Neutral semi-purified glycerin in growing and finishing pigs feeding

Adriana Gomez Gallego, Ivan Moreira, Paulo Levi de Oliveira Carvalho, Dani Perondi, Tiago Junior Pasquetti and Liliane Maria Piano Gonçalves

ABSTRACT
The experiment was carried out to evaluate performance, plasma variables, carcass traits and meat quality of growing-finishing pigs fed on diets with increasing levels of neutralized semi-purified glycerin (NSPG). Eighty growing pig (30.31 ± 0.47 to 60.41 ± 0.87 kg) and 80 finishing pigs (60.45 ± 0.46 to 90.99 ± 0.83 kg) were enrolled. Pigs were allotted in a randomized block design with four inclusion levels of NSPG (3.5, 7.0, 10.5 and 14%), mainly substituted the corn in diets. The experiment included 16 replicates and one pig per pen. Additionally, there was a control diet (0% NSPG). At the end of the finishing phase, all pigs were slaughtered to evaluate quantitative carcass traits and meat quality. The regression analysis showed no effect (p > 0.05) of NSPG on growth performance, backfat thickness and loin depth in the growing and finishing phases. As to plasma variables, cholesterol and triglycerides increased linearly only in the finishing phase. A linear increase was obtained in quantitative carcass traits (p < 0.05), such as hot carcass weight, hot carcass yield, cold carcass weight and cold carcass yield. As to meat quality traits, there was a quadratic effect for water drip loss and total lipids with inclusion levels of NSPG. As a whole, NSPG can be used up to 14% in the feed of growing and finishing pigs (30–90 kg) without impairing performance, plasma variables and quantitative carcass traits and meat quality. However, its use may increase the cost of the diet depending on the feedstuffs prices.

Introduction
Brazil is the third largest producer of biodiesel in the world (13% market share). Annual production amounted to 2.4 billion litres in 2010, while the installed capacity was 5.8 billion litres (ANP 2011). Glycerin is the main by-product of biodiesel making up 10–12% of end products (Thompson & He 2006). During the crude-glycerin purification, the raw material is acidified with hydrochloric acid (35.5–38%) to separate fatty acids, which can be reused in biodiesel production, thus increasing production yields. Afterwards this co-product is base-neutralized (NaOH) to correct the pH. These two processes can change its composition generating a glycerin with approximately 81.75% of glycerol, a high NaCl concentration and low methanol content (Ooi et al. 2004).

In pig farming, feeding accounts for approximately 70–80% of production costs. It is, therefore, necessary to seek alternative energy sources, as glycerin, to evaluate their nutritional and economic benefits.

Studies conducted by Doppenberg and Van Der Aar (2007) to evaluate the use of glycerin in the feed for growing and finishing pigs suggested that an addition of up to 5% can be beneficial. Berenchtein et al. (2010) evaluated quantitative carcass traits and meat quality of pigs fed with increasing levels of semi-purified glycerin (80% glycerol and 3660 kcal/kg ME) and observed no effect on meat quality. This results match those obtained by Lammers et al. (2008) who observed an increase in the water-holding capacity of the pig carcasses when 10% glycerin was added to the diets. This outcome was definitely appreciated by the pork industry. This study was aimed to evaluate the impact of neutralized semi-purified glycerin (NSPG) on growth performance, plasma variables, quantitative carcass traits and meat quality of pigs with a live weight between 30 and 90 kg.

Materials and methods
The experiment was conducted in the pig barn of Iguatemi Experimental Farm, owned by the Center for Agricultural Sciences of Maringá State University. A NSPG, derived from vegetable oil, (soybean) was studied.
The glycerin used was obtained from BSBIOS biofuel plant in Marialva, Paraná, Brazil.

**Animals, diets and experimental design**

A total of 80 crossbred pigs (TOPIGS Genetic), 40 barrows and 40 gilts, in the growing (from 30.31 ± 0.47 to 60.41 ± 0.87 kg) and finishing phase (from 60.45 ± 0.46 to 90.99 ± 0.83 kg of body weight) were used. The treatments consisted of four different levels (3.5, 7.0, 10.5 and 14%) of added NSPG with 16 replicates and one pig per pen. In addition, a control diet was formulated without glycerin (0%). The diet was formulated using the chemical composition of the minerals, especially sodium chloride (5.86%), according to the procedures described by Silva and Queiroz (2002) and energy values of NSPG (2531 kcal/kg metabolisable energy) obtained by Gallego et al. (2014). For other ingredients, chemical composition was determined (Table 1). The diets based on the corn and soybean meal (Tables 1 and 2) were formulated to meet the requirements proposed by Rostagno et al. (2011) for growing (30–60 kg) and finishing (60–90 kg) pigs.

The pigs were housed in a pen (7.60 m² each). Diets and water were provided ad libitum throughout the experiment. The pigs were allotted in a randomized block design with 16 replications and one pig per experimental unit. The animals were weighed at the beginning and at the end of the experiment. The total feed intake was calculated to determine average daily feed intake (ADFI), average daily gain (ADG) and feed:gain (F:G). At the end of the growing and finishing periods, backfat thickness and loin depth were measured at position P2, using a Sono-Grader (Renco ®). The animal care protocol was approved by the Animal Care and Use Committee of Maringá State University.

**Experimental procedure and sampling**

At the beginning and at the end of the study, after 8 h fasting, blood sampling was performed via the cranial vena cava. Samples were transferred into glass tubes with heparin to analyse cholesterol and triglycerides. Plasma glucose was measured using tubes containing sodium fluoride and potassium oxalate. Blood samples were centrifuged (3000 × g for 15 min) to obtain plasma, which was placed in propylene microtubes that were properly identified and stored in a freezer (−18°C). Commercial kits (Gold Analisa Diagnostica Ltd., Belo Horizonte, Minas Gerais, Brazil) were used to measure cholesterol, glucose and triglycerides.

At the end of the finishing phase, after a 24-h fast, all pigs were slaughtered. Carcasses were chilled (1–2°C) for 24 h. Subsequently, a quantitative evaluation was performed according to the Brazilian Method of Carcass Classification of Swine BMCC (Bridi & Silva 2009). The pH of the Longissimus dorsi muscle was measured in the hot carcass (45 min post-mortem, pH45) and in the chilled carcass (kept in cold chamber at 1–2°C during 24 h, pH 24) a portable pH meter (Digital HI 99163, Hanna Instruments, Woonsocket, RI) according to the recommendations of Bridi and Silva (2009). A scanner

### Table 1. Diets composition, during the growing phase (as fed basis).

| Item                              | Inclusion levels of neutralized semi-purified glycerin (%) |
|-----------------------------------|----------------------------------------------------------|
| Ingredients, %                    | 0.0  3.5  7.0  10.5  14.0                                 |
| Corn                              | 74.21 70.16 66.10 61.68 57.25                            |
| Soybean meal, 45% CP              | 22.56 22.89 23.23 23.59 23.95                            |
| Neutralized semi-purified glycerin| 0.00  3.50  7.00 10.50 14.00                             |
| Dicalcium phosphate               | 1.096 1.103 1.109 1.116 1.123                            |
| Soybean oil                       | 0.372 0.783 1.195 1.741 2.287                            |
| Limestone                         | 0.658 0.654 0.651 0.647 0.643                            |
| Mineral-vitamin premix<sup>a</sup> | 0.300 0.300 0.300 0.300 0.300                           |
| NaCl                              | 0.405 0.201 0.000 0.000 0.000                            |
| L-Lys -HCl                        | 0.264 0.262 0.259 0.255 0.255                            |
| DL-Met                            | 0.071 0.079 0.086 0.093 0.101                            |
| L-Thr                             | 0.060 0.065 0.075 0.075 0.081                            |
| Calculated composition<sup>b</sup> |                                                   |
| Metabolizable energy, Kcal/kg     | 3320 3320 3320 3320 3320                                 |
| Crude protein, %                  | 15.67 15.54 15.40 15.24 15.09                            |
| Calcium, %                        | 0.602 0.602 0.602 0.602 0.602                            |
| Available phosphorus, %           | 0.297 0.297 0.297 0.297 0.297                            |
| Digestible lysine, %              | 0.888 0.888 0.888 0.888 0.888                            |
| Sodium, %                         | 0.180 0.180 0.181 0.262 0.342                            |
| Glycerol, %                       | 2.807 5.614 8.421 11.228 11.228                         |
| Diet cost, R$/kg                  | 0.605 0.606 0.607 0.610 0.614                            |

<sup>a</sup>Vitamin and mineral premix for growing pigs (Vit A, 2,300,000 U; Vit D3, 466,667 U; Vit E, 5000 U; Vit K3, 667 mg; Vit B1, 333 mg; Vit B2, 1000 mg; Vit B6, 400 mg; Vit B12, 4000 mcg; pholic acid, 67 mg; niacin, 6660 mg; Ac. pantothenic acid, 4000 mg; biotin, 17 mg; choline, 43 g; iron 26 667 mg; copper, 41 667 mg; cobalt, 183 mg; manganese, 16,667 mg; zinc, 26 667 mg; selenium, 67 mg; iodine, 267 mg; antioxidant 27 g; vehicle q.s.p., 1000 g).

<sup>b</sup>Calculated based on Rostagno et al. (2011).
and Spring software were used to determine the fat area in the Longissimus dorsi muscle (Câmara et al. 1996). At slaughter, liver and kidneys (right and left) were weighed and data were recorded.

For a qualitative carcass assessment, samples from the Longissimus dorsi muscle (between the 8th and the 10th rib) were collected from all pigs (2.5 cm thick) to measure drip loss and cooking loss according to Bridi and Silva (2009).

The colour of the Longissimus dorsi muscle was measured 24 h after slaughter with samples collected between the 8th and the 10th rib. On the muscle surface, six Minolta readings (L*, a* and b*) were performed using a CR-400 Konica Minolta's portable colorimeter (Illuminant D65; 0°/C14 angle and four self-average, Illuminan Inc., San Diego, CA). Components L* (lightness), a* (red-green component) and b* (yellow-blue component) were expressed in the CIELAB colour system. All samples of the Longissimus dorsi were cooked and used to determine texture profile (kg f). For each sample, five cylindrical subsamples were taken along the orientation of muscle fibres (diameter 1.27 cm²), as recommended by Ramos and Gomide (2007). The analysis was performed in a Stable Micro System (TA-XT2i texturometer), coupled with the Warner–Bratzler Shear Force probe and the Exponent Texture Expert – Stable Micro Systems software (Stable Micro Systems, Tasca, IL).

The economic feasibility of NSPG was assessed based on the cost of raw materials sourced on the local market, while the costs of feed per kg of live weight gain were calculated according to Bellaver et al. (1985). Additionally the Economic Efficiency Index (EEI) and the Cost Index (CI) were calculated, as proposed by Gomes et al. (1991).

### Table 2. Diets composition, during the finishing phase (as fed basis).

| Item                               | Inclusion levels of neutral semi-purified glycerin (%) |
|------------------------------------|------------------------------------------------------|
|                                    | 0.0        | 3.5        | 7.0        | 10.5       | 14.0       |
| Corn                               | 77.07      | 73.02      | 68.88      | 64.45      | 60.03      |
| Soybean meal, 45% CP               | 20.17      | 20.50      | 20.85      | 21.21      | 21.58      |
| Neutral semi-purified glycerin     | 0.00       | 3.50       | 7.00       | 10.50      | 14.00      |
| Dicalcium phosphate                | 0.867      | 0.874      | 0.880      | 0.887      | 0.894      |
| Soybean oil                        | 0.418      | 0.829      | 1.272      | 1.818      | 2.363      |
| Limestone                          | 0.586      | 0.583      | 0.579      | 0.575      | 0.572      |
| Mineral–vitamin premixa²           | 0.150      | 0.150      | 0.150      | 0.150      | 0.150      |
| NaCl                               | 0.359      | 0.156      | 0.000      | 0.000      | 0.000      |
| L-Lys -HCl                         | 0.248      | 0.246      | 0.244      | 0.241      | 0.239      |
| DL-Met                             | 0.060      | 0.070      | 0.074      | 0.082      | 0.090      |
| L-Thr                              | 0.060      | 0.065      | 0.073      | 0.078      | 0.083      |
| Calculated composition³            |            |            |            |            |            |
| Metabolizable energy, kcal/kg      | 3250       | 3250       | 3250       | 3250       | 3250       |
| Crude protein, %                   | 14.81      | 14.67      | 14.52      | 14.37      | 14.22      |
| Calcium, %                         | 0.513      | 0.513      | 0.513      | 0.513      | 0.513      |
| Available phosphorus, %            | 0.250      | 0.250      | 0.250      | 0.250      | 0.250      |
| Digestible lysine, %               | 0.821      | 0.821      | 0.821      | 0.821      | 0.821      |
| Sodium, %                          | 0.162      | 0.162      | 0.181      | 0.262      | 0.343      |
| Glycerol, %                        | 2.807      | 5.614      | 8.421      | 11.228     |
| Diet cost, R$/kg                   | 0.583      | 0.584      | 0.586      | 0.589      | 0.592      |

²Vitamin and mineral premix for fishing pigs (Vit A, 2,666,660 U; Vit D3, 533,300 U; Vit E, 4667 U; Vit K3, 1200 mg; Vit B1, 200 mg; Vit B2, 13,336 mg; Vit B6, 133 mg; Vit B12, 6,667 mcg; pholic acid, 34 mg; niacin, 10 000 mg; pantothenic acid, 666,666 mg; biotin, 20 mg; choline, 62 g; iron, 40 mg; copper, 86 805 mg; cobalt, 334 mg; manganese, 30 000 mg; zinc, 46 666,0 mg; selenium, 67 mg; iodine, 400 mg; antioxidant, 40 g; vehicle q.s.p., 1000 g).
³Calculated based on Rostagno et al. (2011).

### Statistical analyses

An analysis of variance was performed according to the following statistical model: \( Y_{ijkl} = \mu + B_i + S_j + N_k + e_{ijkl} \) in which \( Y_{ijkl} \) is the observation of animal \( i \), within block \( i \), on gender \( j \) and inclusion level of NSPG \( k \); \( \mu \) is the constant associated with all observations; \( B_i \) is the block effect, being \( i = 1, 2, 3, 16 \); \( S_j \) is the gender effect (1 = gilt, 2 = male); \( N_k \) is the effect of added NSPG levels (\( k = 0; 3.5; 7.0; 10.5 \) and 14%) and \( e_{ijkl} \) is the random error associated with each observation. The degrees of freedom, related to the NSPG added levels, were broken down into orthogonal polynomials to obtain the regression equations. Data were analysed using the weights of the pigs at the beginning of the study and at the time of slaughter as a covariate for statistical analysis.

### Results and discussion

The regression analysis indicated that the added NSPG levels had no effect on ADFI, ADG, feed:gain, backfat thickness and loin depth of growing and finishing pigs (Table 3). The results also showed that the added NSPG levels did not impair the performance and some carcass traits, but they increased the hot carcass weight, the hot carcass yield, the cold carcass weight and the cold carcass yield.
Likewise, on one hand, Lammers et al. (2008), Berenchtein et al. (2010), Schieck et al. (2010) and Gonçalves et al. (2014) did not find any negative effects on ADFI, ADG and F:G after the addition of up to 10% of semi-purified glycerin (with approximately 3406 kcal/kg ME) in diets for pigs. On the other hand, Kijora and Kupsch (1996) observed the highest feed intake of growing pigs with an addition of up to 10% of crude glycerin with different levels of purification. However, Hansen et al. (2009) did not find any effects on the carcass characteristics (backfat thickness and loin depth) after the addition of 5% glycerin. Similar responses were obtained by Della Casa et al. (2009) and Mendoza et al. (2010) by adding up to 16% of purified glycerin in growing pigs. However, Hanczakowska et al. (2010) observed a reduction in backfat thickness and an increase in loin depth with the addition of up to 10% of crude glycerin, contrary to the results obtained in our study.

No effects of added NSPG levels were found in plasma glucose, cholesterol and triglycerides (Table 4).

### Table 4. Effects of neutralized semi-purified glycerin (NSPG) on blood components of growing and finishing pigs.

| Item     | 0.0  | 3.5  | 7.0  | 10.5 | 14.0 | SEM | L  | Q  |
|----------|------|------|------|------|------|-----|----|----|
| Glucose  | 71.77| 79.56| 76.55| 76.98| 79.83| 0.199| ns | ns |
| Cholesterol | 74.30| 77.32| 83.97| 75.03| 89.01| 0.202| ns | ns |
| Triglycerides | 54.79| 48.39| 50.40| 58.69| 54.03| 0.283| ns | ns |

### Table 3. Average daily feed intake (ADFI), average daily gain (ADG), feed:gain, backfat thickness (BT) and loin depth (LD) of growing and finishing pigs feeding diets with inclusion levels of neutralized semi-purified glycerin (NSPG).

| Item         | 0.0  | 3.5  | 7.0  | 10.5 | 14.0 | SEM | L  | Q  |
|--------------|------|------|------|------|------|-----|----|----|
| ADFI, kg     | 1.953| 1.966| 1.984| 2.099| 2.138| 0.038| ns | ns |
| ADG, kg      | 0.883| 0.873| 0.870| 0.882| 0.934| 0.016| ns | ns |
| Feedgain     | 2.248| 2.252| 2.374| 2.396| 2.318| 0.044| ns | ns |
| BT, mm       | 8.69 | 8.94 | 8.44 | 9.69 | 8.63 | 0.274| ns | ns |
| LD, mm       | 40.25| 38.19| 38.19| 39.56| 40.00| 0.836| ns | ns |

| Item         | 0.0  | 3.5  | 7.0  | 10.5 | 14.0 | SEM | L  | Q  |
|--------------|------|------|------|------|------|-----|----|----|
| ADFI, kg     | 2.351| 2.517| 2.619| 2.549| 2.566| 0.063| ns | ns |
| ADG, kg      | 0.923| 0.928| 0.950| 0.937| 0.915| 0.014| ns | ns |
| Feedgain     | 2.790| 2.752| 2.777| 2.753| 2.820| 0.044| ns | ns |
| BT, mm       | 12.07| 11.87| 11.94| 11.00| 13.00| 0.334| ns | ns |
| LD, mm       | 55.27| 52.00| 52.75| 51.27| 50.88| 0.817| ns | ns |

*SEM, standard error of the mean; ns, non-significant (p ≥ 0.05).*
hens fed on a diet containing 20% glycerin over 3 weeks. Other studies on the addition of glycerin to pig diets (Kijora & Kupsch 1996; Lammers et al. 2008) reported no pathological alterations in the liver and kidneys.

Only two qualitative traits of meat (Table 6) were affected by NSPG. The quadratic effect of NSPG (p < 0.05) was observed on drip loss and total lipids. This can be explained by the effect of glycerin on tissue hydration, as it increases intracellular pressure by water retention, besides having a protective action against protein denaturation during cooking (Mourot 2009). Similar responses were obtained by Carvalho et al. (2013), who found a quadratic effect for drip loss in pigs fed pm mixed crude glycerin. According to Xu et al. (2009), diet changes as well as pre-slaughter stress can affect the fatty acid profile.

Using up to 15% of semi-purified glycerin, Mourot et al. (1994) observed a decrease in drip and cooking losses and an improved meat quality. Likewise, Hanczakowska et al. (2010) observed an increase in the water-holding capacity of pigs slaughtered at 110 and 85 kg, respectively, using a purified and a crude glycerin. Hansen et al. (2009) and Berenchtein et al. (2010) observed no effect of increasing levels of semi-purified glycerin on luminosity (L*, a*, b*) and pH of the pigs’ meat, thus confirming the results of our study. Likewise, Duttlinger et al. (2009) analysed the effect of glycerin and ractopamine on the diet of barrows and gilts and found no effect of glycerin on meat quality, mainly in terms of cooking loss or shear force.

The study of economic feasibility (Table 7) for the growing (30–60 kg) and finishing (60–90 kg) phases showed no difference in cost of feed per kg of live weight gain with the addition of up to 14% NSPG. Cost represents the ratio between the prices of raw materials (soybean meals, soybean oil, corn and NSPG). The energy value of glycerin (2531 metabolizable energy) was lower than that of corn; therefore, it was necessary to add soybean oil with increasing inclusion level of glycerin to the diets. Its inclusion in animal feeding will depend on the relative energy value between corn, soybean meal and glycerin (Kerr et al. 2009). In this study, an addition of up to 14% NSPG to diets with the same energy content for growing (30–60 kg) and finishing pigs (60–90 kg) increased costs by about 3.8% and 8.5%, respectively, compared with diets without glycerin (0%). On the contrary, the carcass weight was positive and linear with growing additions of NSPG.

### Table 5. Effects of neutralized semi-purified glycerin (NSPG) on carcass traits of pigs.

| Item                        | Inclusion levels of NSPG (%) | SEMa L Q |
|-----------------------------|-----------------------------|---------|
| Fasting losses, %           | 3.58 3.52 3.70 3.46 3.36    | 0.134   |
| Hot carcass weight, kg      | 70.90 71.26 71.60 71.94 72.24 | 0.218   |
| Hot carcass yield, %        | 80.22 81.90 82.01 82.08 82.12 | 0.229   |
| Cold carcass weight, kg     | 68.95 69.26 69.58 69.89 70.21 | 0.419   |
| Cold carcass yield, %       | 78.02 79.61 79.70 79.74 79.81 | 0.238   |
| Loss yield, %               | 2.69 2.65 2.85 2.86 2.78     | 0.550   |
| Ham weight, kg              | 10.66 10.99 11.00 11.17 11.03 | 0.080   |
| Ham yield, kg               | 30.07 30.84 30.73 31.05 30.54 | 0.328   |
| Carcass length, cm          | 89.64 88.35 89.27 89.00 88.58 | 0.268   |
| Longissimus area, cm²       | 36.31 35.51 36.10 33.72 35.38 | 0.584   |
| Fat area, cm²               | 15.22 17.06 15.28 16.76 15.74 | 0.344   |
| Lean meat in the carcass, kg| 53.10 53.52 53.46 55.39 54.48 | 0.819   |
| Lean meat in the carcass, % | 74.97 75.92 74.37 76.71 76.18 | 0.012   |
| Lean:fat ratio              | 0.43 0.49 0.43 0.50 0.45     | 0.011   |
| Liver, kg                   | 1.33 1.31 1.33 1.36 1.31     | 0.012   |
| Kidneys, kg                 | 0.218 0.175 0.178 0.175 0.179 | 0.009   |

### Table 6. Effect of neutralized semi-purified glycerin (NSPG) on meat quality of pigs.

| Item                        | Inclusion levels of NSPG, % | SEMa L Q |
|-----------------------------|-----------------------------|---------|
| pH, 45 min                  | 6.43 6.51 6.43 6.52 6.46    | 0.035   |
| pH, 24 h                    | 5.92 5.97 5.95 5.98 5.93    | 0.054   |
| Drip loss, %                | 3.20 3.24 4.17 4.34 3.10    | 0.187   |
| Total fat, %                | 2.77 3.17 3.28 3.63 3.12    | 0.015   |
| Cooking loss, %             | 3.07 3.05 2.97 3.06 2.91    | 0.050   |
| Defrosting loss, %          | 9.23 9.45 8.82 9.45 9.20    | 0.016   |
| Cooked protein, %           | 23.67 23.90 24.19 23.66 24.29 | 0.764   |
| Moisture, %                 | 70.90 70.93 71.26 70.57 70.79 | 0.103   |
| Ash, %                      | 1.42 1.27 1.47 1.36 1.38    | 0.153   |
| Shear force, kg f/seg       | 2.62 2.66 2.72 2.52 2.59    | 0.480   |
| Total fat, %                | 2.77 3.17 3.28 3.63 3.12    | 0.015   |
**Conclusions**

In conclusion, we found that an addition of up to 14% of neutralized semi-purified glycerin does not affect growth performance, blood components, some carcass traits and pork meat quality during the growing-finishing phases (30–90 kg), but it increased carcass weight. Its economic feasibility will depend on the cost ratios among corn, soybean meal, soybean oil and neutralized semi-purified glycerin.

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**Table 7. Effect of neutral semi-purified glycerin (NSPG) on the economic feasibility.**

| Item                      | 0.0  | 3.5  | 7.0  | 10.5 | 14.0 | CVa  | Regression |
|---------------------------|------|------|------|------|------|------|------------|
| Growing, 30–60 kg         |      |      |      |      |      |      |            |
| Initial weight, kg        | 30.68| 30.27| 30.35| 29.84| 30.42| –    | –          |
| Final weight, kg          | 60.84| 60.26| 59.47| 61.23| 60.26| –    | –          |
| Diet cost, R$             | 0.605| 0.606| 0.607| 0.610| 0.614| –    | –          |
| FC, R$/kg BWb             | 1.297| 1.440| 1.325| 1.489| 1.408| 15.02| ns         |
| EElc                      | 100.00| 90.08| 97.89| 87.11| 92.15| –    | –          |
| Index cost                | 100.00| 111.01| 102.16| 114.79| 108.51| –    | –          |
| Finishing, 60–90 kg       |      |      |      |      |      |      |            |
| Initial weight, kg        | 60.25| 59.97| 60.18| 60.64| 61.18| –    | –          |
| Final weight, kg          | 90.66| 90.31| 91.29| 91.51| 91.19| –    | –          |
| Diet cost, R$             | 0.583| 0.584| 0.586| 0.589| 0.592| –    | –          |
| FC, R$/kg BWb             | 1.621| 1.609| 1.627| 1.622| 1.670| 11.57| ns         |
| EElc                      | 99.25| 100.00| 98.88| 99.17| 96.32| –    | –          |
| Index cost                | 100.75| 100.00| 101.13| 100.84| 103.82| –    | –          |

ns, non-significant (p > 0.05).
aCV, coefficient of variation.
bFC = R$/kg BW: feed cost per kg of body weight gain.
cEEL, economic efficiency index.
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