Effect of liquid to feed ratio, steeping time and enzyme supplementation on the performance of weaner pigs

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Running title: Liquid feeding and enzyme supplementation in weaner pigs.

Abstract

Two experiments were conducted to examine the effect of liquid to feed ratio, steeping time and enzyme supplementation on performance of weaner pigs. In Expt. 1, 40 male weaner pigs (weaned at 27 days of age) were randomly allocated to four treatments, including a dry fed control and three liquid diets of differing liquid: feed ratios (2:1, 3:1 and 4:1). Pigs were fed individually. Body weight was measured weekly and feed intake measured daily. The results confirmed the advantage of liquid feeding but indicated that liquid: feed ratio had very little effect on performance of weaner pigs. While the digestible energy (DE) content of the 2:1, 3:1 diets was similar to the control diet, the DE content of the 4:1 diet was significantly lower, possibly due to the removal of the insoluble marker (long chain hydrocarbon) by the amount of water in the diet.

In Expt. 2, the effect of a xylanase and steeping time on pig performance was assessed in a 2 × 2 factorial design (two steeping times, 1 h *v.* 15 h; enzyme addition, + *v.* -). Sixty male weaner pigs (weaned at 27 days of age) were randomly allocated to four treatments and fed individually for three weeks. Body weight was measured weekly and feed intake measured daily. The experiment revealed that both steeping and enzyme addition increased feed intake ($P<0.01$) and growth rate ($P<0.05$), suggesting that both techniques influence the non-starch polysaccharide composition of the wheat based diet. Feed conversion ratio (FCR) tended to be improved more by steeping than by enzyme addition ($P=0.06$). The results would suggest that steeping improves FCR by allowing increased hydration of feed and subsequent activation of the endogenous enzymes present naturally in grains.

The present study was designed to test the hypothesis that the water : solid feed ratio would affect nutrient availability to weaner pigs fed liquid diets.

Additional keywords: Liquid feeding, growth rate, digestible energy, feed conversion ratio

Introduction

The practice of feeding newly weaned piglets a liquid diet was practiced as early as 1814 (Russell *et al.* 1996). As the feed intake of piglets that have been abruptly deprived of the sow's milk and then offered a dry pellet is markedly limited it would seem logical that a piglet would adapt more easily to a diet composed of some liquid in the initial post weaning stages. However, in reality the logistics of providing the newly weaned piglet with a continuous, wholesome, supply of liquid feed are considerable. These have deterred many producers from installing such a system (Russell *et al.* 1996). In recent times there has been an increased interest by piggeries to move to a liquid feeding regime in several areas of production because improved feed conversion and liveweight gain can be attained through the introduction of liquid feed in a pipe line situation (Gill *et al.* 1987). Other reasons for the success of liquid feeding systems include (1) reduction in feed wastage as dust, (2) increased acidity of the diet, (3) increased availability of phosphorus, (4) improved accessibility to substrates by the digestive enzymes, and (5) reduced viscosity in the gut which assists in improving the feed efficiency of the animal (Brooks 1994; Geary *et al.* 1996). In addition, liquid fed pigs are quieter with reduced fighting for feed at the feeding trough (Jordon 1997). From a management point of view, liquid feeding systems offer an excellent point of control over feed intakes of the pig, providing an 'eagle - eye' over production. Many liquid feeding systems are automated in that a computer allows a breakdown on every pen or individual pigs' feed intake, therefore, providing a greater insight to the nutritient requirements of the pig (Jordon 1997).

There are several important components essential to a successful liquid feeding regime, including liquid to feed ratio, steeping time and other feeding strategies such as application of enzymes in liquid feed. At present commercial producers feed weaners liquid diets that vary greatly in their dry matter contents. These ratios range from 2.1:1 to 5:1. From within this range good results are being achieved (Geary *et al.* 1996). There is, however, a lack of research to confirm the ideal dry matter content of the liquid diet. Earlier work has shown feed conversion efficiency was improved as the liquid proportion was increased. Also increasing the water to feed ratio improved both the dry matter and the energy digestibility of the diet (Geary *et al.* 1996). It is also possible that the ideal ratio will change depending on the dietary ingredients being used in the diet and the associated level of non-starch polysaccharides (NSPs). Therefore it is unlikely that a single ratio could be recommended for all diets and that it would need to be more diet specific. Barber *et al.* (1991) conducted a trial in which water to feed ratios ranged from 1.63:1 to 3.25:1. The only water available to the pigs was that contained in the feed. Digestibility coefficient was found to increase from 0.791 to 0.829 as the water to solid ratio was increased from 1.63:1 to 3.25:1. The results from this trial indicate that there is in fact a relationship between digestible energy and the water to feed ratio in which the feed is mixed (Barber *et al.* 1991). However, Kornegay and Thomas (1981) compared a liquid diet (2.1:1) with a dry diet at 3 testing stations and found no significant difference in daily gain and daily feed intake between the two treatment groups. It was also found that FCR was higher in the pigs fed the dry diet, which differs from results obtained in other trials. Presently, there is also a great deal of conjecture surrounding the optimum water: solid feed ratio for liquid diets. In the current commercial liquid feeding systems, the water to solid feed ratio can vary from as little as 2:1 to as much as 7:1. The area requires further investigations.

Soaking feed throughout mixing and prior to feeding increases the apparent availability of phosphorus, calcium, magnesium and copper (Anon 1996). The increase in the availability of minerals results in a reduction of additives required in the diet. An advantageous consequence of this is a decrease in the amount of these nutrients concentrated in the effluent, therefore decreasing the associated environmental problems (Anon 1996). Steeping diet can also lead to a reduction in the pH of the mixture due to accumulation of fermentation by products, mainly lactic acid (Brooks *et al.* 2001). Steeping also activates endogenous enzymatic activity and enhances the benefits of exogenous enzymes (Anon 1996), resulting in improved nutrient utilisation and performance of pigs due to the proliferation of the *Lactobacillus* sp. in the feed (Russell *et al.* 1996). Based on the development of digestion capability of weaner pigs, the beneficial effects of liquid feeding may be only in the initial two weeks following weaning. However, two interesting components of liquid feeding weaner pigs, the duration of steeping and the enzyme supplementation in the liquid feed, require attention.

Two experiments were conducted to examine the effect of water to solid feed ratio, steeping time and the supplementation of exogenous enzymes on the performance of liquid fed weaner pigs.

Materials and methods

Diets and preparations

A medium (3.2 mm screen) mash diet was prepared. The diet was formulated according to previously established requirements of pigs of this age bracket and was used for both experiments (Table 1). Only the cereal (wheat) fraction of the diet was hammer milled. Hexatriacontane was added to the feed at 50 g/t as a marker for estimating digestibility. Pigs on the liquid treatments were fed as frequently as was required throughout the day. To avoid the accumulation of stale feed in feeders, any feed not consumed from the feeder was weighed and recorded the following morning. This enabled an accurate assessment of feed consumed on a daily basis for liquid fed pigs. Pigs on the dry fed treatment were offered the diet *ad libitum*. For Expt. 2, a commercial enzyme product (Bio-feed Wheat, contained 1000 Units of Xylanase per kg product; Roche Vitamins Australia Pty Ltd) was added to the respective treatments at the point of mixing the liquid diets (0.4 g/kg).

Expt. 1-Water to solid feed ratio

Animals and experimental design. Sixty pigs weaned at 27 days of age (15 per treatment) were fed the experimental control diet and allowed a 7-day adaptation period. On the completion of this period all pigs were weighed and the 5 lightest pigs were removed from each of the 4 treatments. These weights became the start weight for the 21-day experimental period. The average start weight was 8.2 ± 0.08 kg. The forty remaining pigs were then randomly allocated to 4 treatments in a completely random design. The treatments comprised a dry fed control and 3 water to solid feed ratios (2:1, 3:1, 4:1). The basal diet was based on wheat hammer milled using a 3.2mm screen to provide a medium grind. The diet was formulated to contain 14.6 MJ DE/kg.

Measurements. Weight gains were recorded on a weekly basis (0 - 7 days, 7 - 14 days, 14 - 21 days) and feed intakes were recorded on a daily basis. From this data, daily feed intake, FCR and daily weight gain were calculated on an individual pig basis. Faecal samples were taken over three days during the second experimental week and were frozen for marker and nutrient analyses at the University of New England nutrition laboratories.

Statistical Analysis. One pig from the control treatment was removed due to ill health. All remaining individual pig data were included in the statistical analysis. Treatment effects were assessed by analysis of variance. Least significant difference (l.s.d.) tests were carried out on significant results to determine differences between treatment means. Start weights and weekly weights were not found to be significant, as such they were not used as a covariate in the statistical analysis.

Expt. 2-Steeping and enzyme supplementation

Animals and experimental design. Sixty-eight male pigs were allowed a 7-day adaptation period. During this period, all pigs were fed one liquid diet with a steeping time of 15 h. On completion of this period, pigs were weighed and the 8 lightest removed (two pigs from each treatment). The remaining 60 pigs were randomly allocated to the 4 treatments at 15 pigs per treatment in a 2 x 2 factorial design. The average start weight was 8.27 kg. The respective factors were steeping time (1h *v.* 15h) and exogenous enzyme addition (+ *v.* – enzyme).

Statistical Analysis. Sixty individual male weaners were selected at the commencement of the 21-day experimental period. No pigs were removed as a result of illness or for any other reason. All individual pig data were included in the statistical analysis. A 2 x 2 analysis of variance was conducted to determine the effect of steeping time and enzyme addition on individual pig performance; l.s.d. tests were carried out on significant results to determine significance of differences between treatment means.

Results

Water to solid feed ratio

Over the experimental period, the water to solid feed ratio had no significant effect on any growth and performance parameters. However, pigs offered the liquid diet had a significantly lower (P<0.05) FCR than those offered the dry diet (Table 2). The DE content was 14.7, 14.8, 14.9 and 13.4 MJ/kg for the dry control diet, 2:1, 3:1 and 4:1 treatment diets, respectively. While the water to dry feed ratio significantly reduced (P<0.05) the DE value when the diet was mixed in a ratio of 4:1, the difference detected in the DE content of the 4:1 treatment was not considerable enough to effect individual pig performance.

Steeping and enzyme supplementation

During the first week of the experiment, daily gain and FCR were not significantly affected (P>0.05) by steeping time or the addition of enzyme (Table 3). Feed intake, however, was higher (P<0.01) for pigs offered the diets containing the enzyme. No significant interactions between steeping time and enzyme addition was detected in this week. When data from the first two weeks were pooled, it was evident that increasing steeping time improved (P=0.054) daily gain and addition of enzyme to the diet increased (P<0.01) feed intake. Overall, there was a significant interaction between the effects of steeping and exogenous enzyme supplementation for growth rate (P=0.045), with a significant improvement in daily gain for pigs fed the enzyme-supplemented diet steeped for 1 h, but not for 15 h. Steeping the diet for 15 h significantly improved feed intake (P<0.01) and growth rate (P<0.05). Enzyme supplementation tended to increase FCR for the diet steeped for 15 h, but not for the diet steeped for 1 h.

There tended to be an interaction (P=0.055) between steeping time and addition of the enzyme on the DE content in the diets. The exogenous enzyme significantly reduced ($P<0.05$) the DE content of the diet steeped for 1 h, but did not affect the DE content in the diet steeped for 15 h (Table 4).

Discussion

The outcomes of this study further confirmed the positive effect of liquid feeding on performance of weaner pigs and demonstrated that the ratio of water and solid up to 4:1 did not affect the performance of piglets, but steeping time and application of enzymes influenced daily gain and intake of piglets over the three weeks after weaning.

Liquid to solid feed ratio

The lack of any effect of the water: solid ratio on FCR is perhaps not surprising given that above a certain threshold level, the amount of water is unlikely to affect the release of endogenous enzymes or changes in particle size. The present results are in agreement with those of Braude and Rowell (1967), who reported no difference in the performance of pigs offered liquid diets with water: solid ratios ranging from 1.5:1 to 4.0:1 although liquid fed pigs tended to perform better than their dry fed counterparts. Geary *et al.* (1996) compared 4 dry matter concentrations ranging from 149 to 255 g/kg and found that treatment had no significant overall effect on weight gain, feed intake or FCR, and that weanling piglets would readily accept liquid feed with dry matter contents in the range of 149-255 g/kg. They did, however, recommend that in order to maintain effluent output, the dry matter content of the liquid diet should not be reduced below 200 g/kg (equivalent to 3.5:1 water to feed ratio).

In the present experiment, pigs on the 4:1 water: solid ratio consumed the same amount of dry matter as those of the 2.0:1 water: solid ratio. Pigs fed liquid feed had a relatively lower ($P>0.05$) dry matter intake than those fed on dry control feed. This could suggest that a

4:1 water: solid ratio might prevent younger animals achieving the energy demand under *ad libitum* feeding situations due to the dilution of nutrients in the liquid feed. Fortunately this was not the case in the current study. In contrast, the similarity in dry feed intakes across the four treatments suggests even young pigs have the ingestive capacity to meet their energy demand when offered feeds containing water: solid ratios between 2:1 and 4:1. The lack of significant effect on daily gain and feed intake further suggests that how the grain is processed has a larger effect on nutrient availability than the way in which it is mixed with water. It was, however, not known whether the length of steeping time would affect nutrient availability under a given liquid to feed ratio.

The present results differ from those of Gill *et al.* (1987) who reported that feed efficiency was improved by increasing the proportion of liquid to the dry matter fraction and liveweight gain and FCR enhanced significantly as the water to feed ratio was increased from 2:1 to 3.5:1. Barber *et al.* (1991) also reported increased dry matter digestibility from 0.791 to 0.829 as the water to feed ratio increased from 1.63:1 to 3.25:1. The difference between the current results and that of Barber *et al.* (1991) and Gill *et al.* (1987) is probably associated with the age of the pigs used. These authors used older pigs (initial weights of 14.6 kg and 33.7 kg, respectively) whereas the current experiment used weaners.

The water to solid ratios ranging from 2:1 to 3:1 had little effect on the digestible energy content of diets although the FCR was improved by 22% in the first week and by 11% over the three-week period. Water: feed ratio at 4:1 significantly reduced the DE content by almost 1.5 MJ/kg, but this effect was not reflected in the feed intake and growth of the pigs. This apparent anomaly may be related to the marker technique used to measure the DE value. It is possible that with increased amount of water, some of the insoluble marker (long chain hydrocarbon, hexatriacontane) was washed out during feeding, thus leading to reduced amount of marker excretion, hence lower digestible energy content.

Steeping and enzyme supplementation

Both steeping (soaking) and exogenous enzyme addition can improve the performance of weaner pigs fed wheat-based diets. For example, steeping the feed for 15 h with or without the supplemental xylanase, increased feed intake by 13-17 % and growth rate by 22% over the 21-day period. These findings demonstrate the extent to which untreated wheat can and does constrain the growth performance of pigs, particularly as the wheat used in the experiment was purposely chosen to be an average and not a low or high quality grain.

The fact that enzyme supplementation of the diet steeped for only 1 h effectively equalled the effects of steeping for 15 h on growth rate and the feed intake suggests that the effects of steeping are probably related to the release and activation of endogenous enzymes in the grain. Both soaking and endogenous enzyme addition affect NSP composition of the diet, consequently alter the rate at which digesta passes through the gastrointestinal tract (Cadogan 2003). It is well established, at least in chickens, that NSPs in wheat are responsible for the increased gut viscosity, thereby slowing the digesta transit time through the gut, allowing the proliferation of fermentative organisms in the fore gut (Choct *et al.* 1996).

The addition of NSP-degrading enzymes to feed partially depolymerises the NSPs, resulting in an increase in the digesta transit time by way of reducing the viscosity of the gut (Choct *et al.* 1996). However, in the current study, enzyme supplementation significantly reduced the DE content of the diet. This effect of the enzyme appears to be real as the pigs increased their feed intake significantly without a concomitant increase in daily gain in response to enzyme supplementation in the first two weeks of the experiment. The mechanism whereby this occurs is difficult to explain. The enzyme product used in this study was purported to be a single activity xylanase and therefore it was not possible that loss of energy via excessive depolymerisation of starch would have occurred during steeping. Furthermore, the significant reduction in DE in the diet steeped for only 1 h by the enzyme does not seem to support the notion of fermentative losses that can occur during an extended period of steeping.

Brooks *et al.* (1996) reviewed the effect of steeping in liquid feeding systems. Phytases that occurred naturally in the pericarp of some grains (such as wheat) were activated when the raw material was soaked. Steeping feed for 8-16 h prior to feeding increased the bioavailability of phosphorus, calcium, magnesium and copper. This increase in the availability of nutrients has a 2-fold beneficial effect. Not only does it enhance the bioavailability of nutrients in the grain; it also allows the dietary inclusion of exogenous minerals to be lowered. The latter can lead to a reduction of the mineral content of effluent, therefore, making feed more ‘environmentally friendly’ (Brooks *et al.* 1996). In the present experiment, steeping may have led to the activation of naturally occurring β-glucanase and xylanase, resulting in partial depolymerisation of the NSPs, thus removing their anti-nutritive effects on nutrient digestion and absorption. However, the effect of steeping on the activation of natural enzymes may depend on the duration of steeping, as suggested by the equivalent performance of pigs fed for diets steeped for 1 h and 15 h with or without addition of enzymes.

The present results differ from those of Crumby (1986) and Barber *et al.* (1962), both of whom reported that steeping diets prior to feeding had no effect on pig performance. Barber *et al.* (1962) used older pigs (10 weeks of age), and a barley and skim milk diet soaked for 24 hours. It is possible that the difference in results reflects concomitant differences in the grain base of the diet and the fact that neither Crumby (1986) nor Barber *et al.* (1962) used exogenous enzymes. It is also possible that steeping for 24 hours may have led to excessive losses of organic matter or proliferation of harmful organisms in the feed.

In conclusion, liquid feeding improves the performance of weaner pigs and soaking the feed increases the nutrient availability by the activation of endogenous enzymes or alternatively by reducing particle size and increasing the surface area of the diet resulting in better access to substrates by the animal’s digestive enzymes. Regardless of the exact mechanism involved, the results have important scientific and commercial applications. For wheat-based diets, exogenous enzyme supplementation is likely to improve both throughput (growth rate) and feed efficiency, therefore, providing the industry with potentially a very cost-effective technique for improving productivity. However, it is difficult to predict whether the present results can be extended to heavier pigs. The decline in the magnitude of FCR associated with liquid feeding with age suggests digestive efficiency may improve with time after weaning and that the findings may be most pertinent to the period from weaning through to 50–55 days. If this is the case then it places doubt on the validity of the use of younger pigs to screen techniques for "grower-finisher" pigs. The value of liquid feeding for finely ground grains needs to be established particularly for older pigs.

Acknowledgments

QAF Meat Industries at Corowa, NSW supported this work. The authors would like to thank the technical staff at the Nutrition Laboratory, University of New England and at R&D Unit of the QAF Meat Industries for the support throughout this work

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Table 1. Composition of the basal diet

Ingredient	kg/t	Ingredient	kg/t
Wheat	715.5	Tallow – mixer	36
Lupin kernels	187.5	Salt	3
Rice pollard	150	Limestone	5
Canola meal	187.5	Rock phosphate	9
Soybean meal	92	Lysine	4.5
Meat meal	75	Methionine	1.3
Blood meal	15	Threonine	4
Water	15	Weaner premix[A]	3

[A] Premix provided the following levels of vitamins and trace minerals per tonne of mixed feed: vit A15 mIU, vit D_3 2.5 mIU, vit E 50 g, vit K 2g, folic acid 0.5 g, niacin 20 g, Ca - D - pantothenate 10 g, riboflavin 5.0 g, vit B_6 2.5 g, vit B_{12} 20 mg, biotin 100 mg, Se 0.30 g, Cu 20 g, Fe 100 g, Mn 50 g, Zn 80 g, I 0.5 g, choline chloride 200 g, betaine 86.6 g, endox 100 g.

Table 2. Effect of water to solid feed ratio on performance of weaner pigs

		0-7 day			0-14 day			0-21 day		
Mixing ratio	Start wt (kg)	Gain (g/day)	FCR*	Intake* (g/day)	Gain (g/day)	FCR*	Intake* (g/day)	Gain (g/day)	FCR*	Intake* (g/day)
Dry fed control	8.20	279	1.16a	306	360	1.16a	414	461	1.16a	548
2:1 ratio	8.18	339	0.83b	279	381	0.86b	327	466	0.99b	460
3:1 ratio	8.20	281	0.88b	241	340	0.96b	323	420	1.07b	444
4:1 ratio	8.22	314	0.83b	253	379	0.97b	361	464	1.04b	479
P value										
Treatment effect		0.305	0.005	0.096	0.704	0.001	0.106	0.422	*0.011*	0.102

[ab] Treatment means within a column followed by the same letter are not significantly different (P>0.05); * values for intake and FCR are expressed on 100% DM basis.

Table 3. Effect of steeping and enzyme supplementation on performance of weaner pigs

			0-7 day			0-14 day			0-21 day		
Steeping (h)	Enzyme	Start wt (kg)	Gain (g/day)	FCR*	Intake* (g/day)	Gain (g/day)	FCR*	Intake* (g/day)	Gain (g/day)	FCR*	Intake* (g/day)
1	-	8.32	194	1.31	216a	228	1.26	262a	279b	1.16	310b
1	+	8.28	226	1.22	265b	275	1.18	313b	321a	1.14	359a
15	-	8.28	222	1.13	235a	282	1.08	297a	340a	1.07	364a
15	+	8.28	231	1.12	256b	281	1.15	317b	324a	1.21	388a
P value											
Steeping (S)		0.906	0.272	0.158	0.596	0.054	0.090	0.091	0.031	0.768	0.001
Enzyme (E)		0.906	0.166	0.614	0.002	0.134	0.911	0.003	0.349	0.179	0.004
S x E		0.906	0.418	0.686	0.173	0.113	0.190	0.175	0.045	0.06	0.263

[abc]Treatment means within a column followed by the same letter are not significantly different (P>0.05); * values for intake and FCR are expressed on 100% DM basis.

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Table 4. The effects of steeping time and enzyme supplementation on the DE of wheat based, liquid fed weaner diets

Steeping time (hr)	Enzyme	DE (MJ/kg)
1	-	13.74a
1	+	12.13b
15	-	12.90a
15	+	12.81a
P value		
Steeping (S)		0.833
Enzyme (E)		0.033
S x E		0.055

[ab] Treatment means followed by the same letter are not significantly different (P>0.05).

First published in the *Australian Journal of Agricultural Research*, volume 55, issue 2 (2004).
Published by CSIRO Publishing.