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Processing and particle size in diets for weaned piglets from 23 to 71 days

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SUMMARY

The objective of this study was to evaluate the effect of diets with different granulometry and processing on performance and economic viability of piglets, using 120 animals, with an initial weight of 6.65 ± 0.20 kg, from 23 to 71 days, distributed in a completely randomized design with a 2x2 factorial arrangement, two physical forms (mash and pellets) and two granulometries (1.2mm and 2.5mm) totaling four treatments and six replications. The treatments consisted of FM (finely mashed meal at 1.2mm), CM (coarsely mashed at 2.5mm), FP (pellets finely mashed at 1.2mm) and CP (pellets coarsely mashed at 2.5mm). The processing promoted significant effects (P <0.05) on weight at 51 days (16.52 x 18.10 kg), FCR from 23 to 37 days (1.20 x 1.02) and ADG from 23 to 51 days (0.35 x 0.41 kg/day), without changes (P> 0.05) in the other parameters. The particle size (1.2mm x 2.5mm), as well as its interaction with the processing, did not affect the performance parameters in any of the evaluated periods. The cost/kg per animal produced in the period from 23 to 37 days was influenced (P <0.05) by the processing and the particle size, without differences (P> 0.05) over the other periods, being found an average cost of R$ 2.46, R$ 1.41 and R$ 1.89 per kg per animal produced in the periods from 37 to 51 days, 51 to 71 days and 23 to 71 days, respectively. It is concluded that processed diets obtained better performance results in up to 51 days, regardless of particle size. The processing only allowed a reduction in the cost/kg per animal produced in the first stage.

Granulometria e processamento em dietas para leitões dos 23 aos 71 dias de idade

RESUMO

Objetivando-se avaliar o efeito de dietas com diferentes granulometrias e processamentos sobre o desempenho e viabilidade econômica de leitões, foram utilizados 120 animais com peso inicial de 6,65±0,20 Kg dos 23 aos 71 dias de idade, distribuídos em um delineamento inteiramente casualizado sob arranjo fatorial 2x2 sendo duas formas físicas (farelada e peletizada) e duas granulometrias (1.2mm e 2.5mm) totalizando quatro tratamentos e seis repetições. Os tratamentos consistiram de dietas FM (farelada finamente moída a 1.2mm), CM (farelada grosseiramente moída a 2.5mm), FP (peletizada moída finamente a 1.2mm) e CP (peletizada grosseiramente moída a 2.5mm). O processamento promoveu efeitos significativos (P<0.05) no peso aos 51 dias (16.52 x 18.10 kg), no FCR de 23 a 37 dias (1.20 x 1.02) e no ADG de 23 a 51 dias (0.35 x 0.41 kg/dia), sem alterações (P>0,05) nos demais parâmetros. O tamanho de partícula (1.2mm x 2.5mm), bem como sua interação com o processamento não afetaram os parâmetros de desempenho em nenhum dos períodos avaliados. O custo/kg de animal produzido no período de 23 a 37 dias sofreu influência (P<0.05) do processamento e do tamanho de partícula, sem diferenças (P>0.05) sobre os demais períodos, sendo encontrado um custo médio de R$2.46, R$1.41 e R$1.89 por kg de animal produzido nos períodos de 37 a 51 dias, 51 a 71 dias e 23 a 71 dias, respectivamente. Concluiu-se que as dietas processadas obtiveram melhores resultados de desempenho até 51 dias de idade, independente da granulometria. O processamento permitiu redução no custo/Kg de animal produzido apenas na primeira fase.

Palavras chave adicionais

Viabilidade econômica.
Peletização.
Forma física.
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INTRODUCTION

In a production system, the feed cost represents about 70% to 80% of the cost of production (Moreira et al., 2001). Therefore, obtaining accurate information about the degree of grinding of the diets, would allow the choice of particle size which best provide the use of nutrients (Wolf et al., 2010).

The nursery phase has been considered critical and challenging due to the stress caused by the weaning, especially the abrupt transition from a liquid to a solid diet. (Tse et al., 2006; Price et al., 2013). Thus, the utilization of nutrients, mainly those from vegetable raw material, can be compromised. The adoption of food processing technologies has been an alternative for young piglets to use nutrients better, especially due to the variability and availability of hydrothermal processing offered by the market (Xing et al., 2004; Lehnen et al,. 2012).

Pelletizing has been the most common form of heat treatment used in the feed manufacturing process since it increases the availability of nutrients, reduces waste and microbiological contamination, ease of transport, among others (Medel et al., 2004; Millet et al., 2012; Poveda Parra et al., 2013; Lewis et al., 2015; Bao et al., 2016). However, even with higher costs due to the processing type adopted, a technical and economic evaluation should be performed, since it could contribute to satisfactory results in animal performance (Costa et al., 2006).

The objective with this work was to evaluate the effect of diets with different particle sizes and processing on the performance of piglets from 23 to 71 days and their economic viability.

MATERIAL AND METHODS

The experiment was conducted at the experimental Center Dr. Henrique Guimarães Fernandes, in Martinho Campos, Minas Gerais, Brazil. After weaning, at 23 days, the animals were weighed and housed in metal cages suspended, with slatted plastic floor, providing an area of 0.68 m2 per animal until 37 days and 0.90 m2 from 38 to 71 days with water drinker type nursing nipple and semi-automatic feeders. The environment warming was made by electric lamp units and ambient temperature was recorded by maximum and minimum thermometers with mercury filling, entries were made daily at 14:00 hours.

We used 96 piglets (48 castrated males and 48 females) of a commercial breed (DanBred x Topigs), with initial weight of 6.65±0.20 Kg, distributed in a completely randomized experimental design consisting of five treatments and six replications, with four animals per experimental unit (two castrated males and two females). The Ethics Committee of Animal Use of the Federal University of Minas Gerais approved this experiment under protocol number 271/2015.

The diets were formulated to meet the nutritional requirements of pigs in the pre-starter and initial phase established by Rostagno et al. (2011). Amino acid relations between lysine and other essential amino acids were maintained in accordance with the concept of ideal protein for pigs in the pre-starting and initial phase. The amount of lactose, protein and metabolizable energy were held constant in the experimental diets per phase.

The treatments consisted in different particle sizes of proposals diets, obtained from different sieves (1.2 mm and 2.5 mm) associated with different physical forms (mash and pelletized), which can be described as: FM: finely mashed feed in 1.2 mm sieve; CM: coarsely mashed feed in a 2.5 mm sieve; FP: finely mashed feed in a 1.2 mm sieve and, later, pelletized and; CP: coarsely mashed feed in a 2.5 mm sieve and, later, pelletized. The pellets were made in a pelletizing machine PCM 3000® with a conditioner. The centesimal composition and calculated diets are shown in **Table I**.

For the calculation of the average geometric diameter (AGD) and geometric standard deviation (GSD), we used the methodology described by Zanotto and Bellaver (1996) through the program SoftGran 2.0, developed by the Embrapa Swine and Poultry Center for Information Technology.

For the calculation of the pellet durability index (PDI), we weighed 600 g of the sample and placed it in an electromagnetic stirrer with a 2.0 mm sieve, for one minute. Then 500 g of the sample was withdrawn and placed in the rotating resistance device for 10 minutes adding four stainless steel spheres of 55.2 g. Afterward, the samples were placed in the electromagnetic agitator mounted with 2.0 mm and 1.18 mm sieves, and a dish to retain the fine particles, for 10 minutes. Subsequently, the retention contained in the 2.0 mm sieve and the dish was weighed and the PDI calculated.

Feed and water were provided ad libitum during the entire trial period and the amount of food provided was weighed daily. The leftovers and waste were collected daily and weighed at the end of each phase in order to determine the calculation of feed intake.

The animals were weighed individually at the end of each stage according to the age of weaning, being: Pre-start 1 phase (23 to 37 days); Pre-start 2 phase (37 to 51 days) and Start phase (51 to 71 days), totaling 48 experiment days.

In this period, the parameters of initial weight (W23), weight at 37 days (W37), weight at 51 days (W51), weight at 71 days (W71), average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) of the accumulated periods studied have been determined and assessed.

To check the economic viability of the experimental diets in the periods studied, we determined the cost in feed per kg of live weight gain per animal produced (Yi) according to Bellaver et al. (1989), where:

$Yi = (Ci \times Pi) / Gi$

Yi = cost of feed per kg of live weight gain per animal produced;

Ci = quantity of feed consumed in the treatment by period;

Pi = price per kilogram of feed used in the treatment by period;

Gi = weight gain in the treatment by period.

The calculation of the cost of the feeds took into account the November 2015 listing for the price of the ingredients and the cost (R$/ton) of the energy (KW) spent for each diet. The final cost of each treatment for each phase was obtained through the cost of energy used in the manufacturing process along with the price of the formula of each treatment (**Table II**).

The experimental design was completely randomized and all data were analyzed in a 2x2 factorial arrangement using two processing methods (mash and pellet), and two particle sizes (1.2 mm and 2.5 mm), as factors and their interactions. Responses were considered significantly different when $P<0.05$. All statistical analyses were performed using Software R (R Core Team, 2017).

Table I. Centesimal and nutritional composition of the experimental diets for piglets in different phases. (Composição nutricional e centesimal das dietas experimentais para leitões em diferentes fases).

Ingredient	Pré-Starter 1	Pré-Starter 2	Starter
Corn	41.35	51.35	56.00
Soybean meal	10.90	16.00	29.15
Biscuit Residue	8.00	6.00	4.00
Meat and bone meal	2.40	2.80	3.95
Sugar	2.50	2.50	2.50
Soybean oil	1.00	1.00	2.30
Fish meal	3.00	3.00	-
Blood Plasma	2.00	1.00	-
Viscera meal	2.00	2.00	-
Acidifier	0.50	0.50	0.30
Adsorbent	0.20	0.20	0.20
Performance improver[1]	0.08	0.08	-
Antioxidant	0.01	0.01	-
Antibiotic	0.06[2]	0.06[2]	0.10[3]
Premix	1.00[4]	1.00[4]	1.50[5]
Pré-starter 1 Concentrate[6]	25.00	-	-
Pré-starter 2 Concentrate[7]	-	12.5	-
Nutritional intake calculated[8]			
Dry Matter, %	91.10	89.69	88.26
Crude Protein, %	19.97	19.37	20.50
Ether Extract, %	7.35	6.21	5.64
Mineral Matter, %	4.74	4.48	5.05
Lactose, %	10.00	5.00	-
Metabolizable Energy, Mcal/Kg	3.571	3.487	3.444
Digestible Lysine, %	1.349	1.247	1.099
Methionine + Cystine Digestible, %	0.754	0.697	0.616
Digestible Tryptophan, %	0.243	0.225	0.198
Digestible Threonine, %	0.850	0.787	0.694
Calcium, %	0.825	0.807	0.898
Available Phosphorus, %	0.498	0.452	0.456

[1]Yeasts; [2]Amoxicillin (50%); [3]0.06% Tiamulin (20%) + 0.04% Doxycycline (50%); [4]Commercial product Qualimix QF MC 1% - Vaccinar ®. Assurance levels (per kg of product): Folic acid: 50 mg; Pantothenic acid: 1,500 mg; Biotin: 25 mg; Cobalt: 20 mg; Copper: 20 g; Choline: 60 g; Etoxiquim: 100 mg; Iron: 15 g; Iodine: 100 mg; Manganese: 4,000 mg; Niacin: 3,000 mg; Selenium: 45 mg; Vitamin A: 1,000,000 U. I.; Vitamin B1: 150 mg; Vitamin B12: 2,000 mcg; Vitamin B2: 500 mg; Vitamin B6: 200 mg; Vitamin D3: 200,000 U. I.; Vitamin E: 10,000 U.I.; Vitamin K3:200 mg; Zinc: 10 g; [5]Commercial product Initial QCarne GSF med - Vaccinar®. Assurance levels (per kg of product): Folic acid: 33, 30 mg; Pantothenic acid: 1,000 mg; Biotin: 13,33mg; Calcium (min): 120 g; Calcium (max): 125 g; Cobalt: 13,30 mg; Copper: 12 g; Choline: 20 g; Colistin: 2,666,60 mg; Etoxiquim: 6,666 mg; Iron: 11,60 g; Phytase: 33,30 FTU; Phosphorus: 77 g; Iodine: 66,60 mg; Lysine: 52,60 g; Manganese: 2,666; Niacin: 2,000 mg; Selenium: 30 mg; Sodium: 104 g; Vitamin A: 666,666 U. I.; Vitamin B1: 100 mg; Vitamin B12: 1,333 mcg; Vitamin B2: 333,30 mg; Vitamin B6: 133,30 mg; Vitamin D3: 133,333 U.I.; Vitamin E: 3,333,30 U.I.; Vitamin K3: 133,30 mg; Zinc: 11,60 mg; [6]Commercial product Qualisui 250 QF-1- Vaccinar ®. Assurance levels (per kg of product): Glutamic acid (mín.) 2.000,00 mg/kg; Calcium (mín e máx) (7.000,00 e 8.500,00) mg/kg; Cellulase (mín) 90 u/kg; Colistin 160,00 mg/kg; Etoxiquim (mín) 100,00 mg/kg; Ether extract (mín) 100,00 g/kg; Crude fiber (máx) 4.280,00 mg/kg; Fluorine (máx) 28,00 mg/kg; Phosphorous (mín) 7.000,00 mg/kg; Glutamine (mín) 2.000,00 mg/kg; Lactose (mín) 400,00 g/kg; Lisine (mín) 22,35 g/kg; Ash (máx) 70,00 g/kg; Metionine (mín) 7.950,00 mg/kg; Protease (mín) 15.000,00 g/kg; Crude protein (mín) 195,00 g/kg; Sodium (mín) 4.680,00 mg/kg; Treonine (mín) 14,00 g/kg; Tryptophan (mín) 3.500,00 mg/kg; Humidity (máx) 150,00 g/kg e Zinc (mín) 10,00 g/kg. [7]Commercial product Qualisui 125 QF-2- Vaccinar ®. Assurance levels (per kg of product): Calcium (mín e máx) (9.000,00 mg/kg e 10,00 g/kg); Cellulase (mín) 180 u/kg; Colistin 320,00 mg/kg; Etoxiquim (mín) 100,00 mg/kg; Ether extract (mín) 122,00 g/kg; Crude fiber (máx) 900,00 mg/kg; Fluorine (máx) 30,00 mg/kg; Phosphorous (mín) 6.000,00 mg/kg; Lactose (mín) 400,00 g/kg; Lisine (mín) 29,05 g/kg; Ash (máx) 50,00 g/kg; Metionine (mín) 12,25 g/kg; Protease (mín) 30.000,00 u/kg; Crude protein (mín) 155,00 g/kg; Treonine (mín) 17,40 g/kg; Tryptophan (mín) 4.050,00 mg/kg; Humidity (máx) 150,00 g/kg e Zinc (mín) 17,60 g/kg. [8]Values calculated according to Rostagno et al. (2011)

RESULTS

Average geometric diameter, geometric standard deviation and pellet durability index

Figure 1A shows the AGD±GSD of the mashed diets, with the FM diet presenting values of 404±6.3, 402±6.4 and 382±5.8 µm and the CM diet presented 457±7.1, 532±9.2 and 598±10.4 µm in the periods from 23 to 37, 37 to 51 and 51 to 71 days, respectively. **Figure 1B** shows the PDI of the pelleted diets, having the FP diet presented 67.9, 66.0 and 58.7% and the CP diet 79.5, 69.3 and 59.4%, in the periods from 23 to 37, 37 to 51 and 51 to 71 days, respectively.

Productive performance

The productive performance results in the accumulated periods are exposed in **Table III**. The processing of the diets (mash x pelletized) promoted significant effects ($P<0.05$) for weight at 51d (16.52 x 18.10 kg), FCR in the period from 23 to 37 days (1.20 x 1.02) and

Table II. Cost (R$/ton) of the energy (KW) for processing and final cost of the diet (R$/kg) for each treatment (Custo (R$/ton) da energia (KW) para o processamento e o custo final das dietas (R$/Kg) para cada tratamento).

Diets	Cost of energy (R$/ton)	Cost of final diet (R$/Kg)		
		Pre-Starter 1	Pre-Starter 2	Starter
FM	26.15	2.75	1.97	0.94
CM	16.75	2.74	1.96	0.93
FP	47.00	2.77	1.99	0.96
CP	32.25	2.75	1.97	0.94

FM: finely mashed feed in 1.2 mm sieve; CM: coarsely mashed feed in 2.5 mm sieve; FP: finely mashed feed in 1.2 mm sieve and, later, pelletized; CP: coarsely mashed feed in 2.5 mm sieve and, later, pelletized..

ADG in the period from 23 to 51 days (0.35 x 0.41 kg/day), however the other parameters were not altered by the processing (P>0.05). The particle size of the diets (1.2mm x 2.5mm) as well as their interaction with the processing did not affect the parameters in any of the evaluated periods.

Economic evaluation

The economic evaluation, given as the cost in R$/kg per animal produced, is shown in **Table IV**. The cost per kg of animal produced in the period from 23 to 37 days was influenced (P<0.05) by the processing (R$ 3.30 for the mashed diets and R$ 2.78 for the pelleted diets) and the particle size (R$ 2.94 for particle size of 1.20 mm x R$ 3.13 for particle size of 2.50mm). There was no significant effect (P>0.05) for the other periods, with an average cost of R$ 2.46, R$ 1.41 and R$ 1.89 per kg of animal produced in the periods from 37 to 51 days, 51 to 71 days and the total period (23 to 71 days), respectively.

DISCUSSION

Average geometric diameter (AGD), geometric standard deviation (GSD) and pellets durability index (PDI)

In the present study, the AGD values of the experimental feed show that the grinding of the ingredients was performed correctly since the data for the variable in question (**Figure 1A**) are less than 2%, as recommended by Zanotto and Bellaver (1996). The results agree with studies that have worked with the reduction in particle size and AGD gauging (Healy et al., 1994; Kim et al., 2002; Ghaid, Al-Rabadi and Gidley, 2009).

The PDI evaluation in processed diets, in this case, pelletized ones, helps to ascertain the quality of the pellet. This measurement is also related to particle size

Table III. Weight at 37 days (W37), weight at 51 days (W51), weight at 71 days (W71), daily weight gain (ADG), average daily consumption (ADFI) and feed conversion (FCR) of piglets fed diets with different processing and particle sizes (Peso aos 37 dias (P37), peso aos 51 dias (P51), peso aos 71 dias (P71), ganho de peso diário (GPD), consumo médio diário (CMD) e conversão alimentar (CA) de leitões alimentados com dietas com diferentes processamentos e tamanhos de partículas).

	Dietary treatments				SEM	P-Value		
	FM	CM	FP	CP		P	PS	P x PS
Period 23-37 days								
W37 (kg)	10.063	9.623	10.261	10.456	0.133	0.0514	0.6276	0.2156
ADG (kg/day)	0.244	0.212	0.258	0.272	0.010	0.0555	0.6258	0.2194
ADFI (kg/day)	0.279	0.264	0.265	0.277	0.009	0.9905	0.9618	0.4882
FCR (kg/kg)	1.144	1.261	1.020	1.022	0.026	<0.001	0.1011	0.1157
Period 23-51days								
W51 (kg)	16.494	16.549	17.881	18.307	0.267	0.0021	0.5959	0.6814
ADG (kg/day)	0.352	0.353	0.401	0.416	0.010	0.0022	0.6011	0.6792
ADFI (kg/day)	0.438	0.455	0.462	0.476	0.013	0.4239	0.5838	0.9609
FCR (kg/kg)	1.251	1.232	1.150	1.141	0.029	0.1091	0.8070	0.9359
Period 23-71days								
W71 (kg)	32.832	32.019	34.030	34.036	0.438	0.0760	0.6438	0.6387
ADG (kg/day)	0.545	0.528	0.570	0.570	0.009	0.0763	0.6417	0.6369
ADFI (kg/day)	0.710	0.731	0.798	0.801	0.023	0.1033	0.7987	0.8506
FCR (kg/kg)	1.328	1.329	1.401	1.404	0.047	0.4609	0.9808	0.9924

FM: finely mashed feed in 1.2 mm sieve; CM: coarsely mashed feed in 2.5 mm sieve; FP: finely mashed feed in 1.2 mm sieve and, later, pelletized; CP: coarsely mashed feed in 2.5 mm sieve and, later, pelletized; SEM: Standard error mean; P: processing; PS: particle size.

Table IV. Cost (R$) per Kg of produced animal fed experimental diets per period (Custo (R$) por Kg de animal produzido alimentado com dietas experimentais por periodo).

	Dietary treatments				SEM	P-Value		
	FM	CM	FP	CP		P	PS	P x PS
Period 23-37 days	3.142	3.450	2,742	2.814	0.072	<0.001	0.046	0.200
Period 37-51days	2.581	2.409	2.447	2.382	0.072	0.603	0.445	0.729
Period 51-71days	1.307	1.295	1.513	1.517	0.064	0.114	0.976	0.949
Period 23-71days	1.850	1.841	1.934	1.935	0.062	0.511	0.973	0.970

FM: finely mashed feed in 1.2 mm sieve; CM: coarsely mashed feed in 2.5 mm sieve; FP: finely mashed feed in 1.2 mm sieve and, later, pelletized; CP: coarsely mashed feed in 2.5 mm sieve and, later, pelletized; SEM: Standard error mean; P: processing; PS: particle size.

and, therefore, the larger the particle size, the greater the chances of the pellet breaking. The literature suggests that the PDI should be between 60 and 95% (Healy et al., 1994, Thomas et al., 1996, Kim et al., 2002) and the values found in this experiment (Figure 1B) are inside the recommended ones. In the present study, the PDI of the processed diets, specifically the CP diet, was better when compared to the FP treatment, although the mean of the FCR was equal (P>0.05) for both.

Processing

The best FCR obtained in the period from 23 to 37 days was found for the diets that went through the pelletizing process. The processed diets provided, on average, a better FCR in relation to the FM diet (1.02 x 1.14 kg/kg) as well as to the CM (1.02 x 1.26 kg/kg). This result can also be related to the greater waste of the mashed feed in relation to the pelleted feed (Moreira et al., 1995). In addition, the feed processing may have allowed greater exposure of the particles to the action of temperature and steam, making the nutrients more digestible and thus allowing better utilization by the piglets (Bao et al, 2016). However, for the W37, ADG and ADFI variables, no significant differences were observed (P>0.05) regarding the effect of the processing, differing from the results found by Surek et al. (2017) in which pelletisation provided better ADG and FCR during the first week after weaning.

According to Kim et al. (2002), by reducing the particle size from 1000 µm to 500 µm with complex diets, the feed efficiency can be increased by up to 3%, also promoting the improvement in pellet durability (**Figure 1B**).

In the period from 23 to 51 days, we observed that the processed diets (FP and CP) when compared to the diets (FM and CM) provided, on average, higher W51 (18.09 x 16.52 kg) and ADG (0.409 x 0.353 kg), respectively. Similarly, Surek et al. (2017) found a significant effect of weight in up to 56 days (P<0.01), evidencing that the best productive performance attributed to the treatments submitted to pressure and heat conditions is in line with the benefits of pelleting (Wolf, Rust and Kamphues, 2010). On the other hand, there were no differences (P>0.05) for the ADFI and FCR variables.

In the total period, there were no differences (P>0.05) for the variables in question, demonstrating that the response to treatments through processing is greater during the first two weeks after weaning, and this effect is lost in the subsequent phases (Healy et al., 1994).

Particle Size

The fact that no difference (P>0.05) was found regarding particle size for W37, ADG and ADFI, in the period from 23 to 37 days, is in agreement with Tse et al. (2006) who did not verify effects of the particle re-

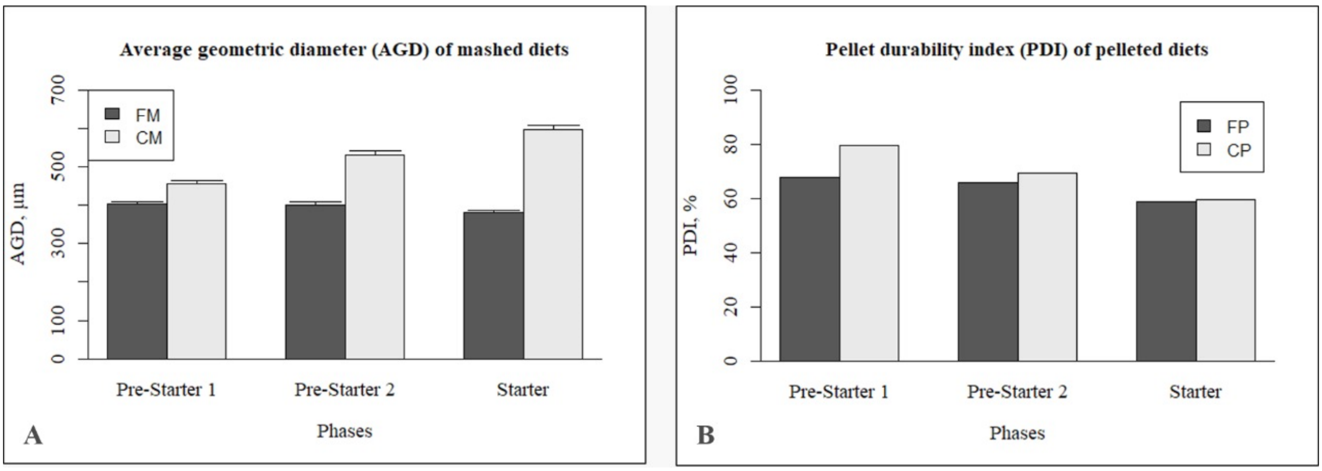

Figure 1. Average geometric diameter (AGD) and its respective geometric standard deviation (GSD) of the mashed experimental diets per phase (A) and; pellet durability index (PDI) of pelletized experimental diets per phase (B) (Diâmetro geométrico médio (DGM) e seu respectivo desvio padrão geométrico (DPG) das dietas experimentais fareladas por fase (A) e; índice de durabilidade do pélete (PDI) das dietas experimentais peletizadas por fase (B)).

duction from 2186 µm to 594 µm among piglets fed dry corn or corn silage feed for the variables in question. In contrast, Ngoc et al. (2011) found that the reduction in particle size increased ADG in the post-weaning period, justified by the improvement of the nutrients' digestibility. The justification for the absence of effect for ADFI suggested by Moreira et al. (2001) may be related to the fact that the fine particles supplied in pelleted and mashed forms may have adhered to the piglets' mouth, forming a sticky plaque that was expelled and not counted in the ADFI.

Conversely, Healy et al. (1994) and Bao et al. (2016) suggest that fine grinding seems to be beneficial for recently weaned piglets mainly because they present an immature gastrointestinal tract at this stage, allowing the smaller particle size to promote a greater contact surface with the digestive enzymes and, consequently, the improvement of the nutrients' digestibility (Tse et al., 2006). In addition, Healy et al. (1994), working with particle size of corn and sorghum for piglets, showed no influence on ADFI when DGM was reduced from 900 to 300 µm.

On the other hand, when evaluating particle size in the period from 23 to 51 days, no differences (P>0.05) were observed in the performance among the treatments evaluated in this study. Probably, at this stage the digestive system of the piglets had already reached its maturity, besides the adequate enzymatic input, allowing the use of both fine particles and those coarsely ground, which would make them insensitive to such differences (Bao et al., 2016). Nonetheless, recent research indicates that the reduction in particle size of grains contributes to better dietary utilization, resulting in better results of the productive performance of the animals (Al-Rabadi, Gilbert and Gidley, 2009; Stewart and Slavin, 2009), although Morel and Cottam (2007) neihter found differences for ADG, ADFI and FCR when swine were fed different particle sizes. The controversial data found in the literature may be related to the different ingredients used in the diets as well as the age at weaning (Healy et al., 1994; Bao et al., 2016).

Previous results have shown no difference (P>0.05) for any of the performance variables studied in the total period (Costa et al., 2006 and Millet et al., 2012). Considering that the morphological structure of the gastrointestinal tract of the piglet acquires maturity from 35 to 42 days of age and that the enzymatic secretion reaches satisfactory levels from the third week of life, possibly from this period the piglets already had the ability to degrade and absorb the products of digestion efficiently, both fine particles and coarse particles, regardless of the physical form of the diet (Xing et al., 2004).

Economic evaluation

The lowest cost/kg per animal produced in the period from 23 to 37 days obtained with the pelleted diets correlates with the best FCR obtained by the animals fed pelleted diets and, in addition, the mashed diets were the ones that presented the worse FCR. This result is in agreement with Garcia and Silveira (1995) when they compared mashed, pelleted, and ground feed after pelleting in piglet feeding.

Considering the cost/kg per animal produced in relation to the particle size, regardless of its physical form, the lower cost obtained for the particle size of 1.20 mm did not influence the performance of piglets (**Table III**). However, if we consider the physical form, better FCR was found in processed diets, such as the FP diet with 1.20mm granulometry. For the remaining periods, no significant difference (P>0.05) was observed in relation to the costs of the treatments, corroborating Costa et al. (2006).

CONCLUSIONS

Processed diets contributed to better performance results in up to 51 days, however, there was no benefit from the processing of diets in the total period, regardless of particle size. Processing allowed reduction in cost/Kg per animal produced only in the first phase (23 to 37 days).

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