



Effects of Liquid Feeding on Growth Performance, Slaughter Performance and Ammonia Emission of Pigs

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ABSTRACT

Background: Liquid feeding could enhance the growth performance of pigs and was extensively used in Europe. Although several reports showed the effects of liquid feeding on growth performance, there was little research on ammonia in farms. The purpose of this study was to compare the effects of liquid feeding and dry feed feeding on growth performance and ammonia emissions of pigs.

Methods: 1200 fattening pigs were randomly assigned to two groups, the dry feed group (DF) consisted of 20 pens with 28 pigs (36.70±1.31 kg). The liquid feeding group (LF) had 20 small pens, each with 32 pigs (35.65±1.51 kg). Each pen had half male and half female. The two groups used the same feeding management practices, environmental control conditions and the same density of 0.8 m²/pig. In the experiment, the feed of Giastar Agro-Pastoral Co., Ltd. was used. At the end of the experiment, 8 pigs (4B ♂4♀) were slaughtered to measure slaughter traits in each group.

Result: Liquid feeding increased average daily gain (ADG) and average daily feed intake (ADFI) ($P<0.05$) and decreased the F/G of pigs between the body weights of 35 to 135 kg ($P<0.05$). Liquid feeding reduced the concentration of ammonia in the enclosure, it does not affect ammonia or even increase. There were no significant differences for slaughter characters of pigs in the DF and LF groups.

Key words: Ammonia emission, Growth performance, Liquid feeding, Pigs, Slaughter characteristics.

INTRODUCTION

Liquid feeding was widely used in Europe because it could utilize a variety of food processing by-products or local feed sources to reduce feed costs (O'Meara, 2020). In the Netherlands, approximately 70% of finished pigs were fed liquid diets and close to 20% were finished on liquid diets as well in Canada (Temple *et al.*, 2012; Tostenson, 2017). The effectiveness of liquid feeding has been demonstrated in earlier studies (Jiang *et al.*, 2019; Xin *et al.*, 2021). Compared with dry feed or dry/wet feed, liquid feeding significantly increased final weight, ADG and digestibility of dry matter (DM), gross energy (GE) and crude protein (CP) (Soo *et al.*, 2015). It also reduced nitrogen output in effluent through improved feed management and decreased phosphorus output in effluent by activating endogenous phytase in cereal grains (Brooks *et al.*, 2001). Liquid feeding also help in maintaining the integrity of intestinal villi and promote intestinal health (Hurst *et al.*, 2020). There are also inconsistent reports about the feeding of liquid feed in the industry. Liquid feeding reduced the weight gain of weaner piglets during the nursery period, because the uncontrollable natural fermentation in liquid feed led to the proliferation of harmful bacteria and other microorganisms, produced highly active biogenic amines, disrupted the balance of amino acids in feed and reduced energy value (Lawlor *et al.*, 2002). Although there have been numerous reports on the effects of liquid feeding on growth performance, there was almost no research on its impact on ammonia in farms. The high ammonia concentration in farms could reduce the growth performance of animals, affect animal welfare and the living and health of residents

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around the farm. The purpose of this study was to investigate the effects of liquid feeding on growth performance and ammonia emissions of pigs.

MATERIALS AND METHODS

Experiment design and animal management

This experiment was conducted by the Giant Star Research Institute at the Animal Experiment Center of Giastar Agro-Pastoral Co., Ltd, Leshan, Sichuan, China. The experiment period was from October 20, 2022 to February 2, 2023. In the experiment, 1200 fattening pigs (PIC 337×Camborough, 36.35±1.45 kg bodyweight [BW]) were randomly assigned to two groups. The dry feed group (DF) consisted of 20 pens with 28 pigs (36.70±1.31 kg). The liquid feeding group (LF) consisted of 20 small pens, each housing 32 pigs (35.65±1.51 kg). Two small pens shared a feeding trough in the LF group, so it was considered to be 10 large pens.

Each pen had equal numbers of males and females. In the experiment, the feed of Giastar Agro-Pastoral Co., Ltd was utilized and refueling time was determined based on Table 1. The composition and nutrient contents of each feed are given in Table 2. The experiment also employed consistent feeding management practices and environmental control conditions and the same density of 0.8 m² per pig with a size of the pen was 22.61 m² in the DF group and 25.50 m² in the LF group. All pigs had free access to feed and water, but the LF group was fed four meals per day with a water-to-feed ratio of 2.7:1 before reaching 100 kg and three meals per day with a water-to-feed ratio of 3:1 after reaching 100 kg. Pigs that died during the trial or needed to be removed due to disease were documented with details such as removal time, removal weight and

remaining feed amount. The body weight data were collected during the test stage, while data on factors like ammonia in the enclosure were collected daily.

Data collection

The data on feed intake was accurately recorded daily by the self-developed precision feeding equipment. To ensure equipment accuracy, daily equipment calibration and sampling of the feeding amount were conducted. Each time, two pens were randomly checked, with errors controlled within 1%. The weighing time was determined based on Table 1, at the day 0, 14, 33, 61, 82 and 105 of the trial and the weighing was conducted in the morning. The liquid feeding group adopted the liquid feeding system (Jiangxi Zengxin Technology Co., Ltd, Jiangxi, China) for accurate feeding. Ammonia data were recorded daily using the equipment (Anhui Scoreman Agricultural Technology Co., Ltd, Wuhu, Anhui, China), which was installed in the middle of each enclosure, 1.5 meters above the ground. The detection threshold of the equipment was 50 ppm for ammonia when the concentration of ammonia in the enclosure needed to be less than 10 ppm.

Slaughter and carcass evaluation

At the end of the experiment, eight pigs (four males and four females) were selected for slaughter in each group according to the principle of similar weight and health. Feeding was terminated 12 hours before slaughter. The pigs selected for slaughter were weighed individually and the carcass weight was weighed within 30 minutes

Table 1: The days of each phase in the experimental design.

Phase	Stage duration, days		Feed variety ¹
	DF	LF	
d 0	0	0	2012P
d 14	14	14	
d 33	19	19	
d 61	28	28	
d 82	21	21	2013P
d 105	23	23	2013PT

All the feed provided by Giastar Agro-Pastoral Co., Ltd, 2012P, 2013P, 2013PT were the names of feed varieties fed in their corresponding stages.

Table 2: Composition and nutrient levels of experimental diets (air-dry basis).

Items	2012P	2013P	2013PT
Ingredients (%)			
Corn	36.24	65.44	68.2
Corn germ meal		6	
Wheat flour	12	12	12
Wheat bran		1.4	4.5
Brown rice mixture	30		
Rice bran meal	2.7		2.3
soybean meal (43%CP)	15.4	12.1	10.1
Premix	3.66	3.06	2.9
Total	100	100	100
Nutrient levels			
NE, MJ/kg	10.25	10.25	10.25
CP, %	15	14	13
Crude fiber, %	2.6	2.66	2.66
DLys, %	0.98	0.87	0.77
DMet+Cys:Dlys, %	58	58	58
DThr:Dlys, %	66	66	66
DTrp:Dlys, %	18	18	18
DVal:Dlys, %	65	65	65
Dlle:Dlys, %	55	55	55
Ca, %	0.6	0.55	0.55
Available phosphorus, %	0.33	0.3	0.3

after slaughter. The backfat thickness at the thickest part of the shoulder, the junction of the chest and waist and the junction of the waist and sacrum were measured, respectively. The flesh color values of the *longissimus dorsi* muscle (LDM) and psoas muscle (PM) were measured at 45 minutes and 24 hours. The meat quality was assessed by measuring the drip loss, cooking loss and shear force of the *longissimus dorsi* muscle. The colour was tested using a Minolta chromameter (CR-300, Minolta Camera Co., Ltd., Japan). According to the Commission Internationale de l'Eclairage (CIE) system, colour was expressed as CIE L*, a* and b* (representing lightness, redness and yellowness). Drip loss was assessed using the gravimetric method. The *longissimus dorsi* muscle located in the 3rd ~ 4th penultimate ribs was trimmed to a length×width×height of 5×3×2 cm and weighed, then placed in an inflated plastic bag and hung for 24 h at 4°C and weighed again (Zhang *et al.*, 2024; Xin *et al.*, 2019). For cooking loss, the middle of the psoas muscle was

trimmed to a length×width×height of 2×2×4 cm and put in a plastic bag after being weighed, which was placed in an 80°C water bath. When the internal temperature reached 75°C, the samples were cooled and weighed again (Peres *et al.*, 2014; Chang *et al.*, 2018). The shear force was measured by taking a 6×3×3 cm sample from the *longissimus dorsi* muscle at the 1-4 lumbar vertebrae and heating it in an 80°C constant temperature water bath. It would be removed, cooled and then refrigerated overnight at 4°C. The measurements were conducted with an Instron Universal Testing Machine (Model 3342; Instron Corporation, USA) equipped with a Warner-Bratzler shear attachment (Miar *et al.*, 2014; Chang *et al.*, 2018).

Statistical analysis

The Statistical Package for the Social Sciences (SPSS), version 20.0, was used for data processing and analysis. The growth performance of pigs was analyzed using an independent-sample T-test. The pen was recognized as a

Table 3: Effect of liquid feeding on growth performance of fattening pigs.

Feeding phase	Experimental treatments		Statistics	
	DF	LF	t	Sig.
BW, kg				
d 0	36.70	35.65	1.878	0.079
d 14	50.97	50.22	1.071	0.293
d 33	71.29	74.18	-2.840	0.008
d 61	102.54	110.30	-7.060	0.000
d 82	127.05	135.12	-6.920	0.000
d 105	149.02	159.61	-7.366	0.000
ADFI, g/d				
d 0-14	1970.12	2049.55	-2.862	0.008
d 14-33	2463.43	2746.12	-9.962	0.000
d 33-61	3051.10	3198.94	-3.642	0.001
d 61-82	3613.18	3643.78	-0.526	0.603
d 82-105	3314.04	3761.53	-7.786	0.000
d 0-82	2837.62	2988.32	-4.281	0.000
d 0-105	2949.00	3104.99	-3.473	0.002
ADG, g/d				
d 0-14	1018.91	1039.92	-1.030	0.312
d 14-33	1062.29	1242.03	-5.973	0.000
d 33-61	1102.08	1224.75	-6.224	0.000
d 61-82	1150.66	1187.34	-1.030	0.311
d 82-105	1038.76	1064.35	-1.087	0.291
d 0-82	1087.16	1187.34	-9.112	0.000
d 0-105	1085.71	1147.10	-5.026	0.000
F/G				
d 0-14	1.94	1.98	-1.149	0.260
d 14-33	2.32	2.23	1.163	0.108
d 33-61	2.77	2.62	2.522	0.018
d 61-82	3.14	3.10	0.525	0.604
d 82-105	3.20	3.54	-5.862	0.000
d 0-82	2.61	2.52	4.976	0.000
d 0-105	2.72	2.71	0.509	0.615

statistical unit for assessing the growth performance of pigs. The selected piglet in each pen was considered an experimental unit for the parameters related to slaughter performance. Values were presented as means with their t-value. Differences were considered significant ($P < 0.05$) at sig. < 0.05 , when sig. > 0.05 but sig. < 0.1 , differences were considered to indicate a trend toward significance, differences were considered insignificant ($P > 0.05$) at sig. > 0.05 .

RESULTS AND DISCUSSION

Growth performance

The results showed that liquid feeding had a positive effect on promoting the growth of pigs (Table 3). From the 33rd day, the weight of the two groups showed a significant difference ($P < 0.05$) and by the end of the experiment, the difference between the two groups was extremely significant ($P < 0.01$). The ADG of pigs in the LF group was significantly increased from days 14 to 33, 33 to 61, 0 to 82 and 0 to 105 ($P < 0.01$). There were some differences in ADFI between the two groups. The ADFI of the LF group significantly increased, except for the days 61 to 82 ($P < 0.05$). F/G between the LF group and the DF group also exhibited

some differences, with the LF group showing lower values than the DF group from days 33 to 61 and days 0 to 82 ($P < 0.1$). However, the F/G of the LF group from days 82 to 105 was significantly higher than that of the DF group ($P < 0.01$).

Many reports have shown that liquid feeding could improve growth performance and feed efficiency (Soo *et al.*, 2015; Hurst *et al.*, 2020; O'Meara *et al.*, 2020). This study was consistent with the results of previous studies. These findings are beneficial for lowering the feed cost per kilogram of weight gain in production. However, some research results were inconsistent with this study, suggesting that the impact of liquid feeding was not as effective as that of dry feeding (Lawlor *et al.*, 2002; Tostenson, 2017). This may be due to differences in water-to-feed ratio, feeding methods and even the growth stage of the pigs used in various studies. The F/G increased significantly from 130 kg to 150 kg, which might be related to its lower feed conversion efficiency. It was found that when the quantity of food provided was reduced and the frequency of feeding was increased, wastage from the feeders was negligible (I'Anson *et al.*, 2013). It might be beneficial to restrict feeding to control the feed-to-gain ratio during the large weight stage. In the existing studies, there

Table 4: Effect of liquid feeding on slaughter character of fattening pigs.

Items	Experimental treatments		Statistics	
	DF	LF	t	Sig.
Live weight, kg	158.88	158.63	0.051	0.960
Left carcass ¹ , kg	68.58	67.69	0.480	0.639
Right carcass ¹ , kg	66.44	64.94	0.746	0.468
Dressing percentage, %	84.99	83.66	1.995	0.067
Body length, cm	104.25	103.56	0.573	0.576
Body diagonal length, cm	92.88	90.69	1.634	0.125
Mean thickness of backfat ² , mm	34.96	32.43	1.407	0.181
LDM 45 min L-value	41.27	42.82	-3.155	0.007
LDM 45 min a-value	4.17	4.87	-1.016	0.327
LDM 45 min b-value	3.09	3.66	-0.923	0.372
LDM 24 h L-value	53.10	49.96	3.324	0.006
LDM 24 h a-value	5.44	5.59	-0.282	0.782
LDM 24 h b-value	4.16	3.51	1.659	0.119
PM 45 min L-value	39.47	40.03	-0.456	0.656
PM 45 min a-value	11.35	10.15	1.156	0.152
PM 45 min b-value	4.01	4.39	-1.038	0.317
PM 24 h L-value	43.90	43.74	0.216	0.832
PM 24 h a-value	13.42	10.67	4.669	0.000
PM 24 h b-value	4.81	4.36	1.025	0.323
shear force (kg)	6.30	4.81	1.770	0.098
Drip loss, %	2.37	2.85	1.153	0.147
Cooking loss, %	34.44	34.15	0.310	0.761

¹The weight of the slaughtered carcass was calculated as the weight of removed hair, viscera, suet and kidney after blood letting, but included the weight of the head and hooves.

²The mean backfat thickness was the average of the thickest part of the shoulder, the junction of the chest and waist and the junction of the waist and acreage.

were also some inconsistencies in reports found that liquid feeding didn't affect the feed-to-gain ratio of pigs, which may be related to the waste of feed during feeding (Choct *et al.*, 2004; l'Anson *et al.*, 2012). At the same time, it was also necessary to pay attention to the abnormal fermentation of feed when the feeding amount was not appropriate. The residual feed was easy to ferment, resulting in a decrease in nutrients and an increase in the number of harmful microorganisms, which further affected the growth performance of pigs, such as feed intake and threatened the health, especially during the piglet stage (Plumed-Ferrer *et al.*, 2009; O'Meara *et al.*, 2020a; Cullen *et al.*, 2021).

Slaughter performance

The results showed no significant differences in slaughtering performance between the LF group and the DF group (Table 4). The L-value of LDM at 45 minutes in the LF group was higher than the DF group, but the L-value of LDM at 24 hours in the LF group was lower than the DF group ($P<0.05$). The a-value of PM at 24 hours in the LF group was lower than in the DF group ($P<0.05$).

The growth performance, carcass characteristics and meat quality in pigs are considerable economic traits (Chen *et al.*, 2023). However, an excessively high water-to-feed ratio negatively impact the slaughtering performance of pigs and reduce dressing percentage. Compared with previous studies, it was observed that there was no adverse effect on slaughtering performance when the water-to-feed ratio was 3.5:1. However, the dressing percentage decreased when the water-to-feed ratio exceeded 4.1:1. This decrease might be associated with the increase in gastrointestinal volume and weight, as well as the reduction in dressing percentages due to high water intake (Llop, 2016; O'Meara *et al.*, 2020b). In our study, there were no significant differences in dressing percentage, backfat thickness, dripping loss, cooking loss, shear force and

other indexes between the LF group and the DF group, which indicates that liquid feeding did not have adverse effects on slaughter performance and meat quality. The result was consistent with those of the previous study (Soo *et al.*, 2015).

Ammonia emission

It was found that during the selected trial period for analysis, the ammonia concentration in the DF group was significantly higher than that in the LF group (Fig 1). In the LF group, the ammonia concentration was below 5 ppm for 77.51% of the trial time, below 10 ppm for 93.01% of the time and above 10 ppm for only 6.99% of the time. In the DF group, the percentage of time above 10 ppm was 26.06% and the percentage above 20 ppm was 7.27% (Table 5). A specific day was selected for comparison based on the ammonia change situation. It was observed that the ammonia concentration of the LF group was significantly lower than that of the DF group, especially during lower nighttime temperatures. When the noon temperature was at its peak, the detected levels of ammonia gas in both groups were the lowest, showing no significant difference (Fig 2).

Ammonia was not only a major contributor to haze but also enter the respiratory tract and directly impact the health of humans and animals. Exposure to 20 ppm of ammonia induced a pro-inflammatory response involving T cells. Exposure to 50 ppm of ammonia caused oxidative damage to DNA, ultimately resulting in the apoptosis of ATII cells. Oxidative stress-mediated ammonia-induced inflammatory response and apoptosis in pig lungs (Li *et al.*, 2023). Diet type also affect gut microbiota structure, reduce the number of ammonia producing bacteria and decrease ammonia emissions (Chinnaman *et al.*, 2024). In previous studies, it has been shown that liquid feeding can improve the digestibility and reduce ammonia emissions during manure accumulation (Soo *et al.*, 2015; Nahm, 2010).

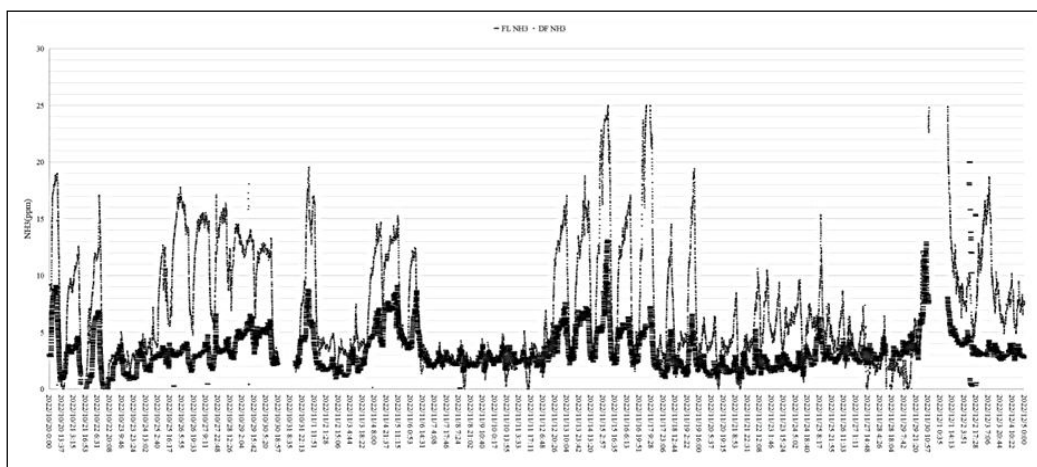


Fig 1: The difference in ammonia emission between the LF and DF groups during most of the feeding stage.

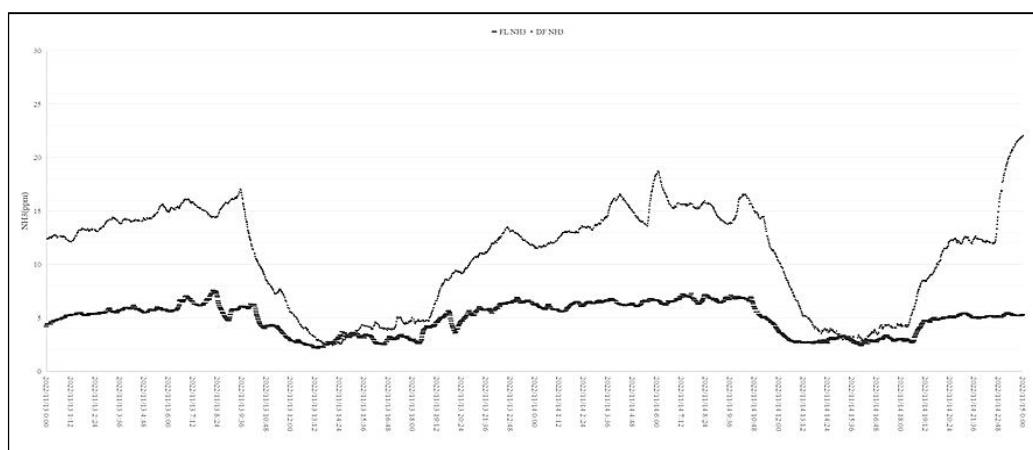


Fig 2: The difference in ammonia emission between the LF and DF groups on a specific day.

Table 5: The proportion of ammonia concentration between the LF and DF groups.

Ammonia concentration	DF (time in %)	LF (time in %)
> 20 ppm	7.27%	2.39%
15~20 ppm	7.39%	0.58%
10~15 ppm	11.40%	4.01%
5~10 ppm	23.74%	15.50%
< 5 ppm	50.20%	77.51%

One study found that liquid feeding could significantly reduce the concentration of ammonia components from the slurry when the ratio of water-to-feed was 4:1 (Hobbs *et al.*, 1997). This method helped in reducing the odorous substances produced by nutrient fermentation in the manure (Brooks *et al.*, 2001). In this experiment, the ammonia concentration of the LF group was significantly lower than that of the DF group, which was consistent with previous studies. At present, there are relatively few studies on the correlation between liquid feeding and ammonia emission, indicating a need for further research in the future.

CONCLUSION

Liquid feeding increase the ADG and final weight, reduce the F/G, lower ammonia concentration and enhance the air quality of the enclosure, without affecting the slaughter performance of pigs.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

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Conflict of interest

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