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# Replacing soybean meal with micronized soybeans in starter piglet diets and their residual effects during growing and finishing phases

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## Abstract

*Aim of study:* To assess the effects of replacing soybean meal (SBM) with micronized soybean (MS) on the digestibility (Experiment I) and performance (Experiment II) of piglets in the starter phase and its residual effects on the growing/finishing phases and carcass and meat quality traits.

*Area of study:* São Paulo, Brazil.

*Material and methods:* The treatments consisted of different levels of dietary replacement of SBM with MS at intervals of 25%, totaling five inclusions (0%, 25%, 50%, 75%, and 100%).

*Main results:* In Exp. I, the administration of the pre-starter I diet resulted in a positive linear effect ($p<0.05$) on the apparent digestibility coefficient (ADC) of crude protein and a quadratic effect ($p<0.01$) on the ADCs of dry matter and crude fat. For the pre-starter II diet, there was a quadratic effect on the ADCs of dry matter and crude fat ($p<0.05$). For the starter diet, a negative linear effect on the ADC of dry matter was observed ($p<0.01$). In Exp. II, the feed intake and weight gain decreased linearly throughout the starter phase ($p<0.01$), while no significant difference ($p>0.05$) in feed conversion was observed with increasing inclusion level of MS.

*Research highlights:* Replacing SBM with MS in the starter diet did not influence performance during the growing and finishing phases. Meat quality was not affected but a lower retail cut weight were observed in animals fed a starter diet with higher levels of MS.

**Additional key words:** carcass meat quality; digestible energy; protein solubility; soybean replacement; urease activity.

**Abbreviations used:** ADC (apparent digestibility coefficient); ADFI (average daily feed intake); ADWG (average daily weight gain); ANF (antinutritional factors); CF (crude fat); CP (crude protein); DE (digestible energy); DFD (dark, firm, dry); DM (dry matter); FC (feed conversion); GE (gross energy); LL (*Longissimus lumborum*); ME (metabolizable energy); MS (micronized soybean); PSE (pale, soft, exudative); SBM (soybean meal); SM (*Semimembranosus*).

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# Introduction

Soybeans are the most used protein source in animal feed because of their attractive nutritional characteristics. Pig farming and experimental studies have investigated different soy products and by-products in order to reduce feed costs. It is known that the use of raw grains in the diet of non-ruminant animals can compromise nutrient digestion and absorption due to the presence of antinutritional factors (ANF). These factors can be inactivated by heat treatment, rendering the ingredient adequate for the mechanism in the gastrointestinal tract of these animals. The micronization process is used to reduce the particle size in order to improve solubility and to maintain the lipid content of the grain. The product generated is called "micronized soybean" (MS), which contains about 39% crude protein and 21.5% fat (Rostagno *et al.*, 2011).

The higher energy content of MS when compared to soybean meal is interesting for the formulation of diets destined for animals that require maximum energy intake per amount of diet ingested, such as weaned piglets. Immediately after weaning, feed intake by piglets is reduced and diets must be able to provide the energy necessary for proper maintenance and growth (Berrocoso *et al.*, 2014).

Knowledge of the nutritional value and digestibility of products destined for animal feed is essential for the formulation of balanced diets. However, most experiments only compare ingredients and few tests the levels of inclusion. Considering the nutritional importance of soybeans for the feeding of non-ruminants animals and the lack of information about the best inclusion level of this product (micronized soybean) in the diet of weaned piglets, the present study evaluated the effects of increasing levels of dietary replacement of soybean meal with MS on diet digestibility and growth performance of piglets in the starter phase, as well as its residual effects on the growing/finishing phases and carcass, and meat quality traits.

# Material and methods

The experimental protocol was developed in accordance with the ethical guidelines on animal experimentation determined by the Ethics Committee on Animal Experimentation of the Institute of Animal Science and Pastures (APTA/SAA), Nova Odessa, SP, Brazil (Protocol No.: 216/2015-CEUA).

The experiments were conducted in Nova Odessa, state of São Paulo, Brazil (22º46'39"S, 47º17'45"W, altitude of 570 m).

## Chemical-bromatological composition

Urease activity and protein solubility of the test ingredients were determined according to Sindirações (2013). In addition, particle size, dry matter at 105°C, crude protein, ether extract and mineral matter were analyzed (AOAC, 2006).

## Digestibility trial

A total of 25 barrows with an average initial body weight of 7.38 ± 0.73 kg were used. The animals were housed in metabolic cages similar to those described by Pekas (1968) and allocated in a randomized complete block design consisting of five treatments and five replications, with one animal per experimental unit.

The treatments consisted of different levels of dietary replacement of soybean meal (SBM) with MS at intervals of 25%, totaling five inclusions (MS0, MS25, MS50, MS75, and MS100). The diets were formulated to meet the minimum nutritional requirements of piglets from 21 to 63 days of age (Table S1 [suppl]), according to NRC (2012). Three diets were tested: pre-starter I, pre-starter II, and starter.

The experimental period lasted 25 days, with 10 days for adaptation to the facilities and determination of feed intake, which was defined as the maximum intake during the period analyzed. After the adaptation period, the samples were collected within 5 days for each test diet (pre-starter I, pre-starter II, and starter).

The animals were fed daily at 8:00 and 17:00 h. The feed was weighed and supplied reducing the amount defined as maximum intake (established during the adaptation period) by 10% in order to avoid leftovers. The total fecal and urine collection method was used. Feces were collected once a day, weighed and stored in a freezer (-20ºC). Urine was collected once a day into plastic buckets containing 10 mL of sulfuric acid solution (1:1) to prevent nitrogen losses and the proliferation of microorganisms. The urine volume produced was measured in a 20% aliquot that was stored in a freezer (-20ºC). Ferric oxide ($Fe_2O_3$) was used at 1% as a fecal marker to determine the beginning and end of the collection period between test diets. At the end of the experiment, the feces of each animal were homogenized and a representative sample was removed to determine the first dry matter (55ºC/72 h). The sample was then ground in a knife mill with a 1-mm screen.

The following parameters were analyzed in the collected material according to the AOAC (2006): dry matter (DM; residue obtained by drying the sample in an oven at 105°C); mineral matter (residue obtained by incinerating the sample in a muffle at 550°C); nitrogen (N; combustion of the sample by the method of Dumas); gross energy (GE; combustion of the sample by bomb calorimetric), and crude fat (CF; residue of petroleum ether-soluble substances). The apparent digestibility coefficients were then calculated using the formulae of Adeola & Cowieson (2001).

## Growth performance evaluation, pre-slaughter and slaughter handling

A total of 70 crossbred weaned piglets (35 females and 35 barrows) with an initial age of 21 days and average initial body weight of 5.52 ± 1.0 kg were used. The animals were housed in experimental pens (2 m² each) equipped with a nipple-type drinking fountains and semiautomatic feeder and were allocated in a randomized complete block design consisting of five treatments and seven replications, with one couple per experimental unit. The weight and gender of the animals were used as criteria for formation of the blocks.

The diets were the same as those formulated for the digestibility assay (Table S1 [suppl]) and were supplied during the following phases: pre-starter I (21 to 35 days of age); pre-starter II (36 to 50 days of age) and starter (51 to 63 days of age).

After the nursery phase, the animals were transferred to growing/finishing facilities where they were kept in individual pens (1.0 × 2.0 m) with smooth concrete floor and metal divisions, equipped with a trough type feeder and nipple-type drinking fountains. The animals were allocated in a completely randomized design consisting of five residual treatments and 14 replications per treatment. During this period, the animals received the same corn and soybean diet formulated according to the nutritional requirements (NRC, 2012) of each phase: growing I – from 64 to 91 days of age; growing II – from 91 to 119 days of age; finishing – from 119 to 140 days of age.

Average daily weight gain (ADWG) was determined by weighing the animals at the beginning and end of each phase. Average daily feed intake (ADFI) and feed conversion (FC) were determined by weighing the feed at the beginning and end of each phase, subtracting leftovers. The total experimental period was 42 days during the nursery phase and 76 days during the growing/finishing phase.

At the end of the growing/finishing phase (140 days of age), the animals were slaughtered in a commercial slaughter house. Feed was withheld for 4 h before the animals (n = 70) were weighed and transported to a packing plant in Piracicaba, SP, Brazil (22º43’31” S; 47º38’57” W; altitude of 547 m). The animals were kept in pens for 6 h before being electrically stunned, exsanguinated from major blood vessels near the heart, and processed according to industry-accepted procedures.

## Evaluation of carcass traits

After slaughter, the hot carcass of the 70 animals was weighed. Then, the carcasses were chilled in a cold storage room for 24 h at 2ºC and weighed again for the determination of cold carcass weight. The pH of the left half-carcass was measured 45 min and 24 h *post mortem* in the center of the *semimembranosus* (SM) muscle with a portable digital pH meter (DM-2 Digimed©). The 24-h pH was also measured in the *longissimus lumborum* (LL) muscle.

Backfat thickness was measured with a caliper at three specific points: near the first thoracic vertebra (P1), near the last thoracic vertebra (P2), and near the last lumbar vertebra (P3). The arithmetic average of the three measurements was used for analysis. The loin eye area was obtained by delimiting the contour of the LL muscle between the last and penultimate rib and the area was calculated using a planimeter.

After the establishment of *rigor mortis* (24 h after slaughter), the LL muscle of the left half-carcass was exposed for 30 min to allow the occurrence of blooming. Three color measurements per animal were then obtained using a Konica Minolta CM-600d spectrophotometer, which uses the CIELAB color scale with the following coordinates: L* (lightness), a* (redness), and b* (yellowness).

For the determination of retail cut weight, the following cuts were obtained from left half-carcass: ham, pork chops, shoulder, ribs, sirloin, and belly. After weighing the cuts, the shoulder and sirloin were deboned to determine the boneless cut weight.

## Pork meat quality

Drip loss was determined as described by Costa *et al.* (2018). Briefly, approximately 100 g of an LL sample collected between the 6$^{th}$ and 7$^{th}$ rib was cut into cubes, placed in a nylon net, and subjected to its own weight for 72 h in a cold chamber (4ºC). The result is reported as the difference between the initial and final weight divided by the initial weight and multiplied by 100.

Samples of LL muscle (approximately 130 g) were collected 24 h after slaughter. The samples were vacuum packed and stored frozen (-20°C). Next, the samples were thawed in a refrigerator at 4ºC for 24 h. After this period, the samples were weighed and cooked in a water bath (80ºC) until their core temperature reached 72ºC. The samples were cooled at room temperature and weighed again for the calculation of cooking losses. For the determination of meat tenderness (shear force), four cubes per sample were removed and placed with the muscle fibers perpendicular to the blades of a TAXT-plus Texture Analyzer 2i equipped with Warner-Bratzler shear force (WBSF) with a 25-kg load cell and crosshead speed of 200 mm/min.

## Statistical analyses

All data were submitted to analysis of variance using the GLM (General Linear Models) procedure of the SAS 9.0 program (SAS Inst., Cary, NC, USA). Means were considered significantly different at the 5% level of prob-

**Table 1.** Chemical-bromatological composition, protein solubility, and urease activity of the test ingredients.

| Description analysed | Soybean meal | Micronized soybean |
|---|---|---|
| Dry matter, % [1] | 87.56 | 91.37 |
| Crude protein, % [1] | 45.72 | 38.68 |
| Ether extract, % [1] | 1.85 | 22.21 |
| Mineral matter, % [1] | 5.99 | 4.77 |
| Particle size, μm [2] | 122.0 | 453.0 |
| Protein solubility in KOH, % [3] | 74.43 | 78.80 |
| Urease activity, Δ pH [3] | 0.09 | 0.03 |

[1] Analyses performed at the Laboratory of Bromatology, Institute of Animal Science and Pastures, São Paulo. [2] Analyses performed at the Laboratory of Analytical and Calibration Resources, UNICAMP/São Paulo. [3] Analyses performed at the CBO Laboratory, São Paulo.

ability ($p<0.05$) by the Tukey test. Regression analyses were performed for the treatments and linear and quadratic effects were evaluated. Regression equations are demonstrated in the table footers when significant.

# Results

## Chemical-bromatological composition

Table 1 shows the chemical-bromatological composition, protein solubility, and urease activity of the test ingredients.

## Digestibility trial

For the pre-starter I diet, the nitrogen retention coefficient and the apparent digestibility coefficient of crude protein ($ADC_{CP}$) increased linearly with increasing replacement of SBM with MS ($p<0.05$), while a quadratic effect was observed for the apparent digestibility coefficients of dry matter ($ADC_{DM}$), crude fat ($ADC_{CF}$) and gross energy ($ADC_{GE}$), digestible energy (DE), and metabolizable energy (ME). For the pre-starter II diet, only $ADC_{DM}$ and $ADC_{CF}$ differed ($p<0.01$), while there was no effect of treatment on the other variables analyzed. The starter diet resulted in a significant difference only for $ADC_{DM}$ ($p<0.01$), which decreased linearly with increasing level of replacement of SBM with MS (Table 2).

## Growth performance during the starter, growing and finishing phases

There was a linear decrease in ADWG and ADFI with increasing level of replacement of SBM with MS throughout all periods of the starter phase ($p<0.05$), while FC increased linearly ($p<0.01$) in the first and second periods analyzed (Table 3). The animals entered the growing phase with the following mean body weights: MS0: 25.07 kg, MS25: 23.57 kg, MS50: 22.02 kg, MS75: 21.33 kg, and MS100: 19.62 kg.

Piglets fed different levels of MS as substitute of SBM during the starter phase had lower ADFI during the grower I phase (Table 4), with the observation of a negative linear effect ($p<0.05$), *i.e.,* the higher the inclusion level of MS during the starter phase, the lower the feed intake of the animals between 64 and 91 days of age. However, piglets receiving different dietary levels of MS during the post weaning phase had better feed efficiency during the grower I phase ($p<0.05$). The higher the inclusion level of MS, the better FC. Consequently, there was no difference in ADWG between treatment during the grower I phase ($p>0.05$) (Table 4).

Analysis of the grower I and II phases (64 to 119 days of age) and of the grower I, II and finisher phases (64 to 140 days of age) showed no difference in any of the zootechnical parameters evaluated when the diet factor was analyzed ($p>0.05$). However, barrows had higher ADFI and ADWG than females ($p>0.05$).

## Carcass and meat traits

There was a difference in body weight ($p<0.05$) before slaughter, with the weight of the animals being higher the lower the inclusion of MS during the starter phase. This fact was confirmed after slaughter of the pigs, with the cold and hot carcass weight, being lower in animals fed starter diets with higher levels of MS (Table 5).

Backfat thickness was not influenced by the addition of MS ($p>0.05$). In addition, carcass yield and loin eye area, which were used to predict the amount of lean meat in the carcass, did also not differ between treatments when the diet factor was analyzed ($p>0.05$). The 24-h *post mortem* pH of the SM muscle was not influenced by diet or gender ($p>0.05$). However, when the gender factor was analyzed, females had higher carcass yield ($p<0.05$) and males exhibited greater backfat thickness ($p<0.05$). In addition, a difference in 45-min *post mortem* pH values of the SM

**Table 2.** Coefficient of nitrogen retention (CNR), apparent digestibility coefficients of dry matter ($ADC_{DM}$), crude protein ($ADC_{CP}$), crude fat ($ADC_{CF}$), gross energy ($ADC_{GE}$), digestible energy (DE), and metabolizable energy (ME) obtained for the pre-starter I, pre-starter II and starter diets.

| Variable | Treatment, % | | | | | Reg | CV% |
|---|---|---|---|---|---|---|---|
| | MS0 | MS25 | MS50 | MS75 | MS100 | | |
| *Pre-starter I* | | | | | | | |
| CNR, % | 66.83 | 68.85 | 70.88 | 72.91 | 74.94 | L** | 3.4 |
| $ADC_{DM,}$ % | 79.97 | 82.07 | 82.76 | 82.05 | 79.92 | Q** | 1.7 |
| $ADC_{CP,}$ % | 81.45 | 82.10 | 82.76 | 83.42 | 84.07 | L* | 2.2 |
| $ADC_{CF,}$ % | 76.52 | 83.44 | 84.01 | 83.77 | 82.86 | Q** | 3.0 |
| $ADC_{GE,}$ % | 83.95 | 85.92 | 86.98 | 87.14 | 86.40 | Q** | 1.4 |
| DE, Mcal/kg | 3.77 | 3.93 | 4.01 | 4.00 | 3.90 | Q** | 1.4 |
| ME, Mcal/kg | 3.72 | 3.87 | 3.95 | 3.94 | 3.85 | Q** | 1.4 |
| *Pre-starter II* | | | | | | | |
| CNR, % | 67.05 | 64.69 | 64.28 | 65.81 | 69.28 | NS | 4.0 |
| $ADC_{DM,}$ % | 80.90 | 82.76 | 83.57 | 83.34 | 82.05 | Q** | 1.4 |
| $ADC_{CP,}$ % | 79.76 | 76.84 | 79.99 | 76.17 | 79.59 | NS | 3.1 |
| $ADC_{CF,}$ % | 76.26 | 72.77 | 72.51 | 75.47 | 81.66 | Q* | 3.5 |
| $ADC_{GE,}$ % | 85.90 | 86.22 | 89.23 | 86.26 | 86.69 | NS | 1.8 |
| DE, Mcal/kg | 3.82 | 3.98 | 4.04 | 4.01 | 3.88 | NS | 1.8 |
| ME, Mcal/kg | 3.78 | 3.94 | 4.00 | 3.97 | 3.83 | NS | 1.9 |
| *Starter* | | | | | | | |
| CNR, % | 71.35 | 70.41 | 64.16 | 69.08 | 66.29 | NS | 5.8 |
| $ADC_{DM,}$ % | 83.37 | 82.82 | 82.27 | 81.72 | 81.17 | L** | 1.5 |
| $ADC_{CP,}$ % | 81.04 | 80.04 | 79.04 | 78.05 | 77.05 | NS | 3.2 |
| $ADC_{CF,}$ % | 70.57 | 76.17 | 73.19 | 75.37 | 76.52 | NS | 2.9 |
| $ADC_{GE,}$ % | 87.31 | 86.88 | 86.46 | 86.03 | 85.61 | NS | 1.6 |
| DE, Mcal/kg | 3.72 | 3.68 | 3.64 | 3.60 | 3.56 | NS | 1.6 |
| ME, Mcal/kg | 3.68 | 3.64 | 3.60 | 3.56 | 3.51 | NS | 1.7 |

CV%: coefficient of variation; Reg: regression. * Significant at $p<0.05$; ** significant at $p<0.01$; NS: nonsignificant ($p>0.05$). L: linear effect: $CNR = 66.825999 + 0.081176X$, $R^2 = 0.79$; $ADC_{CP} = 0.449281 + 0.026238X$, $R^2 = 0.72$; $ADC_{DM} = 83.37588 – 0.0222084X$, $R^2 = 0.93$. Q: quadratic effect: $ADC_{DM} = 79.96706 + 0.112389X – 0.0011X^2$, $R^2 = 0.90$; $ADC_{CF} = 77.16519 + 0.24012X – 0.00188X^2$, $R^2 = 0.91$; $ADC_{GE} = 83.95486 + 0.096675X – 0.000723X^2$, $R^2 = 0.94$; $DE = 3772.681 + 8.042619X – 0.067172X2$, $R^2 = 0.99$; $ME = 3715.621 + 7.91908X – 0.065834X^2$, $R^2 = 0.98$; $ADC_{DM} = 89.7920 + 0.09553X – 0.00084X^2$, $R^2 = 0.79$; $ADC_{CF} = 76.25936 – 0.20407X + 0.00258X^2$, $R^2 = 0.77$.

muscle were observed for the gender-diet interaction. The 24-h *post mortem* pH of the SM and LL muscles was not influenced by diet or gender ($p>0.05$).

There were no differences in the technological quality of the LL samples (drip loss, cooking loss, and shear force) between treatments ($p>0.05$) for the diet or gender factor (Table 5).

A negative linear effect ($p<0.05$) was observed on the L* value, which corresponds to the degree of meat lightness, with an interaction between gender and diet. Males fed higher inclusion levels of SBM during the starter phase had meat with higher lightness values, while those receiving the starter diet with higher inclusion of MS had meat with lower lightness values (Table 5). In addition, there was a difference ($p<0.05$) in lightness (L*) between males fed the MS0 and MS25 diets during the nursery phase and females of the same groups, with higher lightness values in the former (53.54 and 51.35 for males *vs.* 48.06 and 47.53 for females, respectively). Redness values (a*) did not differ between treatments for the diet or gender factor ($p>0.05$). However, b* values (yellowness) were higher ($p<0.05$) in males compared to females (10.72 and 9.72, respectively) (Table 5).

There was a linear decreasing effect ($p<0.05$) on the retail cuts shoulder, boneless shoulder, boneless sirloin, and ribs, *i.e.*, the higher the inclusion level of MS in the starter diet of pigs, the lower the yield of these cuts. The remaining cuts evaluated, including nobles cuts such as ham and pork chops, were not influenced by the diet (Table 6). However, males had higher shoulder yield and higher rib weight than females ($p<0.05$). In addition, there was an interaction

**Table 3.** Average daily feed intake (ADFI), average daily weight gain (ADWG) and feed conversion (FC) of piglets from 21 to 63 days of age according to treatment.

| | Treatment, % | | | | | Reg | CV% |
|---|---|---|---|---|---|---|---|
| | **MS0** | **MS25** | **MS50** | **MS75** | **MS100** | | |
| | | | **21 to 35 days** | | | | |
| ADFI, kg | 0.33 | 0.31 | 0.29 | 0.26 | 0.24 | L* | 31.22 |
| ADWG, kg | 0.25 | 0.23 | 0.20 | 0.18 | 0.15 | L** | 34.85 |
| FC | 1.32 | 1.39 | 1.45 | 1.52 | 1.59 | L** | 12.92 |
| | | | **21 to 50 days** | | | | |
| ADFI, kg | 0.52 | 0.48 | 0.45 | 0.41 | 0.38 | L** | 21.59 |
| ADWG, kg | 0.35 | 0.32 | 0.29 | 0.26 | 0.24 | L** | 21.76 |
| FC | 1.48 | 1.50 | 1.53 | 1.56 | 1.58 | L** | 4.77 |
| | | | **21 to 63 days** | | | | |
| ADFI, kg | 0.76 | 0.72 | 0.68 | 0.64 | 0.60 | L** | 18.11 |
| ADWG, kg | 0.46 | 0.43 | 0.40 | 0.37 | 0.34 | L** | 17.50 |
| FC | 1.67 | 1.65 | 1.66 | 1.70 | 1.78 | NS | 4.25 |

CV%: coefficient of variation; Reg: regression. * Significant at $p<0.05$; ** significant at $p<0.01$; NS: nonsignificant ($p>0.05$). L: linear effect: (21 to 35 days) ADFI = 0.33194 – 0.000919X, $R^2$ = 0.81; ADWG = 0.25288 – 0.001008X, $R^2$ = 0.94; FC = 1.32057 + 0,002657X. $R^2$ = 0.82. (21 to 50 days) ADFI = 0.51774 – 0.00014X, $R^2$ = 0.87; ADWG = 0.34917 – 0.000111X, $R^2$ = 0.94; FC = 1.47914 + 0.00106X, $R^2$ = 0.81. (21 to 63 days) ADFI = 0.760314 – 0.00163X, $R^2$ = 0.92; ADWG = 0.4606 – 0.001199X, $R^2$ = 0.98.

between diet and gender for sirloin weight ($p<0.05$). A decrease in the weight of this cut was observed in females fed increasing levels of MS during the starter phase (Table 6).

# Discussion

## Chemical-bromatological composition

The chemical-bromatological composition found in the present study (39.14% CP and 21.50% CF for MS and 45.22% CP and 1.69% CF for SBM) (Table 1) is similar to that reported in the tables of Rostagno *et al.* (2011). The urease activity values for MS and SBM were within the reference range indicated by Sindirações (2013) (Table 1). Szmigielski *et al.* (2010) demonstrated that micronization is effective in reducing urease activity levels (from 2.0 to 0.10 ΔpH) without compromising protein content. The protein solubility values obtained for SBM were lower than the minimum of 75% recommended by Sindirações (2013). Excessive heating of the ingredient is known to denature proteins, which reduces protein solubility (Woyengo *et al.*, 2017). In the present study, the lower protein solubility of SBM compared to MS may have been responsible for the lower digestibility of the diets containing a higher level of SBM.

## Digestibility trial

The digestibility results obtained for the pre-starter I diet differ from those reported by Valencia *et al.* (2008) who studied the influence of particle size of SBM and full-fat soybean on the digestibility of diets for piglets at 23 days of age. The lower digestibility of diets with a higher SBM percentage can be attributed to the greater crude fiber content of this ingredient compared to MS (5.3 *vs.* 1.36% according to Rostagno *et al.*, 2011). The presence of fiber can negatively affect protein digestion because of the effect of the association with lignocellulose, which reduces protein availability (De Coca-Sinova *et al.*, 2008). On the other hand, the quadratic effect observed for $ADC_{DM}$, $ADC_{GE}$, $ADC_{CF}$, DE and ME might be related to the increase in dietary CF content with increasing replacement level of SBM with MS. Azain (2001) suggested that dietary fat reduces the rate of food passage through the gastrointestinal tract and consequently increases nutrient digestibility because of the longer exposure to digestive enzymes. This higher amount of fat may have exceeded the enzymatic capacity of the gastrointestinal tract of piglets at this age.

The lack of significant differences between variables (except $ADC_{DM}$ and $ADC_{CF}$ for the pre-starter II diet and $ADC_{DM}$ for the starter diet) agrees with the results reported by Berrocoso *et al.* (2014), who found no benefit of micronization of common SBM or high protein content. According to these authors, the effects of micronization appear to be clearer in studies on cereals compared to soybeans. Agunbiade *et al.* (1992) observed a higher digestibility coefficient of diets containing SBM and soybean oil compared to diets with full-fat soybean. The authors suggested that how this ingredient is present in the diet seems to be an important factor for the utilization of soybean products. Thus, the integral oil present in the plant cell may not be fully available for enzymatic digestion even after micronization.

**Table 4.** Residual effect of replacing soybean meal with micronized soybean during the starter phase on average daily feed intake (ADFI), average daily weight gain (ADWG) and feed conversion (FC) of pigs during the grower I and II and finisher phases.

| Variable | Gender | Treatment, % | | | | | | Reg | CV% |
|---|---|---|---|---|---|---|---|---|---|
| | | MS0 | MS25 | MS50 | MS75 | MS100 | Average | | |
| **64 to 91 days of age** | | | | | | | | | |
| ADFI, kg | Male | 1.93 | 1.94 | 1.89 | 1.80 | 1.86 | 1.88 A | | |
| | Female | 1.93 | 1.94 | 1.89 | 1.80 | 1.86 | 1.88 A | | |
| | Mean | 1.94 | 1.86 | 1.88 | 1.84 | 1.77 | | L* | 11.79 |
| ADWG, kg | Male | 0.86 | 0.86 | 0.87 | 0.88 | 0.86 | 0.87 A | | |
| | Female | 0.90 | 0.81 | 0.85 | 0.87 | 0.80 | 0.84 A | | |
| | Mean | 0.88 | 0.83 | 0.86 | 0.88 | 0.83 | | NS | 10.25 |
| FC | Male | 2.24 | 2.25 | 2.18 | 2.03 | 2.17 | 2.17 A | | |
| | *Female* | 2.18 | 2.20 | 2.20 | 2.16 | 2.13 | 2.17 A | | |
| | Mean | 2.21 | 2.22 | 2.19 | 2.10 | 2.15 | | L* | 7.25 |
| **64 to 119 days of age** | | | | | | | | | |
| ADFI, kg | Male | 2.32 | 2.32 | 2.30 | 2.20 | 2.21 | 2.27 A | | |
| | Female | 2.27 | 2.09 | 2.13 | 2.19 | 2.04 | 2.15 B | | |
| | Mean | 2.30 | 2.20 | 2.21 | 2.19 | 2.12 | | NS | 9.69 |
| ADWG, kg | Male | 0.97 | 1.00 | 1.02 | 0.96 | 0.98 | 0.99 A | | |
| | Female | 0.97 | 0.88 | 0.90 | 0.94 | 0.88 | 0.91 B | | |
| | *Mean* | 0.97 | 0.94 | 0.96 | 0.95 | 0.93 | | NS | 7.82 |
| FC | Male | 2.38 | 2.33 | 2.24 | 2.27 | 2.25 | 2.29 A | | |
| | Female | 2.34 | 2.36 | 2.37 | 2.33 | 2.33 | 2.35 A | | |
| | Mean | 2.36 | 2.35 | 2.30 | 2.30 | 2.29 | | NS | 5.17 |
| **64 to 140 days of age** | | | | | | | | | |
| ADFI, kg | Male | 2.51 | 2.50 | 2.49 | 2.38 | 2.40 | 2.46 A | | |
| | Female | 2.41 | 2.19 | 2.23 | 2.31 | 2.18 | 2.27 B | | |
| | Mean | 2.46 | 2.35 | 2.36 | 2.35 | 2.29 | | NS | 9.51 |
| ADWG, kg | Male | 0.99 | 1.01 | 1.03 | 0.96 | 0.99 | 1.00 A | | |
| | Female | 0.98 | 0.88 | 0.89 | 0.96 | 0.88 | 0.92 B | | |
| | Mean | 0.98 | 0.94 | 0.96 | 0.96 | 0.94 | | NS | 7.85 |
| FC | Male | 2.54 | 2.48 | 2.40 | 2.46 | 2.41 | 2.46 A | | |
| | Female | 2.47 | 2.50 | 2.50 | 2.40 | 2.46 | 2.47 A | | |
| | Mean | 2.50 | 2.49 | 2.45 | 2.43 | 2.44 | | NS | 5.26 |

CV%: coefficient of variation; Reg: regression. * Significant at $p<0.05$; NS: non-significant ($p>0.05$). Means in the same column followed by the same capital letter do not differ from one another by the F test at 5%. L: linear effect: ADFI = 1.9330 – 0.00145X, $R^2 = 0.88$; FC = 2.22671 – 0.00103X, $R^2 = 0.62$.

The effects of micronization on nutrient digestibility have not been fully elucidated. Although improving diet digestibility, the reduction in the particle size of the food may also affect gastrointestinal motility and function and health of the piglet (Berrocoso *et al.*, 2014). Thus, the two effects may oppose each other and the magnitude of the responses observed can vary among experiments and phases studied. Furthermore, the differences found in the nutrient and energy digestibility coefficients of the diets compared to those reported in the literature suggest lower digestibili-

**Table 5.** Residual effect of replacing soybean meal with micronized soybean during the starter phase on carcass and meat quality traits of pigs at 140 days of age.

| Variable | Gender | Treatment, % | | | | | | Reg | CV% |
|---|---|---|---|---|---|---|---|---|---|
| | | MS0 | MS25 | MS50 | MS75 | MS100 | Average | | |
| pH SM, 45 min[1] | Male | 6.02 B | 6.19 A | 6.25 A | 6.06 A | 6.05 B | 6.11 | Q# | |
| | Female | 6.29A | 6.26A | 6.05A | 6.18A | 6.27A | 6.21 | Q# | |
| | Mean | 6.16 | 6.22 | 6.15 | 6.12 | 6.16 | | NS | 3.14 |
| pH SM, 24 h[1] | Male | 5.64 | 5.75 | 5.66 | 5.61 | 5.80 | 5.69A | | |
| | Female | 5.82 | 5.70 | 5.60 | 5.50 | 5.86 | 5.70A | | |
| | Mean | 5.73 | 5.72 | 5.63 | 5.56 | 5.83 | | NS | 3.32 |
| pH LL, 24 h[2] | Male | 5.43 | 5.47 | 5.50 | 5.51 | 5.55 | 5.49A | | |
| | Female | 5.61 | 5.56 | 5.53 | 5.39 | 5.73 | 5.56A | | |
| | Mean | 5.52 | 5.51 | 5.51 | 5.45 | 5.64 | | NS | 3.03 |
| BW 140d, kg | Male | 99.16 | 99.60 | 101.29 | 93.20 | 97.47 | 98.14A | | |
| | Female | 102.39 | 92.76 | 91.43 | 97.93 | 87.83 | 94.46A | | |
| | Mean | 100.77 | 96.18 | 96.36 | 95.56 | 92.65 | | L# | 8.81 |
| HCW, kg | Male | 79.43 | 80.06 | 81.28 | 74.47 | 77.35 | 78.52A | | |
| | Female | 82.94 | 74.23 | 74.68 | 78.81 | 70.57 | 76.25A | | |
| | Mean | 81.18 | 77.14 | 77.98 | 76.64 | 73.96 | | L# | 8.97 |
| CCW, kg | Male | 77.93 | 78.31 | 79.54 | 73.03 | 75.85 | 76.93A | | |
| | Female | 81.07 | 72.77 | 72.76 | 76.96 | 69.33 | 74.58A | | |
| | Mean | 79.50 | 75.54 | 76.15 | 74.99 | 72.59 | | L# | 8.94 |
| CY, % | Male | 80.08 | 80.37 | 80.22 | 79.88 | 79.36 | 79.98B | | |
| | Female | 81.01 | 80.02 | 81.73 | 80.42 | 80.35 | 80.71A | | |
| | Mean | 80.55 | 80.19 | 80.97 | 80.15 | 79.86 | | NS | 1.73 |
| BT, mm | Male | 25.89 | 25.38 | 26.03 | 23.95 | 24.57 | 25.17A | | |
| | Female | 24.79 | 20.04 | 22.75 | 24.85 | 23.27 | 23.14B | | |
| | Mean | 25.35 | 22.71 | 24.4 | 24.4 | 23.92 | | NS | 11.28 |
| LEA, cm² | Male | 43.03 | 42.11 | 42.57 | 40.17 | 42.06 | 41.99A | | |
| | Female | 41.54 | 43.87 | 45.54 | 42.42 | 45.19 | 43.71A | | |
| | Mean | 42.29 | 42.99 | 44.06 | 41.29 | 43.62 | | NS | 14.24 |
| DL, % | Male | 7.08 | 5.60 | 5.84 | 7.01 | 4.92 | 6.09A | | |
| | Female | 5.31 | 5.70 | 5.44 | 7.83 | 4.91 | 5.84A | | |
| | Mean | 6.19 | 5.65 | 5.64 | 7.42 | 4.91 | | NS | 16.21# |
| CL, % | Male | 27.15 | 24.42 | 24.93 | 24.69 | 21.97 | 24.63A | | |
| | Female | 27.58 | 28.52 | 27.35 | 28.68 | 23.83 | 27.20A | | |
| | Mean | 27.36 | 26.47 | 26.14 | 26.69 | 22.90 | | NS | 23.96 |
| SF, kgf | Male | 2.51 | 2.64 | 2.93 | 2.98 | 2.31 | 2.68A | | |
| | Female | 2.55 | 2.88 | 2.67 | 2.57 | 2.32 | 2.60A | | |
| | Mean | 2.53 | 2.76 | 2.80 | 2.78 | 2.31 | | NS | 26.35 |
| Color | | | | | | | | | |
| L* | Male | 53.54A | 51.35A | 50.81A | 50.70A | 48.41A | 50.96 | L# | |
| | Female | 48.06B | 47.53B | 48.64A | 53.42A | 48.64A | 49.26 | | |
| | Mean | 50.80 | 49.44 | 49.72 | 52.06 | 48.52 | | NS | 6.72 |
| a* | Male | 2.24 | 2.45 | 1.96 | 2.51 | 2.04 | 2.24A | | |
| | Female | 2.10 | 1.72 | 1.60 | 1.96 | 2.34 | 1.94A | | |
| | Mean | 2.17 | 2.08 | 1.78 | 2.24 | 2.19 | | NS | 17.98 |
| b* | Male | 11.54 | 11.25 | 10.01 | 10.82 | 9.99 | 10.72A | | |
| | Female | 10.03 | 8.95 | 9.48 | 10.60 | 9.53 | 9.72B | | |
| | Mean | 10.79 | 10.10 | 9.75 | 10.71 | 9.76 | | NS | 11.38 |

CV%: coefficient of variation; Reg: regression. # Significant at $p<0.05$; NS: nonsignificant ($p>0.05$). Means in the same column followed by the same capital letter do not differ from one another by the F test at 5%. [1]pH of the semimembranosus muscle 45 min and 24 h *post mortem*; [2]pH of the *longissimus lumborum* muscle 24 h *post mortem*. BW: body weight at 140 days; HCW: hot carcass weight; CCW: cold carcass weight; CY: carcass yield; BT: backfat thickness; LEA: loin eye area; DL: drip loss; CL: cooking loss; SF: shear force; L*: lightness; a*: redness; b*: yellowness. Q: quadratic effect: pH SM 45 $min_{male} = 6.04589 + 0.0006379X – 0.000066X^2$, $R^2 = 0.64$; pH SM 45 $min_{female} = 6.31553 – 0.00695X + 0.000065X^2$, $R^2 = 0.66$. L: linear effect: BW = $78.62929 – 0.057485X$, $R^2 = 0.84$; HCW = $80.37357 – 0.0598X$, $R^2 = 0.82$; CCW = $78.62929 – 0.05748X$, $R^2 = 0.83$; CAL = $78.50067 – 0.02441X$, $R^2 = 0.86$; L*male = $53.14031 – 0.04358X$, $R^2 = 0.89$.

**Table 6.** Residual effect of replacing soybean meal with micronized soybean during the starter phase on the retail cut weight of finished pigs.

| Variable | Gender | Treatment, % | | | | | | Reg | CV% |
|---|---|---|---|---|---|---|---|---|---|
| | | MS0 | MS25 | MS50 | MS75 | MS100 | Average | | |
| Ham, kg | Male | 10.70 | 10.54 | 10.93 | 9.70 | 10.31 | 10.44A | | |
| | Female | 11.22 | 9.30 | 10.16 | 10.89 | 9.78 | 10.27A | | |
| | Mean | 10.96 | 9.92 | 10.55 | 10.29 | 10.04 | | NS | 12.52 |
| Pork chops, kg | Male | 7.08 | 7.20 | 7.08 | 6.91 | 7.09 | 7.07A | | |
| | Female | 7.54 | 6.98 | 6.66 | 7.26 | 6.37 | 6.97A | | |
| | Mean | 7.31 | 7.09 | 6.87 | 7.09 | 6.73 | | NS | 11.83 |
| Shoulder, kg | Male | 5.90 | 5.87 | 5.63 | 5.24 | 5.64 | 5.66A | | |
| | *Female* | 5.76 | 5.22 | 5.20 | 5.48 | 4.93 | 5.32B | | |
| | Mean | 5.83 | 5.54 | 5.42 | 5.36 | 5.29 | | L* | 9.97 |
| Boneless shoulder, kg | Male | 3.89 | 3.94 | 3.69 | 3.50 | 3.66 | 3.72A | | |
| | Female | 3.90 | 3.55 | 3.54 | 3.76 | 3.31 | 3.61A | | |
| | Mean | 3.85 | 3.75 | 3.62 | 3.63 | 3.48 | | L* | 11.54 |
| Sirloin, kg | Male | 2.68 | 2.94 | 3.10 | 2.57 | 2.72 | 2.80 A | | |
| | Female | 3.11 | 2.79 | 2.61 | 2.71 | 2.32 | 2.71 A | L* | |
| | *Mean* | 2.89 | 2.87 | 2.86 | 2.64 | 2.52 | | NS | 14.76 |
| Boneless sirloin, kg | Male | 1.74 | 1.91 | 1.99 | 1.68 | 1.74 | 1.81A | | |
| | Female | 2.02 | 1.81 | 1.72 | 1.90 | 1.41 | 1.77A | | |
| | Mean | 1.88 | 1.86 | 1.85 | 1.79 | 1.57 | | L* | 16.99 |
| Ribs, kg | Male | 4.29 | 4.46 | 4.64 | 4.09 | 4.23A | 4.34A | | |
| | Female | 4.46 | 3.94 | 3.99 | 3.92 | 3.81B | 4.03B | | |
| | Mean | 4.38 | 4.20 | 4.31 | 4.01 | 4.02 | | L* | 13.55 |
| Belly, kg | Male | 2.86 | 2.77 | 2.93 | 2.72 | 2.70 | 2.80A | | |
| | Female | 3.12 | 2.78 | 2.64 | 2.99 | 2.65 | 2.84A | | |
| | Mean | 2.99 | 2.78 | 2.78 | 2.85 | 2.68 | | NS | 13.77 |

CV%: coefficient of variation; Reg: regression. * Significant at $p<0.05$; NS: nonsignificant ($p>0.05$). Means in the same column followed by the same capital letter do not differ from one another by the F test at 5%. L: linear effect: Shoulder = 5.74314 – 0.00509X, $R^2$ = 0.89; Boneless shoulder = 3.83543 – 0.00338X, $R^2$ = 0.94; Sirloinfemale = 3.04028 – 0.00658X, $R^2$ = 0.83; Boneless sirloin = 1.92728 – 0.00271X, $R^2$ = 0.72; Ribs = 4.36671 – 0.001214X, $R^2$ = 0.73.

ty in weaned piglets compared to older animals whose gastrointestinal tract is more developed (Latorre *et al.*, 2004).

## Growth performance during the starter, growing and finishing phases

With respect to the starter phase (Table 3), the results corroborate those reported by Trindade Neto *et al.* (2002) who demonstrated superiority of SBM compared to other protein sources, assuming that this soy by-product triggers less damage to the piglet's digestive process and gastrointestinal system in the early stages of development. However, our findings differ from Berrocoso *et al.* (2014) who observed better FC in animals fed diets with micronized SBM compared to common SBM in the first week of the assay. Although soybean micronization is able to improve nutrient digestibility by improving the mixing with digestive enzymes, this process may also negatively affect gastrointestinal motility and function, as well as the "healthy" status of the piglet, compromising growth performance of the animal.

In general, feed intake was considered low during the starter phase (especially for the treatments containing a higher percentage of MS), which may have caused poor growth performance. According to Jha & Berrocoso (2015), newly weaned piglets do not consume the adequate amount of energy to meet their energy requirements for body weight gain, particularly during the first days after weaning, and may recruit fat reserves only to sustain their body weight. Another factor that may have affected feed intake during the starter phase is the fact that no flavoring was used in the diet. Diet intake by adult pigs is generally regulated so that energy needs can be met (Costa *et al.*, 2018), but the ability to adapt feed intake according to the energy content of the diet is variable in piglets. According to Valencia *et al.* (2008), palatability of the food is the factor that most influences the feed intake level during this stage of the piglet's life. It is possible that the palatability of MS was not acceptable, but scientific studies on this topic are scarce.

The texture of the diets with higher inclusion levels of MS may have also influenced feed intake. The processing and physical form of the diet directly influence the diet preference of newly weaned piglets. Completing this reasoning, after weaning, feed intake is basically controlled by palatability, which mainly includes flavor, but can also be estimated by the texture and physical properties of the dietary ingredients (Lee *et al.*, 2019). As reported by Solà-Oriol *et al.* (2009) and also observed in studies on infants and children, they reject foods that are difficult to move around in the mouth and that take longer to be swallowed. It is possible that foods that require fewer chewing movements are also preferred by newly-weaned piglets. These authors also emphasized that, for piglets, particle size seems to be less important than the texture of the foods. In view of these considerations, the higher fat content of the diets containing MS may have altered their texture, with a subsequently negative influence on feed intake.

Although the urease activity and protein solubility values obtained were within the acceptable range (Table 1), other ANF that were not analyzed could have affected food utilization by the animal because they possess heat resistance features and consequently the growth performance of piglets in this study, in addition the amount of ANF consumed daily is more important than their concentration in the ingredient or diet (Woyengo *et al.*, 2017).

The high fat content of the diets, especially in the early stages, may have influenced the results of the present study. Trindade Neto *et al.* (2002) attributed the poor growth performance of piglets fed diets with ground full-fat soybeans to their high fat content, which would exceed the piglet's digestive capacity at this stage of life. According to Adeola & Cowieson (2011), the total fat digestive capacity is not reached until 40 kg of body weight. In addition, a marked reduction in the activity of different digestive enzymes such as lipase is observed immediately after weaning.

Regarding the subsequent phases (growing/finishing), animals fed diets with higher inclusion of MS entered the grower phase with a lower body weight. Thus, the lower feed intake observed from 64 to 90 days of age in animals previously fed increasing levels of MS would be due to lower body weight (lower gastric capacity) and the better feed efficiency would be related to the higher rate of protein deposition, which is more intense in smaller animals and requires twice less energy than that needed for the deposition of adipose tissue (Pierozan *et al.*, 2016).

Latorre *et al.* (2004) reported higher feed intake and weight gain of male pigs during the growing and finishing phases compared to females of the same age. This fact might be explained by the greater intake capacity and lower maintenance requirements of males.

Good growth performance of piglets in the early stages of growth depends on many factors, including weight upon entry to the nursery, existence of some nutrient restriction, feed intake, health status of the animals, diet composition and digestibility, and the presence of ANF (Jha & Berrocoso, 2015; Woyengo *et al.*, 2017). Thus, considering the same sanitary standards, homogeneous weight at the beginning of the treatments and formulation of diets that were approximately isoproteic and isoenergetic and that met the nutritional requirements of this phase, the factors that could have compromised the animals' growth performance during the previous phase would be the low feed intake, digestibility of MS, or ANF.

## Carcass and meat quality traits

The pH measured 45 min and 24 h after slaughter is one of the parameters most used in slaughterhouses to predict meat quality because of its reliability and easy application. In addition, studies have demonstrated an association between pH values at 45 min and 24 h and the results of technological meat evaluations, such as water retention capacity, color, and drip loss. Quality standard pork is defined when the pH 45 min is between 6.0 and 6.5 and the pH 24 h between 5.5 and 5.8 (Costa *et al.*, 2018). Hence, despite the significant difference in pH at 45 min, with an interaction between gender and diet, these values were within the reference range. These findings show that the inclusion of MS in the starter diet for piglets did not influence the conversion of muscle to meat. The measurement of meat color is essential to ensure attractiveness by consumers. In addition, color measurement assists in the diagnosis of PSE (pale, soft, exudative) and DFD meat (dark, firm, dry). AMSA (2012) established normal L* values for pork meat between 49 and 60. However, other authors defined a L* value between 43 and 49 as normal meat (Bridi *et al.*, 2008; Garbossa *et al.*, 2013). Thus, considering the latter reference, male pigs fed SBM had a L* value outside the expected range, while the L* values were within the range for quality pork meat according to the first reference.

With respect to lightness, males of the MS0 treatment had meat with greater lightness, *i.e.*, paler meat. In addition, males fed the MS0 and MS25 diets in the early stages had meat with greater lightness when compared to females of the same group. Genetic factors, production system, feeding, age, and the final pH of meat can exert important effects on the L*, a* and b* values. These values also tend to change with increasing slaughter weight due to the greater muscularity of the animal (Costa *et al.*, 2018). With development of the muscle, the amount of myoglobin increases, fat deposition becomes more evident, and the amount of water in the muscle decreases, consequently reducing lightness. This fact was not observed in the present study since feeding males higher levels of SBM during the starter phase benefitted their growth performance, resulting in larger pigs with more intense muscle activity, which would favor myoglobin accumulation and fat deposition and consequently result in meat with lower lightness (Garbossa *et al.*, 2013).

The drip loss values found for animals fed diets with higher SBM levels during the starter phase were above those proposed by Bridi *et al.* (2008) for fresh pork meat, who recommend a drip loss of up to 6%. However, other authors define a drip loss of about 9.8% for normal pork meat and of about 12.9% for PSE meat (Latorre *et al.*, 2004).

Taken together, the pH 24 h, L* value and drip loss of animals fed higher inclusions of SBM during the starter phase suggest the occurrence of PSE meat, which would explain the presence of meat with greater lightness. However, considering the literature, the lack of a sudden pH drop within the first 45 min *post mortem* and the fact that pH values at 24 h *post mortem* were close to those recommended by more rigorous references and that the cooking loss was within the quality standard, we conclude that no PSE meat occurred. Similarly, the DFD classification cannot be applied to the present study since the meat derived from the treatments evaluated had a L* value>42, drip loss ≥ 5%, and final pH<6.0 (Bridi *et al.*, 2008).

Analysis of the carcass traits of animals fed the MS100 diet showed that the lower final body weight of these animals resulted in a reduction of 8.22% in rib weight, of 9.26% in shoulder weight, of 9.6% in boneless shoulder weight, and of 16.48% in boneless sirloin weight. In addition, females fed the diet with MS inclusion exhibited a linear reduction in the weight of the sirloin, with the observation of a 25.4% decrease in treatment MS0 compared to MS100.

With respect to gender, the quality of carcasses from barrows was lower than that of female carcasses because of the higher amount of fat and lower carcass yield (about 0.9% lower) in the former. According to Bridi *et al.* (2008), castrated male pigs fed similar diets as females will exhibit a poorer carcass quality (lower carcass yield and greater fat deposition) at the same slaughter age. This fact was also observed in the present study in which backfat thickness in males was 8.77% higher than in females. Higher fat thickness values in males have also been reported by other authors (Peinado *et al.*, 2008). Studies suggest that fat deposition is favored in males compared to females because of higher feed intake (Costa *et al.*, 2018) and the lack of production of testicular steroids.

Rib and shoulder weights also differed ($p<0.05$) between genders, with the observation of a higher weight of these cuts in barrows. Taken together, the results show that animals fed the MS0 diet had a higher weight of some cuts and females exhibited better carcass traits. However, it is important to note that carcass yield and ham and pork chops weight, which are considered noble cuts with a high added value, were not influenced by the diets tested.

In the present study, the lower weight upon entry to the growing phase demonstrates poor growth performance of animals receiving increasing levels of MS during the starter phase. Literature data (Trindade Neto *et al.*, 2002) and those obtained in this study show that the growth performance of animals during the starter phase influences subsequent phases. In this respect, the poor growth performance of animals fed increasing levels of MS in the early stages of growth, despite their better FC in the grower I phase, did not influence the other phases and did therefore not compensate for the losses observed at the beginning of their productive life, resulting in lower slaughter weight, cold and hot carcass weight, and lower retail cut weights.

# Authors' contributions

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