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RESEARCH ARTICLE

Weight Grouping as an Animal Welfare Issue on Performance, Immunity and Meat Composition in Pigs

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Abstract

Animal welfare is an important issue for animal production which can affect the performance and meat composition as well. In our previous study, we observed that, weight grouping was effective for obtaining uniform carcass group with better carcass characteristics and animal welfare. For further detail research, present study was undertaken with an aim to investigate the impact of weight grouping on meat composition as a focus point and in general the growth performance and immunity of pigs. The treatment groups were 1) MW = a heterogeneous group of high and low weight pigs, 2) HW = a homogeneous group of high weight pigs and 3) LW = a homogeneous group of low weight pigs. Overall higher average daily gain was investigated in HW and LW ($P < 0.05$), while tendency of feed intake was found higher in HW than MW ($P < 0.10$). However, gain: feed ratio among the weight groups did not differ significantly ($P > 0.05$). Behavioral aggression was found higher in MW compared to HW and LW ($P < 0.05$). In addition, meat composition was not significantly affected by the weight grouping; however, crude fat content of HW and LW was lower than that of MW ($P < 0.05$). There were observed no significant differences in serum immunoglobulin status among weight groups ($P > 0.05$). Time required for marketing the pigs was lower for HW and LW in comparison to MW ($P < 0.05$). Overall, uniform weight grouping of pigs might be applicable for obtaining uniform carcass groups with better productivity and animal welfare without having a long term negative impact on meat composition and immunity.

INTRODUCTION

Animal welfare is a major issue in most developed countries, and suffering of animals can eventually lead to divergent meat quality. Especially, when the five familiar freedoms are not met for the animals that defines the animal's fundamental needs, including freedom from fear and distress, freedom from thirst, freedom form hunger and malnutrition, safety from discomfortness; safety from pain and injury, and free from risk of disease (Caporale *et al.* 2005). Such issues receive low priority in most of the developing countries, due to lack of education and funding. As a result, rearing and management practices are not of high quality, and abattoirs have limited resources and operating environments. Additionally, handling facilities, infrastructure and operational techniques are poor, and bullying by other pigs is common in most production systems. These practices have detrimental effects on the pork quality, increase individual health risks, influence pig welfare and have negative effects on the ecological sustainability of food systems (Friend *et al.* 1983; Tan & Shackleton 1990; Ekkel *et al.* 1995).

Major welfare and production problems are constituted due to fighting among the individual of domestic pigs since it is the general practice to rear the animals in mixing conditions (Friend *et al.* 1983; Tan & Shackleton 1990).

Indeed, mixing of pigs increases aggression (Bouissou *et al.* 2001), affects productive as well as the reproductive performances (Nakanishi *et al.* 1993; Arey & Edward 1998), causes physiological stress (Mench *et al.* 1990), increases disease via decreasing immunity (Tuchscherer et al. 1998; Bouissou *et al*. 2001), and deteriorates pork quality (Faucitano 1998).

Moreover, consumers of the modern society expected that, food should be produced with ensuring higher welfare to the animals (Windhorst 2001). Indeed, there is an existing belief among meat consumers that, pigs reared under conditions that ensured maximum welfare are better pork producers (Ngapo *et al*. 2004). The level of welfare of animals reflected the nature and safety of the end product and consequently determined the overall quality of the food. On that aspects, in recent decades, alternative housing and management systems, organic farming, and environmental enrichment have gained a great deal of attention from pig producers. In addition, many studies have been conducted to reduce pig aggression to ensure their welfare; while that types of studies have implemented positive improvements through chemical intervention, pen design, changes in time of mixing, and group size (Marchant-Forde & Marchant-Forde 2005). To the best of our knowledge, there were no detail research to date, on the weight grouping of animals. In our previous study, we observed that, weight grouping was effective for obtaining uniform carcass group with better carcass characteristics and animal welfare. For further detail research, present study was undertaken with an aim to investigate the impact of weight grouping on meat composition as a focus point and in general the growth performance and immunity of pigs.

MATERIALS AND METHODS

Experimental design and animal management

A total of 120 crossbred (Landrace × Yorkshire) growing-finishing pigs were allocated according to body weight and reared for 10 weeks based on completely randomized design of three treatment groups with four replications (10 individuals with equal ratio of male and female) per treatment groups. Animals were reared in a slatted floor house where each separate groups were distributed in individual pen and provided 1.3 m^2/pig floor space. The weight groups included MW, a mixed weight group composed of high and low weight pigs; HW, a heterogeneous group of high weight pigs; and LW, a heterogeneous group of low weight pigs. The basal diet provided to the animals was commercial corn-soybean base diet, which was formulated to meet the nutrient requirements of piglets following the recommendation of the National Research Council (NRC, 1998). For the whole experiemtnal period, feeding and watering was *ad libitum* with one-sided self-feeder and a nipple drinker. To ensure the internal environment room temperature was maintained 25°C, while relative humidity was 60%, ventilation and lighting was also maintained according to practitioner's guidelines and general management.

Feeds were analyzed following the basic proximate analysis principles of AOAC (2000); where for moisture was determined based on the oven drying method (934.01); crude ash based on muffle furnace (942.05); and crude protein based on the Kjeldahl method (988.05). Minerals were determined using an Atomic Absorption Spectrophotometer (Model AA-6200, Shimadzu, Japan). Concentration of amino acids were determined by ion exchange chromatography based on acid hydrolysis. Ingredients and chemical composition of the diets provided to the different treatment groups were presented in Table 1. Present experiment was conducted at the Sunchon National University experimental farm, Suncheon, Republic of Korea. Experimental procedure and design was followed according to the guidelines of Animal Care and Use Committee of Sunchon National University, Republic of Korea.

Measurement of growth performance and behavior

Body weights of pigs were measured weekly throughout the experimental period. For the entire experimental period, feed consumption was measured based on the residual amount of feed. After measuring the body weight gain (BWG) and feed intake (FI), feed efficiency was measured for each group. All individuals were monitored to record and observe the frequency of behavioral pattern for 10 minutes duration for every week.

Measurement of carcass composition

Three pigs from each replication were transferred to a commercial slaughterhouse at the end of the experimental period and then slaughtered after electrical stunning. Feed withelding was applied for 24 h before slaughtering and pigs were laired for 4 hour and ensure free access to water only before slaughtering. Warm carcass weight and cold carcass weight was taken for all carcasses from each replication. Meat samples were taken from each carcass from each group for the meat composition. Samples of loin were taken from the carcass after dissection, sealed in polythene bags and stored at −20°C for further use for proximate analysis. Meat sample was chopped into pieces and ground three times through a grinding plate, after which it was divided into aliquots for moisture, crude protein, ether extract and total ash determination. The chemical composition of *Longissimus dorsi* muscles (LDM) samples [crude protein (CP, 990.03), ether extract (EE, 179 991.36), moisture (930.15), and total

ash (942.05)] were analyzed according to the method described by the Association of Official Analytical Chemists (AOAC, 2000).

Trace mineral contents were determined using stock solutions of calcium (Ca), iron (Fe), magnesium (Mg) and sodium (Na) containing 1000 mg/L of each element (Merck, Darmstadt, Germany) with the help of Atomic Absorption Flame Emission Spectrophotometer (Model AA-6200, Shimadzu, Japan). Analytical calibration standards were prepared over 0.5–2.0 ppm for Ca and Fe; and 0.1–0.4 ppm for Mg and Na by suitable dilution with deionized water. A 2.5 g of meat sample was taken in a crucible and dried at 105°C in oven, and burned in a muffle furnace (at 550°C) until the sample was found grayish white, and then finally cooled in a desiccator. After cooling, all crucibles were taken out and in each crucible there was added 10 ml of primary reagent (HCl: DW=1:1), all crucibles were then evaporated by placing on the hot plate. Following evaporation there was added 10 ml of secondary solution (HCl: DW=1:3) and evaporated in a similar way. After final evaporation, 100 ml of sample was filtered by using Whatman No. 6 filter paper where deionized water was used for washing and scratching the individual crucibles. The samples were then further diluted to ensure that the expected concentration fell within the calibration range. By comparing with the calibration curve, finally, the absorbance levels were measured. Results of the trace minerals were expressed as mg/100g of meat.

Measurement of meat fatty acid, cholesterol and pH

The fatty acid compositions of *Longissimus dorsi* muscle (LDM) were determined by fatty acid methyl ester (FAME) synthesis following the method described by O'Fallon et al. (2007). The fatty acid composition of the FAME was determined using a gas chromatograph (Agilent, 7890A series, USA) equipped with a flame ionization detector and a Hewlett Packard HP-88 capillary column (60 m × 0.52 mm × 0.20 µm). Samples were injected using an auto-sampler (Agilent Technologies 7693, USA). The chromatographic conditions were as follows: oven temperature, initial 125°C (held for 1 min), increased to 145°C at 10°C/min (held for 26 min), then further increased to 220°C at 2°C/min (held for 2 min); carrier gases, purified air and H_2 at 400 mL/min and 40 mL/min flow; makeup gas, helium at 40 mL/min; injector and detector temperature, 260°C and the split ratio, 30:1. Fatty acids were identified by comparison of their retention times to those of a standard FAME mixture (Supelco™ 37 Component FAME Mix, 10 mg/ml in CH_2Cl_2, Catalogue Number 47885-U. Supelco, Bellefonte, PA, USA). Sums and ratios of the fatty acids were determined, total saturated fatty acids (∑SFA), total monounsaturated fatty acids (∑MUFA), total polyunsaturated fatty acids (∑PUFA), and the ratio of PUFA to SFA (PUFA/SFA).

About 5 g of ground meat were collected and mixed with a chloroform and methanol mixture (2:1 vol: vol) and a reference material (0.5 ml of 5α-cholesterol) to separate the cholesterol from the fat. The separated cholesterol samples were then exposed to chromatographic analysis in a DS 6200 gas chromatograph (Donam Co., Seongnam, Gyeonggi-do, Korea) equipped with a flame ionization detector and a Hewlett Packard HP-5 capillary column (J&W Scientific, USA) that was 30 m long with a 0.32 mm internal diameter and 0.25 µm polyethylene glycol-film. The chromatographic conditions were as follows: oven temperature: 250°C (held for 2 min), followed by an increase to 290°C at 15°C/min (held for 10 min) and then to 310°C at 10°C/min (held for 10 min). During analysis, the injector and detector temperature were 280°C, the carrier gas was nitrogen, the split ratio was 50:1, and the sample volume was 2µl. The cholesterol content was expressed as mg/100g meat.

By using digital pH meter (Docu-pH+ meter, Sartorius, USA) pH of meat sample was measured. Where around 2 g of meat was blended and homogenized with 18 ml of distilled water with the help of homogenizer (following 1:9 ratio of sample and water). The muscle sample of the loin was chopped into pieces and ground three times through a grinding plate.

Measurement of immunological status

For immunoglobulins quantification, blood samples were collected early in the morning, before pigs were fed. Directly from the jugular vein blood samples were collected by using a 22-gauge sterile needle in a 10 ml syringe and then transferred to a BD Vacutainer (Becton Dickinson, Franklin Lakes, NJ) without anticoagulant. After collection of the blood samples form the individual pigs, the blood was transferred to a centrifuge tube where blood was centrifuged for 15 min at 3,000 rpm (1610 × g) in a cold chamber (4°C). After centrifugation, the sera were carefully removed to plastic vials and then stored at -20°C for further immunoglobulin analysis. According to the manufacturer's instructions, the serum IgG, IgM and IgA were assayed using Pig IgG (Cat. No. E100-104), IgM (Cat. No. E100-100), and IgA (Cat. No. E100- 102) ELISA Quantitation Kits (Bethyl Laboratories Inc., Montgomey, TX), respectively. Each experimental samples were run in duplicate and the absorbance of each well was measured using a micro plate reader (Thermo Lab Systems, Finland) at 450 nm (correction wavelength, 570 nm). The results were expressed as g/L of serum.

Measurement of time required for marketing

The total time required for marketing of pigs (age at marketing) of different weight groups was calculated based on body weight gain. Marketing weight was considered 110 kg body weight. Therefore, standard market weight was divided by the average daily gain (ADG) to obtain the age at marketing as follows:

Age at marketing (Days) = Standard market weight (kg) / ADG (kg)

Statistical analysis

The General Linear Model with the Statistical Analysis System (SAS, 2003) was used for statistical analysis of experimental data. Differences among the means were determined by Duncan's Multiple Range Test (DMRT). Probability values of $P < 0.05$ were considered statistically significant, whereas a $P < 0.10$ was considered a tendency.

RESULTS

Effect of weight grouping on performance and behavior of individuals

The growth performance of the different weight groups are shown in Table 2. The initial live weight of the homogeneous HW and LW, and heterogeneous MW group tended to differ ($P > 0.10$). The final live weight was higher in the HW than the MW ($P < 0.05$). During 0 to 6 weeks, body weight gain, feed intake and gain: feed ratio did not differ significantly among the weight groups ($P < 0.05$). In addition, during 7 to 10 weeks, body weight gain was significantly higher in homogeneous groups (HW and LW) than the heterogeneous (MW) group ($P < 0.05$). However, feed intake and gain: feed ratio did not differ significantly among the weight groups ($P > 0.05$). Furthermore, during the overall experimental period (0 to 10 weeks), body weight gain was significantly higher in the homogeneous group (HW and LW) than the heterogeneous group (MW) ($P < 0.05$). While feed intake and gain: feed ratio tended to be higher in HW and LW respectively, compared to MW ($P < 0.10$).

As shown in Figure 1, the frequency of behavioral aggression of biting among the individuals was significantly higher in heterogeneous MW compared to homogeneous HW and LW group ($P < 0.05$); while, the frequency of behavioral aggression of mounting was significantly higher in MW compared to HW ($P < 0.05$). Throughout the experimental period, more fighting, threshing, knocking and mounting was observed in MW than HW and LW. In addition, vigorous fighting was observed during initial stage among individuals of MW comparatively higher levels than in both HW and LW. Weight differences in MW led to dominant-subordinate interactions that resulted in lower feeding behavior, resulting in weakness and lying among the subordinate individuals.

Effect of weight grouping on carcass characteristics and composition

The carcass composition of the homogeneous and heterogeneous groups is presented in Table 3. The hot carcass weight and the cold carcass weight was significantly higher in case of homogeneous group HW compared to heterogeneous group MW ($P < 0.05$). The crude fat content was lower in both homogeneous groups (HW and LW) than the heterogeneous group (MW) ($P < 0.05$). The moisture content was lower in both homogeneous groups (HW and LW) than the heterogeneous group (MW), ($P > 0.05$); while crude protein and crude ash content was higher in the homogeneous groups (HW and LW) than the heterogeneous group (MW), but there were no significant differences among the weight groups ($P > 0.05$). In addition, among the trace minerals, magnesium and sodium content of meat was slightly lower in the homogeneous weight groups (HW and LW); while calcium and iron content was slightly higher in HW and LW than MW; however, it was observed no significant differences among the weight groups ($P > 0.05$). Furthermore, there was found no significant differences in the meat cholesterol content ($P > 0.05$); however, meat pH value tended to be higher in MW compared to HW and LW ($P < 0.10$). Moreover, it was observed no significant differences ($P > 0.05$) on sum of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA) and the ratio of PUFA/SFA.

Effect of weight grouping on serum immunoglobulins

Figure 2 shows the effects of weight deviation on the serum immunoglobulins (IgG, IgM and IgA) of pigs. The serum immunoglobulins values were higher in the homogeneous groups (HW and LW) than the heterogeneous group (MW), but there were no significant differences ($P > 0.05$).

Effect of weight grouping on time required for marketing

As shown in Figure 3, the total time required to reach market weight was significantly lower for the homogenous groups (HW and LW) than the heterogeneous group (MW) ($P < 0.05$).

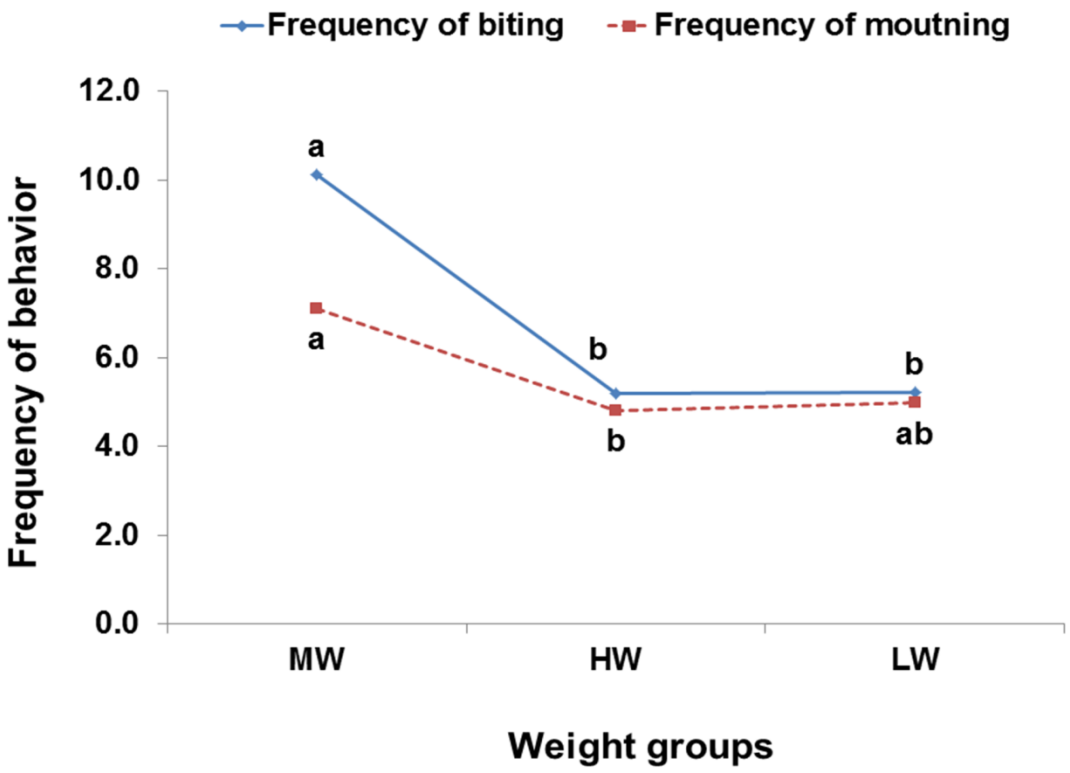

Figure 1 Effect of weight grouping on frequency of behavior among the individuals
[a,b] Means different superscript letters in the same lines are significantly different at P <0.05
Error bars indicate the standard error

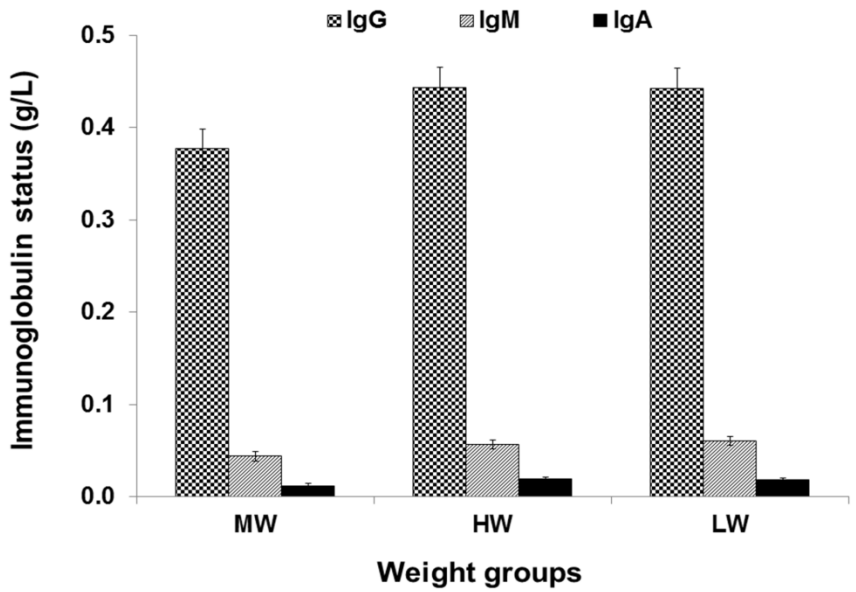

Figure 2 Effect of weight grouping on serum immunoglobulin concentration in pigs (g/L)
A P <0.05 was considered to indicate significance
Error bars indicate the standard error

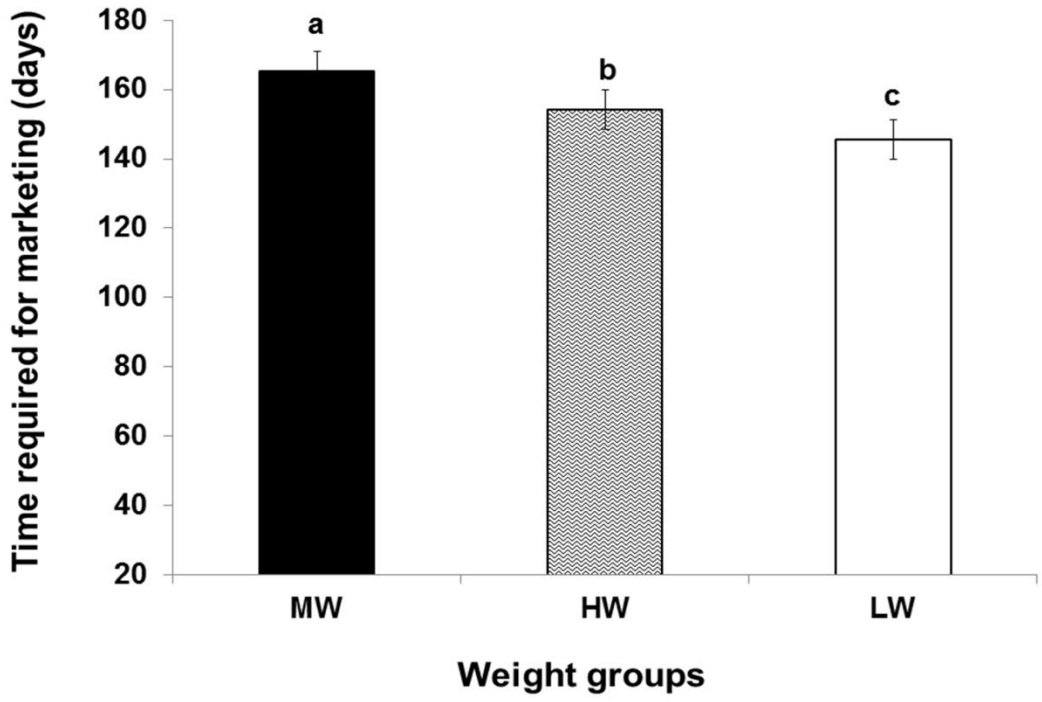

Figure 3 Effect of weight grouping on time required for marketing
[a,b,c] Means different superscript letters in the bars are significantly different at P <0.05

Table 1 Formula and chemical composition of experimental diets (%)

Ingredients	Starter (35–50 kg)	Finisher (50–110 kg)
Yellow corn	45.15	45.15
Wheat	23.00	25.00
Wheat bran	4.00	4.00
Soybean meal	18.00	16.00
Limestone	0.98	0.78
Calcium phosphate	1.10	1.10
Salt	0.25	0.25
Vit-min. premix[1]	0.55	0.55
Animal fat	2.50	2.50
Molasses	4.30	4.50
L-lysine-HCL (78%)	0.17	0.17
Chemical composition[2]		
ME (kcal/kg)	3,265.00	3,265.00
Crude Protein (%)	18.00	16.00
Calcium (%)	0.70	0.50
Available phosphorus (%)	0.55	0.45
Lysine (%)	0.95	0.80
Methionine (%)	0.30	0.27

[1] Vit-min. mix provided the following nutrients per kg of premix: vitamin A, 6,000 IU; vitamin D3, 800IU; vitamin E, 20IU; vitamin K3, 2mg; thiamin, 2mg; riboflavin, 4mg; vitamin B6, 2mg; vitamin B12, 1 mg; pantothenic acid, 11mg; niacin, 10mg; biotin, 0.02mg; Cu (copper sulfate), 21mg; Fe (ferrous sulfate), 100mg; Zn (zinc sulfate), 60mg; Mn (manganese sulfate), 90mg; I (calcium iodate), 1.0mg; Co (cobalt nitrate), 0.3mg; Se (sodium selenite), 0.3mg.

[2] calculated value.

Table 2 Effects of weight grouping on growth performance of pigs

Parameters	Weight groups			SEM	P-value
	MW	HW	LW		
Initial live weight (kg/pig)	47.98	54.74	45.87	2.18	0.09
Final live weight (kg/pig)	94.57[b]	104.89[a]	98.73[ab]	1.95	0.03
0 to 6 weeks					
Avg. daily gain (kg/pig)	0.76	0.80	0.81	0.02	0.17
Avg. daily feed intake (kg/pig)	2.06	2.14	2.10	0.06	0.65
Gain: Feed	0.37	0.37	0.39	0.01	0.49
7 to 10 weeks					
Avg. daily gain (kg/pig)	0.53[b]	0.60[a]	0.64[a]	0.02	0.01
Avg. daily feed intake (kg/pig)	2.01	2.21	2.16	0.09	0.29
Gain: Feed	0.26	0.27	0.30	0.01	0.24
0 to 10 weeks					
Avg. daily gain (kg/pig)	0.67[c]	0.71[b]	0.76[a]	0.01	<0.01
Avg. daily feed intake (kg/pig)	2.06	2.18	2.15	0.03	0.07
Gain: Feed	0.32	0.33	0.35	0.01	0.07

[a,b] Means with different superscript letters within the same row are significantly different (P <0.05)

SEM = Standard error of mean

Table 3 Effect of weight grouping on carcass composition of pigs

Parameters	Weight groups			SEM	P-value
	MW	HW	LW		
Hot carcass weight (kg/pig)	77.84[b]	89.56[a]	83.55[ab]	2.15	0.03
Cold carcass weight (kg/pig)	74.22[b]	85.45[a]	81.15[ab]	2.16	0.03
Moisture (%)	74.02	73.52	73.41	0.81	0.86
Crude fat (%)	0.96[a]	0.43[b]	0.56[b]	0.05	<0.01
Crude protein (%)	24.26	24.92	25.06	1.02	0.87
Ash (%)	1.24	1.35	1.32	0.14	0.88
Calcium (mg/100g)	5.93	5.98	5.95	0.07	0.92
Iron (mg/100g)	0.86	0.88	0.89	0.02	0.63
Magnesium (mg/100g)	21.67	20.67	21.00	1.87	0.93
Sodium (mg/100g)	31.67	30.33	29.67	2.53	0.86
Meat cholesterol (mg/100g)	87.21	84.28	83.65	1.14	0.14
Meat pH	6.13	5.81	5.80	0.09	0.10
∑ SFA (g/100g)	37.01	37.00	36.83	4.76	1.00
∑ MUFA (g/100g)	45.10	47.30	46.52	3.61	0.92
∑ PUFA (g/100g)	14.69	14.75	13.91	2.53	0.97
PUFA/SFA	0.39	0.39	0.37	0.03	0.79

[a, b] Means with different superscript letters within the same row are significantly different at P <0.05
SEM = Standard error of mean
∑ = Sum, SFA = saturated fatty acid, MUFA = monounsaturated fatty acid, PUFA= polyunsaturated fatty acid

DISCUSSION

Growth performance and animal behavior

Mixing of pigs results fighting among the individuals to establish a dominance hierarchy. Fighting among the individuals constituted by a simple linear form, followed by mouth-to-neck attacks over the period (McBride *et al.* 1964). After the establishment of dominance hierarchy during the initial stage of mixing, aggression level decreases gradually (Symoens & Van Den Brande 1969); however, social rank appears to influence productivity in the long run. In the present study, more antagonistic behavior was observed among individuals of the heterogeneous group (MW) than the homogenous group (HW). The lower value of overall body weight gain and tendency of lower feed intake of the MW in the present study might have been due to mixture of higher and lower weight pigs resulting in dominant-subordinate interactions, which prevents subordinates from eating properly (de Jong *et al.* 1999). Large groups containing animals with greatly differing weights can lead to difficulty in animal management, increased aggression, impaired animal welfare and consequently the loss of animal productivity (Stricklin & Mench 1987). Due to mixing and behavioral stress, increased levels of stress hormones ultimately affect the immune and endocrine systems, resulting in restricted feeding and slower growth (Raab *et al.* 1986; Stookey & Gonyou 1994; Otten *et al.* 1999). Nevertheless, other researchers have reported that growth and feed intake were not correlated with dominance hierarchy (Meese & Ewbank 1973).

Carcass characteristics and composition

The carcass characteristics and composition are correlated with aggressive behavior prior to slaughter, as well as stressful situations during rearing, and in the weeks or months before slaughter (Terlouw 2005). Consistent to that, differences in the hot and cold carcass weight were observed in case of weight groups (MW, and HW and LW). In the current study, differences in carcass compositions were observed among homogeneous (HW and LW) and heterogeneous (MW) weight groups (Table 3). Carcass composition and quality of finishing pigs can be influenced by genetics (Langlois & Minvielle 1989); however, environmental factors such as housing, management, age and sex of the animals, diet composition and regimen of feeding can influence the carcass quality (Warner *et al.* 2010; Heyer 2006). Different types of management and rearing systems, including transportation systems, can also

affect carcass composition. Murray and Jones (1994) reported that transportation of mixed groups to the abattoir results in fighting, leading to significant differences in carcass composition. Mixing of heterogeneous groups also causes skin blemishes, carcass damage, and changes in carcass composition, ultimately hampering animal welfare (Warriss & Brown 1985; Guise & Penny 1989; Murray & Jones 1994).

Stress results in reduced moisture content, which reduces meat quality (Channon *et al*. 1997; D'Souza *et al*. 2004). The higher frequency of aggression from initial stage upto slaughter in the heterogeneous group (MW) might have led to alteration of the moisture content; resulted in the higher fat content in the heterogeneous group (MW) than that of the homogeneous groups (HW and LW). It was reported by Savell *et al.* (1986) that, fat content and moisture content is negatively correlated. In the current study, there was observed no apparent relationship for fat and moisture content in the homogeneous (HW and LW); and the heterogeneous group (MW). Slower growth rate pigs with lower fat proportions compared to the fast growth rate pigs was reported in the previous report (Correa *et al.* 2008), which was inconsistent with the results observed in the present study, because the growth rate of MW was lower but the crude fat content was higher (Table 2 and Table 3). I is a well known fact that, stress induces changes in body weight and composition in animal models (Rybkin *et al.* 1997). Behavioral stress can also affect adipose tissue mass and fat contents (Marin *et al.* 1992). Stress results in the accretion of fat (Mårin & Björntorp 1993), and it is possible that the relative enlargement of fat stores is responsible for maintenance of a reduced body weight. Because fat produces circulating feedback signals that regulate energy balance and control body weight (Weigle 1997), adipose tissue in stressed individuals may provide erroneous signals regarding body composition and prevent weight gain.

Crude protein content did not differ significantly between the homogeneous and heterogeneous group, which was in agreement with previous studies (Ellis & Betrol 2001; Latorre *et al*. 2004). However, Rehfeldt and Kuhn (2006) reported the lowest muscular protein concentration in lower weight piglets. In the present study, insignificant differences of the crude ash indicated the no possible effect owing to behavioral stress among individuals. However, Smith and Teeter (1987) reported that social and environmental stress can increase mineral excretion. It was also reported that, stress impairs absorption and the concentration of vitamins and minerals (Beisel 1982; Sahin *et al.* 2001). Specific minerals such as calcium, magnesium, sodium, potassium and chloride concentration and metabolism can also be altered in response to different types of stress due to alteration in electrolyte, acid-base physiology, ionic and mineral imbalance (Klaus-Dietrich 1985; Schaefer *et al.* 1990; Schaefer *et al.* 1997). Present result implicated that, there was no long term impact on trace minerals due to behavioral stress.

Result of meat cholesterol content implicated that there was found no significant impact of long term social stress due to weight grouping. However, changes in the muscle chemistry and consequently in the meat quality could be happened due to short term stress before slaughter (Warriss *et al.* 1998ab; Terlouw *et al.* 2008). Earlier research reported that, dominant subordinate interactions can alter the cholesterol concentration in wild animal model (Sapolsky & Mott 1987). In the present study, the pH was tended to be higher in the heterogeneous group than the homogeneous groups. Depletion of muscle glycogen can be resulted by the stress over a prolonged period (Warriss & Brown 1985; Terlouw 2005), which can be exacerbated by psychological stress and increase in the secretion of catecholamine (Fernandez *et al.* 1994). Breakdown of the glycogen resulted post-mortem acidification of the meat (Fernandez & Tornberg 1991); therefore, absence of glycogen can causes higher pH of meat, resulted dark firm dry meat and changes the meat composition in extreme cases (D'Eath *et al.* 2010). Energy expenditure during fighting alters glycogen levels and ultimately pH (Fernandez et al. 1994; Terlouw 2005). The depletion of muscle glycogen is triggered due to the release of stress hormones such as glucocorticoids and catecholamine which ultimately causes increases in meat pH and other parameters (Lambooij 2000). Behavioral stress might be attributed to the significant impact on meat cholesterol and pH, as well as internal chemistry; because, the release of different hormones (which are often used to assess welfare during handling) are stimulated by the stress or physical exertion (Muchenje *et al*. 2009).

Serum immunoglobulins

The immunoglobulin concentration in the extracellular fluid can be used as an index of humoral immune response (Hessing *et al.* 1994). In the present study, observed no alteration in the immunological value in the heterogeneous group (MW) than the homogeneous group (LW and HW). However, changes in the immunological value and antibodies and susceptibility to disease in the dominant and subordinate pigs were reported owing to behavioral interactions in the previous studies (Barnard *et al.* 1993; Morrow-Tesch *et al.* 1994; Tuchscherer *et al.* 1998).

Generally, socially dominant or submissive pigs in comparison to the socially intermediate pigs, showed alterations in immune function such as the elevation of the numbers of neutrophils and depression of antibody production due to stress factors (Morrow-Tesch *et al.* 1994). In addition, it can have significant effects on a variety

of physiological systems regarding imbalance in the autonomic nervous system, disturbing in the axis of the hypothalamic-pituitary-adrenal system, and in the status of immune system (Kemeny 2003). Fernandez *et al.* (1994) reported that, stimulation of the sympathetic nervous system and physical activity are involved in control of the mobilization of body energy sources in response to aggressive encounters in domestic pigs, which consequently triggers the changes in the plasma metabolites and neuroendocrine systems. To elucidate (in detail) the effects on the body physiology; behavioral and physiological consequences and immunological consequences of social status and different types of aggression were investigated in a rat model (Raab *et al.* 1986; Devoino *et al.* 1993).

Time required for marketing

The average daily gain was significantly higher for the homogeneous groups (HW and LW); consequently, the time required for marketing or age at marketing for standard weight was significantly lower for the homogenous group than the heterogeneous group (MW) ($P < 0.05$). The lower total time required to reach market weight for the homogeneous group indicated that uniform weight grouping would be beneficial for pork producers.

CONCLUSION

Overall the growth performance (average daily gain) was higher in the homogeneous group (HW and LW) than the heterogeneous group (MW); and frequency of behavioral aggression was lower in the homogeneous group (HW and LW) than the heterogeneous group (MW). In addition to that, there was observed no significant alterations in meat cholesterol, pH and fatty acids; however meat crude fat content was found lower in HW and LW in comparison to MW. Furthermore, serum immunoglobulin status among the weight groups was remaining unaffected. Moreover, time required for marketing was found lower for HW and LW in comparison to MW. In conclusion, uniform weight grouping could be beneficial for better productivity and welfare with lower aggression; required lower time to market with uniform carcass group; lower fat content without having a significant long term negative impact on meat composition and immunity.

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