Productivity of Weaning-Starter Pigs Fed Fermented Liquid Feed

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Abstract

The pigs after weaning are very susceptible to developing digestive disturbances and gastrointestinal diseases, resulting in stresses on the pigs and consequently an inability to meet their growth potential. Therefore, this study to evaluate the effect of feeding fermented liquid feed (FLF) to weaning-starter on aspects of growth performance and nutrient digestibility was investigated in four experiments. The first experiment studied the use of total FLF in starter pigs compared to dry feed (DF) and liquid concentrate feed (LCF). The second experiment was studied to find the suitable amount of FLF for starter pig feeding. The third experiment was studied for productive efficiency in starter pigs fed with different inclusion level (20, 30 and 40 %) of FLF and the fourth experiment was studied the effect of using FLF on nutrient digestibility in starter pigs (10-20 kgBW). The results found the suitable concentrate feed for nursery pigs should be fermented using feed and water mixed in the ratio of 1:2.5 (w/w), with addition of 1.1% citric acid, for 48 hours of incubation. It was found that total FLF feeding caused the reduction of feed intake of the pigs. However, the use of FLF in weaning to starter pigs should not be more than 40%. Therefore, it is concluded that the use of FLF in weaning to starter pigs diets should not be more than 40%. Additionally, total FLF should not fed at the first week after weaning due to the sour taste of fermented liquid feeds caused the reduction of piglet feed intake. FLF should be gradually added up in order to let the pigs adjust themselves to fermented liquid feed.

Keywords: fermented liquid feed, concentrate feed, weaning-starter pigs, growth performance

Introduction

The process of weaning results in changes in the gut of pig that make it more susceptible to digestive upset, diarrhea and impaired appetite. The using of suitable fermented liquid feed (FLF) could enhance pig's gastrointestinal health due to microorganism gained from fermentation process, particularly the Lactic Acid Bacteria (LAB) which is the pro-biotic. Mixing feed and water into liquid form could accelerate fermentation process (Canibe, & Jensen, 2003). Pedersen, & Lindberg (2003) had studied fermentation in laboratory condition and found that fermentation could improve digestion of organic substance in feed and protein. It was also better than cooking feed with heat (Hong, & Linberg, 2007). Feeding pigs with FLF have been shown to improve gut health (Canibe, & Jensen, 2003; Lindecrona, et al., 2003). However, the effects of FLF on growth performance are more variable (Russell, Geary, Brooks, & Campbell, 1996; Lawlor, Lync, Gardiner, Caffrey, & O'Doherty, 2002; Canibe, & Jensen, 2003; Canibe, Hojberg, Badsberg, & Jensen, 2007). Pigs fed FLF have shown lower feed intake compared to those fed non-FLF or dry feed (Canibe, & Jensen, 2003), due to

low palatability of FLF from high level of acetic acid, which have been suggested as main factors impairing palatability of FLF (Beal, Niven, Brooks, & Gill, 2005). However, acidity from Lactic acid which the microorganism synthesized from carbohydrate is an organic acid that encourage hunger. This leads to higher acidity in gastrointestinal system and better digestion of nutrients; therefore, pigs are healthy. Therefore, the objectives of the current study were designed to investigate the effect of total FLF feeding to weaning-starter pigs on performance, intake and nutrient digestibility compared to non-FLF or liquid concentrate feed (LCF) and dry feed (DF) and to evaluate the maximum inclusion level of FLF that can be fed to weaning-starter pigs.

Materials and methods

Four experiments were carried out at Naresuan University, Thailand.

Experiment 1: Productive performances of weaning-starter pigs fed fermented liquid feed.

FLF consisted of dietary concentrated and water mixed in a ratio of 1:2.5 (w/w) and 1.1% citric acid was added in the mixture before the incubation modified from (Canibe, et al., 2007). The mixture was incubated in anaerobic condition for 48 hrs. The characteristics of FLF contained higher than 6 $\log_{10}$cfu/g of LAB, Enterobacteriaceae lower than 4 $\log_{10}$cfu/g, pH lower than 4.5, Lactic acid concentration higher than 150 mmol/L. Forty five piglets (23 females and 22 males) Duroc x (Landrace x Large White) were weaned at 21 d of age, and were divided into 3 experimental groups using Completely Randomized Design. The first group, the pigs fed diet as DF. The second group, the pigs fed with 100% FLF during the 1st to the 4th week after that during the 5th to the 6th week of experiment, the pig fed with 50% of FLF + 50% of dry feed. The third group, the pigs fed with LCF using the mixture of dry feed and water at the same ratio of FLF. All animals were raised in individual pens and allowed *ad libitum* access to feed from 06.00 am to 06.00 pm. Additional fresh water was permanently available for all piglets from nipple drinkers. Individual feed intake was recorded weekly by weighing the offered feed and refusals and determining their dry matter content. Individual body weight was recorded weekly until 6 weeks of experimental period. In addition, gastrointestinal tract health of pigs was also recorded in order to evaluate the rate of diarrhea occurred using the characters (shape and color) of pig feces. The analyses were performed using analysis of variance according to the experimental design. Difference of means was compared with Duncan's New Multiple Range Test method.

Experiment 2: Suitable amount of fermented liquid feed for starter pigs.

FLF as in experiment 2 fed to 6 starter pigs (3 females and 3 males) 10 kg BW using 6 x 6 Latin Square Experimental Design to evaluate the appropriate amount of FLF could be fed to starter pigs. All animals fed dietary dry feed mixing with FLF at 0, 10, 20, 30, 40 and 50%, respectively. Each experimental pig received the given ratio of feed for 1 week and then rotated to another ratio in order to study suitable level of FLF in starter pigs before further testing of production efficiency throughout the 10-20 kilograms period. Weights were recorded from the beginning of the experiment, together with weekly weight gain and final weight at the end of the experiment. Daily amount of feed intake by the pigs was also recorded in order to calculate production efficiency factors, such as growth rate, feed efficiency. In addition, gastrointestinal tract health of weaning pigs was also

recorded in order to evaluate the rate of diarrhea occurred using the characters (shape and color) of pig feces. Data from the experiment were analyzed with analysis of variance according to the experimental design. Difference of means was compared with Duncan's New Multiple Range Test method.

Experiment 3: Productive performances of starter pigs (10-20 kg BW) fed fermented liquid feed.

Thirty starter Duroc x (Landrace x Large white) pigs (15 females and 15 males) were divided into 3 experimental groups using Completely Randomized Design. Pigs were fed with 20, 30 and 40 % FLF, respectively, mixed with dry feed and were raised until they gained 20 kilograms of weight. All animals were raised in individual pens and allowed *ad libitum* access to feed from 06.00 am to 06.00 pm. Additional fresh water was permanently available for all piglets from nipple drinkers. Individual feed intake and body weight was recorded weekly until 6 weeks of experimental period by weighing the offered feed and refusals and determining their dry matter content. In addition, gastrointestinal tract health of pigs was also recorded in order to evaluate the rate of diarrhea occurred using the characters (shape and color) of pig feces. The analyses were performed using analysis of variance according to the experimental design. Difference of means was compared with Duncan's New Multiple Range Test method.

Experiment 4: Nutrient digestibility of starter pigs (10-20 kg BW) fed fermented liquid feed.

Six nursery (3 females and 3 males) Duroc x (Landrace x Large white) pigs (initial BW: 10 kg.) were housed in individual pen. Pigs were allotted in change over design with three dietary treatments. Each period lasted 5 days. All 6 pigs were fed with 3 experimental diets which 0.5% TiO_2 was added as indigestible marker. The first group – the pigs fed diet as DF. The second group – Pigs were fed with 25% FLF mixed with dry feed and the third group – Pigs were fed with LCF (dry feed: water at 1: 2.5). The pigs were raised for 5 days. The first 3 days were adaptation period with experimental diet and the last 2 days for fecal sample collection period. Pigs' fecal was randomly collected by 10% of total fecal weight. The collected fecal was immediately stored at -20 °C in order to restrain function of microorganism. Amount of nitrogen in the fecal sample was analyzed *in vitro* study according to AOAC (2000) method. Data from the experiment were analyzed by analysis of variance, using F-test according to the experimental design. Difference of means was compared with Duncan's New Multiple range Test (DMRT) method.

Table 1 Chemical compositions of experimental diet

Ingredient	g/kg dry matter
Corn	450
Rice bran	30
Soybean meal	410
Whey powder	50
Dicalcium phosphate (Phosphorus 18%)	12
Calcium carbonate	12
Palm oil	30

Table 1 (cont.)

Ingredient	g/kg dry matter
Salt	3.5
Premix*	2.5
Chemical composition	
ME (Kcal/kg.)	3,180
Crude protein (%)	20.5
Calcium (%)	0.89
Available phosphorus (%)	0.31
Lysine (%)	1.29
Methionine + cystine (%)	0.72
pH (after 48 hrs. of FLF incubation)	4.00 – 4.15

* DL-methionine 99 %, L-lysine 95%, L-threonine 95%, DL-tryphophane 97%, glycine 97%, calcium-DL-panthothenate 45%, vitamin A, D, E, K, B1, B2, B6, B12 and nicotinic acid 98%, choline chloride 70 %, Ascorbic acid, calcium carbonate, cupric carbonate, ferric chloride, magnesium sulfate, rock phosphate, potassium chloride and zinc oxide.

Results

Experiment 1: Productive performances of weaning-starter pigs fed fermented liquid feed.

The effect of diet on growth performance during 6 weeks showed the greatest ADG for DF and LCF-fed piglets (P<0.05) (Table 2), due to higher feed intake than other groups (P<0.05). However, it gave better feed efficiency of FLF-fed piglets than the pigs fed DF and LCF (P<0.05). As a result, it had the lowest feed cost per 1 kg. weight gain (P<0.05). The use of FLF also tended to improve gastrointestinal health, considering lowest diarrhea percentage, even though this was not statistically significant different.

Table 2 Productive performances of 3-9 week old pigs throughout 6-week experimental period

Items	Diet			SEM	*P*-value
	DF	FLF	LCF		
Initial weight (Kg.)	6.20	6.29	6.19	0.15	0.88
Final weight (Kg.)	20.21 [a]	18.51 [b]	20.17 [a]	0.52	0.04
Weight gain (Kg.)	14.01 [a]	12.22 [b]	13.98 [a]	0.44	0.01
Average Daily Gain (Kg./day)	0.33 [a]	0.29 [b]	0.33 [a]	0.01	0.01
Average Daily Feed Intake (Kg./Pig/Day)	0.60 [a]	0.37 [c]	0.52 [b]	0.08	0.001
Feed Efficiency (Gain : Feed)	0.55 [c]	0.79 [a]	0.64 [b]	2.14	0.001
Feed cost (Baht/kg. of weight gain)	32.40 [a]	23.92 [c]	28.08 [b]	0.83	0.001
Fecal shape*	2.90	2.73	2.75	0.09	0.37
Fecal color*	3.19 [a]	2.98 [b]	3.10 [ab]	0.05	0.02
Diarrhea (%)	0.55	0.30	0.40	0.15	0.49

[a,b,c] different letters in the same row indicates statistical significant difference (P<0.05)

* Fecal score: shape 1= solid form and shape 5 = liquid form; color 1= black and color 5 = yellow

Experiment 2: Suitable amount of fermented liquid feed for starter pigs.

Results in Table 3 showed that dry feed mixed with FLF at 0, 10, 20, 30, 40 and 50% did not have any effects on pig's growth rate. However, the use of fermented liquid feed with this group of pigs resulted in less amount of daily intake (kg./pig/day), but better feed efficiency. Hence, the cost of feed could be greatly reduced when compared to the group fed with dry feed only (P<0.05). From these results, it seems that fermented feed could be mixed in concentration up to 50%. Although feed intake of the pigs was lower, it provided other several good effects.

Table 3 Production efficiency of weaned pigs fed with fermented liquid feed (FLF) mixture at different inclusion rates.

Items	FLF inclusion (%)						SEM	P-value
	0	10	20	30	40	50		
Initial weight (Kg.)	8.30	8.10	8.00	8.10	8.20	8.20	0.14	0.63
Final weight (Kg.)	20.20	20.06	20.09	20.11	20.12	20.10	0.68	0.70
Weight gain (Kg.)	11.90	11.96	12.09	12.01	11.92	11.90	0.36	0.13
Average Daily Gain (Kg./day)	0.28	0.28	0.29	0.29	0.28	0.28	0.06	0.39
Average Daily Feed Intake (Kg./Pig/Day)	0.74[a]	0.65[b]	0.64[b]	0.63[b]	0.63[b]	0.64[b]	0.84	0.05
Feed Efficiency (Gain : Feed)	0.39[b]	0.44[a]	0.45[a]	0.45[a]	0.45[a]	0.44[a]	1.28	0.04
Feed cost (Baht/kg. of weight gain)	46.69[a]	40.77[b]	39.93[b]	39.36[b]	40.26[b]	40.90[b]	0.47	0.02
Fecal shape*	2.62	2.53	2.48	2.54	2.43	2.57	0.06	0.97
Fecal color*	2.79	2.32	2.34	2.58	2.27	2.28	0.07	0.25

[a,b,c] different letters in the same line indicates statistical significant difference (P<0.05)

* Fecal score: shape 1= solid form and shape 5 = liquid form; color 1= black and color 5 = yellow

Experiment 3: Productive performances of starter pigs (10-20 kg BW) fed fermented liquid feed. From results shown in Table 4, the higher addition of FLF by 20, 30 and 40% did not affect growth rate of 10-20 kg BW pigs. The use of FLF at 30% rate gave lower daily intake amount (P<0.05) than the other 2 groups. Nevertheless, the use of FLF at 40% rate gave the highest feed efficiency. As a result, the feed cost per 1 kg. of weight gain was the lowest (P<0.05). This suggest that the FLF feed could be mixed with concentration up to 40% in starter pigs (10-20 kg BW).

Table 4 Production efficiency of starter pigs fed with fermented liquid feed (FLF) mixture at different inclusion levels.

Items	FLF inclusion (%)			SEM	P-value
	20	30	40		
Initial weight (Kg.)	9.90	9.68	9.82	0.18	0.89
Final weight (Kg.)	20.90	20.16	20.12	0.36	0.63
Weight gain (Kg).	11.00	10.48	10.30	0.24	0.48
Experimental period (Day)	28	28	28		
Average Daily Gain (Kg./day)	0.39	0.37	0.37	0.03	0.47

Table 4 (Cont.)

Items	FLF inclusion (%)			SEM	P-value
	20	30	40		
Average Daily Feed Intake (Kg./Pig/Day)	0.66[a]	0.63[b]	0.56[c]	0.90	0.001
Feed Efficiency	0.59[b]	0.59[b]	0.65[a]	0.01	0.05
Feed cost (Baht/kg. of weight gain)	31.94[a]	31.75[a]	28.85[b]	0.64	0.04

[a,b] different letters in the same line indicates statistical significant difference (P<0.05)

Results of nutrient digestibility of pigs at 10-20 kg BW showed in Table 5. It was found that pigs fed with 3 kinds of experimental diets did not show significant difference in various nutrient digestibility, such as dry matters, protein, fat and fiber (P>0.05): 69.18-69.95% for digestion of dry matters; 75.92-77.48% for digestion of protein; 63.82-64.38% for digestion of fat; and 24.65-25.81% for digestion of fiber. However, pigs fed 25% FLF mixed with DF tended to have higher protein digestibility than the other groups.

Table 5 Effect of dry feed (DF), 25% fermented liquid feed (FLF) mixed with DF 75% and liquid concentrate feed (LCF) on nutrient digestibility.

Item	DRY	75%DRY+25%FLF	LCF	SEM	P-value
Dry matters	69.95	69.18	69.73	0.44	0.51
Crude protein	75.92	77.48	75.98	0.39	0.12
Crude fiber	25.81	24.65	25.18	1.21	0.73
Ether extract	64.38	63.82	64.38	1.58	0.90

Discussion

The use of liquid and FLF in pig production is widely spread. Fermentation of liquid feed under adequate and controlled conditions results in a mixture of good nutritional and microbial quality. On the other hand, inadequate management of the mixture during fermentation can be detrimental for the health and growth performance of the animals fed with it. Therefore, preparation of FLF of optimal quality requires good management (Canibe, & Jensen, 2012). Confirmed by reports of 17 trials of Jensen, & Mikkelsen (1998) found the results of FLF that enhances the growth rate of pigs 13.4%, but it did not significant difference in weight gain. As well as reports of Van Winsen, et al. (2001); Demeckova, Kelly, Coutts, Brooks, & Champbell. (2002); Lindecrona, Jensen, Jensen, Leser, Jiufeng, & Moller. (2003); Boesen, Jensen, Schmidt, Jensen, Jensen, & Moller. (2004) found the use of FLF to the pigs and piglets improved the health of the digestive tract of pigs compared with dry and / or liquid feed. However, some report showed that different such as Canibe, & Jensen. (2003) compared with the dry matters feed. Through the fermentation broth (1:2.5 concentrate feed mixed with water) and liquid fermentation at 20 ^{o}C for 4 days, which indicated that the most LAB fermentation volume is 9.4 log cfu/g and lactic acid, about 169 mmol/L. *Enterobacteriaceae* is lower than 3.2 log cfu/g and pH 4.4 compared to non-liquid feed through fermentation with LAB 7.2 log cfu/g,

Enterobacteriaceae 6.2 log cfu/g and pH 4.4.

Growth performance of piglets fed the DF and LCF presented in the current study is not directly comparable with the results of FLF, due to the effect of FLF on pig's feed intake. Low pH combined with high concentration of some metabolites (e.g., acetic, biogenic amines) in fermented liquid feed has been suggested to impair it palatability (Brooks, Beal, Niven, & Demeckova, 2001) and consequently, decrease feed intake. Feeding FLF to piglets has given varying results on growth performance (Russell, et al., 1996; Lawlor, Lync, Gardiner, Caffrey, & O'Doherty, 2002). Disappearance of free amino acids, mainly lysine, by microbial fermentation in FLF as the main reason for the negative effect of feeding it on growth performance compared to LCF (Niven, Bea, & Brooks, 2006; Canibe, et al., 2007)

The higher feed intake of pig fed DF and LCF generally were associated with higher weight gain (Table 2). Similarly to our results, Partridge, Fifher, Gregory, & Prior, (1992), Braude, & Rowell. (1967) as well as Kim, Heo, Odle, Han, & Harrell. (2001) reported that liquid feeding increased weight gain of weaned pigs. However, this result is contrary to the finding of Lawlor, et al. (2002), who found that liquid feeding decreased daily gain in a 27 day trial. Lawlor, et al. (2002) also reported that feed conversion decreased as a result of liquid feeding. Moran, Scholten, Tricarico, Brooks, & Verstegen. (2006) concluded that the use of liquid feed in weaning pigs for 10 or 20 days helped increase amount of feed intake and growth rate, but did not have continuous effect on pigs in later stage. However, this research showed effect of feeding FLF to weaning-starter pigs on the reduction of feed intake. Hence, it means that FLF had negative effect on palatability of feed (Brooks, et al., 2003). From our results showed that when the pigs fed 10 to 40% of FLF mixing with dry feed, feed intake could be improved and there were no difference ($p>0.05$) of average daily gain compared to the pigs fed DF. Canibe, & Jensen (2003) found that growth rate of pigs fed with non-fermented liquid feed, as well as amount of intake, was better than that of pigs fed with FLF. This difference might be caused by type of feed used in fermentation (Jensen, & Mikkelsen, 1998). For researches in tropical region, such as report of Nguyen, Manh, & Ogle. (2005), it was found that FLF helped to increase growth rate of pigs. They suggested that starch feed should be fermented before mixing in pig feed, in order to protect the loss of nutrient of protein. Therefore, starch feed should be fermented before feeding to pigs in liquid form (Canibe, & Jensen, 2003). In addition, Canibe, et al. (2007) also found that pigs fed with fermented cereals mixed with concentration had higher growth rate than pigs fed with FLF. Fermentation of cereals before mixing in protein helps protect change of free amino acid, due to microorganism in protein. However, the use of FLF had bad effect on palatability of the feed and needed to be improved later.

Brooks, et al., (2003) reported that acidity in fermented feed helped control disease and contamination in feed and in gastrointestinal system. It also helped in digestion of protein in starter pigs which had insufficient acidity in their stomach. Furthermore, low pH in fermented feed helped reduce toxic microorganism, such as *Coliforms* and *Salmonella* spp. in pig feed (Russell, et al., 1996; Scholten, et al., 1999; Van Winsen, et al., 2001). It also maintained condition of cell wall inside small intestines of weaning pigs, which led to better absorption of nutrients (Scholten, et al., 2002). In this study, we found only the pigs fed 25% FLF mixed with DF tended to have higher of protein digestibility than the pig fed DF and LCF.

Conclusion

In conclusion, FLF prepared from dry feed and water mixed in a ratio of 1:2.5 (w/w) and 1.1% citric acid was added in the mixture before the incubation for 48 hrs. The use of FLF in weaning-starter pigs should not be more than 40% mixing with dry feed. Additionally, the total FLF should not fed in the first week after weaning, but should be gradually added up in order to let the pigs adjust them to FLF.

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