan (%)	0.26	0.26	0.26	0.26	0.26

[1] Vit.- min. mixture contains per kg : vitamin A, 2,000,000 IU; Vitamin D_3, 400,000 IU; Vitamin E, 250 IU; Vitamin K_3, 200 mg; Vitamin B_1, 20 mg; Vitamin B_2, 700 mg; Riboflavin, 10,000 mg; Pantothenic calcium, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 mg; Folacin, 200 mg; Vitamin B_{12}, 13 mg; Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; Co, 100 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Calculated value.

[3] Analyzed value.

For the digestibilities of experimental diets, pigs were fed diets containing 0.25% Cr_2O_3 during the second week of the experimental period and feces was collected three times (08:00, 14:00, 20:00) a day after four days of adjustment period. Fecal samples were dried in an air-forced drying oven at 60℃ for 72 hours and ground with 1 mm mesh Wiley mill for chemical analysis.

Feed and fecal samples were analyzed for proximate analysis and mineral composition by AOAC methods (1990). Chromium was measured using Atomic Absorption Spectrophotometer (Shimadzu, AA6145F, Japan). For energy utilization, energy values of feed and feces were measured by Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL).

Statistical analysis were conducted using GLM procedure of SAS package (1985), and treatment means were compared using Duncan's multiple range test (Duncan, 1955)

RESULTS AND DISCUSSION

1. Growth performance

The effect of carbohydrate sources on growth performance of weanling pigs is given in table 3. From d 0 to 7 postweaning, average daily gain (ADG) and average daily feed intake (ADFI) improved ($p < 0.05$) for pigs fed diets containing lactose, sucrose and dried whey compared to pigs fed diets starch and glucose, but pigs fed diets containing lactose had improved F/G compared with pigs fed diets with sucrose and dried whey ($p < 0.05$).

From d 7 to 14 postweaning, ADG and ADFI showed similar trend with the performance of the first week. However, feed conversion (FC) was not significant among treatment except starch diet. This indicates that sucrose can be utilized as well as lactose and this can be supported by the fact that pigs have appreciable level of sucrase in their intestine at over 2 weeks of age (Bailey et al., 1956; Dahlqvist, 1961; Walker, 1959).

From d 15 to 21 postweaning, no significant difference was found in ADG and ADFI among treatment. It seemed that pigs' growth rate was not affected by different carbohydrate sources by the time two weeks after weaning.

For overall period, pigs fed lactose, sucrose and dried whey diets showed similar growth performance. Starch and glucose did not support pigs to grow at similar rate with pigs fed lactose, sucrose and dried whey diets.

Table 3. Growth performance of pigs fed different carbohydrate sources

	Starch	Lactose	Glucose	Sucrose	Dried Whey	SE[1]
D 0 to 7						
ADG (g)	241.43^{c}	294.00^{a}	258.57^{b}	291.72^{a}	286.00^{a}	6.36
ADFI (g)	297.71^{c}	329.43^{a}	316.00^{b}	338.86^{a}	333.73^{a}	7.59
F/G	1.22^{c}	1.11^{a}	1.21^{c}	1.15^{b}	1.16^{b}	0.01
D 8 to 14						
ADG (g)	391.43^{b}	421.71^{a}	399.43^{b}	423.71^{a}	417.72^{a}	7.96
ADFI (g)	534.86^{bc}	552.00^{a}	529.71^{c}	556.57^{a}	548.57^{a}	12.26
F/G	1.36^{b}	1.31^{a}	1.32^{a}	1.31^{a}	1.31^{a}	0.01
D 0 to 14						
ADG (g)	316.43^{c}	357.86^{a}	329.00^{b}	357.71^{a}	351.86^{a}	5.57
ADFI (g)	416.29^{b}	440.72^{a}	422.86^{b}	447.72^{a}	441.15^{a}	8.09
F/G	1.31^{d}	1.23^{a}	1.28^{c}	1.24^{b}	1.25^{b}	0.01
D 15 to 21						
ADG (g)	523.71	528.86	526.57	528.56	530.00	8.64
ADFI (g)	786.86	785.14	784.00	782.00	785.43	9.42
F/G	1.50^{b}	1.48^{ab}	1.49^{ab}	1.48^{a}	1.48^{ab}	0.02
D 0 to 21						
ADG (g)	385.52^{c}	414.86^{a}	394.86^{b}	414.76^{a}	411.24^{a}	5.28
ADFI (g)	539.81^{b}	555.52^{a}	543.24^{b}	559.14^{a}	555.91^{a}	6.60
F/G	1.40^{d}	1.33^{a}	1.37^{c}	1.34^{ab}	1.35^{b}	0.01

[1] Pooled standard error, n=30.

[a,b,c,d] Figures within the same row bearing different superscripts are significantly different at $p < 0.05$.

Between sucrose and glucose treatment, pigs fed sucrose grew more efficiently than pigs fed glucose. This result is in contrast with the report by Mahan and Newton (1993) who reported that dextrose was utilized as well as lactose by 3 or 4 weeks old piglets. However, in their experiment, since 45% of dried skim milk was used in all experimental diets, direct comparison might not be meaningful. Veum and Mateo (1981) also reported that glucose was utilized as well as sucrose by 1 week old piglets. However, in our study carbohydrate sources was used at 20% of the experimental diet compared to 52% of the diet in the study by Veum and Mateo (1981), thereby might produce different results. Also the fact that the protein sources were all different in each study may have some reason for the different results observed. In other study, Becker et al. (1954b) found that even though five out of eight pigs scoured and died when fed the sucrose diet, the surviving pigs gained more efficiently than the pigs fed glucose diet.

The results of growth performance are in good agreement with the reports of increased sucrase activity with an increase in age (Bailey et al., 1956; Walker, 1959; Dahlqvist, 1961) and of an increased rate of hydrolysis of sucrose as the pig matures (Dollar et al., 1957; Kidder et al., 1963).

This experiment clearly indicates that baby pigs utilized sucrose as early as 21 days of age with performance similar to that of pigs fed the diet containing lactose and glucose. These results are in agreement with the earlier work (Becker et al., 1954a) suggesting that body weight gains were similar when pigs were fed dextrose or sucrose from 7 to 35 days of age. Also, Aherne et al. (1969) reported that sucrose was utilized by baby pigs as early as 7 day of age without mortality, but that ADG was lower than those of pigs fed glucose or lactose diets.

It has been reported that sucrose is utilized about as well as glucose by 1-week-old piglets (Mateo and Veum, 1980; Veum and Mateo, 1981), but not by piglets less than 1 week of age (Becker et al., 1954b; Kidder et al., 1963; Aherne et al., 1969) because the newborn do not produce adequate amount of intestinal sucrase (Johnson, 1949). Piglets reared artificially and fed diets containing sucrose adapted physiologically by increasing inestinal production of sucrase as compared with piglets nursing sows (Manners and Stevens, 1972). Piglets weaned at 2 weeks of age and fed a cereal-based diet adjusted physiologically, as evidenced by a greater total amylase activity (primarily due to greater pancreatic activity) as compared with piglets weaned at an older age (Shields et al., 1980).

The literature has not always been consistent on the age at which functional levels of intestinal sucrase develop in neonatal pigs. Dahlqvist (1961) reported that intestinal sucrase was present at birth and that it increased considerably by 4 weeks of age. An increase in sucrase activity from birth to 7 weeks of age was also reported by Hartman et al. (1961). Bailey et al. (1956) examined the intestinal mucosa and found no sucrase activity in newborn pigs, some sucrase activity in 1-week-old pigs and appreciable levels of activity by 2 weeks of age. Walker (1959) found that sucrase activity was very low in the intestinal tissue of newborn pigs, but then increased slowly during the first week and very rapidly until 3 weeks of age. The differences reported in the age at which functional levels of intestinal sucrase activity were obtained may be attributed in part to both genetic differences and environmental variability such as that associated with the different methods of rearing baby pigs.

Manners and Stevens (1972) reported that considerable variation existed among baby pigs in activity of intestinal sucrase, although sucrase activity was present in the small intestine of 1-week-old pigs and continued to increase until maturity. Baby pigs reared artificially on diets containing sucrose had higher levels of intestinal sucrase activity than did the pigs reared naturally (Manners and Sevens, 1972). Thus, the addition of sucrose to the diet of the 1-week-old pig may have stimulated the production of intestinal sucrase activity.

Pigs fed the lactose diet tended to be more efficient in utilization of feed ($p < 0.05$) than pigs fed the sucrose and dried whey supplemented diet during first week. No differences were found in ADG and ADFI at 1 to 3 weeks. Lactose addition to starter pig diets have been previously shown to improve pig performance (Sewell and West, 1965; Giesting et al., 1985).

2. Nutrients digestibility

The effects of different carbohydrate sources on nutrient digestibility are presented in table 4. The best gross energy digestibility was found in pigs fed lactose, sucrose and dried whey diets, and the worst was found in pigs fed starch diet ($p < 0.05$). Dry matter digestibility was not significantly affected by treatment except starch which showed significantly lower dry matter digestibility ($p < 0.05$). Pigs fed lactose, sucrose and dried whey showed the best nitrogen digestibility ($p < 0.05$). In all nutrients digestibility, there was no significant difference among treatment except starch and glucose diet. This may explain why pigs fed lactose, sucrose and dried whey showed similar growth performances.

Owsley et al. (1986a) also reported an increase in DM

Table 4. Effects of different carbohydrate sources on nutrient digestibilities in weaned pigs (%)

Treatment	GE	Dry matter	Nitrogen	Crude fat	Crude ash	Phosphorous
Starch	83.14[b]	87.01[b]	82.66[c]	81.77[b]	69.35[ab]	66.62[b]
Lactose	86.71[a]	87.75[a]	84.84[a]	84.64[a]	70.19[a]	68.72[ab]
Glucose	85.19[ab]	87.93[a]	83.33[bc]	82.45[a]	70.64[a]	68.80[ab]
Sucrose	86.05[a]	88.41[a]	83.86[ab]	82.04[a]	68.71[ab]	69.22[a]
Dried Whey	86.21[a]	87.85[a]	84.54[a]	82.74[a]	68.19[b]	67.61[ab]
SE[1]	4.61	0.35	0.63	1.57	2.10	3.21

[1] Pooled standard error, n=24.
[a,b,c] Figures within the same column bearing different superscripts are significantly different at $p < 0.05$.

and energy digestibility with the addition of 20% dried whey to a corn-soybean meal diet. Wilson and Leibholz (1981a,b) and Leibholz (1982) found similar improvement in digestibility when skim milk was used as the milk product. Lactose also has been shown previously to improve N and DM digestibility (Sewell and West, 1965). This improvement may result from the high level of lactase, the enzyme responsible for lactose degradation, present in the digestive system of the young pig (Corring et al., 1978). Our results confirmed these previous findings.

Several recent reports (Newton and Mahan, 1990; Mahan, 1991; Radke et al., 1991) supported the hypothesis that young pigs cannot utilize dietary amylose as completely as lactose. therefore, the level of dietary lactose is important in diets of early-weaned pigs. However, our results indicate that the level of lactose inclusion in the baby pig diets should be considered carefully, since pigs fed sucrose grew at similar growth rate with pigs fed lactose.

In some research, palatability problems have been encountered when pigs were fed corn starch or wheat starch as carbohydrate sources (Cunningham, 1959; Sewell and Maxwell, 1966; Giesting et al., 1985). To avoid these problems, dextrose was chosen rather than starch as the carbohydrate source to compare to lactose (Johnson et al., 1949). Previous work suggested the young pigs would respond differently to dextrose and lactose in the diet (Sewell and Maxwell, 1966; Buraczewski et al., 1971).

3. Nutrients excretion

Table 5 summarized the effect of different carbohydrate sources on the nutrient excretion and clearly showed that nutrient excretion obviously affected by carbohydrate sources. Dry matter excretion was reduced in pigs fed lactose, sucrose and dried whey than pigs fed starch and glucose, and pigs fed glucose excreted less amount of dry matter than pigs fed starch ($p < 0.05$). Pigs fed starch excreted significantly more amount of nitrogen than pigs fed other carbohydrate sources. Among lactose, sucrose and dried whey, no significant difference was found in nitrogen excretion, however there was a tendency that pigs fed lactose containing diet (lactose or dried whey) excreted less amount of nitrogen than pigs fed sucrose. This can be explained by some previous studies (Owsley et al., 1986a; Wilson and Leibholz, 1981a,b; Leibholz, 1982; Sewell and West, 1965) which reported an increased nitrogen digestibility of pigs fed lactose containing diets.

Table 5. Effects of different carbohydrate sources on nutrient excretion in weaned pigs (g/1,000 g body weight gain)

Treatment	Dry matter	Nitrogen	Phosphorous
Starch	177.84[a]	7.98[a]	3.66
Lactose	154.82[c]	6.86[c]	3.37
Glucose	157.31[b]	7.30[b]	3.25
Sucrose	152.04[c]	7.11[bc]	3.23
Dried Whey	154.79[c]	6.62[c]	3.30
SE[1]	3.65	1.20	0.25

[1] Pooled standard error, n=24.
[a,b,c] Figures within the same column bearing different superscripts are significantly different at $p < 0.05$.

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