Optimum Lactose : Sucrose Ratio for the Pigs Weaned at 21 Days of Age

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ABSTRACT : A total of 240 weaned pigs (BW 5.4 kg) were allotted in a completely randomized block design to find out the optimum lactose:sucrose ratio for the weaned pigs. Treatements were 100:0 (A), 75:25 (B), 50:50 (C), 25:75 (D) and 0:100 (E) in lactose:sucrose ratio. For the first week after weaning, average daily gain (ADG) and feed/gain (F/G) were improved ($p<0.05$) for pigs fed A, B and C diets compared to pigs fed diets D and E, but the average daily feed intakes (ADFI) of the pigs were not different. From d 7 to 14, no significant differences was found in ADG and ADFI among the treatments, but pigs fed the diets A, B and C had improved F/G compared with the pigs fed diets D and E ($p<0.05$). From d 15 to 21, no significant differences were found in ADG, ADFI and F/G among the treatments. The digestibility of nutrients was not influenced by the lactose : sucrose ratio except nitrogen. Nitrogen digestibility of A diet was significantly higher than D and E diets ($p<0.05$) but no significant differences were found among diets A, B and C. Dry matter and phosphorus excretions were not influenced by the treatments. The pigs fed diets A, B and C excreted significantly less nitrogen than the pigs fed diets D and E. In conclusion, the results suggest that sucrose can effectively replace up to 50% lactose in starter diets.

(**Key Words** : Pigs, Lactose, Sucrose, Growth)

INTRODUCTION

Newly weaned pigs are subjected to nutritional, psychological and environmental stressors that are imposed simultaneously. There are marked changes to the morphology and function of the small intestine that happen within 24h of weaning, and changes are generally comprised with a decrease in villous height, an increase in crypt depth, reductions in the specific activity of the digestive enzymes lactase and sucrase and reduced absorptive capacity (Gay, 1976; Gay et al., 1976; Armstrong and Clawson, 1980; Hampson, 1983; Hampson and Kidder, 1986; Miller et al., 1986; Kelly et al., 1991a, b). The combined effect of these factors probably causes reduced digestive and absorptive capacity of the small intestine and contributes to the low voluntary food intake and poor growth observed after weaning (Smith and Lucas, 1956, 1957; Leibbrandt and Ewan, 1972; Gay et al., 1976; Hampson, 1983).

For the pigs weaned at early age, palatability of the starter diet is important to insure adequate consumption of required nutrients. 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). Young weaned 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). Early work with sucrose (Aherne et al., 1969; Diaz et al., 1956; Kidder et al., 1963; Lewis et al., 1955; Mateo and Veum, 1980) demonstrated that baby pigs could utilize sucrose at 15 and 21 days of age without mortality and with performance similar to those pigs fed a diet containing glucose and lactose. Jin et al. (1997b) compared sucrose with lactose and with dried whey and confirmed those previous findings. However, there is little information on optimal ratio of lactose : sucrose for weaned piglets. Since the high nutrient density ingredients, such as plasma protein, used in modern pig diets, the importance and the inclusion level of lactose in the starter diets need to be re-estimated. Therefore, this experiment was desinged to determine the appropriate level of lactose and sucrose for weaned pigs.

MATERIALS AND METHODS

Three way crossbreed (Landrace × Large White × Duroc) barrows weaned at 21 days of age were used as

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an experimental subject. At 21 days of age, a total of 240 pigs (averaged 5.4 kg of body weight) were chosen and allotted in a completely randomized block design. Treatments were 100:0 (A), 75:25 (B), 50:50 (C), 25:75 (D) and 0:100 (E) in lactose:sucrose ratio. Each treatment consisted of 6 replicates with 8 pigs per replicate.

During phase I (0 to 7 d postweaning), all pigs were fed with the high nutrient density diets (table 1). The phase I diets were formulated to supply 3.41 Mcal ME/kg, 1.55% lysine (Jin et al., 1997a). Phase II diets (table 2) were formulated to contain 3.39 Mcal ME/kg, 1.35% lysine with fortified methionine, threonine, tryptophan to get optimal inter-amino acids ratio suggested by Chung and Baker (1992), 0.9% Ca and 0.8% P.

Table 1. Formula and chemical composition of experimental diets in phase I

Treatments	Lactose : Sucrose				
	100:0	75:25	50:50	25:75	0:100
Ingredients (%)					
Corn	38.46	38.46	38.46	38.46	38.46
Soybean meal	22.50	22.50	22.50	22.50	22.50
Spray-dried plasma protein	6.00	6.00	6.00	6.00	6.00
Fish meal	5.00	5.00	5.00	5.00	5.00
Spray-dried blood meal	2.00	2.00	2.00	2.00	2.00
Corn oil	5.00	5.00	5.00	5.00	5.00
Lactose	20.00	15.00	10.00	5.00	–
Sucrose	–	5.00	10.00	15.00	20.00
Limestone	0.30	0.30	0.30	0.30	0.30
Monocalcium phosphate	1.90	1.90	1.90	1.90	1.90
Salt	0.30	0.30	0.30	0.30	0.30
Vit.-min. mix.[1]	0.25	0.25	0.25	0.25	0.25
Antibiotics	0.20	0.20	0.20	0.20	0.20
DL-Methionine	0.09	0.09	0.09	0.09	0.09
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 (Mcal/kg)	3.41	3.41	3.41	3.41	3.41
CP (%)	22.80	22.80	22.80	22.80	22.80
	(22.48)[3]	(22.52)	(22.55)	(22.49)	(22.50)
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.80	0.80	0.80	0.80	0.80
	(0.73)	(0.76)	(0.72)	(0.73)	(0.74)
Lysine (%)	1.55	1.55	1.55	1.55	1.55
	(1.52)	(1.53)	(1.53)	(1.54)	(1.53)
Methionine (%)	0.46	0.46	0.46	0.46	0.46
	(0.45)	(0.44)	(0.43)	(0.44)	(0.43)
Threonine (%)	1.01	1.01	1.01	1.01	1.01
	(0.96)	(0.95)	(0.96)	(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; Pantothenic acid, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 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; sucrose to make 1 kg vit.-min. mixture.

[2] Calculated value.

[3] Analyzed value.

From day 7 to day 20 of preweaning period, creep feed was fed on *ad libitum* basis from creep feeders. The creep feed was formulated to contain approximately 1.65% lysine and 3.45 Mcal ME/kg of diet. The diet contained 7.5% spray-dried plasma protein (SDPP), 2.5% spray-dried blood meal (SDBM), 20% whey and 10% lactose in a pelleted meal. Daily feed intake was recorded during the creep feeding and the average consumption per piglet was 150.5 ± 23.1 g over the 15 days.

At 21 days of age, the pigs were moved to an experimental unit and kept in concrete-floored pens. The experimental 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 out the experimental period. Body weight and feed intake were recorded weekly.

For measuring the digestibilities of experimental diets, pigs were fed diets containing 0.25% Cr_2O_3 during the

Table 2. Formula and chemical composition of experimental diets in phase II

Treatments	Lactose : Sucrose				
	100:0	75:25	50:50	25:75	0:100
Ingredients (%)					
Corn	42.89	42.89	42.89	42.89	42.89
Soybean meal	22.00	22.00	22.00	22.00	22.00
Spray-dried plasma protein	2.00	2.00	2.00	2.00	2.00
Fish meal	5.00	5.00	5.00	5.00	5.00
Spray-dried blood meal	2.00	2.00	2.00	2.00	2.00
Corn oil	3.00	3.00	3.00	3.00	3.00
Lactose	20.00	15.00	10.00	5.00	–
Sucrose	–	5.00	10.00	15.00	20.00
Limestone	0.20	0.20	0.20	0.20	0.20
Mono calcium phosphate	2.10	2.10	2.10	2.10	2.10
Salt	0.30	0.30	0.30	0.30	0.30
Vit. min.[1]	0.25	0.25	0.25	0.25	0.25
Antibiotics	0.20	0.20	0.20	0.20	0.20
Methionine	0.04	0.04	0.04	0.04	0.04
Threonine	0.01	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[2]					
ME (Mcal/kg)	3.39	3.39	3.39	3.39	3.39
CP (%)	20.20	20.20	20.20	20.20	20.20
	(20.02)[3]	(19.88)	(19.89)	(19.95)	(19.93)
Ca (%)	0.90	0.90	0.90	0.90	0.90
P (%)	0.80	0.80	0.80	0.80	0.80
	(0.73)	(0.73)	(0.75)	(0.72)	(0.74)
Lysine (%)	1.35	1.35	1.35	1.35	1.35
	(1.34)	(1.33)	(1.33)	(1.34)	(1.33)
Methionine (%)	0.41	0.41	0.41	0.41	0.41
	(0.38)	(0.39)	(0.37)	(0.38)	(0.39)
Threonine (%)	0.88	0.88	0.88	0.88	0.88
	(0.86)	(0.85)	(0.86)	(0.84)	(0.86)
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; Pantothenic acid, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 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; sucrose to make 1 kg vit.-min. mixture.

[2] Calculated value.

[3] Analyzed value.

second week of the experimental period and feces were collected three days and 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 was conducted using GLM procedure of SAS package (1985), and treatment means were compared using Duncan's multiple range test (Duncan, 1955)

RESULTS AND DISCUSSION

From d 0 to 7 postweaning, average daily gain (ADG) and feed/gain (F/G) were improved ($p < 0.05$) for pigs fed A, B and C diets compared to pigs fed the diets D and E, but the average daily feed intakes (ADFI) of the pigs in all treatments were approximately equal. No significant differences were found in ADG and F/G among the treatment A, B and C. The results suggested that sucrose could replace up to 50% of lactose in weaned pig diets. This has been interpreted by the reports of Jin et al. (1997b), Sewell and Maxwell (1966) and Buraczewski et al. (1971). Jin et al. (1997b) reported that sucrose was utilized by baby pigs as early as 21 days of age without sacrificing the growth rate. ADG and ADFI of pigs fed sucrose were similar with those pigs fed lactose diets. Some researchers showed that young pigs preferred some level of sugar or sweetener in the diet (Sewell and Maxwell, 1966; Buraczewski et al., 1971).

From d 7 to 14 postweaning, no significant differences were found in ADG and ADFI among the treatments but pigs fed diets A, B and C had improved F/G compared with pigs fed diets D and E ($p < 0.05$). However, the improvement in F/G was small in the

Table 3. Effects of dietary lactose : sources ratio on growing performance in weaned pigs (g)

Treatments	Lactose : Sucrose					SE[1]
	100:0	75:25	50:50	25:75	0:100	
D 0 to 7						
ADG (g)	247[a]	253[a]	252[a]	237[b]	235[b]	15.41
ADFI (g)	270	273	275	270	272	16.19
F/G	1.08[a]	1.08[a]	1.09[a]	1.14[b]	1.16[b]	0.03
D 8 to 14						
ADG (g)	343	339	338	335	335	19.89
ADFI (g)	456	456	456	457	456	26.12
F/G	1.33[a]	1.35[a]	1.35[a]	1.37[b]	1.36[b]	0.03
D 0 to 14						
ADG (g)	291	295	294	287	287	14.37
ADFI (g)	358	365	365	364	364	24.79
F/G	1.23[a]	1.24[a]	1.24[a]	1.27[b]	1.27[b]	0.02
D 15 to 21						
ADG (g)	472	470	468	471	468	12.59
ADFI (g)	762	755	757	760	757	16.00
F/G	1.61	1.61	1.62	1.61	1.61	0.01
D 0 to 21						
ADG (g)	352	354	353	348	348	9.68
ADFI (g)	493	495	496	496	495	13.54
F/G	1.40	1.40	1.41	1.43	1.43	0.01

[1] Pooled standard error, n=25.

[a,b,c] Figures in the same row without the same superscript are significantly different at $p < 0.05$.

ADG: Average daily weight gain.

ADFI: Average daily feed intake.

F/G: Daily feed intake/daily weight gain.

second week compared to the first week.

From d 15 to 21 postweaning, no significant differences were found in ADG, ADFI and F/G among the treatments. It seemed that pig's growth rate was not affected by lactose level by the time two weeks after weaning.

The pigs fed the lactose diet tended to be more efficient in feed utilization ($p < 0.05$) than pigs fed the sucrose diet during the first week. Lactose addition to pig starter have been previously shown to improve pig performance (Sewell and West, 1965; Giesting et al., 1985, Jin et al., 1997b).

The effects of lactose:sucrose ratio on the nutrient digestibility are recorded in table 4. The nutrient digestibility was not influenced by the lactose:sucrose ratio except for nitrogen. Nitrogen digestibility of A diet was significantly higher than D and E diets, respectively ($p < 0.05$) but no significant differences were found among diets A, B and C.

Table 4. Effects of dietary lactose : sucrose ratio on nutrient digestibilities in weaned pigs (%)

Lactose : Sucrose	GE	Dry matter	Nitrogen	Crude fat	Crude ash	Phosphorus
100:0	85.63	86.32	84.14[a]	82.47	71.81	71.29
75:25	85.24	85.58	83.45[ab]	81.32	71.25	71.81
50:50	86.12	86.54	83.53[ab]	81.49	72.56	71.90
25:75	84.01	85.20	82.85[b]	81.74	70.71	70.43
0:100	84.69	85.45	82.25[b]	79.39	70.85	70.87
SE[1]	3.26	2.89	2.28	1.07	1.26	1.54

[1] Pooled standard error, n=24.
[a,b] Figures in the same column without the same superscript are significantly different at $p < 0.05$.

Pigs fed diets containing lactose had higher ($p < 0.05$) apparent N digestibility (Sewell and West, 1965). This improvement may be caused by the high level of lactase, the enzyme responsible for lactose degradation, present in the digestive system of the young pig (Corring et al., 1978). In contract, Turlington et al. (1989) and Jin et al. (1997b) reported no differences in proximate nutrient digestibility of pigs fed lactose, glucose and sucrose at 17 days and 28 days of age, respectively.

Factors other than age which influence the development of carbohydrases in the small intestine include: creep feeding during the suckling period (Hampson and Kidder, 1986); weaning on to dry diets or liquid diets (Deprez et al., 1987); growth factors, e.g. epidermal growth factor (James et al., 1987; Jaeger et al., 1990); and hormones, e.g. insulin (Shulman, 1990), corticosteroids (Kreikemeier et al., 1990); and ACTH (Sangild et al., 1991).

In this trial, pigs were fed creep feed from 7 days old, and consumed about 150 g/head of solid feed before weaning. Several studies have shown that the provision of solid feed containing complex carbohydrates to suckling pigs increases acid and pepsin secretion in the stomach (Cranwell, 1977, 1985; Cranwell and Stuart, 1984) and the activity of some stomach and pancreatic enzymes (Friend et al., 1970; Aumaitre, 1972; Corring et al., 1978; English et al., 1980; Sloat et al., 1985). Friend et al. (1970) and Okai et al. (1976) observed a significant increase in daily gain of pigs offered creep feeding.

Table 5. Effects of dietary lactose and sucrose ratio on excretion in weaned pigs (g/1,000 g body weight gain)

Lactose : Sucrose	Dry matter	Nitrogen	Phosphorus
100:0	191.58	8.52[a]	4.47
75:25	194.42	8.67[a]	4.36
50:50	191.50	8.63[a]	4.46
25:75	190.41	9.10[b]	4.42
0:100	193.42	9.12[b]	4.43
SE[1]	2.62	1.21	0.32

[1] Pooled standard error, n=24.
[a,b] Figures at the same column without the same superscript are significantly different at $p < 0.05$.

Table 4 summarized the effect of lactose:sucrose ratio on the excretion of dry matter, nitrogen and phosphorus. Dry matter and phosphorus excretion were not affected by the treatments. In nitrogen excretion, pigs fed diets A, B and C excreted significantly less nitrogen than pigs fed diets D and E. This seems to be related to high nitrogen digestibility of nitrogen as mentioned above.

In conclusion, the results suggest that sucrose can replace up to 50% lacotse in pig starter. For the better nitrogen utilization, some extent of lactose or lactose containing by products should be added in the diets.

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