Effects of the Duration of Liquid Feeding on Performance and Nutrient Digestibility in Weaned Pigs

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ABSTRACT : A total of 72 castrated, crossbred (Landrace×Yorkshire) piglets (5.7±0.7 kg BW) were allotted to one of three treatments including: a dry crumbled feed fed for 40 days; liquid feed provided for 10 days followed by dry crumbled feed for 30 days; and liquid feed provided for 20 days followed by dry crumbled feed for 20 days. Liquid feed was produced fresh each day by mixing water with dry crumbled feed at a ratio of 3:1. Pigs fed liquid feed for 10 days had a higher weight gain during the first 10 days (+16.8%; p = 0.01) and over the entire experimental period (+4.9%; p = 0.07) than pigs offered dry feed. Pigs fed liquid feed for 20 days also had a higher weight gain during the period from d 0 to 10 (+12.8%; p = 0.01), from d 10 to 20 (+8.5%; p = 0.06) and from d 0 to 20 (+9.7%; p = 0.01) than pigs offered dry feed. Pigs fed liquid feed for the first 10 days had higher feed intakes from d 0 to 10 (+22.6%; p = 0.01) and from d 0 to 40 (+5.3%; p = 0.02) than pigs offered dry feed. Pigs fed liquid feed for the first 20 days had a higher feed intake from d 0 to 10 (+21.8%; p = 0.01), from d 10 to 20 (+10.6%; p = 0.06), from d 0 to 20 (+14.6%; p = 0.01) and from d 0 to 40 (+6.6%; p = 0.02) than pigs offered dry feed. Feed conversion from d 0 to 40 tended to be poorer for pigs fed liquid feed during the first 20 days (p = 0.08) indicating an increase in feed wastage with liquid feeding. Nutrient digestibility at day 10 was unaffected by dietary treatment. However, at day 30, pigs fed liquid feed for 10 days had higher digestibility of dry matter (p = 0.08), energy (p = 0.10), crude protein (p = 0.03) and neutral detergent fibre (p = 0.05) than pigs fed liquid feed for 20 days. In conclusion, liquid feeding for 10 or 20 days increased the performance of weaned pigs during the specific time period that liquid feeding occurred but there were no carry over effects into subsequent production periods. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 3 : 396-401)***

Key Words : Liquid Diets, Duration, Weaned Pigs, Performance, Nutrient Digestibility

INTRODUCTION

The process of weaning, no matter how carefully managed, results in changes in the gut of the pig that make it more susceptible to digestive upset, diarrhea and impaired appetite (Thacker, 1998). The objective in developing feeding programs for weaned pigs is to recognize these unique needs and facilitate a smooth transition to solid feed resulting in rapid and efficient growth and limited health problems (Cranwell and Moughan, 1989). How well this is accomplished, has a significant effect on future pig performance (Goodband et al., 1993).

Feed intake is an important determinant of the performance and health status of weanling pigs (McCracken et al., 1995; Thacker, 1999). Liquid feeding has been reported to stimulate feed intake after weaning and thus increase growth (Brooks et al., 1996; Kim et al., 2001). Jensen and Mikkelsen (1998) summarized the results of ten studies on liquid feeding of newly weaned pigs and found that weight gain was increased by 12.3% compared with dry feeding. In contrast, Lawlor et al. (2002) reported that liquid feeding for weaned pigs decreased growth.

A review of the literature failed to reveal any experiments conducted to determine whether or not there is a relationship between the length of time that liquid feeds are provided to weaned pigs and their subsequent performance in later stages of production. Therefore, the objective of this experiment was to determine the effect of the duration of liquid feeding on the post-weaning performance of pigs and to determine if there were any residual effects on pig performance after switching from liquid to dry feeding.

MATERIALS AND METHODS

Growth trial

A total of 72 castrated, crossbred pigs (Landrace× Yorkshire), weighing an average of 5.74±0.68 kg were used in this experiment, which was conducted in two replicates. Pigs (21.0±2.8 d of age) were allotted to one of three treatments in a randomized block design using outcome groups based on initial weight. The three treatments used were a dry crumbled feed provided for 40 days, liquid feed provided for 10 days followed by dry crumbled feed for 30 days and liquid feed provided for 20 days followed by dry crumbled feed for 20 days. Liquid feeds were offered eight times daily. Dry feed was provided *ad libitum* with care being taken to avoid feed wastage.

Liquid feed was produced fresh each morning by mixing water with dry crumbled feed at a ratio of 3:1 (wt:wt). The appropriate amounts of dry crumbled feed and

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Table 1. Ingredient composition (% as fed) and chemical analysis of the experimental diets

	Diet 1 (d 1 to d 20)	Diet 2 (d 21 to d 40)
Ingredients		
Expanded corn	38.15	0.00
Corn	0.00	28.00
Wheat	0.00	25.00
Bakery by-product	10.00	0.00
Dried whey	10.00	0.00
Rice protein concentrate	3.00	0.00
Soybean meal 48% CP	25.47	25.40
Fermented soy powder	0.00	5.00
Fish meal	2.50	0.00
Fermented whey	0.00	4.00
Lard	3.00	5.00
Soybean oil	1.50	0.00
Molasses cane	0.00	4.00
Limestone powder	0.20	0.20
Tri-calcium phosphate	1.40	1.10
Salt	0.20	0.35
Probiotics	2.00	0.10
Vitamin-trace mineral premix[a]	0.50	0.50
L-lysine HCL	0.30	0.10
DL-methionine	0.12	0.10
L-threonine	0.18	0.00
Antibiotic[b]	0.13	0.10
Phytase 1,000 IU/g	0.05	0.05
Zinc oxide	0.30	0.00
Celite 545	1.00	1.00
Chemical Analysis (% DM)		
Crude protein	22.89	22.17
Crude fat	8.61	8.05
Neutral detergent fibre	11.04	16.20
Ash	8.54	7.14
Calcium	1.18	0.85
Phosphorus	0.86	0.65

[a] The vitamin and trace mineral premix for the experimental diet provided the following per kilogram of diet: Fe, 100 mg; Cu, 10 mg; Mn, 20 mg; Zn, 100 mg; I, 0.35 mg; Se, 0.20 mg; Vitamin A, 20,000 IU; Vitamin D_3, 2,000 IU; Vitamin E, 100 mg; Vitamin K, 3 mg; Thiamin, 4 mg; riboflavin, 7.0 mg; pyridoxine, 5 mg; Vitamin B_{12}, 0.05 mg; Pantothenic acid, 16 mg; Niacin, 35 mg; Biotin, 0.18 mg; Folic acid 1.3 mg; Choline, 350 mg.

[b] Diet 1 contained 55 mg Carbadox, diet 2 contained 44 mg Tylosin.

water were weighed out separately and then placed into a 20 L plastic bucket. The feed was allowed to soak in the water for 10 min and then the slurry was stirred with a motorized agitator for 15 min. The liquid feed was poured from the bucket into a simple, cube-type design, stainless steel feeder measuring 600×170×160 mm (length×width×height) equipped with a sloped bottom. The feed thus prepared was then fed throughout the next 24 h.

Two experimental diets were formulated (Table 1). The first diet, fed for the first 20 d, was a complex diet based on expanded corn, bakery by-product and dried whey. The diet was formulated to meet the nutrient requirements of 5-10 kg pigs and provided 3,775 kcal DE, 1.32% lysine and 0.86% threonine. The second diet, fed from day 20-40, was based on corn and wheat. The diet was formulated to meet the nutrient requirements of 10-20 kg pigs and provided 3,575 kcal DE**,** 1.20% lysine and 0.78% threonine. Both diets were supplemented with sufficient vitamins and minerals to meet or exceed the levels recommended by the National Research Council (1998). Celite 545 (1%) was added to both diets as a digestibility marker.

The pigs were housed in groups of two in 1.2×2.0 m concrete floored pens equipped with a single feeder and a nipple waterer to provide free access to feed and water. Each treatment was fed to twelve replicate pens of pigs. Air temperature was controlled at 30°C during first 10 days and the temperature was decreased by 1°C every five days until it reached 24°C at the end of the experiment. Pigs weights and feed disappearance were recorded every 10 d to determine daily gain, feed intake and feed conversion.

Digestibility trial

During the first replicate, fecal samples were collected from each pen on days 9 and 10 (Diet 1) and days 29 and 30 (Diet 2), with the accumulation of the two-day fecal collection subsequently being pooled. The fecal samples were oven dried for 72 h at 55°C, allowed to equilibrate for 24 h at room temperature and then ground through a 1.0 mm screen with a Cyclotec (Model 1093, FOSS). Digestibility coefficients for dry matter, crude protein, calcium, phosphorus, neutral detergent fibre and energy were calculated using the equations for the indicator method described by Schneider and Flatt (1975).

Chemical analysis

Samples of the diets and feces were analysed in triplicate according to the methods of the Association of Official Analytical Chemists (1990). Analyses were conducted for moisture (AOAC method 930.15), crude protein (AOAC method 984.13), ash (AOAC method 942.05) and ether extract (AOAC method 920.39). Neutral detergent fibre was analysed by the method of Van Soest et al. (1991). Calcium was determined by an atomic absorption Spectrophotometer (Shimazu, AA625 Japan), and phosphorus was analyzed using a UV-vis. Spectrophotometer (Hitachi, U-1100, Japan). Gross energy was measured using an Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL). Celite (HCL-Insoluble Ash) analysis was conducted according to the description provided by Prabucki et al. (1975).

Statistical analysis

The data were analyzed as a randomized block design using analysis of variance procedures as described by Snedecor and Cochran (1980). Pigs were blocked on the

Table 2. Effect of duration of liquid feeding after weaning on performance during the nursery phase*[a]

Item	Dry crumble feeding	First 10 d liquid feeding	First 20 d liquid feeding	SEM	p-Value
Daily weight gain (g)					
0-10 d	183.5[b]	214.4[a]	207.0[a]	6.59	0.01
10-20 d	485.0[b]	492.4[ab]	526.4[a]	12.36	0.06
0-20 d	334.2[b]	353.4[ab]	366.7[a]	6.93	0.01
20-40 d	584.2	610.5	584.2	9.26	0.11
0-40 d	459.2[b]	481.9[a]	475.4[ab]	6.46	0.07
Daily feed intake (g)					
0-10 d	235.9[b]	289.2[a]	287.2[a]	10.62	0.01
10-20 d	661.7[b]	664.7[b]	732.0[a]	17.98	0.02
0-20 d	444.9[b]	479.2[ab]	509.6[a]	13.65	0.01
20-40 d	1,036.9	1,076.8	1,055.6	23.16	0.52
0-40 d	713.0[b]	750.8[a]	759.7[a]	11.52	0.02
Feed conversion					
0-10 d	1.30	1.36	1.39	0.05	0.43
10-20 d	1.37	1.35	1.39	0.02	0.22
0-20 d	1.33	1.35	1.39	0.03	0.28
20-40 d	1.77	1.77	1.81	0.02	0.46
0-40 d	1.55[b]	1.56[ab]	1.60[a]	0.01	0.08

* Twelve replicate pens of two pigs per pen for the performance data.
[a, b] Within a row, means with no or a common superscript do not differ.

basis of initial weight and the pen was considered the experimental unit for analyses of performance and digestibility data. The model included the effects of replication (i.e., block), treatment, and replication× treatment (error). The level of statistical significance was predetermined to be p<0.10. The significance of differences between means was determined by the Least Significant Difference (LSD) method. A stepwise regression analysis was conducted to relate the digestibility coefficients (dry matter, crude protein, neutral detergent fibre, energy) tested to the feed intake during the period from d 0 to 20 and from d 21 to 40 of the post-weaning period, respectively.

RESULTS AND DISCUSSION

The effect of dietary treatment on pig performance is presented in Table 2. Pigs fed liquid feed for the first 10 days had a higher feed intake during the period from d 0 to 10 (+22.6%; p = 0.01) and from d 0 to 40 (+5.3%; p = 0.02) than pigs offered dry feed. Pigs fed liquid feed for 20 days had a higher feed intake from d 0 to 10 (+21.8%; p = 0.01), from d 10 to 20 (+10.6%; p = 0.02), from d 0 to 20 (+14.6%; p = 0.01) and from d 0 to 40 (+6.6%; p = 0.02) than pigs offered dry feed. These results agree with previous research demonstrating an increase in feed intake as a result of liquid feeding after weaning (Kornegay et al., 1981; Partridge et al., 1992; Lawlor et al., 2002). The improvement in feed intake seen with wet feeding has been suggested to be behaviourally based due to the fact that the newly weaned pig does not have to learn new and separate feeding and drinking behaviour immediately following weaning (Thacker, 1998).

Although feed intake was increased with liquid feeding, the beneficial effect was only observed during the specific time period that the pigs received liquid feed and there was no carryover effect of liquid feeding on feed intake during subsequent periods. For example, for pigs which received liquid feed for the first 10 days, feed intake was increased during the period from day 0 to 10 but from day 10 to 20 and subsequently during the period from day 20 to 40, when the pigs received dry feed, the feed intake of these pigs did not differ from that of the pigs fed dry feed throughout the experiment. Similarly, for pigs that were fed liquid feed for 20 days, feed intake was increased only during the 20 day period of liquid feeding and as soon as the liquid feeding was halted, feed intake was similar to that of the pigs receiving dry feed.

The higher feed intake of pigs fed liquid feed generally was associated with higher weight gain (Table 2). Pigs fed liquid feed for the first 10 days had a higher weight gain during the period from d 0 to 10 (+16.8%; p = 0.01) and from d 0 to 40 (+4.9%; p = 0.07) than pigs offered dry feed. Pigs fed liquid feed for the first 20 days had a higher weight gain from d 0 to 10 (+12.8%; p = 0.01), from d 10 to 20 (+8.5%; p = 0.06) and from d 0 to 20 (+9.7%; p = 0.01) than pigs offered dry feed. Similar to our results, Partridge et al. (1992), Braude and Rowell (1967) as well as Kim et al. (2001) reported that liquid feeding increased weight gain of weaned pigs. However, this result is contrary to the findings of Lawlor et al. (2002), who found that liquid feeding decreased daily gain in a 27 day trial (weaning weight from 7.8 to 8.4 kg). There was no carry over effect from liquid feeding as there was no difference due to dietary treatment in weight gain during the period from 20 to 40 days.

Pigs fed liquid feed for the first 20 days had a higher feed conversion during the period from d 0 to 40 than pigs

Table 3. Effect of duration of liquid feeding on nutrient digestibility*

Item	Dry crumble feeding	First 10 d liquid feeding	First 20 d liquid feeding	SEM	p-value
Day 10					
Dry matter	78.73	78.61	79.52	0.61	0.53
Crude protein	73.95	74.03	72.35	1.36	0.63
Calcium	32.68	33.31	39.63	3.29	0.29
Phosphorus	22.87	25.17	28.66	3.05	0.43
Energy	79.99	80.04	80.10	0.59	0.99
Neutral detergent fibre	51.97	51.78	56.54	1.79	0.15
Day 30					
Dry matter	83.29[ab]	84.43[a]	81.00[b]	0.97	0.08
Crude protein	83.76[ab]	85.46[a]	81.14[b]	1.02	0.03
Calcium	32.68	33.31	39.63	3.29	0.29
Phosphorus	51.42	53.75	45.93	2.54	0.12
Energy	83.76[ab]	85.30[a]	81.94[b]	0.99	0.10
Neutral detergent fibre	65.81[ab]	69.71[a]	61.23[b]	2.14	0.05

* Seven replicate pens of two pigs per pen for the digestibility data.

[a, b] Within a row, means with no or a common superscript do not differ.

offered dry feed (p = 0.08). Feed conversion during all other periods was unaffected by dietary treatment. These results are consistent with those of Brooks et al. (1996) and Russell et al. (1996). Lawlor et al. (2002) also reported that feed conversion decreased as a result of liquid feeding and cautioned that the term ‘feed usage’ should be used rather ‘feed intake’ because high levels of feed wastage can occur when newly weaned pigs are liquid fed.

Improved feeder design may help decrease this wastage. Partridge et al. (1992) found that feed conversion was unaffected by liquid feeding when an experimental automated liquid feeder that dispensed feed and water at a ratio of 1:1 was used. Brooks et al. (1996) also found that feed conversion of pigs offered liquid feed was similar to that found for pigs offered dry pelleted feed when the feeder design was improved. In the present experiment, feeder design probably allowed for some feed wastage, although the wastage was collected and weighed every day.

In the present experiment, liquid feed was prepared fresh each morning and then fed throughout the next 24 h. Mikkelsen and Jensen (2000) reported a rapid growth in the microbial flora in liquid feed during the first 24 h after preparation of liquid feed. Therefore, even though feed was prepared daily, the protocol used would have allowed for the growth of microorganisms in the feed, and in effect the liquid feed used in the present experiment was a partially fermented material. High microbial activity in the feed could be responsible for the production of biogenic amines (Fox and Wallace, 1997; Kim et al., 2005), a disruption of the amino acid balance in the feed (Scholten et al., 2000), and a reduction in the energy content of the fresh liquid feed (Smith, 1976). These changes could also account for the poorer feed conversion observed with liquid feeding.

There was no effect of liquid feeding on the digestibility of dry matter, crude protein, gross energy, and neutral detergent fibre measured on day 10 (Table 3). Barber et al. (1991), also reported that dry matter digestibility was unaffected when liquid diets with water to dry ingredient ratios ranging from 2:1 to 3.3:1 were fed. However, the lack of improvement is surprising given that Makkink et al. (1994) showed that digestive enzyme development was related to feed intake and higher feed intakes resulted in higher enzyme activities. In addition, Pluske et al. (1991) reported that wet feeding prevented the villus atrophy and crypt hyperplasia commonly associated with weaning and these changes would normally be expected to increase nutrient digestibility.

There are no previous reports in the literature relating to the effects that feeding liquid diets to newly weaned pigs have on nutrient digestibility in subsequent stages when pigs are fed dry diets. The results of the present trial indicated a modest improvement in nutrient digestibility on day 30 when pigs were fed liquid diets for 10 days but negative effects when they were fed liquid diets for 20 days. Pigs fed liquid feed for the first 10 days had higher digestibility on day 30 for dry matter (p = 0.08), energy (p = 0.10), crude protein (p = 0.03) and NDF (p = 0.05) than pigs fed liquid feed for 20 days.

This finding was unexpected and an explanation as to why different durations of liquid feeding should produce opposite effects in nutrient digestibility is not readily apparent. The results of the present experiment suggest that there may be some degree of interaction between the duration of liquid feeding and gut development during the subsequent stages when dry diets are fed but that there is also a component of the adaptive response, which is independent of nutrient intake. More knowledge is needed about the responsible factor or combination of factors that contribute to the observed effects of liquid feeding duration on nutrient digestibility and performance.

On day 10, the linear regressions relating daily feed intake to nutrient digestibility were:

Feed intake (g/d) = 824.5×kDM
(p = 0.00, R^2 = 0.964, RSD = 128),
= 881.9×kCP
(p = 0.00, R^2 = 0.956, RSD = 142),
= 1,205×kNDF
(p = 0.00, R^2 = 0.952, RSD = 148),
= 812.9×kEnergy
(p = 0.00, R^2 = 0.963, RSD = 130)

On day 30, the linear regressions relating daily feed intake to nutrient digestibility were:

Feed intake (g/d) = 1,494.7×kDM
(p = 0.00, R^2 = 0.992, RSD = 110),
= 1,483.6×kCP
(p = 0.00, R^2 = 0.992, RSD = 111),
= 1,878.8×kNDF
(p = 0.00, R^2 = 0.989, RSD = 128),
= 1,480.3×kEnergy
(p = 0.00, R^2 = 0.993, RSD = 109)

Toplis and Tibble (1995) reported that feed intake was heavily influenced by diet digestibility with increases in diet digestibility associated with increased voluntary feed intake by weaned pigs. In the present study, although feeding liquid feed for 10 days resulted in the highest nutrient digestibility and highest feed intakes, feeding liquid feed for 20 days resulted in the lowest diet digestibility but this reduction in digestibility was not associated with a reduction in feed intake.

In conclusion, liquid feeding for 10 or 20 days increased feed intake and weight gain of weaned pigs during the specific time period that liquid feeding occurred but there was no carry over effects into subsequent production periods. Feed conversion was impaired indicating an increase in feed wastage with liquid feeding. Nutrient digestibility was unaffected by liquid feeding when measured on day 10 whereas liquid feeding for 20 days appeared to have negative effects on nutrient digestibility when determined on day 30. Under the conditions of the present experiment, there appeared to be little benefit from liquid feeding pigs during the immediate post-weaning period and there was no evidence of a carry over effect on subsequent performance.

It should be noted that the present experiment was carried out at a research farm with pigs of excellent health status. In addition, the experimental diets were formulated to contain antibiotics, probiotics and zinc oxide. Therefore, it is possible that if the experiment had been conducted under more stressful conditions, that a more positive response in terms of pig performance might have been obtained.

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