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Review

Effect of stocking density on pig production

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Numerous stressors such as environmental, nutritional, pathological or equipment related ones are operative in swine facilities. Among many factors, socking density increases social stress and influences pig performance. Many studies have reported that reducing space allowance could induce decreases in growth performance of pigs. In addition, high stocking density induces a behavioral problem and influences physiological stress during transport. Thus, the optimum stocking density has to be defined for improving pig production.

Key words: Performance, pigs, stocking density, stress.

INTRODUCTION

Under commercial conditions, because marginal profit increases with the size of pig operations (Martin and Kruja, 2000), the pork industry is shifting toward larger production units. Housing pigs in large numbers and groups is a means of reducing housing costs and simplifying some aspects of management challenges. The provision of an adequate space allowance gives pigs sufficient space for drinking, lying and feeding. The main requirement for a pig during feeding is to be able to get to, and remain at the feed trough without feeling that their feeding space is threatened (Baxter, 1985a). Also, pigs will choose a resting area based on the security of that area (Baxter, 1985b). From 25 kg to heavier body weights, pigs lie together most of the day. As they grow up, pigs begin to prefer recumbent lying postures (Ekkel et al., 2003). Space allowances should facilitate these behaviors (Table 1).

High stocking density may cause a behavioral problem for pigs. At higher stocking densities, the likelihood of heightened aggression, competition and disease outbreak rapidly rises, and when this happens, the negative relationship between space and growth becomes even worse (Lebret et al., 2006). Curtis (1996) reported that the reduction in feed intake found in large groups may be caused by an increase in social pressure in larger as compared to smaller groups.

Stressors existing in swine production systems would include cold/hot environmental temperatures (Stahly and Cromwell, 1979), microbial infections (Webel et al., 1997), insufficient space allowances (Brumm and Miller, 1996; Wolter et al., 2000), social mixing (Barnett et al., 1993; Marchant et al., 1995) and nutritional deficiencies or imbalances (NRC, 1998). These stressors cause growth retardation, changes in hormone release, increases in disease susceptibility, and/or behavioral changes. Also, physiological response to stressors (such as heat and spacial restriction) results in activation of the sympathetic nervous system and release of catecholamines and glucocorticoids reduce body weight (Breinekova et al., 2006). Pig performance being subjected to stressors is common in commercial swine production. Stress may cause oxidative changes due to an increase in reactive oxygen species (ROS) or a decrease in the antioxidant status (Lykkesfeldt and Svendsen, 2007).

The primary goal of this review is to describe an optimum stocking density and its effects on growth performance and stress in pigs.

SPACE ALLOWANCE

Space allowance is an important factor in the establishment of social rank (Baxter, 1985a). When pigs are housed in space restricted environments, the dominance hierarchy becomes less stable (Jensen, 1982). Decreased stability most often results from the inability of a subordinate pig to retreat from a threat or act of

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Table 1. Categories of space requirements of pigs.

Group	Space requirement
Body-occupation space	A pig lying down occupies more space than one standing up, a supine pig occupies more space than one in the semi-sternum position.
Body-activity space	The space required for body posture changes, like getting up or down, lying supine, turning round/grooming itself.
Social space	The space required for socialization with other pigs or access by stockpersons.
System space	The space required by different management systems, e.g. straw vs. slats, gestation stalls, group in yard, wet feeding vs. dry hoppers, etc.
Dead space	The space required for partitions, passages, corners and pen furniture

Gadd (2003).

aggression on behalf of the dominant pig. Therefore, the dominant pig does not recognize submission, and a fight may continue unnecessarily or resume later (Baxter, 1985a; Turner et al., 2003).

McGlone and Newby (1994) attempted to determine the optimal amount of space required by a pig to achieve maximum performance. Authors evaluated group sizes of 10, 20 and 40 pigs per pen during the grow-finish period (23 to 95 kg of BW) and found no difference in growth performance. However, in a group of growing pigs, those with a restricted space allowance (0.25 m^2/pig), grew more slowly than pigs with a greater space allowance (0.56 m^2/pig) (Hyun et al., 1998) for each week of the four weeks study. Pigs with the restricted space allowance showed reduction in feed intake at the 4th week. Pigs with restricted floor space showed an increase uncharacteristically in the behaviours and amounts of aggression (Hyun et al., 1998). As pigs become more aggressive, they use more energy and growth rates decline (Hyun et al., 1998). Increased aggression may also lead to increased injury levels and disease, and thus, increased stress. With an increase in stress, it is possible to reduce the gains potential, which in turn reduces appetite and average daily feed intake (Chapple, 1993). Furthermore, increased stress can increase the occurrence of stereotypic behaviors and vices, such as tail biting (Baxter, 1985b).

Space allowance has traditionally been expressed empirically by categorizing pigs into a series of weight ranges and by designating space on a per animal basis (Brumm and NCR-89 Committee on Management of Swine, 1996).

Recommendations on space allowance for optimum feed intake have been set by the National Research Council (1988) with 0.6 m^2/pig at 25 to 60 kg live weight and 1.0 m^2/ pig at 60 kg live weight. In Korea, there is legislation on pig stocking density. Also, in the EU, minimum stocking rates, listed in Table 2, are the minimum space requirements mandated by EU law.However, in the US, there is no legislation on pig stocking density. The National Pork Board does, however, made recommendations in its Swine Care Handbook (Table 2). These recommendations are based on the minimum space required to achieve maximum performance.

EFFECT OF STOCKING DENSITY ON GROWTH PERFORMANCE

Stocking density has a significant impact on growth performance. Stocking rate can have a major effect on feed intake as shown by Brumm and Gonyou (2001) who found that a major response to space restrictions was a decrease in feed intake. Stocking density allowances were seen excessively in pigs which have been shown to be necessary for maximum performance (Edwards et al., 1988).

When growing-finishing pigs are given less than optimal space per pig, feed intake always decreases (Brumm et al., 2001), often resulting in a reduction in average daily gain (ADG), with variable effects on the gain : feed ratio (G:F). Social interaction with another pig reduces growth performance and feed intake regardless of stocking density. Certain studies have demonstrated a reduction in growth performance with increasing stocking density (Petherick et al., 1989; Gonyou et al., 1992). Swine producers try to maximize profits by minimizing both performance retardation and underutilized space. Crowding stress deleteriously affect the growth performance of pigs. Pigs, housed on deep-straw for six weeks in groups of 20 or 80, were provided with a low (50 kg/m^2) or high (32 kg/m^2) space allowance in Turner et al. (2003) study. They reported that groups of 80 pigs had a lower ADG than groups of 20 (0.684 vs. 0.732 kg). Wolter et al. (2002) demonstrated that double stocking (0.64 m^2/pig vs. 0.32 m^2/pig) reduced growth rate to ten weeks after

Table 2. Minimum recommended stocking densities for growing-finishing pigs in Korea, EU and US.

Country	Live weight (kg)	Space allowance (m^2)
Korea[1]	10-30	0.30
	30-85	0.60
	85-110	0.90
Europe[2]	<10	0.15
	10-20	0.20
	20-30	0.30
	30-50	0.40
	50-85	0.55
	85-110	0.65
	>110	1.00
U.S.A[3]	5.4-13.6 (12-30 lb)	0.15-0.23 (1.7-2.5 ft^2)
	13.6-27.2 (30-60 lb)	0.27-0.37 (3-4 ft^2)
	27.2-45.6 (60-100 lb)	0.46 (5 $ft^{2)}$
	45.6-68.0 (100-150 lb)	0.55 (5 $ft^{2)}$
	68.0-market (150 lb -market)	0.74 (8 $ft^{2)}$

[1] http://english.mifaff.go.kr; [2]httpp://www.dardni.gov.uk; [3]http://www.pork.org.

weaning. Wolter et al. (2003) investigated the subsequent effects of eight weeks space restriction in weanling pigs. For eight weeks, space restricted pigs showed growth retardation when compared with pigs provided with adequate space (27.4 vs. 29.3 kg of BW). Smith et al. (2004) reported that nursery pigs with the greatest space allowance (0.35 m^2/pig) were 5.6% heavier than pigs with the least amount of space (0.23 m^2/pig). Kerr et al. (2005) demonstrated that growing pigs maintained at low stocking density had a higher weight gain (8.23 kg) than their high stocking density counterparts (7.42 kg) for five weeks at the same room temperature. White et al. (2008) reported that reducing stocking density from 0.93 to 0.66 m^2/pig resulted in 4.0% less body weight, 17.0% less ADG, 10.7% less average daily feed intake (ADFI) and a 7.8% less G : F ratio. Recently, Cho et al. (2010) reported that for the six-week nursery period, the crowding reduced ADG of gilts (577: 0.50 m^2/pig, 536: 0.25 m^2/pig, and 558 g/d: 0.25 m^2/pig) and barrows (578, 539 and 527 g/d).

Numerous previous studies evaluated the effects of space restrictions while using similar nutrient densities for all treatments (Moser et al., 1985; NCR-89, 1993). In these studies, ADFI reduced as a result of space restriction. However, Kornegay et al. (1993) did not observe a space × lysine interaction in nursery pigs. Further studies revealed no improvement in performance when finishing pigs were fed higher levels of energy and lysine with reduced space (NRC-89, 1993) or amino acids (Hahn et al., 1995). A study by Brumm and Miller (1996) indicated that added energy and lysine in growing-finishing pig diets did not overcompensate for the reduction in performance from a reduced space allowance. Edmonds et al. (1998) suggested that pigs with lower feed intakes as a result of space restriction did not have higher CP requirements than those with more space. Krohn et al. (2000) distributed pigs in nine groups with six pigs in each at three different stocking densities (0.27, 0.44 and 0.52 m^2/pig). They reported that no significant differences within any of the different behavioral categories could be observed between the three housing densities. Brumm et al. (2001) reported no residual effects of nursery crowding on grow-finish performance. Pigs that were crowded during the nursery period and uncrowded during the grow-finishing period had similar, although numerically rather lower, daily gains (849 vs. 867 g/d, during the grow-finishing period) than pigs that were uncrowded during both the nursery and grow-finishing period.

EFFECT OF DIFFERENT SUPPLEMENTATION FOR REDUCING CROWDING STRESS

Marco-Ramell et al. (2011) demonstrated that plasma proteins in animals stressed by increased stocking density (0.50 m^2/pig vs. 0.25 m^2/pig) were more oxidized and an increase in oxidative stress markers was detected in the high density animals.High stocking density is an agriculture-related situation which causes crowding stress in pigs and potentially affects their immune systems. Protection against disease can be induced through immune system, enhancing defense mechanisms. Stress has been generally shown to affect the immune function of animals (Kelly, 1985), while vitamin C supplementation has been associated with enhanced immune system competence. Vitamins E (150 vs. 120 mg/kg) and C (300 vs. 100 mg/kg) have been shown to depress the stress responses of pigs (25.1 ± 4.4 kg) undergoing vibration stimulation during transportation (Peeters et al., 2005). Also, essential oils have demonstrated ability to reduce stress, stimulate sluggish circulation, boost the immune system and induce uplifting or relaxing effects. Wenk (2003) reported that the beneficial effects of essential oils on farm animals may arise from activation of feed intake and secretion of digestive juices, immune system stimulation and anti-bacterial, coccidiostatic, antiviral and antioxidant properties.

EFFECT OF STOCKING DENSITY ON REPRODUCTIVE PERFORMANCE

Rutledge (1980) reported that there was gilts allowance in small groups (six pigs) with an average of 11 piglets given birth to whereas gilts reared in a larger group (ten pigs) had an average of ten pigs given birth to. Kuhlers et al. (1985) selected gilts at about 30 kg and reared them in pens of eight or 16 pigs. Gilts reared in the smaller groups were more than the total pigs given birth to with 1.0. When comparing gilts raised in litters of either five or ten pigs, Kirkpatrick and Rutledge (1988) found that gilts in small litters had 1.1 more embryos at day 30 post-mating. Stewart and Diekman (1989) reported that gilts raised in litters of 6 had 0.3 more pigs in first parity than gilts raised in litters of 12. However, the impact of stress post-weaning has not been adequately studied to determine if group size or space allowance has a negative impact on reproduction.

CONCLUSION

Now, swine industry is changing on a large scale. High stocking density reduces the welfare of pigs. Numerous results of researches show that the negative effects on performance was associated with large groups and the reduced floor-space allowance. According to this review, nursery, growing and finishing pigs require space allowances of >0.30, 0.60 and 0.90 m^2/pig, respectively. Future researches are needed to evaluate environmental configuration designs that may enhance growth and reproductive performance of pigs.

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