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Respuesta de cerdos en engorde a dietas con soja integral desactivada artesanalmente

Respuesta de cerdos en engorde a dietas con soja integral desactivada artesanalmente

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Abstract

The response of pigs receiving handmade deactivated soybean in isoenergetic and isonitrogenous corn-based diets was evaluated. Twenty-eight barrows between 40 and 105 kg live weight were assigned to four treatments varying supplemental protein: T1: soybean meal, T2: cooked soybean, T3: roasted soybean, T4: raw soybean. Daily intake (CD) and total intake (CT) of food, daily weight gain (GP), feed conversion index (IC), dressing percentage (R), carcass lenght (L), backfat thickness (GD) and lipid profile of the fat (PL) were evaluated. T4 animals had lower CD ($P \leq 0.01$) but no differences in CT. The GP was higher ($P \leq 0.01$) for T1, with no difference between T2 and T3, and less for T4. T1 had better IC than T4 ($P \leq 0.01$) and T2 and T3 ($P \leq 0.05$), while T4 was lower ($P \leq 0.01$). No differences were observed for R or GD; while L was higher ($P \leq 0.01$) for T1. Differences in PL, with higher content of PUFA and oleic, linoleic, linolenic in the treatments including whole soybean ($P \leq 0.01$) were observed. We concluded that the treatments used to deactive soybeans improved their nutritional value, although the results of the control diet were not achieved. Carcass from diets with whole soybeans have less industrial value, but better nutritional value for fresh consumption than those based on soybean meal.

Keywords: swine nutrition, soybeans deactivation methods, carcass quality, lipid profile

Resumen

Se evaluó la respuesta de cerdos a soja desactivada artesanalmente en dietas isoenergéticas e isoproteicas en base a maíz. Se utilizaron 28 machos castrados entre 40 y 105 kg de peso vivo asignados a cuatro tratamientos variando el suplemento proteico: T1: harina de soja, T2: poroto de soja cocido, T3: poroto de soja tostado, T4: poroto de soja crudo. Se evaluaron: consumo diario (CD) y total (CT) de alimento, ganancia diaria de peso (GP), índice de conversión (IC), rendimiento de carcasa (R), largo de res (L), espesor de grasa dorsal (GD), perfil lipídico de la grasa dorsal (PL). Los animales del T4 presentaron menor CD ($P \leq 0,01$) sin diferencias en el CT. La GP fue mayor ($P \leq 0,01$) para T1, sin diferencias entre T2 y T3 y menor para T4. T1 tuvo mejor IC que T4 ($P \leq 0,01$) y T2 y T3 ($P \leq 0,05$) mientras que T4 fue inferior ($P \leq 0,01$). No se observaron diferencias en R ni GD, mientras que L fue mayor ($P \leq 0,01$) para el T1. Se observaron diferencias en PL, con mayor contenido en PUFA y en los ácidos oleico, linoleico y linolénico en los tratamientos incluyendo poroto de soja integral ($P \leq 0,01$). Se concluye que los tratamientos realizados al grano de soja mejoraron su valor nutricional con respecto al poroto crudo, aunque no se igualaron los resultados de la dieta testigo. Las carcasas provenientes de dietas con poroto de soja integral presentan menor valor industrial, pero mejor valor nutricional para consumo fresco que las basadas en harina de soja.

Palabras clave: alimentación de cerdos, métodos de desactivación de soja, calidad de carcasas, perfil lipídico

Introduction

Soybean production in Uruguay has seen an increase associated with the expansion of sown areas and productivity. Soybean area transformed from 7 thousand tons in the agricultural year 1999/2000 to 1:817 thousand tons in 2010/2011 (Ferrari, 2012), driven by the increase in global demand and prices of oils and flours caused by the development of biofuels (Souto, 2011).

Currently, in Uruguay, there are several co-products derived from the processing of soybeans for the production of biodiesel (Hernández, 2008).

On the market, there is also whole grain soybean, deactivated by heating or extruded, as well as raw whole grain, which must go through a deactivation process for use in animal feed.

The soybean is classified as a protein and energy supplement (Solano and others, 2012), valuable for its contribution of lysine, linoleic acid and choline (de Blas and others, 2003; Wijeratne, 2005; Echegaray, 2006; Cervantes-Pahm and Stein, 2008).

Soybean oil has 54% linoleic acid (18:2) and 8% linolenic acid (18:3) (Navarro, 1993; de Blas and others, 2003), determining its nutritional value (Bañón and others, 2000).

Soy contains less than 1% starch and 6-8% soluble sugars and has about 6% non-starchy carbohydrates, oligosaccharides (de Blas and others, 2003; Van Kempen and others, 2006).

Soybean also has anti-nutritional factors: trypsin inhibitors (or Kunitz and Bowman-Birk factors), which form stable, inactive complexes with trypsin and chymotrypsin, causing its production to increase, causing pancreatic hypertrophy and greater endogenous losses (Han and others, 1991; Huisman, 1991; Fan and others, 1995); lectins, thermolabile glycoproteins that damage the intestinal mucosa increasing endogenous losses (Bellaver, 1999; Palacios and others, 2004); thermostable antigenic factors (glycinin and β-conglycinin) that cause villous atrophy with reduced absorption and diarrhea (Li and others, 1991; Braun, 2000; from Blas and others, 2003).

Herkelman and others (1992) and Zollitsch and others (1993) mention that at least 80% of inhibitors must be inactivated for use in animal feed. As most are thermolabile, a heat treatment is carried out (Bellaver, 1999) establishing an optimal range between 80 and 100 °C since, according to Ramos and others (2006), treatments higher than 100 °C cause loss of nutritional value, and they are insufficient below 70 °C.

The effectiveness of the deactivation depends on the performance conditions, especially the treatment times and temperature management (Ramos and others, 2006; Hirigoyen and others, 2010; Bratschi and others, 2010; González and others, 2010).

The Urease Activity Index (UAI) and the Nitrogen Solubility Index (NSI) are used to control the quality of thermal processing (Gaviria Restrepo, 2003). The UAI is based on the fact that heat denatures urease and trypsin inhibitors in similar proportions (Bellaver, 1999) establishing an acceptability range between 0.05 and 0.20 of pH increase (Ramos and others, 2006).

Overheating can cause even greater protein damage than lack of processing (Van der Poel and Melcion, 1995). To detect them, the Protein Solubility Index (NSI) or the Protein Dispersibility Index in water (PDI) are used (Araba and Dale, 1990; de Blas and others, 2003). A treatment is optimal when the PDI of products ranges between 15 and 30% (Gaviria Restrepo, 2003; Ramos and others, 2006)

Raw whole soybean causes a quadratic decrease in pig yields when it replaces increasing percentages of soybean meal, due to the lower digestibility of protein (Pontif and others, 1987; Southern and others, 1990). Heat treatments improve results compared to using raw beans, but the digestibility and performance values of diets based on soybean meal are not always achieved (de Blas and others, 2003; Opapeju and others, 2006; Bauza and others, 2007; González and others, 2010, 2011, 2014), attributable to insufficient inactivation of anti-nutritional factors.

The energy source changes with high levels of whole soybean, a product with greater contribution of DE, around 4280 kcal/kg (de Blas and others, 2003) in the diet, being lipids more important than carbohydrates (Leszczynski and others, 1992a), with changes in the Energy/Protein ratio of the diet, causing some differences in the performance results. Cannon and others (1992), Leszczynski and others (1992a), Zollitsch and others (1993), and Shelton and others (2001) observed no differences in the performances of finishing pigs when they replaced soybean meal with deactivated whole-grain beans by different methods (roasted, extruded or cooked) working with isoenergetic diets.

Muscle development in pigs receiving raw whole-grain soybeans was lower than in pigs receiving diets with soybean meal, improving when supplemented with lysine, tryptophan and threonine (Southern and others, 1990).

Shelton and others (2001) observed that the whole soybean extruded as the only supplement in isoprotein (but not isoenergetic) diets for fattening pigs produces carcasses with higher backfat content, without changing the intramuscular fat content (Bañón and others, 2000; Leszczynski and others, 1992b; Warnants and others, 1999; Apple and others, 2009).

Diets high in whole soybean produce changes in the fat composition of bacon, with a significant increase in the content of polyunsaturated fatty acids (Leszczynski and others, 1992b; Zollitsch and others, 1993; Spiner and others, 1994) without many differences in the content of saturated fatty acids producing a change in the PUFA:SFA ratio compared to a conventional diet (Warnants and others, 1999; Apple and others, 2009). The greatest changes are observed in 18-carbon fatty acids with increased linoleic acid, offset by a reduction in oleic acid and an increase in α-linolenic acid (18:3) (Leszczynski and others, 1992b; Apple and others, 2009).

A poor industrial quality fat is generated, soft and with high potential for rancidity (Pontif and others, 1987; Zollitsch and others, 1993; Bañón and others, 2000; Apple and others, 2009), but in turn, the α-linolenic acid is a member of the fatty acid series ω-3, of recognized interest for its health benefits (Cannon and others, 1992; Leszczynski and others, 1992b).

De Blas and others (2003) and Yacentiuk (2010) recommend from 90 kg of weight, not to exceed 10% of whole-grain soybeans, in combination with corn, to 20% with another cereal, in order to avoid the risk of deterioration of fat quality,

Within the framework of the project on the evaluation of the nutritional value of soybeans, carried out at the Agronomy College with CSIC funding, a wood-fired roaster and a gas cooking system were designed and put into operation, carrying out adjustment tests until obtaining a handcrafted product that meets the acceptability levels.

This study aimed to evaluate the performance, the characteristics of the carcasses and the lipid profile of the backfat of pigs receiving diets containing, as the only complementary protein source, soybean cooked in water or roasted to deactivate the anti-nutritional factors, quantifying the results obtained compared to the raw bean and relative to a standard diet of corn and soybean meal.

Material and methods

The trial was conducted between October 2010 and January 2011 at the Pig Test Station of the Agronomy College in Montevideo.

Four isoenergetic and isoprotein diets were evaluated using different soy grain treatment products. These were:

T1: conventional diet based on corn and soybean meal (positive control).

T2: diet with corn and soybean deactivated by cooking.

T3: diet with corn and soybean deactivated by roasting.

T4: diet with corn and raw soybean (negative control).

Evaluated feed

The soybean meal used as a "positive control" corresponds to an oil extraction flour by pressing and solvent, acquired in the local market.

The raw soybean was acquired at COOPAGRAN in the city of José Enrique Rodó, taken from the cooperative's storage silos, from the 2010 harvest. This bean was used raw and processed for the evaluated deactivating treatments.

The whole soybean deactivated by roasting was heated in a manually operated, wood-fired toaster, for 30 minutes (Figure 1). According to previous tests (Bratschi and others, 2010) the temperature was kept around 85 °C, managing the intensity of the fire and the rotation speed of the drum. The roasted bean was ground before mixing with the rest of the ingredients that made up the diet.

The whole soybean deactivated by cooking was obtained through Lon Wo's indications (2007) and based on the results presented by Hirigoyen and others (2010). The beans were subjected to a soaking process for 4 h in a 2:1 water:bean ratio and then cooked in boiling water for 30 minutes. Cooking was carried out in a bowl heated by a gas nozzle (Figure 2). The cooked bean was used in the 48 hours following its preparation to avoid fermentation risks, given its consistency it was not necessary to grind, incorporating it directly into the premix with the rest of the ingredients.

Figure 1. Wood roaster used in the trial.

Figure 2. Gas heater and bowl used for cooking the soybeans.

Table 1 presents the results of chemical composition analyses performed in the animal nutrition laboratory on the products evaluated in the trial.

Table 1. Chemical composition of the soy products used (1).

	Meal	Cooked bean	Roasted bean	Raw bean
Dry matter (DM) %	87.25	38.81	89.22	88.61
% on dry basis				
Crude Protein	46.99	38.6	39.5	39.3
Ether Extract	2.41	15.32	16.25	15.56
Urease activity index	0.00	0.04	0.03	2.56

(1) Analyses carried out in the Animal Nutrition Laboratory of the Agronomy College.

Table 2. Percentage and chemical composition on a dry basis of the rations used in rearing.

Ingredients %	T1	T2	T3	T4
Corn	69.00	58.00	59.00	59.00
Defatted rice bran	——	6.00	6.00	6.00
Soybean meal	27.50	——	——	——
Cooked soybean	——	32.50	——	——
Roasted soybean	——	——	31.50	——
Raw soybean	——	——	——	31.50
Vitamin-mineral concentrate	3.00	3.00	3.00	3.00
Table salt	0.50	0.50	0.50	0.50
Nutrient supply (*)				
Dry matter %	86.30	55.51	87.65	87.61
Crude Protein %	17.92	17.93	17.90	17.93
Digestible energy (Mcal/kg DM) (**)	3.40	3.43	3.44	3.44

(*) Based on the analyses carried out in the Animal Nutrition Laboratory of the Agronomy College.
(**) Calculation of GE from chemical composition and combustion heats; DE by NRC equation (2).

Table 3. Percentage and chemical composition on a dry basis Dof rations used in rearing.

Ingredients (%)	T1	T2	T3	T4
Corn	37.50	35.00	35.00	35.00
Sorghum	38.00	34.50	34.50	34.50
Defatted rice bran	———	1.00	1.00	1.00
Soybean meal	21.00	———	———	———
Cooked soybean	———	26.00	———	———
Roasted soybean	———	———	26.00	———
Raw soybean	———	———	———	26.00
Vitamin-mineral concentrate	3.00	3.00	3.00	3.00
Table salt	0.50	0.50	0.50	0.50
Nutrient supply (*)				
DM %	87.25	67.89	88.89	87.37
Crude Protein %	15.84	15.71	15.92	15.87
DE (Mcal/kg of DM) (**)	3.47	3.51	3.56	3.52

(*) Based on the analyses carried out in the Animal Nutrition Laboratory of the Agronomy College. (**) Calculation of GE from chemical composition and combustion heats; DE by NRC equation (2).

Animals: 28 barrows, of the same genetic type (Large White x Landrace hybrid), acquired in commercial husbandry, were used, which were randomly allocated at the rate of seven animals per treatment. The evaluated pigs were in the range of 42.4 (± 2) to 101.4 (± 3.2) kg of live weight, identifying two stages: rearing, up to 61.2 (±1.91) kg, and finishing, from 61.2 (±1.91) kg to final weight.

Accommodation and experimental management conditions: the animals were housed in individual pens, with concrete floors, located on the roofed premises of the Pig Testing Station of the Sayago Farm of the Agronomy College (Figure 3). The pens had an automatic dummy-type drinker for ad libitum supply of drinking water and pan-type concrete troughs. The ration supply was ad libitum, with weekly intake control.

Figure 3. Pigs in individual pens at the Pig Testing Station.

Feeding was carried out manually, once a day, removing and weighing the leftovers if any. Dry matter was determined in the leftovers for the purpose of making intake corrections. Weekly weight control was performed: animals were weighed every seven days, before feeding, in the early morning.

Slaughter and carcass evaluation: when the animals reached the final weight of the trial, they were moved and slaughtered in Matadero Puerto del Sauce. The weight of entry to the slaughterhouse was determined and, at the end of the slaughter line, the weight of the hot carcasses was recorded, with head, to determine yield. Carcasses were transferred to BELISAR SA's cutting plant, after cooling, where, carcass length (from the front edge of the first rib to the center of the pubic symphysis) was measured with a measuring tape on the hanging left half-carcass, as well as backfat thickness (average of the measurements on the dorsal midline at the points corresponding to the last rib and gluteus medius muscle).

Fat composition: in the cutting plant, subcutaneous fat samples were collected from four carcasses per treatment of animals receiving the experimental diets, on the dorsal line of the left half-carcass, at the level of the last rib. They were frozen and sent to the Fats and Oils Laboratory of the Chemistry College for determination of lipid profile by gas chromatography. The lipids extraction was done at room temperature with hexane:isopropanol in a 3:2 ratio.

The extracted fat was derivatized according to the IUPAC 2.301 technique to obtain the methyl esters and then the analysis was carried out by gas chromatography (according to AOCS Ce 1c-89, AOCS Ce 1f-96 technique). A Shimadzu equipment model 14B was used, equipped with a Supelco SP-2560 capillary column.

Parameters evaluated: for each of the periods and the whole trial, the performance parameters evaluated were: average daily intake expressed as a kilogram of feed intake in each period/number of days in the period and evolution of the average weekly daily intake throughout the trial); growth rate (weight gain in the period considered/the number of days in the period, expressed in g/day) and feed conversion rate (kg of food necessary for 1 kg of weight gain). In order to obtain comparable information between treatments, the intake data were corrected to a standardized feed value with 90% DM. Hot yield with head, carcass length and backfat thickness, were calculated with the slaughter data. From the analysis of the backfat samples, the relationships between saturated, monounsaturated and polyunsaturated fatty acids, expressed as a percentage of total fatty acids, were evaluated; and the concentration of stearic, oleic, linoleic and linolenic fatty acids was studied for each of the feeding systems evaluated.

Model and statistical analysis

A random parcel design was applied, with the observation unit being each animal or carcass. The adjusted model corresponds to a random variable with normal distribution, with the following general formula:

$$y_{in} = \mu + D_i + \varepsilon_{in}$$

where:

y_{in} the response variable; D_i the effect of the soybean by-product used; ε_{in} the experimental error. Results were analyzed through the F test with precision levels of 1 and 5%, performing, in case of finding significant differences, the means comparison using the test of least significant difference (LSD) at the same significance levels.

Results and discussion

Performances

Performance results are presented in Table 4.

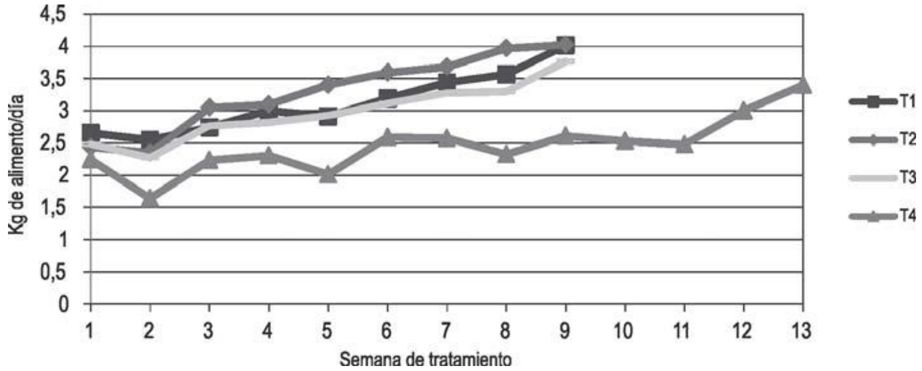
Table 4. Performance results.

	T1	T2	T3	T4
Rearing period				
Daily feed intake (kg)	2.73 ± 0.16 A	2.62 ± 0.17 A	2.63 ± 0.18 A	2.20 ± 0.25 B
Growth rate (g/day)	741 ±93A	564 ±92B	618 ±30B	472 ±77C
Conversion ratio (kg/kg)	3.73 ± 0.62 A	4.64 ± 0.65 B	4.24 ± 0.22 A	4.70 ± 0.36 B
Finishing period				
Daily feed intake (kg)	3.49 ± 0.22 A	3.58 ± 0.15 A	3.44 ± 0.42 A	2.71 ± 0.24 B
Growth rate (g/day)	1063 ± 65 Aa	973 ± 61 Ab	980 ± 75 Ab	639 ± 110 Bc
Conversion ratio (kg/kg)	2.82 ± 0.33 Aa	3.26 ± 0.39 Abc	2.98 ± 0.48 Aa	3.84 ± 0.48 Bc
Total period				
Daily feed intake (kg)	3.16 ± 0.22 A	3.08 ± 0.15 A	2.99 ± 0.42 A	2.46 ± 0.24 B
Growth rate (g/day)	933 ±43A	801±74B	807±70 B	550±95 C
Conversion ratio (kg/kg)	3.05 ± 0.27 Aa	3.61 ± 0.45 Ab	3.36 ± 0.30 Aab	4.23 ± 0.46 Bc

Aa: averages followed by different subscripts differ significantly ($P \leq 0.01$ and 0.05, respectively).

Pigs receiving the T4 diet had lower daily feed intake ($P \leq 0.01$), attributable to the presence of antinutritional factors that affect the palatability of raw beans, an aspect mentioned by Pontif and others (1987), Southern and others (1990), Cannon and others (1992), Gallardo and Gaggioti (2003) and consistent with the UAI values determined in the soybean products used (Table 1). In the case of diets containing handcrafted deactivated beans, no differences were observed in the daily intake of dry matter relative to the soybean meal diet, also explained by the low concentration of antinutritional factors in these products. In the case of T2, fresh feed intake was higher (3.97 kg) than in the T1 and T3 diets, since the animals adjusted their intake to compensate for the lower DM content of the ration offered. Figure 4 shows the evolution of the average weekly daily intake of the diets under study. Coinciding with what was observed by Cannon and others (1992), Leszczynski and others (1992a), Zollitsch and others (1993) and Shelton and others (2001), with the use of isoenergetic diets, there are no differences in intake mentioned by Shelton and others (2001) and Palacios and others (2004), attributable to the higher energy density generated by the higher lipid content of the whole bean when the direct substitution of meal by deactivated whole grain in isoprotein diets is carried out.

Figure 4. Evolution of daily feed intake.



Animals receiving the control diet presented the highest growth rate (P≤0.01), reaching the slaughter weight in 10 weeks, while those who received the diets with deactivated integral beans took one more week.

The highest growth rate of T1 animals occurred mainly in the rearing stage (Table 4), and taking into account that there were no differences in feed intake, we associate it with a better contribution in amino acids available from the diet with meal, an aspect raised by Southern and others (1990).

On the other hand, the fattening period of the pigs receiving the T4 diet (negative control) with raw beans lasted for 14 weeks, the test being interrupted without the animals reaching the 102 kg established in the protocol. The daily weight gain of T4 (550 g/day) was almost half of T1 (933 g/day), which is associated with lower consumption of this diet and worse efficiency in its use. Pontif and others (1987) and Southern and others (1990) observed that the raw whole soybean causes a quadratic decrease in pig performances when it replaces increasing percentages of soybean meal, which the authors attribute to the lower digestibility of the protein. These results are a reflection of the presence of anti-nutritional factors, that affect the palatability and digestibility of diets, as mentioned by Cannon and others (1992) and González and others (2010, 2014). In this trial, meal was completely substituted by whole grain bean, which would explain the importance of the differences observed between treatments.

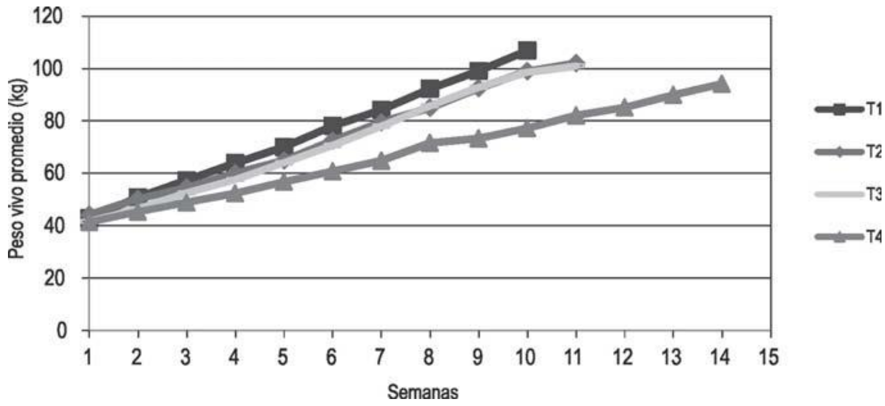
No differences were observed between the treatments containing handcrafted deactivated soybean, but both were lower than the control (P≤0.01).

This result coincides with the assessments of de Blas and others (2003); Opapeju and others (2006); Bauza and others (2007) and González and others (2010, 2011, 2014), who affirm that with heat treatments the results improve compared to using raw beans, but the values of digestibility and performance of diets based on soybean meal are not always reached, which is attributed to an insufficient or inadequate inactivation of anti-nutritional factors.

These limitations can be attributed both to incomplete inactivation and to a negative effect of heating on protein quality, especially on lysine availability, an aspect mentioned by Gaviria Restrepo (2003) and Ramos and others (2006). The difficulty to obtain a uniform degree of heating/inactivation in the different batches of elaboration is noteworthy, especially when roasting with firewood, coinciding with the assertions of Roger and others (2003) regarding the difficulty of generalizing conclusions when it comes to the effectiveness of handcrafted inactivation treatments.

From the practical point of view, this fact translates into one more week of fattening time, on average (Figure 5), an aspect that may not be of much importance as long as the feed acquired is cheaper than the control diet.

Figure 5. Evolution of live weight per treatment.



Regarding the Dry Matter Conversion Index, the results obtained indicate significant differences (P≤0.01) in the diets with treated bean or soybean meal relative to T4, which was lower than the rest. Significant differences were detected (P ≤0.05) in the diet with meal compared to the deactivated by cooking, while the treatments with handcrafted deactivated beans do not differ from each other. This result is consistent with what has already been observed for the parameters of intake and weight gain, coinciding with that observed by Zollitsch and others (1993), Bauza and others (2007) and Yacentiuk (2010).

To sum up, the performance results obtained with the diet with untreated beans leave no doubt about its inconvenience, given that not only does it take 50% longer to reach the slaughter weight, but its cost in kg of feed is also 30% higher than the meal or the other deactivation methods evaluated, which does not justify its adoption even in a position to obtain this product at a very low cost.

With the diets containing handcrafted deactivated beans, the values of weight gain or efficiency obtained with the control diet are not achieved, which would be demonstrating that these processes were not sufficiently effective. However, a significant improvement in performance is achieved with respect to diets including untreated beans. The convenience of using these products will depend on the economic analysis in each situation, especially considering the possibility of using locally obtainable soybean at a low cost, deactivated by their own users.

Carcasses

The carcasses (Table 5) of the T1 pigs were longer, which could be explained by the higher growth observed in the initial stages. No differences were observed for hot yield or backfat thickness, despite the higher lipid content in diets containing whole soybean compared to the soybean meal diet, possibly as a result of maintaining similar energy and protein levels between treatments. Southern and others (1990), Cannon and others (1992), Shelton and others (2001), and Capra and others (2007b) had reached similar results, as well as Bratschi and others (2011).

Table 5. Carcass characteristics

	T1	T2	T3	T4
Hot yield %	75.64 ± 1.89 Aa	77.05 ± 1.36 Aa	75.96 ± 2.84 Aa	76.29 ± 2.17 Aa
Carcass length (cm)	87.02 ± 0.89 A	83.14 ± 3.44 B	83.29 ± 2.36 B	81.63 ± 0.9 B
Backfat thickness (mm)	26.38 ± 3.68 Aa	28.47 ± 2.80 Aa	27.52 ± 1.52 Aa	26.67 ± 2.41 Aa

Aa: averages followed by different subscripts differ significantly (P≤0.01 and 0.05, respectively).

Lipid profile

The lipid profile of the backfat (Table 6) of pigs receiving diets containing whole soybean, deactivated or raw, presented differences in its composition compared to the animals that received soybean meal as a protein source. The concentration of saturated fatty acids did not differ between treatments, but the relative proportion between individual fatty acids varied, with a higher palmitic acid content (P≤0.05) in pigs receiving soybean meal.

Table 6. Lipid profile of backfat

	T1	T2	T3	T4
Saturated %	37.27 ± 3.81 A	35.42 ± 0.64 A	33.46 ± 3.03 A	32,36 ± 1,41 A
Monounsaturated %	45.35 ± 1.32 A	43.23 ± 0.65 A	40,67± 4,57 A	42,19 ± 1,26 A
Polyunsaturated %	14.01 ± 2.01 A	19.36 ± 1.89 B	24,21 ± 2,37 B	24,89 ± 0,91 B
PUFA:SFA ratio	0.38A	0.55 B	0.72 B	0.77 B
Stearic acid %	11.59 ± 2.19 A	13.33 ± 1.53 A	11.68± 2,51 A	10,08 ± 1,03 A
Palmitic acid %	23.28 ± 2.09 a	20.75 ± 1.89 b	21.34 ± 2.37 b	21.09 ±0 .91 b
Oleic acid %.	42.99 ± 0.97 a	41.21 ± 0.64 b	40.33± 1,71 b	40,69 ± 1,10 b
Linoleic acid %	11.70 ± 1.10 A	18.35 ± 0.69 B	21.85± 2.25 B	22,64 ± 0,80 B
Linolenic acid %	0.56 ± 0.10 A	1.47 ± 0.14 B	1.61 ± 0.12 B	1.64 ± 0.11 B

Aa: averages on the line followed by different subscripts differ significantly (P≤0.01 and 0.05, respectively).

The proportion of polyunsaturated fatty acids is higher in diets with whole soybean (P≤0.01), a consistent result with that observed by Leszczynski and others (1992b); Zollitsch and others (1993) and Spiner and others (1994). Consequently, a change was generated in the PUFA:SFA ratio, which went from 0.38 in diets with soybean meal to values of 0.55 to 0.72 in diets with whole soybean, which coincides with what was pointed out by Warnants and others (1999), Capra and others (2007a) and Apple and others (2009). In diets with whole grain, an increase in 18-carbon fatty acids was detected, with a higher content (P≤0.05) of oleic acid, as well as linoleic and linolenic acids (P≤0.01).

This result coincides with the observations of Leszczynski and others (1992b), Warnants and others (1999) and Apple and others (2009), who explain the significant increase in the content of linoleic acid, an essential fatty acid that cannot be synthesized *a novo* by the pig, depending directly on the contribution in the diet, which is compensated by a reduction in oleic acid content. In our case, we observed no decrease in oleic acid concentration.

The fatty acid composition of pig tissues is determined by the synthesis *a novo* and the deposition of dietary fatty acids. Polyunsaturated fatty acids of dietary origin are easily incorporated into the body fat of pigs, while monounsaturated and saturated fatty acids have less effect on body fat composition (Warnants and others, 1999). Apple and others (2009) highlight that dietary fat is effective in inhibiting the a novo synthesis of fatty acids, in favor of the direct deposition of dietary fatty acids in adipose tissue. Warnants and others (1999) and Xu and others (2010) showed that the supply of diets high in PUFAs reduces the synthesis of 18:1 in adipose tissue, by decreasing the activity of stearoyl-CoA desaturase.

As a consequence, a fat of inadequate industrial quality is generated, soft and with high potential for rancidity, as indicated by Pontif and others (1987), Zollitsch and others (1993), Bañón and others (2000) and Apple and others (2009). In case of allocating these carcasses to the cold cuts and sausages industry, coinciding with de Blas and others (2003) and Yacentiuk (2010), it is advisable to modify the diet at the end of the fattening period, limiting or eliminating the inclusion of whole soybeans, to maintain the industrial value of the carcasses.

However, if these carcasses are destined for the market of cuts for fresh consumption, the nutritional value of meat from diets containing whole grain soy is higher, associated with the higher concentration of α-linolenic acid, a member of the ϖ-3 fatty acid series, of recognized interest for its benefits on health, an aspect highlighted by Cannon and others (1992) and Leszczynski and others (1992b).

Conclusions

The supply of raw soybeans negatively affects the performance of pigs, due to lower intake and low use efficiency, which is reflected in lower growth rate, while diets containing deactivated beans are a little below those that receive soybean meal as a protein supplement.

The handcrafted deactivation processes of roasting or cooking evaluated improved the nutritional characteristics of the soybean even if the performance levels obtained with the diet based on soybean meal were not reached. The practical convenience of its use will depend on the economic result achieved.

The use of whole soybean in isoprotein and isoenergetic diets does not affect carcass characteristics such as yield and backfat thickness.

The lipid profile of the carcasses from pigs receiving whole soybean have a higher content of polyunsaturated fatty acids, being significant the higher values of oleic, linoleic and linolenic acids, which although they decrease the quality of the product, determine a product of greater nutritional value when it is destined for fresh consumption.

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