
**NONRUMINANT NUTRITION:
NUTRIENT DIGESTIBILITY OF
INGREDIENTS FOR
MONOGASTRIC DIETS**

0447 Digestible, metabolizable, and net energy in diets containing 0, 15, or 30% wheat bran fed to growing pigs. N. W. Jaworski^{*1}, D. Liu², D. Li³, and H. H. Stein¹, ¹University of Illinois at Urbana-Champaign, Urbana, ²State Key Lab of Animal Nutrition, China Agricultural University, Beijing, ³Ministry of Agriculture Feed Industry Centre, Beijing, China.

An experiment was conducted to determine the effects of including 0, 15, or 30% wheat bran in a corn-soybean meal based diet fed to growing pigs. Eighteen barrows (initial BW: 54.4 ± 4.3 kg) were individually housed in metabolism cages and randomly allotted to 1 of 3 dietary treatments in a completely randomized design. The experiment had 3 periods and 6 replicate pigs per diet. The control diet contained corn, soybean meal, and no wheat bran, and 2 additional diets were formulated by mixing 15 or 30% wheat bran with 85 or 70% of the control diet, respectively. Each period lasted 15 d. During the initial 7 d, pigs were adapted to their experimental diets and housed in metabolism crates in an environmentally controlled room and fed 573 kcal/kg BW^{0.6} per d. On d 8, metabolism crates with the pigs were moved into open-circuit respiration chambers for measurement of O₂ consumption and CO₂ and CH₄ production. The feeding level was the same as in the adaptation period and feces and urine were also collected during this period. On d 13 and 14, pigs were fed 225 kcal/kg BW^{0.6} per day, and pigs were then fasted for 24 h to obtain fasting heat production. The apparent total tract digestibility of DM, GE, crude fiber, ADF, and NDF linearly decreased ($P < 0.01$) as wheat bran inclusion increased in the diets. The DE (3454, 3257, and 3161 kcal/kg), ME (3400, 3209, and 3091 kcal/kg), and NE (1808, 1575, and 1458 kcal/kg) of diets linearly decreased ($P < 0.01$) as wheat bran inclusion increased. The daily O₂ consumption and CO₂ and CH₄ production by pigs fed increasing concentrations of wheat bran linearly decreased ($P < 0.01$). However, there was no effect of wheat bran on daily heat production per kg BW^{0.6}. In conclusion, increasing inclusion of wheat bran decreased DE, ME, and NE in diets, but did not change daily heat production if expressed as kg BW^{0.6}.

Key Words: dietary fiber, energy concentration, heat production

0448 Effects of feeding barley on growth performance and diet nutrient digestibility of weaned pigs.

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Cereal grains vary considerably in price and quality. Barley is usually priced 10 to 20% lower than wheat in Western Canada. Wheat contains more NE than barley and is preferred during the energy-dependent phase of growth. We investigated if feeding of low quality barley (LB) will reduce growth performance and diet apparent total tract digestibility (ATTD) in weaned pigs compared with high quality barley (HB) or hard red spring wheat. Diets contained 20% soybean meal and 62% cereal grain varying in NE (Mcal/kg) content (2.33, 2.23, and 2.44 for HB, LB, and wheat, respectively). Grain constituents used to predict the NE value were predicted by near-infrared reflectance spectroscopy. Starting 1 wk after weaning at 28 d of age, 280 weaned pigs (initial BW 8.7 ± 0.9 kg) were fed diets for 3 wk (d 1 to 21). Five pelleted diets were formulated as (Mcal NE/kg using canola oil; g standardized ileal digestible (SID) Lys/Mcal NE using synthetic AA): (A) wheat (2.39, 4.47); (B) HB (2.39, 4.46); (C) LB (2.33, 4.57); (D) LB, corrected for NE (2.39, 4.45); and (E) LB, low NE (2.25, 4.68). Feed intake and BW were measured weekly to calculate pen ADFI, ADG, and G:F. Feces were collected to calculate diet ATTD of DM, GE, and CP and diet DE and NE value. Compared with Diet A and B, pigs fed Diet D had greater ($P < 0.05$) ADFI (542, 596 vs. 652 g/d), ADG (365, 403 vs. 443 g/d), and G:F (0.646, 0.662 vs. 0.681); while differences were not observed among diets C, D, and E. Pigs fed Diet A had ADFI and ADG lower ($P < 0.05$) than pigs fed the other 4 diets. The ATTD of CP, GE, and DM of Diet E (77.0, 77.3, 76.9%) was greater ($P < 0.05$) than of Diet B (72.4, 74.3, 74.0%) and C (74.9, 75.3, 74.7%), and similar to Diet D (75.9, 76.4, 75.8%), respectively. Pigs fed Diet A had ATTD of GE greater ($P < 0.05$) than pigs fed other 4 diets. The DE value (Mcal/kg) of diet D (3.62) and E (3.55) were greater ($P < 0.05$) than of diet B (3.46) and lower than of diet A (3.71). In conclusion, feeding LB instead of HB and wheat did not reduce growth performance. Feeding barley instead of wheat is economical and achieved greater growth performance even though diet energy digestibility was lower.

Key Words: barley, pig, digestibility

0449 Nutrient profile and in-vitro digestibility of tubers

in swine. U. P. Tiwari*, A. K. Singh, H. M. Zaleski, and R. Jha, *University of Hawaii at Manoa, Honolulu*.

To assure the sustainability of swine production in areas where traditional feed ingredients cannot be grown or fed to animals, it is important to study and develop alternative feeding systems. Tubers are grown widely in the tropics and are generally rich in starch, and thus have potential as an alternative energy source. Their use, however, is limited by limited information on nutritional value and digestibility. Five tuber samples grown in Hawaii [purple sweet potato (PSP), Okinawan sweet potato (OSP), *Dioscorea alata* yam (yam), taro, and cassava] were analyzed for their nutritional profile. In vitro digestibility of samples was determined using a 3-step enzymatic assay. On a DM basis, gross energy ranged from 3332 Kcal/kg (taro) to 4272 (yam), sweet potatoes and cassava were in between (PSP = 4137, OSP = 4157, and cassava = 4196 Kcal/kg). The CP content ranged from 3.4% (cassava) to 13.6 (taro), ether extract from 2.8% (PSP) to 14.5 (cassava), ADF from 5.7% (PSP) to 10.4 (taro), NDF from 8.0% (PSP) to 11.5 (taro), ash from 2.0% (PSP) to 3.8 (taro), and in vitro DM digestibility of PSP (87.4%), OSP (87.1%), and cassava (82.3%) was significantly higher ($P < 0.05$) than yam (30.0%), while taro was in between (66.0%). In conclusion, both sweet potato and cassava are rich in energy content with high in vitro DM digestibility and can be used as an alternative source of energy in swine diets, but protein needs to be supplemented as these tubers are low in protein.

Key Words: in vitro digestibility, tubers, swine

0450 Nutritional enhancement of dried distiller's grains with solubles via *Sporobolomyces roseus* fermentation.

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Whole stillage and thin stillage from the ethanol production process were evaluated as substrate sources for the production of β -carotenes by *Sporobolomyces Roseus* (ATCC28988). This product has the potential to be used as a novel feed ingredient for poultry, swine or cattle diets. β -carotenes have been supplemented in animal diets, typically from 150 to 300 mg/kg to improve animal health, enhance meat color and quality, and increase vitamin A levels in milk and meat. By supplementing a stillage fermentation with easily consumable carbon sources and protein sources the fermentation lag time will be reduced and the protein levels of the resultant product will be unaffected or increased. Microbial growth kinetics and stillage fermentations were performed in 500-mL baffled shake flasks and in a 5-L fermentation bioreactor. The HPLC method was used to analyze and quantify the β -carotenes. A 50-L bioreactor has been specifically designed to evaluate the scalability of the process and to perform subsequent feed production trails. Media optimization was conducted in shake flasks using supplemented glucose or glycerol and ammonium sulfate or urea.

By supplementing the fermentation with additional protein sources which are easily consumed by the microbes, such as urea, the protein level of the resultant feed ingredient would be unaffected. Final β -carotene concentration was found to be highest for the whole stillage, with 10 g/L added glucose and 10 g/L N added through ammonium sulfate, at $272.57 \pm 4.34 \mu\text{g } \beta\text{-carotene/g biomass}$. Glycerol addition yielded no significant increase ($P > 0.05$) in β -carotene yield, while urea addition significantly decreased ($P > 0.05$) the final β -carotene concentrations. The resulting fermented product can be effectively blended with regular feed to generate a premium nutritionally enhanced feed product using either whole stillage as a dry feed ingredient or thin stillage as a liquid feed additive.

Key Words: β carotene, DDGS, feed, fermentation

0451 Performance of pigs fed diets containing canola meal produced from high protein or conventional varieties of canola seeds.

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Two experiments were conducted to determine effects of including high protein canola meal (CM-HP) or conventional canola meal (CM-CV) in diets fed to weanling pigs or growing-finishing pigs. In Exp. 1, 405 weanling pigs (10.07 ± 1.41 kg) were randomly allotted to 9 dietary treatments, with 9 replicate pens per treatment and 4 to 6 pigs per pen. Nine diets were prepared with the control diet being based on corn and soybean meal (SBM) and 8 diets were formulated by adding 10, 20, 30, or 40% of either CM-HP or CM-CV to the control diet. The experiment lasted 21 d. Increased inclusion rate of CM-CV increased (quadratic, $P < 0.05$) ADG of weanling pigs. Increased inclusion rate of CM-HP or CM-CV decreased (linear, $P < 0.05$) ADFI, but increased (linear, $P < 0.05$) G:F of weanling pigs. Weanling pigs fed CM-CV had greater ($P < 0.05$) ADG and G:F than weanling pigs fed CM-HP. In Exp. 2, 280 pigs (27.4 ± 2.92 kg) were randomly allotted to 7 dietary treatments. A 3-phase feeding program was used with grower diets fed from 27 to 57 kg, finisher-1 diets from 57 to 85 kg, and finisher-2 diets from 85 to 112 kg. The 7 treatments consisted of a corn-SBM diet (control) and 6 diets containing a low, medium, or high level of either CM-HP or CM-CV. Low, medium, and high levels of canola meal were defined as the levels needed to replace 33, 66, or 100% of SBM in the diets. Increased inclusion rate of CM-HP decreased (linear, $P < 0.05$) pig BW at the end of phase 2 and at the end of the experiment, decreased (linear, $P < 0.05$) G:F in Phase 2 and the overall period, and decreased (quadratic, $P < 0.05$) ADG in Phase 3. Increased inclusion rate of CM-CV increased (linear, $P < 0.05$) ADFI, but reduced (linear, $P < 0.05$) G:F in Phases 2 and 3 and for the overall period. Growing-finishing pigs fed CM-CV had greater ($P < 0.05$) ADG and ADFI than pigs fed CM-HP. In conclusion, inclusion of 20 to 30% CM-HP or CM-CV have no negative effects on growth performance

of weanling pigs and CM-CV and CM-HP may replace up to 66% of the SBM in diets for growing-finishing pigs.

Key Words: canola meal, high protein canola meal, pigs

0452 Physiochemical and nutritional composition of sorghum as potential food and feed for humans and poultry.

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Sorghum is the fifth most important grain crop after wheat, rice, maize, and barley. Sorghum is cultivated for food and beverages for humans, and for feed and fodder for animals in America, Asia, Australia, and Africa. Physical characteristics, proximate composition, total phenols and antioxidant activity, mineral content, and AA profile of sorghum were studied. Forty-eight (± 2.5 kg) adult male broiler chickens were allocated to a complete randomized design with 4 sorghum diets to determine AA digestibility and metabolizable energy. Twelve birds per diet were starved for 24 h before receiving feed allowance of 50 g. Thousand-kernel weights ranged from 33 to 28 g, with brown visual colour and texture that is somewhat corneous to floury. The sorghum grains were higher ($P < 0.05$) in total phenolic and condensed tannins contents for NS5511 and PAN8625. The antioxidant activity of sorghum varieties PAN8816 and PAN8609 were higher ($P < 0.05$) than NS5511 and PAN8625. Crude protein content of PAN8609 (9.54%) and PAN8625 (9.53%) were higher ($P < 0.05$) than those of NS5511 (8.12%) and PAN8816 (8.45%). Starch (%) and GE (MJ/kg) contents differed among sorghum varieties. Mg (mg/kg) content was significantly higher ($P < 0.05$) for PAN8625 than that of NS5511. P and Zn (mg/kg) contents of PAN8609 were higher ($P < 0.05$) than those of PAN8625, NS5511, and PAN8816. Similarly, PAN8625 had higher ($P < 0.05$) P and Zn contents than those of NS5511 and PAN8816. Thr, Leu, Phe, Val, Pro, and Ala contents of varieties PAN8625 and PAN8609 were ($P < 0.05$) higher than those of NS5511 and PAN8816, which had similar ($P > 0.05$) contents. Sorghum NS5511 had low AA digestibility values for Arg, His, Phe, Thr, and Try. Apparent metabolizable energy corrected for nitrogen (AMEn) was the highest ($P < 0.05$) for PAN8816, followed by PAN8609 with lowest value for NS5511. True metabolizable energy corrected for nitrogen (TMEn) values were similar ($P > 0.05$) for PAN8816 and PAN8609, and low in NS5511.

Key Words: sorghum, total phenols, antioxidant activity, amino acid profile, minerals

0453 Comparative digestibility of energy and nutrients in feed ingredients fed to sows and growing pigs.

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The objective of this experiment was to determine if there is a difference between growing pigs and gestating sows in DE

and ME values and apparent total tract digestibility (ATTD) of energy and nutrients in diets and feed ingredients. Eleven feed ingredients were used. Three ingredients were cereal grains (corn, sorghum, and wheat), 4 were common protein sources (soybean meal, canola meal, distillers dried grains with solubles [DDGS], and low-fat DDGS), and 4 were high-fiber ingredients (corn germ meal, corn bran, wheat middlings, and soybean hulls). Eleven diets were formulated. Three diets were based on corn, wheat, or sorghum, and 8 diets were based on a combination of corn and each of the remaining 8 ingredients. A total of 88 gestating sows (parity 2 to 6) and 88 growing barrows (40.1 ± 4.69 kg BW) were randomly allotted to the 11 diets, with 8 replicate animals per diet. Fecal and urine samples were collected for 4 d following a 5-d adaptation period. The DE, ME, and ATTD of ADF, NDF, and CP in corn, wheat, and sorghum were calculated using the direct procedure, and the DE, ME, and ATTD of ADF, NDF, and CP in the other ingredients were calculated using the difference procedure. No differences were observed in DE and ME (as-fed and DM basis) or in the ATTD of GE, NDF, and CP between gestating sows and growing pigs for any of the ingredients. Gestating sows had less ($P < 0.05$) ATTD of ADF for soybean meal and greater ($P < 0.05$) ATTD of NDF for soybean hulls compared with growing pigs, but for the average of all ingredients, gestating sows had reduced ($P < 0.05$) ATTD of ADF compared with growing pigs. These results indicate that, under the conditions of this experiment, the ATTD of CP, NDF, and GE and values for DE and ME in growing pigs are not different from values obtained in gestating sows. However, the ATTD of ADF obtained in growing pigs is not always representative of the ATTD of ADF in gestating sows.

Key Words: digestibility, gestating sows, growing pigs

0454 Performance and nutrient digestibility of weaned rabbits fed cooked albizia seed meal (*Albizia* spp.) as replacement for full-fat soybean meal.

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Nine weaned rabbits, 6 wk of age, were housed singly and fed cooked albizia seed meal (CASM) in a completely randomized design (CRD) to evaluate the performance and digestibility. The rabbits were randomly allotted to 3 dietary treatment groups of 3 replicates each. The control diet, T₁ (maize, maize offal, groundnut cake full fat soybean, blood meal, palm kernel cake, wheat offal, bone meal, limestone, lysine, methionine, salt, and vitamin-mineral premix), had no CASM, while T₂ and T₃ contained 50% and 100% levels of CASM, respectively, as a replacement for full-fat soya meal (FFSM) on a crude protein (CP) basis. The proximate analysis, fiber fraction, and antinutrient content of cooked *Albizia* seeds were determined. Weekly body weight and feed intake were measured. At the end of wk 3, fecal samples were collected and analyzed to determine the level of digestibility. Data collected

were subjected to ANOVA, and significant means were separated using Duncan Multiple Range Test. Results showed that rabbits fed with the T₁ had the highest ($P < 0.05$) average weight gain of 81.11 g/rabbit, as against 63.90 and 51.11 g obtained for T₂ and T₃, respectively (Table 0454). The feed intake was best ($P < 0.05$) for rabbits on T₁, with value of 930 g/wk. Rabbits on T₂ had the best feed conversion efficiency (12.41). The high crude protein value 29.84 in CASM indicated that the seed could be used as a protein source in rabbit diet. However, the saponin content may serve as an antinutrient, inhibiting its digestibility and utilization. Feed intake, weight gain, as well as a digestibility coefficient were significantly affected above 50% inclusion of CASM in the diets. Cooked albizia seed could replace FFSM up to 50% on CP basis.

Key Words: performance characteristics, cooked albizia seed, digestibility, weaned rabbit

Table 0454. Weekly performance of weaned rabbits fed cooked albizia seed meal

Variable	T1	T2	T3
Feed intake, g	933 ^a	767 ^b	844 ^{ab}
Weight gain, g	81.11 ^a	63.9 ^{ab}	51.11 ^b
FCE ¹	13.14 ^{ab}	12.41 ^b	17.24 ^a
Digestibility values, % Dry matter	61.93 ^b	62.31 ^a	62.29 ^a
Ash content	86.91 ^b	88.47 ^{ab}	89.15 ^a
Crude protein	73.88 ^b	75.55 ^a	76.00 ^a
Crude lipid	87.35 ^a	87.14 ^a	84.02 ^b
Calcium	81.64 ^a	86.46 ^{ab}	86.09 ^b
Phosphorous	85.06 ^a	81.29 ^{ab}	76.48 ^b

¹FCE, feed conversion efficiency.

0455 Nutritional evaluation of raw *Anthonotha macrophylla* seed meal as a replacement for soybean meal in the diet of broiler chickens.

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The objective of this study was to develop a high quality animal protein at reduced cost through the use of alternative feedstuffs (e.g., *Anthonotha macrophylla*). One-hundred-and-twenty-day-old Marshal broiler chicks were used to assess the quantitative replacement of soybean meal with raw *A. macrophylla* seed meal. Ten birds per treatment were replicated thrice in a completely randomized design. Diet 1 was soybean-based (control), while the test feedstuff (*A. macrophylla*) quantitatively replaced 5, 10, and 15% soybean in Diets 2, 3, and 4, respectively. Feed and water were given ad libitum for 56 d. The crude protein (27.74%) and gross energy values (4.69 Kcal/g) makes it a potential feedstuff. It contains antinutritional factors, namely: phytate (0.43%), tannin (0.06%), hydrogen cyanide (13.71 mg/kg), and nitrate (0.14%). For growth performance, there were significant differences ($P < 0.05$) among the treatment means for all the parameters measured, except initial weight. The final weight, weight gain/bird, and weight

gain · bird⁻¹ · d⁻¹ supported Diet 2. The feed conversion ratio also favored Diet 2 (2.93) among others (Diet 1 = 2.96, Diet 3 = 3.07, and Diet 4 = 4.14). For cut-parts, there were significant differences ($P < 0.05$) for all parameters measured, with Diet 2 comparing favourably with the control diet (Diet 1). All the organ weight parameters showed no significant difference ($P > 0.05$). The haematological parameters measured were within the normal range established for broiler chickens, except for monocytes in all the diets and lymphocytes and neutrophils for Diets 3 and 4, respectively. For serum chemistry, Diets 1, 2, and 3 fall within the normal range established for broiler chickens for albumin and globulin, while for alkaline phosphatase, all the diets fall within the normal range established for broiler chickens. Considering the economics of the diet, Diet 2 had the least cost/kg weight gain, highest revenue, and highest gross margin, making Diet 2 an economically viable diet. Diet 2 enhanced a high-quality animal protein production at reduced cost. This will lead to an increase in animal protein intake globally. It is therefore recommended.

Key Words: nutritional, evaluation, *Anthonotha macrophylla*, soybean, chickens

0456 Effect of graded levels of defatted green microalgal inclusion into broiler diets on growth performance and digestibility.

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The objective of this experiment was to determine an optimal inclusion level of a defatted marine green microalgae (*Nannochloropsis oceanica*), a byproduct of biofuel production, in broiler diets. A total of 180 hatching Ross broiler chicks were divided into 5 groups ($n = 6$) fed a corn-soybean meal diet containing 0 (Control), 2, 4, 8, or 16% algal biomass (Cel-lana, Kailua-Kona, HI) for 6 wk. Body weights, feed intake, organ weights, and blood samples were collected at wk 3 and 6; and water intake was measured over the first 3 wk. Over the 6-wk period, ADG, ADFI and G:F were not affected by the algal inclusion up to 8%. However, the 16% inclusion reduced ADG ($P < 0.01$) and G:F ($P < 0.001$). Water intake was increased ($P < 0.001$) by 16 and 39% in chicks fed 8 and 16% microalgae diets, respectively. Relative heart weights were increased by feeding the 16% microalgae diet at both wk 3 ($P < 0.05$) and wk 6 ($P < 0.01$). However, relative liver, breast, gizzard, proventriculus, and intestinal weights or lengths were not affected by the dietary treatments. The same was also true for plasma uric acid, inorganic phosphorus, and protein concentrations at wk 3 or 6. Dry matter concentrations of total excreta collected from 2 birds per cage over a period of 3 d at wk 6 were reduced ($P < 0.05$) in the birds consuming the 8 and 16% microalgae diets, compared with the control. However, the excreta total dry matter or N retention was similar among the 5 experimental diets. In conclusion, dietary inclusion of this new defatted microalgal biomass up to 8% did not exert

any negative effects on growth performance or nutrient metabolism, except for the elevated water intake. *Supported in part by USDA/DOE Biomass R&D Initiative Grant.*

Key Words: green microalgae, broiler nutrition, biofuel

0457 Effects of duration of mixing diets with high inclusion of cereal grain co-products on growth performance and carcass measurements in finishing pigs. M. E. Morts*, J. D. Hancock, K. L. Kohake, and J. D. McAtee, *Kansas State University, Manhattan.*

A total of 200 finishing pigs (average initial BW of 68 kg) were used in a 62-d growth assay to determine the effects of mix time in corn-soybean meal-based diets with high inclusion of distillers dried grains with solubles (32% DDGS) and wheat middlings (32% midds). The pigs were sorted by gender and ancestry and assigned to pens (5 pigs/pen and 8 pens/treatment) in a completely randomized design. A Davis and Sons horizontal ribbon mixer (model DS30) was used to mix 1-t batches of the diets. All ingredients (corn, DDGS, midds, soybean meal, crystalline AA, limestone, salt, vitamin mix, mineral mix, and tylosin) were added with the mixer stopped. Mix times were 0, 15, 30, 60, and 420 s before discharge, transfer to a surge bin, and sacking into 22.6 kg bags for delivery to the swine farm. Diets were formulated to at least

120, 120, and 110% of requirements for essential AA, vitamins, and minerals for 75 to 100 and 100 to 135 kg pigs according to NRC (2012) nutrient requirements of swine. Feed and water were consumed on an ad libitum basis until the pigs were harvested (average BW of 125 kg) and processed at a commercial abattoir. As for results, there was a trend (quadratic effect, $P < 0.07$) for ADG to decrease as mix time was increased from 0 to 30 s and increase as mix time was further increased to 420 s. There was a trend (linear effect, $P < 0.06$) for G:F to increase as mix time was increased. Mix time did not affect ($P > 0.19$) ADFI, HCW, dressing percentage, or fat thickness at the last rib (BF). In conclusion, increasing mix time from 0 to 420 s in diets with high inclusion of DDGS and midds had inconsistent effects in growth performance, and no effect in carcass measurements.

Key Words: duration of mixing, distillers dried grains with solubles, pigs

Table 0457.

Item	0 s	15 s	30 s	60 s	420 s	SE	Linear	Quadratic
ADG, g	931	936	894	904	936	27	0.33	0.07
ADFI, kg	3.02	3.19	3.05	3.07	2.99	0.11	0.19	0.83
G:F, g/kg	308	293	293	294	313	7	0.06	0.12
HCW, kg	91.0	89.9	88.9	88.8	90.9	3.3	0.81	0.23
Dressing, %	72.2	72.2	72.5	71.9	72.1	0.6	0.56	0.58
BF, mm	21	21	21	20	20	1	0.29	0.76