EFFECTS OF POST-WEANING NUTRITIONAL CONDITIONS ON ISOWEAN PIGS

H. Xin, J. D. Harmon, H. Dong, D. L. Harris, H. J. Chepete, R. C. Ewan, M. L. Gramer

ABSTRACT. *This study quantifies the responses of isowean pigs to post-weaning nutritional conditions as may be encountered during extended shipment. PIC breeding stock pigs at 8 to 12 days of age (3.5 to 4.0 kg body weight) were subjected to four nutritional regimens for 72 h. The pigs were then raised with ad libitum feeding for 14 days. Thermoneutral environments were used throughout the experiment. Pigs deprived of feed and water (i.e., Fast) had higher body weight loss (of 0.61 kg/pig or 17% of their initial body weight) as compared with pigs provided with feed and water supplement (0.39 kg/pig or 11% of their initial body weight) or water supplement only (0.43 kg/pig or 11.5% IBW) ($P < 0.05$). All the treatments led to significant rise in blood urea nitrogen but fall in blood glucose ($P < 0.05$). However, the glucose levels were much higher than the generally considered hypoglycemic level (75 mg/dL). All pigs showed a similar degree of dehydration, as evidenced by elevated hematocrit and blood electrolyte concentrations ($P < 0.05$). The physiological responses returned to normal during the 14-day growth period and were similar for all the pigs. The results suggest that isowean pigs (PIC genetic line) responded well to post-weaning nutritional conditions typically encountered during extended shipments. Supply of bacteria-resistant water supplement such as Aqua-Jel seemed beneficial in reducing stress and may be considered for extended commercial shipment. However, in-transit supply of feed added little benefit to the pigs and thus may be omitted. This omission has special implications for international shipments because certain countries prohibit inclusion of feed in shipment. The energetics data of this study may be used to design and operate ventilation systems in transportation and production facilities for the isowean pigs.*
Keywords. *Pigs, Transportation, Isowean, Energetics, Physiology, Indirect calorimeter, Well-being.*

The increasing need to export breeder pigs worldwide calls for exploration of shipping protocol that provides a more effective delivery of quality breeder stock. Such protocol is of particular importance for air shipments to Asia, where journey duration generally ranges from 36 to 72 h, as encountered by shipment of breeder poultry (Xin and Rieger, 1995; Xin and Lee, 1996). One potentially effective export protocol is to ship isowean pigs. However, information in the literature is meager concerning the effects of extended in-transit nutritional conditions on isowean pigs during both treatment/shipment and subsequent growth periods. A classic study by Swiatek et al. (1968) examined the effect of fasting on physiological responses of newborn pigs with emphasis on starvation hypoglycemia. The authors concluded that 4-day, 1-, 2-, and 3-week-old pigs maintained normal blood glucose levels (> 75 mg/dL) after 72 h fasting. Gentz et al. (1970) studied the metabolic and physiological effects of starvation for four to five days on neonatal pigs at birth to 16 days of age. In that study, blood glucose levels of newborn, 24-h, 3-day, and 9-day-old pigs all fell below 60 mg/dL after 72 h fasting. In comparison, the 16-day-old pigs were able to maintain a glucose level greater than 80 mg/dL. These studies were conducted as alternatives to human experiments. Neither study reported pig performance following fasting as would be important for breeder pig production/shipment. Several other studies have been reported concerning the effects of short-distance (< 24 h) transportation of feeder pigs (Jesse et al., 1990), short-term (24 h) fasting of newborn pigs (Dividich et al., 1994), or prolonged fasting of growing pigs (Klain et al., 1977).

The goal of this project was to investigate the feasibility of shipping 10- to 12-day-old pigs overseas. The specific objective of the study was to quantify the energetic, physiological, and performance responses of the isowean pigs to selected post-weaning nutritional regimens that could be encountered during extended international shipments.

MATERIALS AND METHODS

EXPERIMENTAL ANIMALS AND NUTRITIONAL REGIMENS

For each of the three trials conducted in the present study, 60 PIC isowean pigs were transported by truck from

Article was submitted for publication in January 1999; reviewed and approved for publication by the Structures & Environment Division of ASAE in August 1999. Presented as ASAE Paper No. 99-4183.

This is Journal Paper No. J-18210 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Project No. 3355. Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or their affiliations nor exclusion of other suitable products.

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a neighboring state breeder farm to the Livestock Environment and Animal Physiology (LEAP) Research Lab of Iowa State University, Ames, Iowa. Upon arrival, the pigs were weighed and randomly assigned, in 15-pig groups, to four environmentally controlled calorimeter chambers (1.5W × 1.8L × 1.8H m each). Efforts were made to equalize the average initial body weight (IBW) across the chambers. Each chamber contained a specific nutritional regimen that lasted for 72 h, a duration that is often encountered during shipment of poultry breeding stock to Asia (Xin and Rieger, 1995). The four regimens were: (1) feed (0.45 kg/pig) and Aqua-Jel* water replacement (AJ) (0.9 kg/pig), denoted as FAJ; (2) AJ only (0.9 kg/pig), denoted as AJ; (3) AJ mixed with BlueLite® electrolytes supplement (0.125% by weight) (0.9 kg/pig), denoted as AJBL; and (4) no feed or AJ, denoted as Fast. The feed and AJ were initially provided with shallow pans, which proved to be ineffective because the pigs quickly scooped the materials out of the pan and mixed them with the bedding. Subsequently, the pans were replaced by wooden troughs (18W × 183L × 10H cm) with dividers that were built along the chamber walls.

During the treatment period, rigid insulation board (2.5 cm thick, $R = 0.88\ m^2 \cdot °C \cdot W^{-1}$) and woodshavings (5 cm deep) were used for the floor and bedding of the calorimeter chambers, as would be used in commercial shipments. Air temperature at the pig level was maintained at 26.7 ±0.5°C with a concomitant, low relative humidity (RH) of 28 to 33%. Air draft at the pig level was less than 0.15 m/s. Darkness was imposed during the treatment to simulate transportation situation, except that a red light was used to observe the pigs.

Following the 72 h treatment was a 14-day, *ad lib* feeding growth period during which the pigs were on plastic coated expanded metal (TenderNova®) floor. Thermal neutral temperature near the pig level, determined by observing the postural behavior of the pigs, was maintained at 28.9 ± 0.5°C during the first week and 27.8 ± 0.5°C during the second week. The concomitant RH during this period ranged from 35% to 50%. Lighting was continuous at 27 lux intensity for the first two days of growth period and 12L:12D (i.e., 12 h light and 12 h dark per day) thereafter. At the end of each week, the pull-plug manure pits were emptied, refilled with clean water, and the chambers cleaned to maintain a good air quality inside the calorimeters.

Upon switching the pigs from treatment to growth phase, they were allowed about one hour to access drinking water. Feed was then introduced. To prevent excessive eating, a limited amount of feed was initially provided, namely, 1.0 kg/pen to the FAJ, AJ, and AJBL pigs and 0.5 kg/pen to the Fast pigs. About 3 h later, another 0.5 kg feed was added to the Fast pigs. Thereafter, feed was added every 4 h during the first two days (except for nighttime), followed by less frequent but larger quantities of feed addition. Two types of commercial starter diets, Vigortone SEW 50® (0.64 kg/pig on average) and CIF 9/12® (remaining amount), from a local feed company† were used. Nutritional compositions of the diets are listed in table 1. The ME content was 14 143 kJ/kg for the Vigortone diet and 14 585 kJ/kg for the CIF9/12 diet.

* Aqua-Jel is a commercial water replacement that contains more than 93% water, hydrocolloid, phosphoric acid, and potassium sorbate with a pH of 3.2 (Transport Container Corporation, Columbus, Ohio). It had been proven to be an effective water supplement for breeder chicks exported overseas (Xin and Lee, 1996).

Measurement and Analysis of Response Variables

The following response variables of the pigs were monitored at the onset and end of the treatment and at the end of the growth period: body weight (BW), serum protein, hematocrit, blood urea nitrogen (BUN), blood glucose, and concentrations of blood electrolytes (Na^+, K^+, Cl^-, and HCO_2^-). Whole blood (2 mL/pig) and serum (3 mL/pig) samples were obtained by a skilled veterinarian from five randomly chosen pigs of each regimen during each trial. The blood samples were obtained using vacuum type needles, hubs, and tubes. The pigs were held by the forelegs with their heads down and their dorsum against the handler. With the neck extended by pressure on the lower jaw, the needle (22 gauge, 2.5 cm for pigs less than 7 kg or 20 gauge, 3.8 cm for larger pigs) was inserted slightly lateral and rostral to the manubrium sterni, in the hollow formed by the deepest portion of the right jugular fossa. The needle entered at approximately 90° angle to the skin and was directed slightly medially. Upon insertion, the tube was slipped onto the hub and the needle advanced slowly to its full depth, if necessary. Oftentimes, blood was obtained as the needle was slowly withdrawn, if not, then the angle or depth was adjusted. The left side of the neck could be used without serious side effects if necessary. Once collected, the samples were delivered to the ISU Animal Pathology Laboratory for analysis.

Total heat production rate (THP) and respiratory quotient (RQ) of the pigs were continuously measured at 30-min intervals by indirect calorimetry (THP measurement accuracy of ±0.3 W/chamber). Concurrent with the THP measurement were moisture production (MP) and sensible heat production (SHP) by the pigs and their environment. The average specific THP, MP, and SHP were obtained by dividing the magnitude of each respective

Table 1. Nutritional compositions of the commercial starter diets used in the experiment

Composition	Diet: Vigortone	Diet: CIF 9/12
Active drug ingredient		
Carbadox [%]	0.0055	0.0055
Guaranteed analysis		
Crude protein, min [%]	24.00	21.00
Lysine, min [%]	1.90	1.80
Methionine, min [%]	0.50	
Crude fat, min [%]	9.50	8.00
Crude fiber, max [%]	2.00	3.00
Calcium (Ca), min [%]	0.90	1.00
Calcium (Ca), max [%]	1.40	1.50
Phosphorus (P), min [%]	0.90	0.90
Salt (NaCl), min [%]	0.90	0.25
Salt (NaCl), max [%]	1.40	0.75
Selenium (Se), min [ppm]	0.3	0.3
Zinc (Zn), min [ppm]	250	175
Vitamin A, min (IU/kg)	17,600	13,200
Vitamin D_3,min (IU/kg)	3,080	2,640
Vitamin E, min (IU/kg)	220	125

† Central Iowa Feed, State Center, Iowa.

variable for the entire calorimeter by the total BW of pigs in the calorimeter at the given time. A detailed description of the calorimeter system, i.e., structure, performance, and operational procedure, was reviewed by Xin and Harmon (1996). Weekly feed intake and feed conversion (FC) during the growth period, mortality, morbidity, and behavior of the pigs were also measured or recorded.

The response variables were subjected to analysis of variance and multiple means comparison with a complete randomized block design.

Results and Discussion

Effects of the Nutritional Regimens on BW and FC

Average pig BW for the regimens during the course of the experiment is summarized in table 2. The Fast pigs had greater BW loss (BWL), averaging 0.61 kg/pig or 17% of the initial BW (IBW) than the other pigs (P < 0.05). This BWL coincided with the 18% BWL from a 72-h fasting as reported by Swiatek et al. (1968) for 9-day-old pigs with an IBW of 2.37 kg. The extra BWL of the Fast pigs was not totally compensated for during the two-week growth period. The FAJ pigs, compared with the AJ or AJBL pigs, did not show additional benefit from the feed supplied during the treatment period. However, the FAJ pigs did show a somewhat (6 to 7%) improved weight gain compared to the AJ or AJBL pigs during the two-week growth period. The overall FC during the two-week growth period for the FAJ, AJ, AJBL, and Fast regimens was 1.03, 1.05, 1.12, and 1.08, respectively, with no statistical significance among the regimens (P > 0.05). The two-week cumulative FC (1.07 on average) for these pigs weaned at 8 to 12 days of age was better than that for pigs weaned at 13 to 16 days of age (1.21 on average) as reported by Harmon et al. (1997), although re-hydration of the pigs following the treatment could have contributed to the weight gain in the present study that would normally be achieved by ingestion of feed rather than water.

Pigs in all regimens, following the 72 h treatment, were actively involved in drinking water once it became accessible. To alleviate the aggressive behavior in competing for the nipple drinkers, a shallow pan of water was placed on the floor to provide an additional water source.

Effects of the Nutritional Regimens on Physiological Responses

The results of blood analysis at the three points in the trial are summarized in table 3. During the 72 h treatment period the concentrations of serum protein, hematocrit, BUN, sodium, potassium, chloride, and bicarbonate all increased, but the concentration of glucose decreased. With the exception of BUN and glucose, the increase during the treatment was probably an effect of dehydration. The marked increase in BUN concentration is an indication that the pigs were degrading protein to supply energy to meet the daily energy needs and offset the decline in glucose concentration. The trend of declined blood glucose levels paralleled that of the study by Gentz et al. (1970) for newborn to 16-day-old pigs. At the same time, results of the current study differed from those of Gentz et al. in that the glucose content was much higher than the generally recognized hypoglycemic level of 75 mg/dL (Swiatek et al., 1968); whereas, glucose contents of pigs less than nine days of age used by Gentz et al. were all below 60 mg/dL after 72 h fasting. By comparison, glucose levels of the current study coincided more with those reported by Swiatek et al. (1968) for 1-week-old pigs fasted for 72 h. The blood concentrations generally returned to normal during the subsequent growth period. For most measures, the nutritional supplements imposed during the 72-h treatment period reduced the magnitude of the change during this period but there was no clear effect that would suggest one regimen was better than another. These

Table 2. Body weight (BW, kg/pig) and its changes of isowean pigs as affected by 72 h post-weaning nutritional regimens (presented as mean [μ] and standard error [SE] of three replicates)

Regimen*		IBW† (kg/pig)	72 h-BW (kg/pig)	BWL† (kg/pig)	% IBW 72 h	1wk-BW (kg/pig)	% IBW 1 wk	2wk-BW (kg/pig)	% IBW 2 wk
FAJ	μ	3.69	3.30^{a}	0.39^{a}	89^{a}	5.33	145^{a}	8.08	220^{a}
	SE	0.10	0.02	0.09	2	0.14	2	0.23	4
AJ	μ	3.76	3.32^{a}	0.44^{a}	88^{a}	5.21	140^{a}	8.00	214^{ab}
	SE	0.12	0.07	0.07	2	0.22	1	0.34	5
AJBL	μ	3.77	3.36^{a}	0.42^{a}	89^{a}	5.16	141^{a}	8.03	213^{ab}
	SE	0.11	0.05	0.08	2	0.35	3	0.36	7
Fast	μ	3.70	3.09^{b}	0.61^{b}	83^{b}	4.91	133^{b}	7.60	207^{b}
	SE	0.11	0.09	0.02	0	0.17	1	0.24	2

Column means with different superscripts were significantly different (P < 0.05).

* FAJ = feed & Aqua-Jel; AJ = Aqua-Jel only; AJBL = AJ mixed with BlueLite; Fast = no feed or AJ.

† IBW = initial body weight; BWL = body weight loss.

Table 3. Results of blood analysis of isowean pigs subjected to four post-weaning nutritional treatments for 72 h at three points in the trial period (mean and standard error *in italic*)

Trial Day	FAJ		AJ		AJBL		Fast		Avg.	
	Serum Protein (g/dL)									
0	6.07	*0.10*	6.24	*0.03*	6.24	*0.03*	6.15	*0.05*	6.18^{a}	*0.04*
3	7.10^{x}	*0.13*	7.05^{x}	*0.05*	7.10^{x}	*0.01*	7.49^{y}	*0.08*	7.18^{b}	*0.10*
17	5.13	*0.05*	4.96	*0.03*	5.15	*0.06*	5.00	*0.05*	5.06^{c}	*0.05*
	Hematocrit (%)									
0	35.8^{y}	*0.2*	35.5^{x,y}	*0.6*	34.9^{x,y}	*0.6*	33.5^{x}	*0.4*	34.9^{a}	*0.5*
3	41.0	*0.4*	41.4	*0.5*	41.3	*0.7*	40.1	*0.4*	40.9^{b}	*0.3*
17	34.0^{x,y}	*0.3*	34.5^{x,y}	*0.1*	35.7^{y}	*0.2*	32.9^{x}	*0.4*	34.3^{a}	*0.5*
	BUN (g/dL)									
0	8.3	*0.6*	10.2	*0.4*	8.9	*0.2*	10.2	*0.6*	9.4^{a}	*0.4*
3	31.6^{y}	*0.9*	35.1^{x}	*0.4*	33.9^{x,y}	*0.7*	38.7^{z}	*0.9*	34.8^{b}	*1.4*
17	7.0	*0.3*	6.9	*0.4*	6.1	*0.3*	6.6	*0.4*	6.6^{c}	*0.3*
	Glucose (mg/dL)									
0	125.6^{x,y}	*1.0*	120.7^{x}	*1.4*	130.7^{y}	*1.2*	122.4^{x}	*1.6*	124.8^{a}	2.2
3	106.3^{x,y}	*1.6*	100.9^{x}	*2.1*	110.2^{y}	*1.2*	106.5^{x,y}	*1.9*	106.0^{b}	*1.9*
17	122.5^{x}	*1.5*	122.2^{x}	*1.8*	132.4^{y}	*1.5*	123.6^{x}	*1.1*	125.2^{a}	*1.9*
	Sodium (meq/L)									
0	140.9	*0.3*	141.3	*0.1*	140.2	*0.2*	140.9	*0.2*	140.8^{a}	*0.2*
3	148.4^{y}	*0.5*	146.2^{x}	*0.5*	147.1^{x,y}	*0.5*	156.5^{z}	*0.4*	149.5^{b}	*2.4*
17	138.1	*0.4*	138.5	*0.2*	138.2	*0.1*	138.6	*0.3*	138.4^{c}	*0.2*
	Potassium (meq/L)									
0	4.83	*0.08*	4.57	*0.04*	4.73	*0.04*	4.62	*0.16*	4.69^{a}	*0.06*
3	5.17^{z}	*0.10*	4.62^{x}	*0.02*	4.74^{x,y}	*0.09*	5.15^{y,z}	*0.13*	4.92^{b}	*0.15*
17	5.40^{y}	*0.15*	5.04^{x}	*0.07*	5.23^{x}	*0.08*	4.87^{x}	*0.11*	5.14^{c}	*0.12*
	Chloride (meq/L)									
0	107.5^{x,y}	*0.3*	106.1^{x}	*0.3*	107.2^{x,y}	*0.1*	107.8^{y}	*0.1*	107.2^{a}	*0.4*
3	115.9^{y}	*0.3*	111.6^{w}	*0.7*	114.3^{x}	*0.4*	124.0^{z}	*0.3*	116.5^{b}	*2.7*
17	103.6	*0.3*	103.4	*0.2*	103.0	*0.2*	103.9	*0.3*	103.4^{c}	*0.3*
	Bicarbonate (meq/L)									
0	23.6^{x,y}	*0.4*	24.4^{x}	*0.3*	22.2^{y}	*0.2*	23.3^{x,y}	*0.2*	23.4^{a}	*0.5*
3	25.4^{y}	*0.3*	27.3^{x}	*0.5*	24.2^{y}	*0.6*	24.7^{y}	*0.4*	25.4^{b}	*0.7*
17	25.2	*0.3*	26.0	*0.4*	24.6	*0.4*	26.3	*0.4*	25.5^{b}	*0.3*

a,b,c Means for days with different superscripts within a measure were significantly different (P < 0.05).

w,x,y,z Within day and measure, treatment means with different superscripts were significantly different (P < 0.05).

* FAJ = feed and Aqua-Jel; AJ = Aqua-Jel only; AJBL = AJ mixed with BlueLite; Fast = no feed or AJ.

physiological results coincide with those of the growth performance as discussed above.

Effects of the Nutritional Regimens on Energetic Responses

Daily average THP (W/kg), MP (g/kg-h), SHP, (W/kg), and RQ of the pigs during the treatment and growth periods along with the interpolated daily BW (from measured weekly BW) are shown in figures 1 through 4. In addition, pooled averages of THP, MP, SHP, and RQ during the treatment and growth periods (week 1 and week 2) are summarized in table 4. During the treatment, pigs subjected to FAJ, AJ, and AJBL regimens had somewhat higher THP than the Fast pigs. This outcome agreed with the higher BUN level of the Fast pigs for the same period. THP of the group-housed Fast pigs in the current study, an equivalent O_2 consumption of 9.8 mL/[kg-min], was considerably lower than that of individually caged, 9-day-old pigs, 13.1 mL/[kg-min] O_2 consumption, as found by Gentz et al. (1970). In particular, THP on the third day for the Fast pigs, 3.27 W/kg or 89 kcal/[kg$^{0.75}$-d], was similar to the fasting THP of 91 kcal/[kg$^{0.75}$-d] reported by Close and Mount (1975) for fasting growing pigs at 30°C. The fasting THP values of the current study and the study by Close and Mount (1975) were both higher than the basal metabolic rate of 70 kcal/[kg$^{0.75}$-d] predicted by Kleiber's equation (1961). This difference could be attributed to the inter-

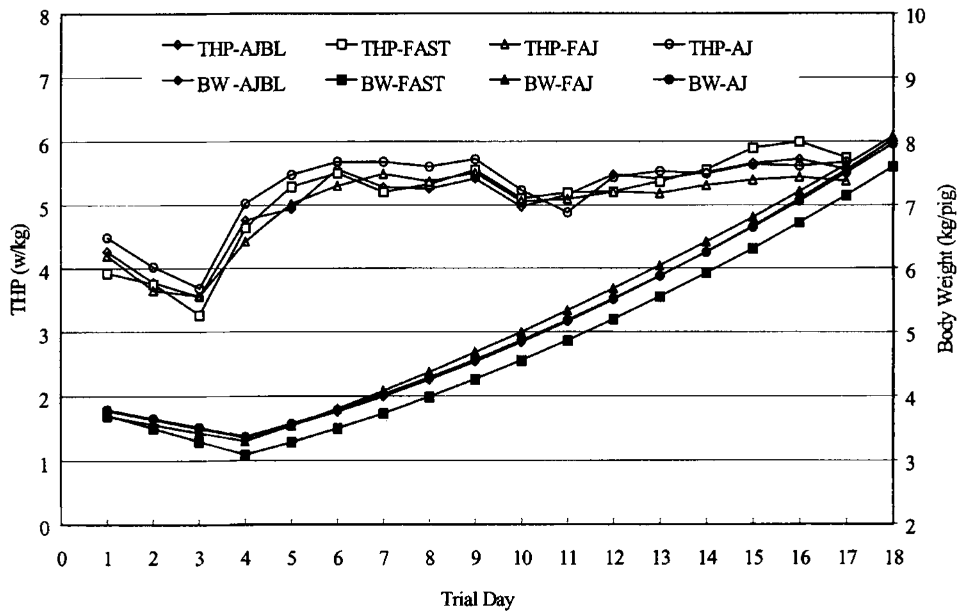

Figure 1–Daily average total heat production rate of the pigs during 3-d treatment and 14-d growth.

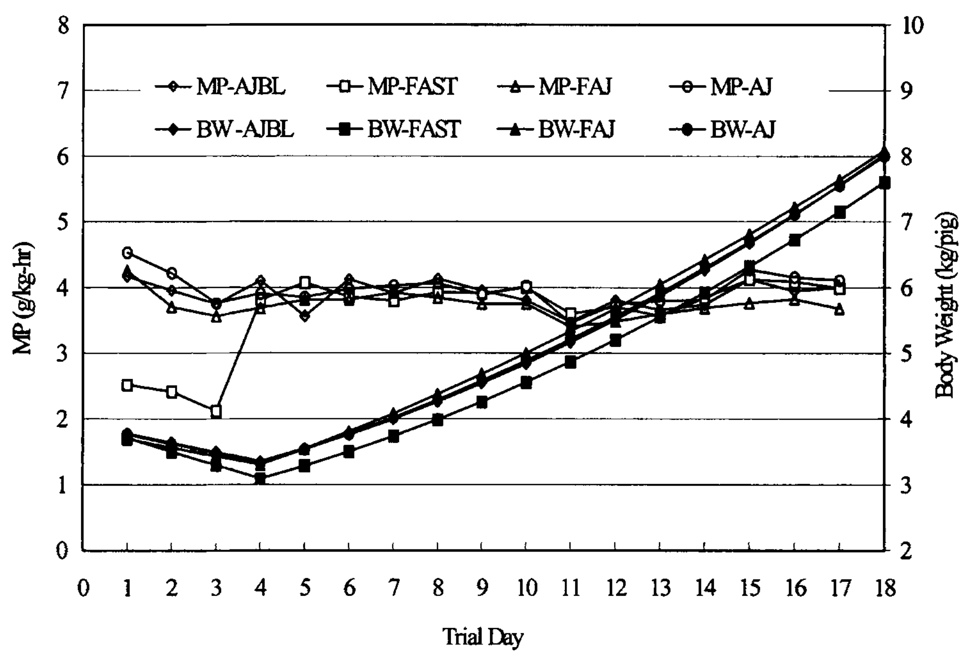

Figure 2–Daily average moisture production rate of the pigs during 3-d treatment and 14-d growth.

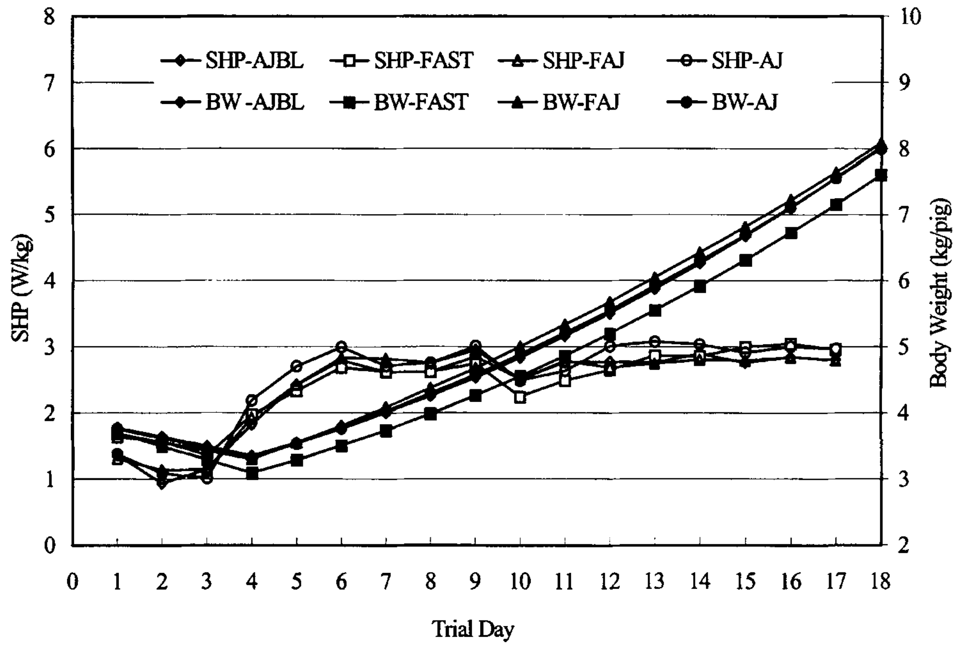

Figure 3–Daily average sensible heat production rate of the pigs during 3-d treatment and 14-d growth.

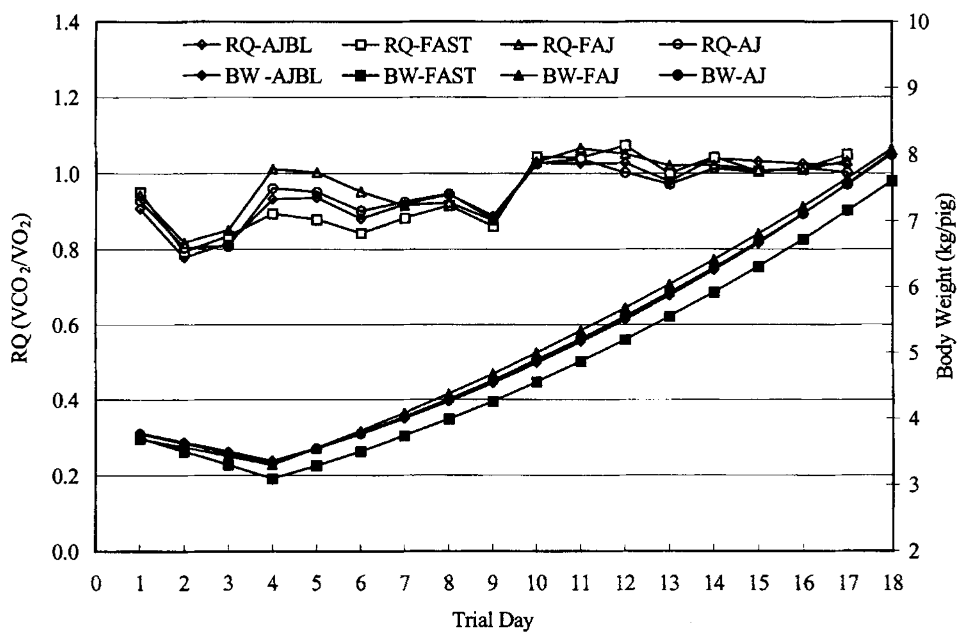

Figure 4–Daily average respiration rate of the pigs during 3-d treatment and 14-d growth.

species differences in fasting metabolism that are not reflected by the mean coefficient of Kleiber's equation.

The most drastic difference between the Fast regimen and the other three was the lower MP for the Fast regimen ($P < 0.05$). This result was expected since evaporation of the AJ in the FAJ, AJ, and AJBL regimens would add to the MP of the environment. Evaporation of AJ converted part of the SHP to MP, which explains the somewhat lower SHP for the FAJ, AJ, and AJBL regimens. The RQ values (0.83 ~ 0.87) indicate that the pigs were primarily metabolizing protein (RQ = 0.81) and glucose (RQ = 1.0). This is consistent with the results of elevated BUN and reduced glucose levels in the blood.

During the growth period, all the pigs shared similar energetic characteristics, and hence averages of the regimens were computed (table 4). The average THP, MP, SHP, and RQ for the current study compared well with those measured in a previous study on the energetics of isowean or segregated early weaned pigs at different constant temperatures from our laboratory (Harmon et al., 1997). Specifically, THP, MP, SHP, and RQ of pigs weighing 5.3 kg (five-day average) at an air temperature of 29°C were 5.3, 3.7, 2.8, and 1.00, respectively, in the current study, as compared to 5.2, 4.6, 2.1, and 0.94, respectively, for pigs of same BW at air temperature of 30°C in the previous study. Similarly, THP, MP, SHP, and RQ of pigs weighing 7.5 kg at air temperature of 28°C

Table 4. Energetic responses of isowean pigs during the 72 h treatment and growth periods*

72 h Treatment†		BW (kg/pig)	THP (W/kg)	MP [g/(kg-h)]	SHP (W/kg)	RQ (VCO_2/VO_2)
3-day Treatment Period (T_a = 26.7°C, woodshavings bedding)						
FAJ	μ	3.5	3.8	3.8[a]	1.2	0.87
	SE	0.1	0.1	0.2	0.1	0.03
AJ	μ	3.5	4.1	4.2[a]	1.2	0.85
	SE	0.1	0.2	0.4	0.2	0.01
AJBL	μ	3.6	3.9	4.0[a]	1.1	0.83
	SE	0.1	0.1	0.3	0.1	0.03
FAST	μ	3.4	3.6	2.4[b]	1.5	0.86
	SE	0.1	0.3	0.2	0.3	0.02
First-week Growth (T_a = 29.0°C, plastic coated expanded metal floor)						
FAJ	μ	4.3	5.1	3.8	2.6	0.96[a]
	SE	0.1	0.2	0.1	0.1	0.03
AJ	μ	4.3	5.2	4.0	2.7	0.94[ab]
	SE	0.1	0.3	0.2	0.1	0.01
AJBL	μ	4.3	5.2	3.9	2.5	0.93[ab]
	SE	0.2	0.2	0.1	0.2	0.03
FAST	μ	4.0	5.3	3.9	2.5	0.90[b]
	SE	0.1	0.4	0.4	0.1	0.02
Avg.	μ	4.2	5.2	3.9	2.6	0.94
	SE	0.1	0.3	0.2	0.1	0.02
Second-week Growth (T_a = 27.8°C, plastic coated expanded metal floor)						
FAJ	μ	6.7	5.3	3.6	2.8	1.03
	SE	0.2	0.3	0.2	0.1	0.04
AJ	μ	6.6	5.5	3.9	2.9	1.01
	SE	0.3	0.1	0.2	0.2	0.01
AJBL	μ	6.6	5.5	3.8	2.8	1.02
	SE	0.4	0.2	0.1	0.1	0.01
FAST	μ	6.3	5.6	3.8	2.8	1.03
	SE	0.2	0.4	0.2	0.3	0.02
Avg.	μ	6.5	5.5	3.8	2.8	1.02
	SE	0.3	0.3	0.2	0.2	0.02

* MP data include moisture from both pigs and their surroundings [mean (μ) and standard error (SE)]. Column means with different superscripts are significantly different ($P < 0.05$).

† FAJ = feed and Aqua-Jel; AJ = Aqua-Jel only; AJBL = AJ mixed with BlueLite; Fast = no feed or AJ.

averaged 5.6, 3.9, 2.9, and 1.02, respectively, in the current study, as compared to 5.7, 4.3, 2.6, and 0.97, respectively, for pigs weighing 7.6 kg at the same air temperature in the previous study. The heat and moisture production data obtained in the current study further confirmed the higher THP and MP by modern young pigs and their housing system as compared to those used in the literature (*ASAE Standards*, 1998) for design and operation of building ventilation systems.

Belly Nosing (BN) Behavior, Mortality, and Morbidity

Some pigs, especially the smaller-size pigs, in all treatment groups were noticed to initiate and engage in various degrees of BN during the growth period. This behavior generally started within the first two days of the growth period. The intensity of BN tended to increase with time initially and then gradually decreased. There were a few cases of an enlarged navel as a result of this behavior. There was no indication that the BN behavior was related to certain post-weaning nutritional treatment. Borgman et al. (1998) stated that BN was aesthetically annoying but did not seem to be detrimental to the performance of the pigs. They further reported that the most rapidly growing pigs were the most attacked targets.

No mortality occurred in any trial. Two morbid pigs in AJBL regimen and one in AJ regimen were culled during the first-week growth in Trial 1. Diagnostic examination revealed starvation. For Trials 2 and 3, one morbid pig in the Fast group was culled for each trial. These morbid pigs, though still fairly lively, were loosing or barely maintaining their BW during the first week of growth.

Conclusions

The following conclusions were drawn from this study:

- Isowean pigs of PIC breeding stock at 8 to 12 days of age responded well to supply of feed and water, water only, or deprivation of feed and water imposed on them during a 72-h post-weaning period, although pigs deprived of feed and water had the highest body weight loss (17% IBW vs 11-12% IBW for other pigs) ($P < 0.05$).
- Supplying feed during the 72-h post-weaning period showed no additional benefits to the pigs when compared with supplying water only. Hence, omission of feed from shipments, especially for international shipments of isowean pigs, seems justifiable. Supplying a bacteria-resistant water replacement such as the commercial Aqua-Jel seemed beneficial in reducing post-weaning holding stress and thus may be considered in long-journey transportation.
- Heat and moisture production rates of modern isowean pigs under certain, unique post-weaning conditions and subsequent growth have been quantified. The data provide a fundamental basis for design and operation of environmental control systems for both transportation and production of isowean pigs.

Acknowledgments. We wish to express our gratitude to Pig Improvement Company (PIC)–USA for its financial support to the project; to Dr. Tami Boettcher for her generous assistance in collecting the blood samples; and to Bin Shao and Wendy Ye, graduate assistants of ABE, for their valuable assistance during the course of the experiment.

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