Effects of Feeder Type, Space Allowance, and Mixing on the Growth Performance and Feed Intake Pattern of Growing Pigs

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ABSTRACT: The effect of crowding and mixing on growth performance and feed intake pattern were investigated in growing pigs in a 4-wk study. Feeding pattern was monitored using automated feed intake recording equipment (F.I.R.E.). A total of 256 Yorkshire × Hampshire and purebred Duroc pigs (initial weight 35.8 ± .86 kg) were allocated to one of the eight treatment combinations in a 2 × 2 × 2 factorial arrangement (feeder type [conventional feeder vs F.I.R.E. feeder], space allowance [.56 vs .25 m^2/pig], and mixing strategy [mixed vs unmixed; mixing at start of wk 1 and 3]). Pigs were housed in groups of eight, balanced for genotype and sex (barrows and gilts), and had free access to a corn-soybean meal diet (17% crude protein, 3,296 kcal ME/kg). There was no difference in growth performance between feeder types. Crowding and mixing had no effect on daily feed intake but they depressed growth rate by 15.7 and 7.1%, respectively, and the effects of the two stressors were additive. Gain:feed ratio was reduced by crowding (10.0%) but not by mixing. Crowded pigs made fewer (11.2 vs 15.7; SEM = .51), and longer (12.5 vs 8.9 min; SEM .41) feeder visits and had higher feed intake per visit (196.2 vs 145.5 g; SEM = 5.94) than uncrowded animals. Mixing produced changes in feeding pattern in the 1st wk after mixing but not over the 4-wk period. This study showed that crowding and mixing depressed growth rates in an additive manner and altered feeding behavior.

Key Words: Pigs, Spacing, Mixing, Growth, Feeding Behavior

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Introduction

Under commercial conditions, growing-finishing pigs commonly experience more than one stressor concurrently. A number of studies have investigated the influence of single stressors on swine growth. For example, Randolph et al. (1981), Kornegay and Notter (1984), and Kornegay et al. (1993a) reported that decreasing the floor space allowance reduced daily feed intake and daily gain in growing pigs. The initial aggression that follows mixing of pigs has also been shown to reduce growth (McGlone and Curtis, 1985; Bjork et al., 1988). However, the influence of multiple stressors has not been widely studied in pigs. In studies with chicks, McFarlane et al. (1989) reported that ADG, feed intake, and feed efficiency were depressed by multiple concurrent stressors, including aerial ammonia, beak trimming, coccidiosis, intermittent electric shock, heat stress, and noise. In a previous study (Hyun et al., 1998), the effects of three concurrent stressors–namely, high ambient temperature, low space allowance, and mixing–on growth performance were investigated in growing pigs. The availability of automated feed intake recording equipment has allowed the feeding behavior of individual animals housed in groups to be studied (Hyun et al., 1997). The objective of this study was to use an automated feed intake recording system and conventional feeders to study the effects of space allowance and mixing on growth performance and feed intake patterns in growing pigs.

Materials and Methods

Treatments and Experimental Design. The study was a completely randomized design in a 2 × 2 × 2 factorial arrangement; the treatments consisted two space allowances (.25 and .56 m^2/pig), two mixing strategies (unmixed or mixed groups), and two types of feeder (conventional two-hole feeder and Feed Intake Recording Equipment [F.I.R.E.; Osborn Industries, Osborn, KS]).

Housing and Facilities. The study was carried out in a mechanically ventilated building at the Swine Research Center of the University of Illinois. Pens had

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partially slotted floors and a nipple waterer. A total of 16 pens were used: half of them were equipped with a two-hole conventional feeder and the other half had a F.I.R.E. system feeder. The temperature within the building was maintained at 21°C, and a 24-h lighting regimen was used throughout the study. Minimum and maximum temperatures were monitored daily. Aerial ammonia and hydrogen sulfide concentrations were measured in the building using MSA kits (Mine Safety Appliances Company, Pittsburgh, PA) on two occasions during the study (in wk 1 and 3). The average ammonia concentration was 1.5 ± .25 ppm. Hydrogen sulfide was not detected on either occasion.

Animals. Growing pigs (n = 256; Yorkshire × Hampshire and purebred Duroc) with an initial weight of 35.8 ± .86 kg were used in an experiment that was carried out over a 4-wk period. The experiment was carried out as two trials, with 16 pens being used in each trial. For the allotment procedure, pigs were put into outcome groups of eight pigs on the basis of genotype, sex, and weight. Pigs were randomly allocated from within outcome group to produce eight test groups of eight pigs and equal numbers of each sex and of each genotype within each group. Groups were randomly allocated to treatments. This procedure was repeated to give a total of 16 pens. Pigs on the F.I.R.E. system were fitted with a commercial ear tag transponder with an individual identification, and pigs on conventional feeders were fitted with an ear tag for identification and to simulate the treatment of pigs on the F.I.R.E. system. Animals were allowed a 1-wk acclimation period before the start of the study at a space allowance of .56 m^2/pig.

The mixing treatment was applied twice during the 4-wk period, on d 1 of the lst and 3rd wk, respectively. The mixing procedure was accomplished as follows. Within feeder type, the 2 × 2 factorial arrangement of space allocation and regrouping was replicated twice. Two barrows and two gilts randomly selected from one treatment replicate were switched with two barrows and two gilts randomly selected from the other (i.e., pigs switched pens but not treatments). At the beginning of wk 3, four pigs (two barrows and two gilts) from one replicate were regrouped with the four unfamiliar pigs (two barrows and two gilts) from the other, again creating two treatment replicates with unfamiliar pigs. There were two pens on each of the space allocation and mixing treatments.

Pigs were provided ad libitum access to a corn-soybean meal-based diet, which was formulated to exceed NRC (1988) nutrient requirements for a grower pig (17% crude protein, .9% lysine, and 3,296 kcal ME/kg). Copper sulfate (to provide 250 ppm of added copper) and Bacitracin Methylene Disalicylate®-60 (A.L. Laboratories, Fort Lee, NJ) were added as growth promoters (Table 1). Body weight for all pigs and feed intake for the conventional feeders were measured weekly.

Table 1. Percentage composition of the experimental diets

Ingredient	Composition, %
Corn	73.6
Soybean meal (48% CP)	23.0
Limestone	1.50
Dicalcium phosphate	1.25
Trace mineral mixture[a]	.35
Vitamin mixture[b]	.20
Copper sulfate	.05
Bacitracin Methylene Disalicylate®-60	.05
Calculated composition[c]	
Crude protein, %	17.4
ME, kcal/kg diet	3,296
Total lysine, %	.90

[a]Trace mineral mixture provided the following (per kilogram of diet): Se, .30 mg; I, .35 mg; Cu, 8 mg; Mn, 20 mg; Fe, 90 mg; Zn, 100 mg; NaCl, 2.73 g.

[b]Vitamin mixture provided the following (per kilogram diet): retinal acetate, 3,300 IU; cholecalciferol, 330 IU; all-*rac*-α-tocopheryl acetate, 44 IU; menadione sodium bisulfite, 2.2 mg; vitamin B_{12}, .02 mg; riboflavin, 4.4 mg; D-pantothenic acid, 12.1 mg; niacin, 16.5 mg; choline chloride, 165 mg.

[c]Calculated values based on published estimates for ingredients (NRC, 1988).

Feed Intake Recording. The F.I.R.E. system feeders consisted of a feed trough connected to a load cell and receiving equipment to identify radio signals from the ear tag transponder carried by the pigs. Pigs had 24-h access to the feed station, which was equipped with a full-length protective crate in front of the feed trough to prevent access to the trough by more than one pig at any time. All feed stations were connected to control equipment that continuously logged the time and duration of every feeder visit and the weight of feed consumed per visit and per day for each pig in the group. Data were downloaded daily from the control equipment memory and stored on diskette until required for analysis. All feed stations were calibrated at the start of the study and once per week thereafter, using a 1-kg test weight.

Statistical Analysis. Data on daily feed intake traits were used to estimate mean values for individual animals for daily feed intake, number of feeder visits per day, feed intake per visit, feeder occupation time per visit, feeder occupation time per day, and feed consumption rate, which was defined as feed intake per visit divided by feeder occupation time per visit. Feeding pattern variables were checked for normality using the UNIVARIATE procedure of SAS (1990), which confirmed that they were all normally distributed. All data were analyzed using the PROC GLM procedure of SAS (1990). For feed intake, growth rate, and gain:feed ratio, the pen was used as the experimental unit. The statistical model used for these data included the effects of trial, feeder type, space allowance, mixing, and two- and three-way interactions. For feeding pattern of pigs on the F.I.R.E. system, the experimental unit was the individual pig. In this case, the model included the effects of trial, space allowance, mixing, sex, and two- and three-way interactions.

Diurnal patterns for feed intake traits were estimated by counting the number of visits, feeder occupation times, and feed intake per visit for every hour of 24 h for the study period for all animals on the F.I.R.E. system; treatment comparison of the hourly means was carried out using *t*-tests.

Results and Discussion

Growth performance. The effects of feeder type, space allowance, and mixing on growth performance are summarized in Table 2. The performance of pigs on the two feeder types was very similar throughout the study, with the exception of wk 4, in which growth rate on the conventional feeders was lower. Growth rates were lower on the restricted space allowance in every week of the study and over the 4-wk period; pigs on this treatment grew 120 g/d more slowly on average than those on the higher space allowance, over the study period. However, feed intake was lower for the restricted space allowance in wk 4 only ($P < .05$). Gain:feed was also lower for the restricted space treatment, and the difference was statistically significant for the 1st and 3rd wk of the study, and over the 4-wk study period.

Restricted space allowances have been shown to reduce growth rate in growing and finishing pigs in several studies (Jensen et al., 1973; Randolph et al., 1981; Kornegay et al., 1993b, NCR-89 Committee, 1993). However, the effect of low space allocation on feed intake has been variable, with some studies showing a reduction (Moser et al., 1985; Kornegay et al., 1993a,b) and others showing little change (Randolph et al., 1981; Edwards et al., 1988). The floor space allowances compared have generally differed between studies, and the variable response observed in growth traits is, therefore, not unexpected. Restricted floor space allowances have been shown to increase abnormal behaviors and levels of aggression (Jensen, 1971; Bryant and Ewbank, 1972; Randolph et al., 1981), which are likely to increase energy expenditure and reduce growth rate and feed efficiency even when the feed intakes on low and high space allowances are similar.

The mixing treatment reduced growth rates in wk 2 and 4 of the study and over the 4-wk study period, and gain:feed in wk 2 only. However, there was no effect of mixing on feed intake (Table 2). The space allowance and mixing treatments used in the current study are identical to those used in a recent study carried out at the University of Illinois (Hyun et al., 1998) to investigate the interaction between environmental temperature, floor space allowance, and mixing on

Table 2. Least squares means for the effects of feeder type, space allowance, and mixing on growth, feed intake, and feed efficiency

	Feeder type		Space allowance, m^2/pig		Mixing		
Trait	Conventional	F.I.R.E.[a]	.56	.25	Unmixed	Mixed	Avg SE
Number of pens	16	16	16	16	16	16	—
Wk 1							
Daily gain, g[b]	704	663	746[e]	620[f]	685	681	24.3
Daily feed intake, kg	1.958	1.814	1.882	1.890	1.878	1.894	.0482
Gain:feed, kg/kg	.364	.373	.402[e]	.335[f]	.370	.367	.0151
Wk 2							
Daily gain, g[c]	701	760	776[e]	685[f]	776[e]	684[f]	21.9
Daily feed intake, kg[c]	1.989	1.996	2.025	1.960	1.961	2.023	.0539
Gain:feed, kg/kg	.363	.384	.384	.353	.395[e]	.342[f]	.0120
Wk 3							
Daily gain, g[d]	692	717	774[e]	635[f]	713	697	17.3
Daily feed intake, kg	2.128	2.029	2.156	2.001	2.116	2.041	.0525
Gain:feed, kg/kg	.326	.355	.361[e]	.321[f]	.338	.343	.011
Wk 4							
Daily gain, g	653[f]	735[e]	755[e]	633[f]	743[e]	645[f]	24.2
Daily feed intake, kg	2.069	2.160	2.231[e]	1.998[f]	2.127	2.103	.0550
Gain:feed, kg/kg	.316	.346	.339	.323	.351	.311	.0163
Wk 1 to 4							
Daily gain, g	688	718	763[e]	643[f]	729[e]	677[f]	11.1
Daily feed intake, kg	2.036	2.000	2.073	1.962	2.020	2.015	.0465
Gain:feed, kg/kg	.338	.362	.369[e]	.332[f]	.362	.339	.0093

[a]F.I.R.E. = feed intake recording equipment.
[b]Feeder type × space allowance × mixing interaction, $P < .05$.
[c]Feeder type × mixing interaction, $P < .05$.
[d]Space allowance × mixing interaction, $P < .05$.
[e,f]Means within a row, within treatment, that lack a common superscript letter differ, $P < .05$.

Table 3. Space allowance × mixing subclass means for growth rate, feed intake, and feed efficiency

Space allowance[a]	Mixing[a]	Daily gain, g	Daily feed intake, kg	Gain:feed kg/kg
–	–	800[b]	2.11	.38[b]
–	+	726[c]	2.04	.36[bc]
+	–	659[d]	1.94	.34[cd]
+	+	628[d]	1.99	.32[d]
Avg. SE		15.7	.0658	.0132

[a]– stressors not applied; + stressor applied.
[b,c,d]Means within a column that lack a common superscript letter differ, $P < .05$.

growth performance. In that study, growth rates were reduced by 16.4 and 9.6% as a result of crowding and mixing, respectively, which is similar to the reductions observed in the current study of 15.7 and 7.1%, respectively.

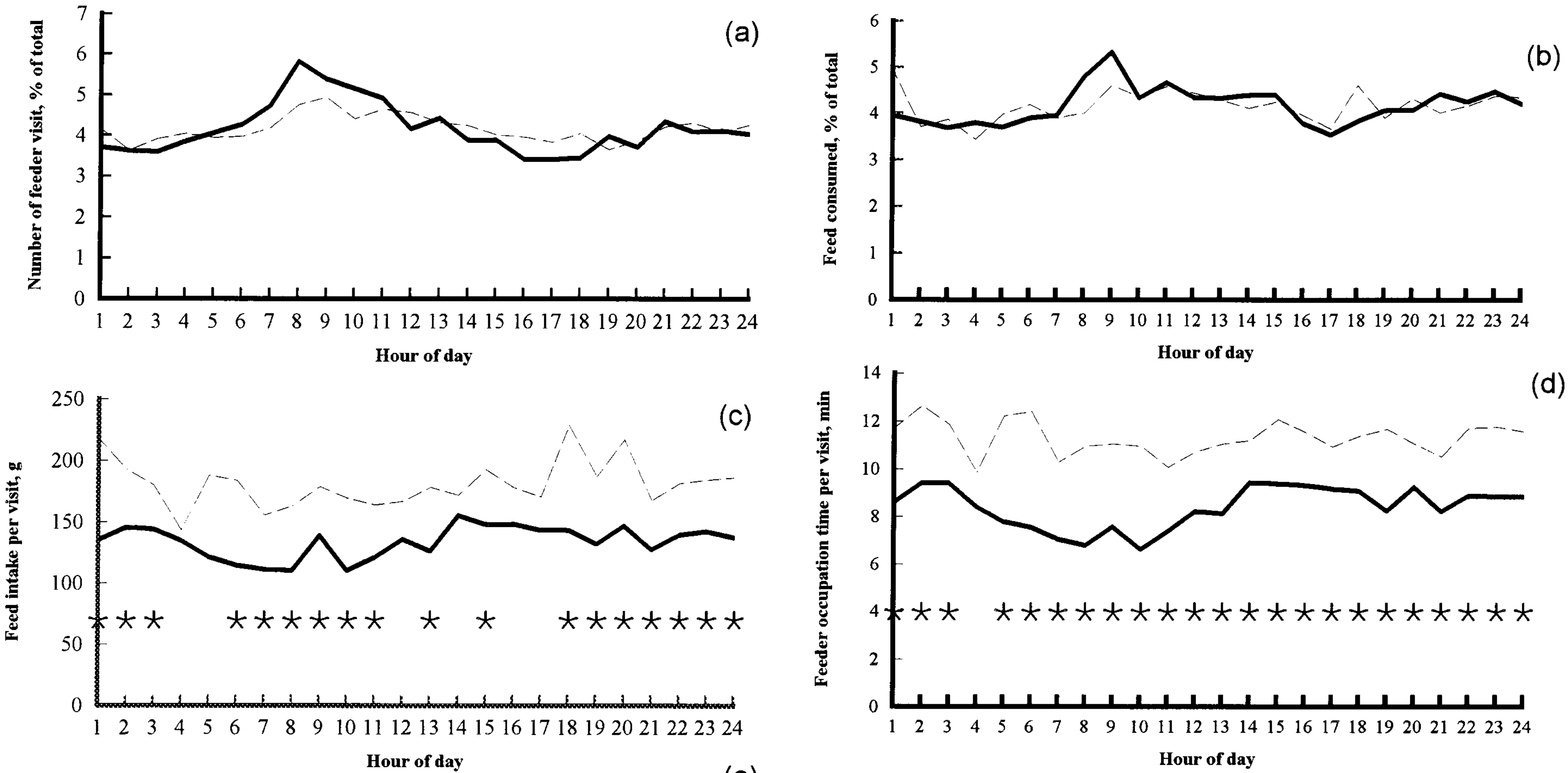
There were interactions between feeder type and mixing for growth rate and feed intake in wk 2 and between space allowance and mixing for growth rate in wk 3. In addition, there was a three-way interaction between feeder type, space allowance, and mixing for growth rate in wk l. These interactions were, however, of little practical or biological significance and have not been reported. In addition, there were no treatment interactions for performance levels measured over the 4-wk study period. This, therefore, suggests that the effects of mixing and of reduced space allowance on overall performance are additive, and this is illustrated in Table 3, in which the two-way interaction means for growth performance for the 4-wk study period are presented. Thus, growth rate was reduced by 141 and 74 g/d for pigs subjected to reduced space allowance and mixing, respectively, and by 172 g/d for pigs subjected to the two stressors simultaneously. Corresponding figures for reductions in gain:feed ratio were .025, .039, and .059, resulting from mixing, restricted space allowance, and the two stressors combined, respectively. Studies with chicks (McFarlane et al., 1989; McKee and Harrison, 1995) and with growing pigs (Hyun et al., 1998) have demonstrated additive effects with multiple stressors.

Feed Intake Pattern. The least squares means for the effects of space allowance and mixing on growth performance and feed intake pattern for pigs on the F.I.R.E. feeders are summarized in Table 4. There were no treatment interactions for any of the variables. The restricted space and mixing stressors reduced average daily gain by 12.5 and 7.9%, respectively. Feed intakes were similar for the space allowance and mixing treatments. The restricted space allowance depressed gain:feed ratio by 7.9%, but there was no effect of mixing on feed efficiency.

Total daily feeder occupation time per pig, feed consumption rate, and the proportion of time that the feeder was occupied were similar for the crowded and uncrowded pigs (Table 4). However, pigs on the restricted space allowance made fewer feeder visits (29%) but spent more time in the feeder (40%) and consumed more feed (45%) at each visit than pigs on the higher space allowance (Table 4). This suggests that the response of pigs to crowding was to make fewer but longer feeder visits. This response may have occurred because it was easier for pigs in the crowded pens on the F.I.R.E. systems to stay in the feeder. The protective crate in front of the feed hopper extends for the full length of the animal and affords the feeding pig considerable protection, and it may have been more difficult for crowded pigs to access the entrance to the protective race and displace the feeding animal in the crowded pens. Thus, the differences in feeding behavior that were due to crowding observed in the present study may not apply to situations in which there is less protection for a feeding pig, such as with commercial feeders. McGlone and Curtis (1985) showed that providing areas where pigs could hide during bouts of aggression tended to reduce some of the negative effects of regrouping in young pigs. Nielsen et al. (1995) compared a protective crate similar to the one used in the present study with a head guard on the feeder that gave much less protection to the feeding animal and showed relatively small differences in feeding behavior between the two crate designs with pigs at recommended stocking densities. There is a need for further research to quantify the effects of crowding on feeding behavior when commercial feeders are used.

Diurnal patterns for feeding behavior of crowded and uncrowded pigs are illustrated in Figure 1. T he pattern for number of feeder visits (Figure 1a), feed consumed (Figure 1b), and feed consumption rate (Figure 1e) were similar for crowded and uncrowded pigs. However, feeder occupation time per visit (Figure 1d) and feed intake per visit (Figure 1c) were consistently higher for the crowded pigs throughout the 24-h period.

There was no effect of mixing on the means for feed intake behavior traits (Table 4). In addition, the 24-h behavior patterns for feed intake traits were also similar for mixed and unmixed groups over the study period (data not shown). However, the mixing treatment did influence feeding behavior in the week



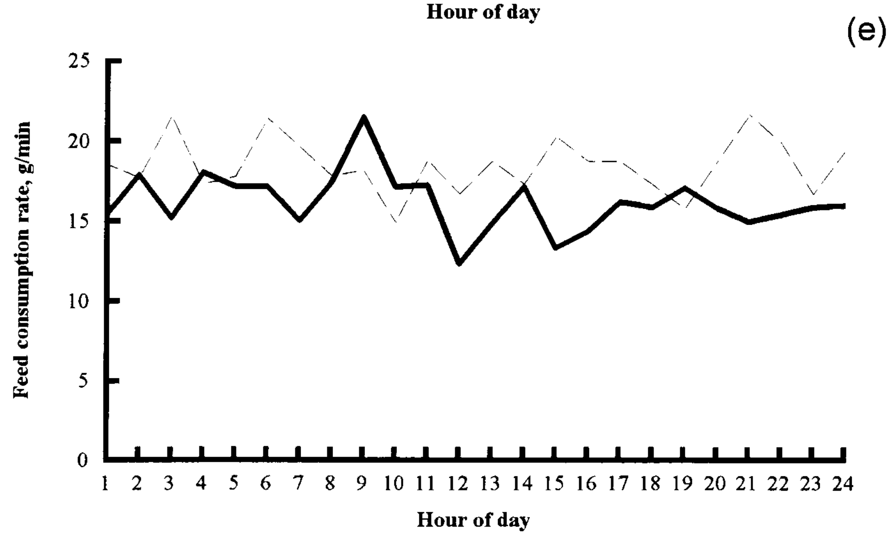


Figure 1. Diurnal distribution of feed intake traits for space allowances of .56 m^2/pig (solid line) and .25 m^2/pig (dashed line) by hour of day: (a) number of feeder visits, (b) feed consumed, (c) feed intake per visit, (d) feeder occupation time per visit, and (e) feed consumption rate. *Space allowance means differ (P < .05).

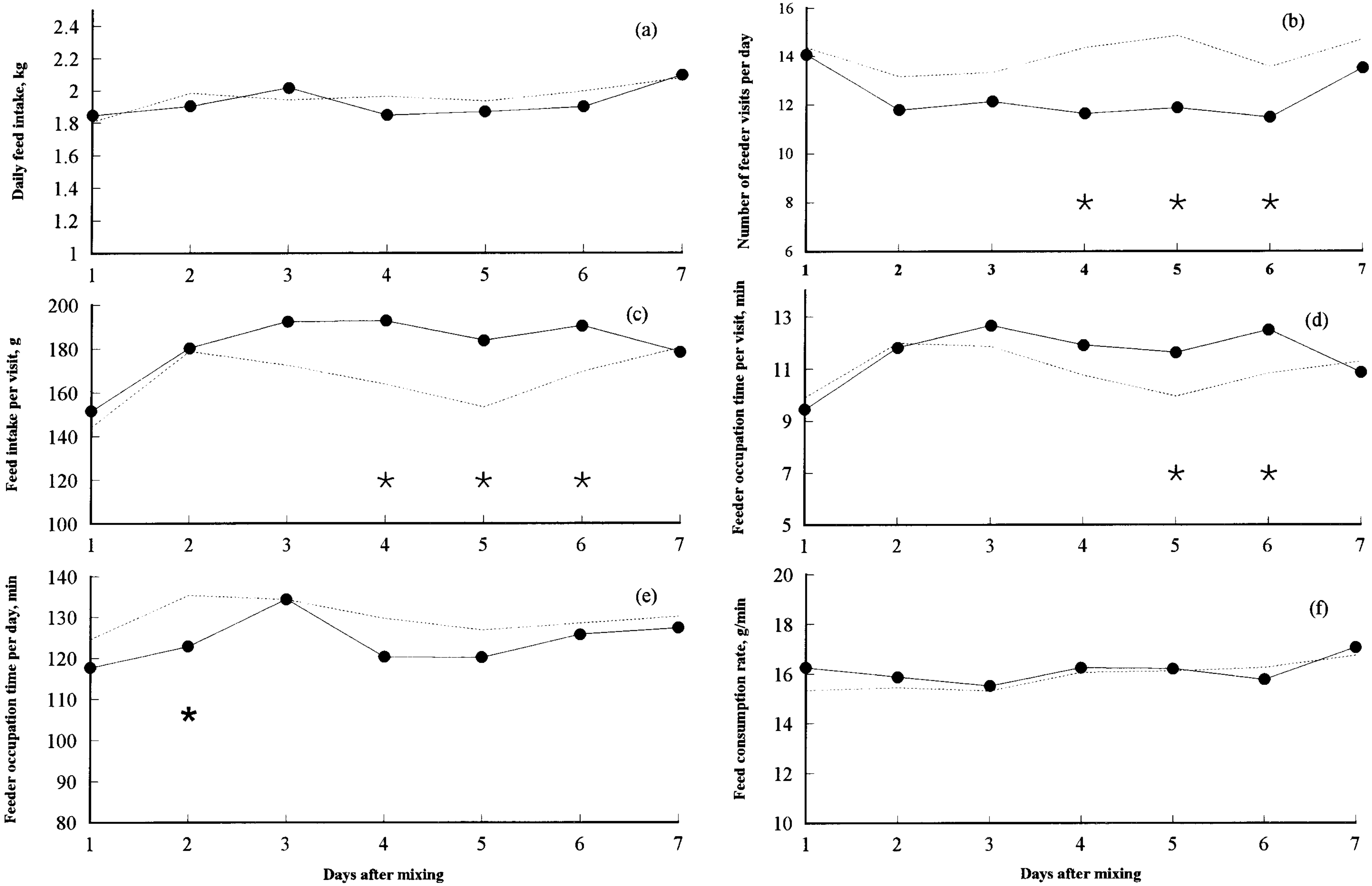


Figure 2. Feeding behavior in the days following mixing for mixed (●) and unmixed (dotted line) groups: (a) daily feed intake, (b) number of feeder visits per day, (c) feed intake per visit, (d) feeder occupation time per visit, (e) feeder occupation time per day, and (f) feed consumption rate. *Mixing means differ ($P < .05$).

Table 4. Least squares means for the effects of space allowance and mixing on the growth, feed intake, feed efficiency, and feed intake pattern for pigs on the F.I.R.E. (feed intake recording equipment) feeders

	Space allowance, m^2/pig		Mixing		
Trait	.56	.25	Unmixed	Mixed	Avg SE
Number of animals	64	64	64	64	—
Initial body weight, kg	35.9	35.7	35.8	35.8	.33
Final body weight, kg	57.4[a]	54.5[b]	56.6	55.3	.83
Daily gain, g	767[a]	671[b]	742[a]	695[b]	16.4
Daily feed intake, kg	2.000	1.966	1.992	1.973	.0468
Gain:feed, kg/kg	.38[a]	.35[b]	.37	.36	.009
Number of feeder visits per day	15.7[a]	11.2[b]	14.0	12.8	.51
Feed intake per visit, g	145.5[b]	196.2[a]	167.4	174.4	5.94
Feeder occupation time per visit, min	8.9[b]	12.5[a]	10.5	10.9	.41
Feeder occupation time per day, min	123.8	125.5	126.2	123.0	4.03
Percentage of feeder occupation time per day	68.8	69.7	70.1	68.3	2.24
Feed consumption rate, g/min	17.0	16.6	16.7	16.8	.48

[a,b]Means within a row, within treatment, that lack a common superscript letter differ ($P < .05$).

immediately following mixing (Figure 2). Thus, the number of feeder visits (Figure 2b) tended to be lower and the feeder occupancy time (Figure 2d) and feed intake (Figure 2c) per visit tended to be higher for mixed compared with unmixed pigs; the treatment differences were greatest for d 4, 5, and 6 after mixing. However, the daily means for feeder occupation time per day (Figure 2e), feed consumption rate (Figure 2f), and feed intake per day (Figure 2a) were generally similar for mixed and unmixed pigs. This suggests that pigs adjust their feeding behavior after mixing, but this adjustment occurs several days after they are mixed. This result is somewhat surprising given that aggression starts soon after pigs are mixed and that the most severe aggression normally occurs during the first few hours after mixing (McGlone, 1986). However, a number of studies have shown that the reduction in growth associated with mixing can persist for several days (Rundgren and Lofquist, 1989) or even weeks (Stookey and Gonyou, 1994) after pigs are regrouped.

Implications

The additive relationship between the two stressors suggests that, in practice, the removal of either one would improve growth performance. On the feed intake recording equipment (F.I.R.E.) system, crowded pigs changed feeding pattern but not total feeder occupation time, and they maintained feed intakes. Mixing affected feeding behavior in the week following regrouping but had no long-term effect on either feeding behavior or feed intake levels.

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