The Effects of Group Sizes on Behaviors, Meat Characteristics and Growth Performance of Growing and Finishing Pigs Under Tropical Conditions in Thailand

Thunwa Wiyabot

Animal Production Technology, Department of Agricultural Technology, Faculty of Agricultural Technology and Industrial Technology, Nakhon Sawan Rajabhat University, 60000

Coresponding author. E-mail address: Thunwa_art@hotmail.com

Abstract

The objectives of this study was to evaluate the effect of group size on growth performance of growing and finishing pigs under tropical conditions in Thailand. The group sizes were 4, 8, and 12 pigs per pen, providing a floor allowance of 1.50, 0.75, and 0.51 m^2/pig, respectively. The pigs that were reared in a group size of 12 pigs per pen ate, drank, walked, mouth piped, rooted the floor, rooted the pipe and pawed more significantly often ($P<0.05$) than did the pigs that were reared in group sizes of 4 and 8 pigs per pen. These feeding behaviors and the high temperature of Thailand caused high rectal and skin temperatures, which were the highest in the group size of 12 pigs per pen. Moreover, the high temperature and the increased group size may cause heat stress, which would decrease the average daily gain (ADG). The largest group size of 12 pigs per pen presented the lowest ADG in both growing and finishing phases, which significantly differed ($P<0.05$) compared to the group sizes of 4 and 8 pigs per pen. In addition, the high temperature and the feeding frequency in the group sizes of 8 and 12 pigs per pen provided a better back fat thickness that was significantly less than that of the group size of 4 pigs per pen ($P<0.05$). So the appropriate group sizes and floor allowance for feeding growing and finishing pig were 8 pigs per pen or 0.75 m^2 due to the high rate of ADG and the thinner back fat thickness ($P < 0.05$)

Keywords: Group Size, Growing and Finishing Pigs, Growth Performance

Introduction

Pig products from Thailand are accepted by ASEAN countries regarding farming and processing standards. Thailand has a better potential for the production and export of pork products compared to other ASEAN countries (Reodecha, Ingkaninun, & Kunavongkrit, 2000). The climate in Southeast Asia is 27 - 31°C from April to October and the highest temperature can be greater than 42°C for several weeks of the year (Tantasuparuk, Lundeheim, Kunavongkrit, & Einarsson, 2000), which may be a significant problem that decreases pig performance and meat quality. The Thai climate can be both hot and dry or hot and wet and can decrease pig performance and meat quality due to heat stress (Harapin, Bedrica, Hahn, & Gracner, 2003). Heat stress causes behavioral disturbances and negatively affects feed intake, weight gain, and feed conversion (Kiefer, Meignen, Sanches, & Carrijo, 2009). According to Bellego, Van, Milgen, and Noblet (2002), the reduction in feed intake that was observed in pigs that were submitted to high ambient temperatures is probably a defense mechanism of the organism to reduce heat production resulting from digestive and metabolic processes. Moreover, the high temperature more significantly affected the carcass weight during autumn than during winter and spring (Trezona, Mullan, Antuono, & Williamsi, 2004). Farmers understand this problem very well and have tried many ways to resolve it. Air conditioning or evaporative cooling systems are used in boar (AI) housing. Dripping and fogging systems are used in sow houses. (Somparn, 2016). Both systems help to improve performance. However, these systems require much investment and redesign, which some older farms cannot implement (Tantasuparuk et al., 2000). The choice of appropriate group size is a way to solve this problem ; small group sizes may become a new approach to decrease cost and should be studied (Harold & Stricklin, 1998). Schmolke, Li, and Gonyou (2003) reported that in growing and finishing pigs during the first 2 wk, the ADG was lower for pigs in groups of 40 (554 g/d) than for pigs in groups of 10 (632 g/d; $P < 0.05$), Gonyou and Stricklin (1998) found that the ADFI and ADG decreased with an increasing group size (i.e., 3, 5, 6, 7, 10, and 15 pigs/pen) during both the growing and finishing phases (25 to 97 kg body weight). Quiniou and Noblet (1999) found that the feed intake decreased to avoid an excessive increase in body temperature, Hyun and Ellis (2002) found that finishing pigs changed feeding behavior and had decreased ADFI and ADG with increasing group size. Therefore, the objectives of our study were to determine the effect of group size on productivity over a range that is typical of experimental and small commercial pens reared during hot season in Thailand

Materials and Methods

Forty-eight (24 males and 24 females) of three-way crossbred pigs (Large White × Landrace × Doroc Jersey) were blocked by sex and randomly assigned to each pen within a block. Three group size treatment as 4, 8, and 12 pigs per pen provided the floor area allowance as 1.50, 0.75, and 0.51 m^2 respectively. Pigs were watered and fed with ad libitum access to complete pellet diets based on corn, soybean meal, wheat bran, and broken rice in the growing and finishing stages. The mean initial weight of pigs in the growing stage was 25± 0.08 kg and in the finishing stage was 70 ± 0.24 kg. The pigs were fed with complete pelleted concentrate diets according to National Research Council (1994), formulated to provide 3,159 and 3,301 kcal/kg of energy and 16% and 14% CP during the growing and finishing stages, respectively (Table 1).The samples of concentrate were taken from the feed storages at weekly intervals and the kept at −20°C for chemical analysis by proximal analysis (AOAC, 1990). Internal and external parasites were controlled by injecting Ivomec@ in all of the piglets.

The data was collected at 14.00 pm and consisted of ambient temperatures, wet-dry bulb temperatures and relative humidity (RH). From this data, Temperature-Humidity index (THI) was derived using the following equation (Armstrong, 1994) : $THI = Tdb + 0.36 (Tdp) + 41.2$

Where Tdb is the dry bulb temperature (°C) and Tdp is the dew point temperature (°C). The feeding behavior, drink walk, mouth pipe, root floor, root pipe, and paw behaviors were recorded continuously on video tape. Skin temperature (ST) and rectal temperature (RT) were measured three times per day at 3 and 7 h (daily heat stress period) and 2 h after lowering the thermostat for the warm period; the rectal temperature was measured by inserting a clinical thermometer into the rectum to a depth of 7 cm while the animal was placed in a racing stall with head support near the paddock, and the skin temperature was measured using punctual samples (Bull, Harrison, Skowski, & Gonyou, 1997). After feeding for 22 wk in the growing stage (18-22 wk) and for 26 wk in the finishing stage (22-26 wk), the pigs were individually weighed and the data were calculated for the ADG by ADG calculated from the body weight gain divided by feeding period (days) while ADFI calculated from feed intake quantity divided by feeding period (days) and feed efficiency (gain/intake).

Table 1 Composition of experimental diets

Ingredient (%)	Amount	
	Growing	Finishing
Yellow Corn (7.8% CP)	54.90	52.90
Soybean meal (44% CP)	16.90	18.40
Wheat bran	16.70	16.70
Broken rice	6.70	7.70
Limestone	2.00	1.90
Dicalcium diphosphate (P17)	1.10	0.70
Molasses	1.00	1.00
Salt	0.40	0.30
Vitamin-Mineral premix[a]	0.20	0.20
Lysine	0.20	0.20
DL-Methionine	0.10	0.01
Total	100	100
Chemical Composition[b]		
Dry matter	89.30	89.78
Crude protein, (CP)	16.00	14.00
Gross energy (kcal/kg)	3,159	3,301
Calcium (Ca)	0.78	0.67
Total phosphorus (P)	0.66	1.04
Crude fiber (CF)	5.04	5.63

[a]vitamin - mineral premix contained 11% Fe, 11%Zn, 2.6%Mn, 1.1%Cu,0.02%Se, 909,091 IU of vitamin A, 136,364 IU of vitamin D, 3,636 IU of vitamin E, 0.6 mg of D-pantothenic acid, and 4,546 mg of niacin per kilogram

[b]Based on ingredient values measured and analysis in our laboratory

At the end of the experimental period, the animals were put on a fast from solid feed for 18 h, after which they were weighed and slaughtered for carcass characteristics and meat quality evaluation. Immediately after stunning by electronarcosis, the animals were bled via jugular incision and scalded, eviscerated and divided into two half-carcasses. Then, 45 min after slaughter, the pH and temperature of the carcasses were recorded using a pH meter that was coupled to a penetration probe and inserted into the center of the *Longissimus dorsi* muscle in the left half-carcass between the 12^{th} and 13^{th} thoracic vertebrae. The procedure was repeated 24 h after slaughter. The carcasses were weighed in order to obtain the hot carcass weight (HCW). The length of the carcasses was recorded using the Brazilian method for carcass classification (BMCC). The back fat thickness between the 7^{th} and 8^{th} thoracic vertebrae, between the 3^{rd} and 4^{th} lumbar vertebrae, and at the point P2 was measured using calipers. The loin eye area (LEA) was recorded according to the methodology that was proposed by Boggs and Merkel (1993), which consisted of the section between the 10^{th} and 11^{th} ribs of the left half carcass, where a cross section of the *Longissimus dorsi* was exposed. The fat area (FA) and *Longissimus dorsi* muscle area (LA) were measured to calculate longissimus muscle area/fat area (LA/FA) according to standard methods described previously by Sripromma (1984).The fat-lean ratio was expressed according to the LSQ (Lenden-Speck-Quotient) system of Pfeiffer and Falkenberg (1972). Briefly, the LSQ is calculated as (B1 + B2)/(2 × B3), where B1 = the back fat thickness at the front base of the gluteus muscle, B2 = the back fat thickness on top of the gluteus muscle (at the thinnest part of the back fat), and B3 = the shortest distance from the front base of the gluteus muscle to the dorsal border of the spinal cord.

The qualitative measurements of the *Longissimus dorsi* muscle were performed using the methodologies described as follows: *Meat color*: Aiming for muscle oxygenation, each sample remained exposed to the air for 15 min. After this period, the meat was slightly dried with paper towels, and the color was measured using a portable color meter (Minolta CR 410). The components L* (lightness), a* (red-green) and b* (yellow-blue) were shown in the CIELAB color system and assessed at three different points of the muscle surface using the D65illuminant and an observational angle of 10° (Caldara et al., 2013).

Exudate loss (EL): Samples in steak form with a 2.5 cm width were prepared with the external fat removed and were weighed on a semi-analytic scale. The samples were kept as in a simulated retail sale on a shelf with a 45° angle of inclination in trays that were covered with a plastic film at 4 ± 1°Cfor 48 h. After this period, the exudate was discharged, and the samples were weighted again. The EL was expressed as a percentage of the initial weight (Caldara et al., 2013).

Weight loss by cooking (WLC): Samples in steak form with a 2.5 cm width were prepared with the external fat removed and were weighed on a semi-analytic scale and roasted without the addition of condiments. The oven was pre-heated to a temperature of 170°C. The internal temperature of the samples was monitored during cooking using sensors that were tied to a digital thermometer. When the samples' internal temperature reached 80°C, they were removed from the oven and cooled at room temperature, after which they were weighed. The WLC was expressed as a percentage of water lost in relation to the original sample weight (Caldara et al., 2013).

Shear force (SF): Three cylindrical sub-samples were removed from each WLC sample, parallel to the muscle fiber orientation. These sub-samples were placed with the fiber oriented perpendicular to the Warner-Bratzler lamina as described by Froning, Bagabji, and Mater (1978). The average of three repetitions and the value of shear force for each sub-sample were used to assess the tenderness of the meat (Caldara et al., 2013).

The data were analyzed by ANOVA (Steel & Torrie, 1980) and the means compared by Least Significant Different (LSD) using the General Linear Model (GLM) procedure of SAS (SAS Institute 1999) as a randomized complete block design. Orthogonal single degree-of-freedom contrasts were used to determine the main effects of group size (4, 8, and 12 pigs per pen). These effects were considered significant at $P<0.05$. Probability values of $P>0.05$ and $P<0.10$ were considered trends, and probability values of $P>0.10$ were considered not significant.

Results and Discussion

The temperature during this experiment from February to July 2014 of Thailand, averaged across rooms were 30.8±1.1°C and the highest temperature was 34°C and relative humidity of 85%. Bull et al. (1997) reported that heat stress occurs at a temperature of 34.2±2.8°C, resulting in increased respiration rates and rectal temperatures, slowed growth, and poor reproduction. Although the temperature in this experiment was not high but the average humidity was at high rate. Humidity is the evaporate factor for releasing heat from the pigs body. In the high humidity and temperature condition, animals release heat difficultly and feel uncomfortable. They would gasp to make another way of heat release except sweating. If the humidity in the air was too high to release body's heat, the animals would frustrate. The proper relative humidity is 50 – 80% which animals can feel comfort. (Sawangtub, 1996). For this experiment found that the larger group sizes of 4 to 12 pigs per pen affect to increase of temperature in rectal and skin of pigs, which was the highest in the largest group size with 12 pigs per pen. After 42 days of experiment during summer in Thailand, it was found that in 8 and 12 pigs cattle affected the Rectal and Skin temperature higher than 4 pigs per pen significantly ($P < 0.05$) (Table 2).

Table 2 Rectal and skin temperature during the hot season of Thailand

Date after rearing	Rectal			SEM	Skin			SEM
	4	8	12		4	8	12	
7	37.5^{b}	37.7^{b}	38.3^{a}	0.33	34.2^{b}	34.6^{b}	35.5^{a}	0.11
14	37.4^{b}	38.1^{a}	38.4^{a}	0.40	34.1^{b}	35.1^{a}	35.8^{a}	0.43
21	37.5^{b}	38.2^{a}	38.7^{a}	0.34	34.1^{b}	34.8^{b}	35.7^{a}	0.40
28	37.3^{b}	38.1^{a}	38.4^{a}	0.53	34.2^{b}	34.5^{b}	35.1^{a}	0.16
35	37.2^{b}	38.1^{a}	38.5^{a}	0.62	35.4^{b}	35.2^{b}	36.6^{a}	0.40
42	37.5^{b}	38.2^{a}	38.9^{a}	0.58	35.4^{b}	36.4^{a}	36.8^{a}	0.53

^{ab}Means within rows showing different superscripts are significantly different ($P<0.05$)

The larger group sizes of 4 to 12 pigs per pen changed their feeding behavior to increase frequency in eating, drinking, urinating, defecating, turning, walking, mouth watering, mouth piping, rooting the floor, rooting the pipe and pawing in both the growing and finishing stages. Which these behavior in a group size of 12 pigs per pen more often (time/day) than did the group sizes with 4 and 8 pigs per pen by significant difference ($P<0.05$) in both the growing and finishing stages (Table 3). The similar report of Hyun and Ellis (2002) found that finishing pigs changed feeding behavior with increasing group size of 2 and 12 pigs during either the growing or finishing periods, particularly showing an increase in the rate of feed consumption. Although the feeding behavior in a group size of 12 pigs per pen more often (time/day) than the group sizes with 4 and 8 pigs per pen, but it had no effect on the feed intake. (Hyun & Ellis, 2002). As we can observe, it was shown that the 12 pigs per pen can influence the pigs behavior both growing and finishing pigs due to the state of social animals among pigs whereas conglomerate they would imitate behavior each other including the way they eat, drink and walk. In addition, Gonyou & Striklin (1998) reported that ADG decreased with increasing group size (3, 5, 6, 7, 10, and 15 pigs per pen) during both the growing and finishing stages. For this report showed that the group size of 12 pigs per pen had a lower ADG than that of group sizes with 4 and 8 pigs per pen during the growing and finishing stages (Table 4), which was significantly different at ($P<0.05$). This result affect form the highest body temperature in the group size of 12 pigs per pen, which Harapin et al. (2003) reported that the high temperature was caused heat stress related to decrease of growth performance. And when they conglomerate, the body's temperature and skin temperature would be high as shown in Table 2 together with the high relative humidity during the experiment. The 12 pigs per pen affected the lower ADG especially on the higher behavior and activities such as walking all the time of experiment which using high energy for the activity. On carcass traits and meat qualities, the group size did not affect the carcass length, Lenden-speck-quotient, hot carcass weight, lion eye area, fat area, longissimus muscle area/fat area (LA/FA) and all of the studied meat qualities ($P>0.05$). Except on the Backfat thickness which found that 8 and 12 pigs per pen caused it thinner than 4 pigs per pen significantly ($P < 0.05$).Similar report of Wolter et al. (2001) presented that the group size did not affect the hot carcass weight, loin-eye depth or carcass dressing percentage. However, this report shows that a larger group size of 8 and 12 pigs per pen reared under the high temperature of Thailand had the less back fat thickness than that in a group size of 4 pigs per pen (Table 5), which was significantly different (P<0.05). In addition, Trezona et al. (2004) found that pigs that were slaughtered from July to October were heavier and fatter than pigs that were slaughtered from January to March (hot season)

Table 3 Feeding behavior of pigs during the growing and finishing stages

Behaviors (time day^{-1})	Group size, pigs/pen 4	8	12	SEM	P-value
Growing stage					
Eat	74.2^{b}	75.2^{b}	84.2^{a}	4.1	0.03
Drink	26.1^{b}	25.3^{b}	37.2^{a}	2.3	0.02
Urinate	3.0	3.9	3.5	0.1	0.12
Defecate	3.8	3	3.6	0.9	0.22
Turn	2.5	2.7	2.6	0.7	0.31
Walk	3.3^{b}	3.6^{b}	13^{a}	0.3	0.01
Mouth water	1.5	1.2	1.8	0.6	0.12
Mouth pipe	4.2^{b}	4.5^{b}	14.6^{a}	0.9	0.03
Root floor	8.3^{b}	11.7^{b}	31.1^{a}	0.5	0.04
Root pipe	0.3^{b}	0.8^{b}	38.7^{a}	0.9	0.03
Paw	0.2^{b}	0.3^{b}	24.8^{a}	4.1	0.02
Fishing stage					
Eat	2.3^{b}	3.4^{b}	6.6^{a}	0.9	0.03
Drink	1.2^{b}	1.2^{b}	2.5^{a}	0.4	0.03
Urinate	0.3	0.2	0.3	0.3	0.11
Defecate	0.2	0.3	0.3	0.6	0.08
Turn	2.4	2.6	2.8	1.54	0.09
Walk	1.4^{b}	1.5^{b}	7.1^{a}	0.4	0.04
Mouth water	0.2	0.2	0.3	0.5	0.06
Mouth pipe	2.21^{b}	2.11^{b}	6.2^{a}	2.1	0.03
Root floor	3.2^{b}	3.5^{b}	9.3^{a}	1.6	0.03
Root pipe	0.5^{b}	0.6^{b}	2.5^{a}	4.4	0.02
Paw	2.2^{b}	2.3^{b}	6.1^{a}	2.7	0.03

[ab]Means within rows showing different superscripts are significantly different (P<0.05)

Table 4 Effects of group size on performance in growing and finishing phases

Item	Group size, pigs/pen 4	8	12	SEM	P-value
Growing Pigs, (18-22 wk)					
ADG (g/d)	780^{a}	778^{a}	772^{b}	0.15	0.04
ADFI (kg/d)	2.25	2.22	2.20	0.35	0.08
Efficiency (ADG/ADFI)	0.34	0.34	0.34	0.47	0.54
Finishing Pigs (23-26 wk)					
ADG (g/d)	850^{a}	849^{a}	825^{b}	0.11	0.03
ADFI (kg/d)	2.95	2.93	2.90	0.24	0.09
Efficiency (ADG/ADFI)	0.28	0.27	0.28	0.10	0.10

[ab]Means within rows showing different superscripts are significantly different (P<0.05)

Table 5 Effects of group size on carcass traits and meat qualities

Item	Group size, pigs/pen			SEM	P-value
	4	8	12		
Carcass length (cm)	106.31	106.25	105.93	0.49	0.11
Back fat thickness (cm)	3.54[a]	3.35[b]	3.31[b]	0.31	0.03
LSQ	0.36	0.34	0.35	0.34	0.10
Hot carcass (kg)	103.13	101.26	100.31	0.42	0.09
Lion eye area (cm^2)	53.50	53.40	53.67	0.15	0.12
Fat area (cm^2)	19.9	18.52	18.72	0.44	0.08
Lion eye area/Fat area	2.55	2.82	2.86	0.24	0.09
pH 45 min	6.64	6.68	6.70	0.15	0.08
Temperature 45 min (°C)	39.02	39.2	38.98	0.31	0.11
L* (lightness)	53.51	52.79	52.70	0.31	0.10
a* (redness)	5.04	5.64	5.70	0.32	0.12
b* (yellowness)	2.44	2.53	2.43	0.45	0.13
Cooking loss (%)	30.01	30.2	30.23	0.44	0.10
Drip loss (%)	2.18	1.19	1.86	0.67	0.11
Shear force (kg/cm^3)	3.62	3.36	4.15	0.15	0.08

[ab]Means within rows showing different superscripts are significantly different ($P<0.05$)

Conclusion

This study indicates that group size affects feeding behaviors and that these feeding behaviors do not affect the average daily feed intake (ADFI). However, the average daily gain (ADG) of the larger group size (12 pigs per pen) was lower than that of the smaller group size (4 and 8 pigs per pen). This result may have resulted from changed feeding behaviors and from heat stress during the experiment. Moreover, the high temperature decreased the back fat thickness, as the larger group size had a significantly lower back fat thickness than that of the smaller group ($P<0.05$). So the appropriate group sizes and floor allowance for feeding growing and finishing pig were 8 pigs per pen or 0.75 m^2 due to the high rate of ADG and the thinner back fat thickness ($P < 0.05$). In short, the opportunity to perform natural behavior may be an effective way improves farm animal welfare in practice.

Acknowledgments

This work received financial support from The National Research Council of Thailand and Nakhon Sawan Rajabhat University.

References

AOAC. (1990). *Association of official Analytical Chemists (AOAC) Official Methods of Analysis* (15th ed.). Earlington, Virginia: AOAC Inc.

Armstrong, D. V. (1994). Heat stress interaction with shade and cooling. *Journal of Dairy Science*, 77, 2044-2050.

Bellego, L. E., Van, I., Milgen, J., & Noblet, J. (2002). Effect of high temperature and low-protein diets on the performance of growing-finishing pigs. *Journal of Animal Science*, *80*(3), 691-701.

Boggs, D. L., & Merkel, A. R. (1993). *Live animal carcass evaluation and selection manual* (4th ed.). Kendal/Hunt Pub. Co: Dubuque.

Bull, R. P., Harrison, P. C., Skowski, G. L. R., & Gonyou, H. W. (1997). Preferenceamong cooling systems by Gilts under heat stress. *Journal of Animal Science*, *75*, 2078-2083.

Caldara, F. R., Moi, M., Santo, L. S. A., meida, I. C. L., Paz, R. G., Garcianääs, I. A., & Ernandes, A. R. M. (2013). Carcass Characteristics and Qualitative Attributes of Pork from Imunocastrated. *Journal of Animal Science*, *26*, 1630-1636.

Froning, G. W., Bagabji, A. S., & Mater, F. B. (1978). The effect of preslaughter temperature, stress, stuggle and anesthetization on color and textural characteristics of turkey muscle. *Journal of Poultry Science*, *57*, 630-633.

Gonyou, H. W., & Strickl, W. R. (1998). Effects of floor area allowance and group size on the productivity of growing/finishing pigs. *Journal of Animal Science, 76*, 1326-1330.

Harapin, I. L., Bedrica, V., Hahn, B. S., & Gracner, D. (2003). Hematological and biochemical values in blood of wild boar (susserofaferus). *Journal of VeterinarskiArhiv*, *73*(6), 333-343.

Hyun, Y., & Ellis, M. (2002). Effect of group size and feeder type on growth performance and feeding patterns in finishing pigs. *Journal of Animal Science*, *80*, 568-574.

Harold, W. G., & Stricklin, W. R. (1998). Effects of floor area allowance and group size on the productivity of growing /Finishing pigs. *Journal of Animal Science*, *76*, 1326-1330.

Kiefer, C., Meignen, B. C. G., Sanches, J. F., & Carrijo, A. S. (2009). Resposta de suínos em crescimento man tidos em diferentes temperaturas. *Archivos de Zootecnia*, *58*(221), 1-11.

National Research Council. (1994) *Nutrient requirements of swine* (9th ed.). Washiugton, D.C.: National Research Press.

Pfeiffer, H., & Falkenberg, H. (1972). *MasseamLendenlspiegelzurobjektivenErmittlungderSchlachtlkorperzusam mensetzungbeiSchwein*. *Journal of Tierzucht*, *26*, 466-467.

Quiniou, N., & Noblet, J. (1999). Influence of Highambient temperatures on performance of multiparous lactating sows. *Journal of Animal Science*, *77*, 2124-2134.

Reodecha, C., Ingkaninun, P., & Kunavongkrit, A. (2000). *Swine Research Status in Thailand* (1958-2000). Faculty of Veterinary Science, Chulalongkorn University, Bangkok.

SAS Institute. (1999). *SAS/STAT@ uger's Guide v"9*. Cary, North Carolina: SaSInstituleInc.

Schmolke, S. A., Li, Y. Z., & Gonyou, H. W. (2003). Effect of group size on performance of growing-finishing pigs. *Journal of Animal Science*, *81*, 874-878.

Sripromma, J. (1984). *EinflussderFütterungsintensitätundderKörpermasseaufdieSchlachtkörperQualitätbeim Schwein*. Dissertation, Hohemheim University, Stuttgard, Germany.

Sawangtub, J. R. (1996). *Principle of livestock*. Buriram: Animal science program, Faculty of Agricultural Technology Buriram Rajabhat University.

Steel, R. G. D., & Torrie, J. H. (1980). *Principle and procedure of statistics*. New York: McGraw-Hill Book company.

Somparn, P. P. (2016). Natural Behaviour : Pig and Chicken Welfare. *Journal of Science and Technology*, *24*, 87-101.

Tantasuparuk, W., Lundeheim, N. D., Kunavongkrit, A. M., & Einarsson, A. S. (2000). Reproductive performance of purebred Landrace and Yorkshire sows in Thailand with special reference to seasonal influence and parity number. *Journal of Theriogenology*, *54*, 481-496.

Trezona, M. B. P., Mullan, M. D., Antuono, R. H., & Williamsi, I. (2004). The causes of seasonal variation in back fat thickness of pigs in Western Australia. *Australia Journal of Agricultural Research*, *55*, 273-277.

Wolter, B. F., Ellis, M., Curtis, S. E., Augspurger, N. R., Hamilton. D. N., Parr, E. N., & Webel, D. M. (2001). Effect of group size on pig performance in a wean-to-finish production system. *Journal of Animal Science*, *79*, 1067-1073.