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ECOSISTEMAS Y RECURSOS AGROPECUARIOS

Productivity of pigs fed with solid-state fermented apple pomace and an enzymatic complex

Productividad de cerdos alimentados con bagazo de manzana fermentado en estado sólido y un complejo enzimático

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ABSTRACT. The productive performance of pigs fed with solid-state fermented apple pomace (FAP) and an enzymatic complex (ENZ) was evaluated. Twenty-four Landrace x York (38.9 ± 3.6 kg) pigs were fed *ad libitum* with different diet treatments including FAP and ENZ: *T0-0* (0 g kg^{-1} FAP - 0 g kg^{-1} ENZ), *T0-1* (0 g kg^{-1} FAP + 1 g kg^{-1} ENZ), *T50-0* (50 g kg^{-1} FAP + 0 g kg^{-1} ENZ), *T50-1* (50 g kg^{-1} FAP + 1 g kg^{-1} ENZ), *T100-0* (100 g kg^{-1} FAP + 0 g kg^{-1} ENZ) and *T100-1* (100 g kg^{-1} FAP + 1 g kg^{-1} ENZ). Productivity; Feed intake, F:G ratio, Weight gain, return on investment by monetary unit (profitability index, PI) and carcass traits; Carcass dressing percent and primary cuts, were evaluated. Data were analyzed according to the randomized complete block design. Productivity and feeding characteristics were not affected by FAP or ENZ ($p > 0.05$). Hot dressing percent was affected by ENZ ($p = 0.0497$). *T100-0* and *T100-0* showed similar ($p > 0.05$) value to *T0-0*. Primary cut yield was not negatively affected ($p > 0.05$). The best PI was obtained with *T50-0* in growing phase. FAP improved PI only in growing phase and ENZ combined with FAP showed variant PI. Results showed that FAP may be considered as a suitable option for feeding pigs because it maintains animal productivity.
Key words: Pig carcass, solid-state fermented apple, pig performance, pig feeding, primary cuts

RESUMEN. El comportamiento productivo de cerdos alimentados con bagazo de manzana fermentado en estado sólido (FAP) y un complejo enzimático (ENZ) fue evaluado. En el experimento se utilizaron 24 cerdos Landrace x York (38.9 ± 3.6 kg), se alimentaron *ad libitum* con diferentes dietas de tratamiento incluyendo FAP y ENZ; *T0-0* (0 g kg^{-1} FAP - 0 g kg^{-1} ENZ), *T0-1* (0 g kg^{-1} FAP + 1 g kg^{-1} ENZ), *T50-0* (50 g kg^{-1} FAP + 0 g kg^{-1} ENZ), *T50-1* (50 g kg^{-1} FAP + 1 g kg^{-1} ENZ), *T100-0* (100 g kg^{-1} FAP + 0 g kg^{-1} ENZ) and *T100-1* (100 g kg^{-1} FAP + 1 g kg^{-1}ENZ). Se evaluó la productividad; consumo de alimento, conversión alimenticia, ganancia de peso, índice de rentabilidad (PI) y características de la canal; rendimiento en canal y rendimiento en cortes primarios. Los datos fueron analizados considerando un diseño en bloques completamente al azar. La productividad y las características de alimentación no fueron afectadas por FAP o ENZ ($p > 0.05$). El rendimiento en canal caliente se afectó por ENZ ($p = 0.0497$). Los tratamientos *T100-0*, *T50-0* y *T0-0* fueron similares ($p > 0.05$). El rendimiento en cortes primarios no fue afectado negativamente ($p > 0.05$). El mejor PI fue obtenido para *T50-0* en la fase de crecimiento. FAP mejoró el PI únicamente en la fase de crecimiento y la combinación con ENZ mostró un PI variante. Los resultados obtenidos mostraron que FAP puede ser considerado como una opción adecuada para alimentar cerdos y mantener su productividad.
Palabras clave: Canal de cerdo, bagazo de manzana, comportamiento del cerdo, cortes primarios

INTRODUCTION

To improve pig production efficiency, it is necessary to decrease feeding expenses because they account for nearly 70 % of production costs (González-Razo *et al.* 2010). This requires finding a low-cost feeding alternative. Therefore, fruit by-products and exogenous enzymes may be an effective means to meet this challenge.

It has been reported that exogenous enzymes (amilases, proteases, xylanases, phytases) improve digestibility of proteins, polysaccharides and oligosaccharides from soy and other grains, promote better digestibility of agro-industrial by-products, and may optimize productive efficiency, thereby improving pig growth (Oliveira-Teixeira 2005, Ristanović *et al.* 2009).

Agro-industrial by-products from vegetables, fruit pomace, plant extracts, and distillery and extraction have been proposed as an effective low-cost alternative, as a source of nutrients, in order to meet the nutritional needs of animals (Kim *et al.* 2006, Xandé *et al.* 2007, Taasoli and Kafilzadeh 2008, Lee *et al.* 2009, Newman *et al.* 2011, Fang *et al.* 2016). Jeong *et al.* (2014) have proposed the use of a fermented carrot by-product to feed pigs in the finishing phase, and a bamboo by-product was proposed to feed pigs by Chu *et al.* (2013) in order to improve pig productivity.

Apple pomace is a by-product of apple juice processing and is produced in high amounts in Chihuahua State, Mexico, which produces 573.5 tons yearly (SIAP, 2016). Due to this, pomace is not used after processing, and it is disposed of in the environment, which makes it a potential source of pollution (Rodríguez-Muela *et al.* 2010). Apple pomace has good nutritional characteristics, palatability, and digestibility; moreover, it contains dietetic fiber and polyphenols which may improve intestinal function (Rodríguez-Muela *et al.* 2010). It has only been used as an ingredient in silage mixtures to feed pigs, with positive results in food intake, but with variant effects on carcass traits (Fang *et al.* 2016, Lee *et al.* 2009, Bowden and Berry, 1959).

Apple pomace has been processed using the solid-state fermentation process, as a way to shift carbohydrates contained in it to a single cell protein, improving its crude protein contribution from 6 to 21 % and its true protein (TP) one to 15.5 % (Nikolić and Jovanović 1986, Bhalla and Joshi 1994, Joshi and Shandu 1996, Rodríguez-Muela *et al.* 2010), transforming apple pomace into a highly nutritious ingredient for animal diets (Villas-Bôas *et al.* 2003, Teixeira-Macagnan *et al.* 2015), which makes it feasible to be considered as an important ingredient in ruminant diet formulation (Pérez-Guerra *et al.* 2003, Rachana and Gupta 2010).

However, it is important to determine if the nutritional improvement obtained from this agro-industrial by-product is suitable to feed pigs as an alternative way to increase their productivity (Joshi and Attri 2006, Descalzo and Sancho 2008). However, although information about its use as feed for ruminants and other species is currently known (Gasa *et al.* 1992, Anrique and Dossow 2003), there is a lack of information about its use in non-ruminants, especially pigs.

In this sense Kim *et al.* (2006) stated that diets with fermented by-products did not affect the productive performance of pigs when added at a level of 3 %. Nevertheless, other studies have mentioned that the addition of by-products in diets does affect the growth and development of pigs (Bowden and Berry 1959), but, in the case of solid-state fermented apple pomace (FAP), there is very little information available about its effect on productive performance of pigs. In fact, there is no research focused specifically on feeding FAP and its effect on carcass traits and primary cut yield. Consequently, the aim of this work was to evaluate the productive performance and carcass traits of pigs fed with FAP and ENZ in a productive period.

MATERIALS AND METHODS

For this experiment, twenty-four, 105-day-old (Landrace x York) pigs (12 males, 12 females) with 38.9 $\pm$ 3.6 kg live weight were placed in individual pens (0.9 X 1.5 m), and received an adaptation diet (Table 1) for two weeks prior to the start of

Table 1. Growth and finishing diet compositions for pigs fed with solid-state fermented apple pomace and an enzymatic complex (g kg^{-1} as fed basis).

Ingredient	Treatments (FAP - ENZ) g kg^{-1}					
	0-0	0-1	50-0	50-1	100-0	100-1
Growth						
Corn	666.0	676.0	617.0	614.0	547.0	546.0
Soybean meal	283.0	281.0	275.0	275.0	270.0	270.0
Vegetal plant oil	17.0	8.0	19.0	20.0	36.0	36.0
Premix V and M	7.0	6.0	8.0	8.0	9.0	9.0
Calcium carbonate	12.0	12.0	14.0	14.0	16.0	16.0
Dicalcic phosphate	6.0	6.0	7.0	7.0	9.0	9.0
Salt	7.0	6.0	8.0	8.0	9.0	9.0
Synthetic methionine	2.67	2.59	3.07	3.09	3.62	3.64
FAP	0.0	0.0	50.0	50.0	100.0	100.0
ENZ	0.0	1.0	0.0	1.0	0.0	1.0
Finishing						
Corn	756.0	763.0	707.0	708.0	643.0	642.0
Soybean meal	209.0	208.0	201.0	200.0	195.0	195.0
Vegetal plant oil	10.0	2.0	12.0	10.0	25.0	25.0
Premix V	5.0	5.0	6.0	6.0	7.0	7.0
Calcium carbonate	9.0	9.0	11.0	11.0	13.0	13.0
Dicalcic phosphate	5.0	4.0	6.0	6.0	7.0	7.0
Salt	5.0	5.0	6.0	6.0	7.0	7.0
Synthetic methionine	1.96	1.89	2.34	2.33	2.85	2.87
FAP	0.0	0.0	50.0	50.0	100.0	100.0
ENZ	0.0	1.0	0.0	1.0	0.0	1.0

FAP= Solid-state fermented apple pomace; ENZ = Allzyme Vegpro® enzymatic complex; Alltech.

the experiment. Four pigs per treatment were randomly assigned with the same number of males and females to each treatment. After the adaptation period, experimental feeding was applied using diets with different levels of FAP and ENZ (Allzyme Vegpro®; Alltech, IL. USA) inclusion as treatments, where: *T0-0* (0 g kg^{-1} FAP - 0 g kg^{-1} ENZ), *T0-1* (0 g kg^{-1} FAP + 1 g kg^{-1} ENZ), *T50-0* (50 g kg^{-1} FAP + 0 g kg^{-1} ENZ), *T50-1* (50 g kg^{-1} FAP + 1 g kg^{-1} ENZ), *T100-0* (100 g kg^{-1} FAP + 0 g kg^{-1} ENZ) and *T100-1* (100 g kg^{-1} FAP + 1 g kg^{-1} ENZ). Iso-energetic and iso-proteinic diets were formulated according to National Research Council (NRC) requirements for pigs (NRC 2012), at growing and finishing periods (Table 2). For FAP elaboration, a solid-state fermentation process using apple pomace as a basic substrate was carried out. Apple pomace was placed on a flat surface to create a bed 1.2 x 10 m and 30 cm in height, and 15 g kg^{-1} of urea [CO (NH2)2; Univex, Gto. Méx], 4 g kg^{-1} of ammonia sulphate Std. [(NH4) 2SO4; Univex, Gto., Mex] and 5 g kg^{-1} of mineral mix (BASE ELITE LE, Lechero 12 %, MNA, NL. Méx), on a wet basis, were added and mixed every four hours during a 72-hour period to keep pH between 5.8 - 6.2 and temperature in the range of 28 - 32 °C, to allow fermentation and to achieve the appropriate conditions for yeast growth. All processes were developed according to Rodríguez-Ramírez *et al.* (2007). After fermentation, FAP was dried, ground, and stored until use. To incorporate FAP and ENZ into rations, they were premixed with minerals and synthetic methionine (MetAMINO®; Evonik, USA), then added to corn and soy. Prepared meal was stored until the start of the experiment.

This experiment lasted nine weeks: growth phase (week one to week four) and the finishing phase (week five to week nine). For the evaluation of productivity growing characteristics, initial weight (IW), weight-gain (WG), average daily gain (ADG) and final weight (FW) were measured in both phases. In the same way, feeding characteristics, namely feed intake (FI), average feed intake (AFI)

Table 2. Nutrient content (percentage on dry basis) of growing and finishing diets, and from solid-state fermented apple pomace.

Nutrient	Treatments (FAP - ENZ) g kg^{-1}						FAP
	0-0	0-1	50-0	50-1	100-0	100-1	
Growth period							
Moisture	5.8	6.3	6.0	6.0	5.8	4.5	30.2
Dry matter	94.2	93.7	94.0	94.0	94.2	95.5	69.8
Organic matter	88.5	88.9	88.9	88.8	89.7	82.5	96.8
Crude ashes	11.5	11.1	11.1	11.2	10.3	17.5	32.3
Fat	3.1	2.9	3.7	3.9	4.2	3.2	3.2
Crude fiber	2.9	3.4	4.1	4.4	6.7	4.0	35.1
Crude protein	18.2	20.5	20.1	20.7	20.6	19.9	19.0
Digestible Energy** (kcal kg^{-1})	3098.8	3160.9	3137.3	3127.3	3123.9	2313.7	
Finishing							
Moisture	5.9	6.4	5.6	5.8	5.3	5.1	
Dry matter	94.1	93.6	94.4	94.2	94.7	94.9	
Organic matter	88.9	89.3	90.9	90.7	91.7	91.7	
Crude ashes	11.1	10.7	9.1	9.3	8.3	8.3	
Fat	3.2	2.5	4.0	5.2	6.5	3.7	
Crude fiber	2.8	2.5	3.0	3.7	5.2	4.1	
Crude protein	15.4	18.0	17.7	18.6	17.3	18.2	
Digestible Energy** (kcal kg^{-1})	3093.4	3194.6	3407.9	3405.0	3450.5	3435.2	

FAP = Solid-state fermented apple pomace, ENZ = Allzyme Vegpro® enzymatic complex; Alltech.
** Estimated according to NRC (1998).

and feed/gain ratio (F:G), were measured. Digestible energy intake (kcal/day) was estimated according to NRC (2012) models. An economic analysis through profitability index estimation (PI) was used to obtain the return on investment by monetary unit (Oliveira-Teixeira *et al*. 2005) spent on feed cost, which was calculated using the formula:

$$PI = (\sum Yi \times P - \sum Cri \times PRi) / (\sum Cri \times PRi)$$

Where Yi = animal weight in each treatment, P = Price per kg live weight, Cri = Diet intake in each treatment, PRi = Diet price for each treatment. It is important to consider that in PI calculation only the costs for meal formulation were considered, and the price per live-weight-kilogram came from the Mexican Pig Producers Confederation reports (CPM, 2016).

At the end of the feeding period the pigs were slaughtered, following Mexican harvesting regulations (SAGARPA 1995). Carcass traits: slaughter weight (SW), hot dressing percent (HDP), commercial dressing percent (CDP), and back fat (BF) were measured and recorded. Primary cuts: Ham, Loin, Brisket, Ribs, Filet and Lard were cut, and their yield was calculated, according to García-Macías *et al*. (1996).

The results from productive performance, carcass traits, and cut yields were analyzed according to the randomized complete block design in a 3 x 2 factorial arrangement, with gender (male, female) as the block, and FAP and ENZ as the fixed effects. The data were processed using the GLM procedure in SAS® (1990) software; means were expressed as mean and variability data were expressed with standard error of the mean. To identify differences among treatment means, a principal mean-differences analysis was made with PDIFF statement from SAS® (1990). Means were considered different when $p < 0.05$.

RESULTS

Results showed that during the growth and finishing phases, productivity was not affected by FAP and ENZ addition (Table 3), at any level of inclusion. Constant feed intake was observed while the F:G ratio showed better values in growth than during the finishing phase; in addition, weight in-

Table 3. Growing and feed-intake characteristics of pigs fed with solid-state fermented apple pomace and an enzymatic complex during growth and finishing periods.

Item	Treatments (FAP-ENZ) g kg^{-1}							Significance level (*P-value*)			
	0-0	0-1	50-0	50-1	100-0	100-1	SEM	FAP	ENZ	FAP x ENZ	GEN
Growth period											
Initial body weight	46.6	45.9	47.6	44.7	44.2	46.6	2.8	0.9480	0.8730	0.6397	0.0309
Weight gain	23.4	26.9	25.3	21.8	22.7	23.2	2.0	0.5536	0.9331	0.2569	0.4075
Average daily gain	0.8	1.0	0.9	0.8	0.8	0.8	0.1	0.5536	0.9331	0.2569	0.4075
Final weight	66.6	72.8	72.9	66.5	66.9	69.8	3.1	0.6627	0.9523	0.2548	0.1433
Feed intake	72.7	76.7	76.5	70.0	71.5	71.4	3.2	0.6341	0.7507	0.3177	0.2695
Average feed intake	2.6	2.7	2.7	2.5	2.6	2.5	0.1	0.6341	0.7507	0.3177	0.2695
Feed:Gain	3.1	2.9	3.1	3.4	3.3	3.1	0.3	0.6660	0.8477	0.5284	0.9006
DEI (kcal d^{-1})	612.9	670.2	671.0	611.9	616.1	644.5	28.1	0.7342	0.0732	0.0615	0.3745
Finishing period											
Initial weight	66.6	72.8	73.8	66.5	66.9	69.8	3.3	0.8924	0.7368	0.1648	0.0751
Weight gain	33.9	30.1	26.7	30.3	30.3	30.2	2.4	0.4189	0.9615	0.3706	0.1249
Average daily gain	1.0	0.9	0.8	0.9	0.9	0.9	0.1	0.4189	0.9615	0.3706	0.1249
Final weight	100.4	102.9	100.5	96.8	97.2	100.0	3.6	0.6361	0.8713	0.6396	0.0164
Feed intake	103.5	101.4	103.3	99.2	106.2	99.6	4.9	0.9446	0.3104	0.8977	0.9024
Average feed intake	3.0	2.9	3.0	2.8	3.0	2.8	0.1	0.9446	0.3104	0.8977	0.9024
Feed:Gain	3.1	3.4	3.9	3.3	3.5	3.4	0.2	0.2387	0.4799	0.1476	0.0416
DEI (kcal d^{-1})	697.6	679.8	697.0	717.1	715.3	700.2	13.7	0.0541	0.5627	0.4615	0.6372

Data displayed as Mean $\pm$ SEM, Significance level = significant effect is showed when $p < 0.05$.
SEM = Standard Error of the mean, FAP = Solid-State Fermented Apple Pomace, ENZ = Allzyme Vegpro®, DEI = digestible energy intake.GEN = Gender (male, female) considered as block. FAP and ENZ = Individual effect of FAP or ENZ. FAP x ENZ = Interaction between FAP and ENZ.

crease was constant and similar during the growth phase since all pigs were above 60 kg at the end of the phase. As noted in the growth phase all pigs showed similar weight at the end of the finishing phase ($p > 0.05$).

Carcass characteristics shown in Table 4 indicate that *T0-0* showed the highest ($p < 0.05$) HDP, while ENZ addition decreased ($p = 0.0497$) it. Treatments with ENZ addition (*T0-1*, *T50-1*, and *T100-1*) diminished HDP in a 2.8 to 3.1 percentage point range, while treatments *T50-0* and *T100-0* showed similar performance to the control ($p > 0.05$). With respect to CDP, *T0-0* showed the best ($p < 0.05$) level, while an effect of the interaction of FAP and ENZ ($p < 0.05$) was observed, decreasing the dressing in treatments *T50-1* and *T100-1* in a range from 2.6 to 3.2 percentage points. However, treatment *T0-1* showed a lower ($p < 0.05$) dressing in a greater level (3.1), with respect to treatment *T0-0*. Treatments *T50-0* and *T100-0* showed similar results ($p > 0.05$) to the control. The obtained results indicated that the effect of ENZ and its interaction with FAP decreased carcass yield. Back fat thickness and primal cut yields were not affected ($p > 0.05$) by FAP and ENZ inclusion and were similar ($p > 0.05$) to the values of conventionally-fed pigs.

Results from PI (Table 5) showed that the return on investment by monetary unit in the growth phase was better for *T50-0*, while *T0-0* showed the lowest profitability. However, in the finishing phase it was observed that *T0-1* had the best profitability and *T100-0* the lowest.

DISCUSSION

Results showed stability in the average feed intake and F:G ratio, allowing a constant weight gain, which is positive to maintain pig productivity. The reason why the use of FAP showed this stability is probably because it is an appropriate feed for the pig diet since this product was able to maintain the pig intestinal function, because when it is fermented the proportion of crude fiber decreases from 19.6 - 3.5 % (Joshi and Sandhu 1996) or from 2.8 to 6.7 %, as mentioned by Noblet and Le Goff (2001) and Heimendahl *et al.* (2010). Furthermore, fermented feeds improve digestive functions by controlling pa-

Table 4. Carcass traits and primal cut yield from pigs fed with solid-state fermented apple pomace and an enzymatic complex.

Item	Treatments (FAP-ENZ) g kg^{-1}							Significance level (*P-value*)			
	0-0	0-1	50-0	50-1	100-0	100-1	SEM	FAP	ENZ	FAP x ENZ	GEN
Slaughter weight (kg)	102.7	102.6	104.0	102.3	98.3	103.9	2.8	0.7581	0.5976	0.4373	0.0946
Hot dressing percent (%)	77.2^{a}	74.1^{b}	76.3^{b}	74.2^{b}	76.4^{ab}	74.4^{b}	0.8	0.1400	0.0497	0.1171	0.0517
Commercial dressing percent (%)	75.3^{a}	72.2^{b}	74.2^{b}	72.7^{b}	74.4^{a}	72.1^{b}	0.8	0.1393	0.0809	0.0495	0.0605
Back fat (cm)	2.3	2.1	2.1	2.4	2.5	2.2	0.2	0.8198	0.6771	0.4469	0.0291
Ham (%)	24.7	24.7	28.3	26.5	26.3	23.8	1.0	0.0547	0.1236	0.4656	0.1323
Loin (%)	19.1	21.1	19.8	20.1	21.6	19.8	0.9	0.7098	0.8426	0.1367	0.5761
Shoulder (%)	26.7	25.7	27.6	26.4	27.7	26.0	0.8	0.6197	0.0712	0.9153	0.2476
Ribs (%)	12.7	12.5	11.9	11.8	11.4	12.4	0.7	0.5833	0.6989	0.6386	0.1437
Filet (%)	1.4	1.6	1.3	1.3	1.3	1.6	0.1	0.3870	0.1715	0.4545	0.1535
Bacon (%)	12.9	12.9	11.7	13.1	12.2	13.1	0.6	0.7468	0.1654	0.5361	0.9506

Data displayed as mean ± SEM
Rows with different letters mean difference at $p < 0.05$ significance level.
SEM = Standard Error of the mean, FAP = Solid-State Fermented Apple Pomace, ENZ = Allzyme Vegpro®; Alltech
GEN = Gender (male, female) considered as block. FAP and ENZ = The fixed effect (individual effect of FAP or ENZ). FAP x ENZ = The interaction between FAP and ENZ effect.

thogenic bacteria (Jeong *et al.* 2014).

Fang *et al.* (2016) reported that pigs fed with 50 g kg^{-1} of apple pomace-mixed silage decreased average feed intake and feed efficiency, but maintained average daily gain and the finished body weight was not affected. On the other hand, Lee *et al.* (2009) reported that using fermented apple pomace (40 g kg^{-1} and 60 g kg^{-1}) in Berkshire pigs increased food intake, while feed conversion decreased when the by-product was added at 20 g kg^{-1}. Bowden and Berry (1959) reported that pigs fed with dried apple pomace (inclusion ranged from 100 to 400 g kg^{-1}) did not show negative effects on feed intake, recording an average feed intake of 2.7 kg, similar to the results obtained in this experiment. However, they mentioned that the F:G ratio and average feed intake were negatively affected when apple pomace levels increased to 400 g kg^{-1}. In this study, when 50 and 100 g kg^{-1} were used, average feed intake and F:G ratio did not decrease during the growth period, which indicates that pigs were able to intake FAP at this level, since the start of the experimental period. On the other hand, using other by-products in pig feed, Jeong *et al.* (2014) reported that the addition of 671 g kg^{-1} of carrot by-product on the finishing pig diet improved average daily gain and final weight. Kim *et al.* (2006) reported that feeding finishing pigs with persimmon by-product (30, 50, and 70 g kg^{-1} addition levels) improved feed efficiency when 50 g kg^{-1} were added, but when the addition level was increased to 70 g kg^{-1} the evaluated characteristics did not improve. Thus, the importance of this experiment can be found in the fact that when FAP addition was 100 g kg^{-1}, productive characteristics were similar to control feeding conditions, probably because FAP contains good quality protein (Cuoto and Sanromán 2006, Nasseri *et al.* 2011). In this regard, it has been demonstrated that the crude protein provided by FAP maintains its biological value similar to soy, wich is used as a main protein source in the feeding of pigs (Ahmadi *et al.* 2010). In addition, Slagle and Zimmerman (1979) mention that the protein obtained from a solid-state fermentation process combined with soy maintains its

Table 5. Profitability index for diet cost for pigs fed with a solid-state fermented apple pomace and an enzymatic complex.

Treatments	Diet cost (USD$K^{-1})		Profitability index	
FAP - ENZ (g kg^{-1})	Growing	Finishing	Growing	Finishing
0-0	0.37	0.33	0.18	0.29
0-1	0.38	0.33	0.22	0.31
50-0	0.36	0.32	0.25	0.29
50-1	0.4	0.34	0.22	0.28
100-0	0.38	0.33	0.22	0.26
100-1	0.42	0.35	0.21	0.29

FAP= Solid-state fermented apple pomace ENZ= Allzyme Vegpro®.

biological value and does not affect the productive characteristics of the pig.

ENZ addition did not show improvement for average feed intake, F:G ratio, and average daily gain. However, results obtained in this experiment using ENZ are contrary to those of Oliveira-Texeira (2005) and Soria-Flores (2009), who reported that the addition of this enzymatic complex improved average feed intake and weight gain. However, our results agree with those of Ruiz *et al*. (2008), Ristanović *et al*. (2009), and Zamora *et al*. (2011), who did not assure productivity improvement with ENZ addition; this means that its usage is controversial because it only increased the production costs, when added or combined with FAP. Additionally, results obtained in this experiment agree with those of experiments made using other agricultural by-products to feed pigs (Xandé *et al*. 2007, Oddoye *et al*. 2009, Newman *et al*. 2011, Chu *et al*. 2013, Jeong *et al*. 2014), where growth and finishing characteristics were not negatively affected.

Regarding carcass traits, the addition of ENZ, alone and with 50 g kg^{-1} and 100 g kg^{-1} of FAP, negatively affected HDP, while CDP was affected by the addition of 50 g kg^{-1} and 100 g kg^{-1} of FAP in combination with ENZ, although an effect of ENZ (treatment *T0-1*) was observed. There are currently no reports on the effect of ENZ on the dressing percent or pig carcass, so the results of this experiment are considered relevant. However, for the use of apple pomace, Fang *et al*. (2016) reported that feeding 50 g kg^{-1} of apple pomace-mixed silage did not affect the dressing ratio. Lee *et al*. (2009) reported an increase in dressing percentage with 20 g kg^{-1} of apple pomace mix addition, but when the level increased to 40 and 60 g kg^{-1} it resulted in a dressing percentage that was similar to the control group. Bowden and Berry (1959) reported that 100 to 300 g kg^{-1} of dried apple pomace addition did not affect HDP, but when 400 g kg^{-1} were included, HDP decreased significantly. Jeong *et al*. (2014) reported that the use of a fermented carrot by-product did not affect HDP or CDP and that the carcass traits were positively related to the addition of the by-product. Finally, the same performance in carcass was reported by Xandé *et al*. (2007) and Newman *et al*. (2011), who used agricultural by-products. Results of this experiment may indicate that 50 g kg^{-1} and 100 g kg^{-1} of FAP without ENZ were suitable to feed pigs because productivity and dressing percentages were not negatively affected, and a beneficial effect on commercialization may be shown.

In this work, only when ENZ was added (alone or in combination with FAP) was dressing percentage affected. Furthermore, an improvement in productive characteristics was not observed; therefore, it is possible that for farmers the use of ENZ is not economically feasible, when the pigs are sold and when the carcasses are retailed.

Back fat thickness (BFT) was similar for all treatments, although a gender effect was observed. Back fat for males was higher ($p = 0.0291$) than females (2.5 cm versus 2.02 cm; respectively); nevertheless, these effects were considered as a block in the statistical model, due to the differences that exist between genders for pig carcass traits, due to the effects of castration (Bérard *et al*. 2010 and Monziols *et al*. 2005). Fang *et al*. (2016) reported that a diet with 50 g kg^{-1} of apple pomace did not affect BFT. Conversely, Lee *et al*. (2009) using an apple pomace mix including reported an increase in BFT and they mentioned that their results were related to the high fat content in the diet. For this experiment FAP provided only 32 g kg^{-1} of fat, which could explain the non-difference in BFT. The fact that the carcass characteristics were not affected is an advantage for the use of FAP.

Primal cut yields were similar in all treatments. Reports on the effect of FAP on primal cuts have been poorly reported and only Bowden and Berry (1959) mentioned that feeding pigs with 100 to 300 g kg^{-1} of dried apple pomace did not affect ham shoulder, loin and bacon yield. But when they included 400 g kg^{-1} of by-product, loin and ham yield increased.

In general, pigs fed with 50 and 100 g kg^{-1} of FAP grew consistently and after nine weeks of feeding the FW was similar. Thus, if a producer decides to use FAP, adding 100 g kg^{-1} will maintain adequate growth and result in similar characteristics when compared with animals fed in a standard way. Also, carcass dressing percentage will not show a significant decrease that would result in financial losses. Furthermore, at retail sale, the fact that similar yields for ham, loin, shoulder, and bacon, which are considered to be the most important pig cuts (Correa *et al*. 2008, Kouba and Bonneau, 2009), were not affected implies that economic profitability will be maintained, making FAP addition a good option in pig diet formulation.

Oliveira-Teixeira (2005), who used ENZ, mentioned that PI has increased when 1 g kg^{-1} of ENZ was added but when ENZ addition was 4 g kg^{-1} only a tendency to increase was shown. This agrees with the PI increase in this work, although a positive ENZ effect was observed when it was added alone in the finishing phase; when ENZ was combined with FAP, PI showed a tendency to decrease. Finally, the FAP and ENZ addition did not affect pig productivity, but affected HDP, while 100 g kg^{-1} of FAP addition resulted in an HDP similar to that for pigs fed with a standard diet (corn and soy), and 50 g kg^{-1} of FAP kept a good PI, which means that 50 g kg^{-1} of FAP with or without ENZ could be added to obtain a similar final weight and good PI.

In reference to the above information, if producers want to sell pigs at farm point they may use ENZ in combination with 50 g kg^{-1} or 50 g kg^{-1} of FAP as there are no negative effects on growth. If producers want to sell pork carcasses, they may use 50 g kg^{-1} or 100 g kg^{-1} of FAP addition without ENZ, since the HDP will be similar to pigs conventionally fed and the economic income will not be drastically affected. Moreover, if producers want to sell primary cuts, an addition of 50 g kg^{-1} or 100 g kg^{-1} of FAP with ENZ will produce a similar cut yield, improving PI and stabilizing the price and value of the meat.

CONCLUSION

Pigs fed with FAP and ENZ displayed similar growth as conventionally-fed pigs. Addition of 1 g kg^{-1} of ENZ with or without FAP decreased HDP by 4.6 % and CDP by 5.4 %. Inclusion of 100 g kg^{-1} of FAP produced similar HDP, CDP, and primal cuts. Pigs fed with 100 g kg^{-1} of FAP and 1 g kg^{-1} of ENZ obtained a similar PI to conventionally-fed pigs. Under these experimental conditions, the use of FAP may be considered as a suitable option to feed pigs.

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