EFFECT OF FERMENTABLE LIQUID DIET BASED ON TOMATO SILAGE ON THE PERFORMANCE OF GROWING FINISHING PIGS

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SUMMARY

This study was performed to evaluate the use of tomato silage as part of a fermentable liquid diet for growing finishing pigs. Thirty two crossbreed (Duroc × York) male pigs of 27 ±3 days age and 8.4 ±1.3kg body weight (BW) were randomly assigned to one of two diets: diet 1, basal diet with 30% (DM basis) of tomato silage (TS); and diet 2, basal diet with 30% (DM basis) of wet brewers grains (WBG) as control. Growth and carcass characteristics were measured. The average daily weight gain (ADG) was improved (P<0.05) in pigs fed TS diet at 0-40 and 40-80 days feeding periods. Pigs on TS diet grew faster (P<0.05) than pigs on WBG diet. Carcass characteristics were unaffected (P>0.05) by TS addition. It is concluded that tomato silage can be added at 30% DM basis in fermentable liquid diets of growing-finishing pigs, because this diet improved growth performance without affect carcass characteristics.

EFECTO DE LA ALIMENTACIÓN DE CERDOS EN CRECIMIENTO Y FINALIZACIÓN CON DIETAS LÍQUIDAS FERMENTABLES A BASE DE ENSILAJE DE TOMATE

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RESUMEN

Este estudio fue conducido para evaluar el uso de ensilaje de tomate como parte de dietas liquidas fermentadas para cerdos en crecimiento y finalización. Treinta y dos cerdos machos (Duroc × York) de 27 ±3 días de edad y con un peso inicial de 8,4 ±1,3kg de peso vivo (PV) fueron asignados aleatoriamente a una de dos dietas experimentales: dieta 1, una dieta basal con 30% (en base a MS) de ensilaje de tomate (ET); y la dieta 2, una dieta basal con 30% (en base a MS) con bagazo de cervecería húmedo (BCH) como control. Se evaluaron los parámetros productivos y las características de la canal. La ganancia diaria de peso (GDP) se incrementó (P<0,05) en los cerdos alimentados con ET en los periodos de alimentación de 0-40 y 40-80 días. Los cerdos alimentados con la dieta ET crecieron más rápido (P<0,05) que los cerdos alimentados con la dieta BCH. Las características de la canal no fueron afectadas (P>0,05) por la adición de ET. Se concluye que el ensilaje de tomate puede ser incluido en un 30% de las dietas liquidas fermentadas de cerdos en crecimiento-finalización, debido a que esta dieta mejora los parámetros productivos sin afectar las características de la canal.

Introduction

The traditional swine feeding is based on soybean meal, and corn or sorghum grains, which have had price increases becoming expensive in recent times. The average price for cereals during 2000 to 2005 was USD204/ton; however, for 2006 to 2010 the price increased up to USD417/ton (FAOSTAT, 2013). Therefore, the pork industry is including now agro industrial byproducts as a strategy to maintain its profitability (Aguilera-Soto *et al*., 2009). Some byproducts have a high level of humidity and are therefore frequently dried before being stored or transported; nevertheless, due to environmental concerns and the additional expenses from fuel cost for drying, the use of wet byproducts is becoming popular among farmers. Moist feed are usually perishable due to aerobic decay, which produces nutrient loss and contamination with microorganism and their toxins. Thus, fermentation is an option for storage of wet byproducts.

Fermentable liquid diets (FLD) are used as an option to include wet byproducts on swine diets (Jensen and Mikkelsen, 1998). The FLD enhances swine health by dropping stomach pH, increasing lactic acid concentration and decreasing populations of

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EFEITO DA ALIMENTAÇÃO DE PORCOS EM CRESCIMENTO E FINALIZAÇÃO COM DIETAS LÍQUIDAS FERMENTÁVEIS A BASE DE ENSILAGEM DE TOMATE

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RESUMEN

Este estudo foi conduzido para avaliar o uso de ensilagem de tomate como parte de dietas líquidas fermentadas para porcos em crescimento e finalização. Trinta e dois porcos machos (Duroc × York) de 27 ±3 dias de idade e com um peso inicial de 8,4 ±1,3kg de peso vivo (PV) foram designados aleatoriamente a uma de duas dietas experimentais: dieta 1, uma dieta basal com 30% (com base a MS) de ensilagem de tomate (ET); e a dieta 2, uma dieta basal com 30% (com base a MS) com bagaço de cervejaria úmido (BCU) como controle. Avaliaram-se os parâmetros produtivos e as características da trincheira. O ganho diário de peso (GDP) se incrementou (P<0,05) nos porcos alimentados com ET nos períodos de alimentação de 0-40 e 40-80 dias. Os porcos alimentados com a dieta ET cresceram mais rápido (P<0,05) que os porcos alimentados com a dieta BCU. As características da trincheira não foram afetadas (P>0,05) pela adição de ET. Conclui-se que a ensilagem de tomate pode ser incluída em um 30% das dietas liquidas fermentadas de porcos em crescimento-finalização, devido a que esta dieta melhora os parâmetros produtivos sem afetar as características da trincheira.

pathogens such as *E. Coli* and *Salmonella* spp. (Mikkelsen and Jensen, 2000; Van Winsen *et al*., 2001). It also has the potential to utilize co-products from the food industry (Geary *et al*., 1999; Scholten *et al*., 2002). The weight gain, feed intake and feed efficiency of pigs fed FLD are variable in some cases, but most of the time these are similar to obtained by pigs fed dry diets (Lawlor *et al*., 2002).

Tomato originated in South America, but it is considered to have been domesticated in Mexico (Pickersgill, 2007). It is one of the main vegetable crps cultivated in the world, with a global production of 159×10^6ton in 2011, 44% more than was produced in 2000 (FAOSTAT, 2013). Tomatoes are consumed in fresh form, and a minor proportion is used in processed products such as juice, paste, sauce, ketchup and others (Peralta and Spooner, 2007). However, more than 10% of the total production does not meet consumer requirements, resulting in post-harvest waste (Geisman, 1981). The percentage of waste could be greater in regions where a tomato processing industry is not present, when tomato is produced in open field, or when greenhouse tomatoes are exported and more products is discarded (Riggi and Avola, 2010). All of these situations occur in the central region of Mexico and therefore high amounts of tomato are available and could be used as animal feed. Thus, the aim of the present study was to evaluate growth performance and carcass characteristic of pigs consuming a FLD with 30% of tomato silage on dry basis.

Materials and Methods

Tomato collection sites

Discarded tomatoes (*Solanum lycopersicum* L. var. Saladette) were collected from the selection line in open field production at three sites located in Zacatecas, Mexico: Guadalupe (22º50'4"N, 102º24'4"W), Panuco (22º56'0"N, 102º27'18"W), and Villa de Cos (23º5'34"N, 102º15'30"W). Altitude varies from 1750 to 2400masl, average temperature 14-19ºC, and annual rainfall 375-430mm (INIFAP, 2013).

The collected tomatoes were transported to the experimental site, stored under roofed facilities with sloped concrete floor, and covered with plastic for 5 days. Tomatoes were then ensiled in 200 liter metallic containers and were covered with a plastic film. Water was added over the top of the plastic cover to ensure the absence of oxygen. The containers were checked every 14 days, and additional water was added over the plastic cover when necessary. The silage period lasted for at least 140 days.

Thirty-two Duroc × York castrated male pigs (27 ±3 days of age and 8.4 ±1.3kg weight) were randomly allotted in groups of four pigs per pen, and pens were assigned to one of two experimental groups (16 pigs and 4 pens per treatment). The basal diets considered three feeding periods (post-weaning, growing and finishing) with 22.5, 20.5 and 18% of crude protein (CP), respectively, as recommended by Fabian *et al.* (2004). Basal diets consisted of a mix of corn grain and soybean meal (Table I) to which $300 g \cdot kg^{-1}$of TS or WBG (as control) on DM basis were added. To prepare the experimental diets as FLD, water was added to the ration treatments in order to get 50% humidity. Mixed diets were then stored in metallic containers of 200 liters during an average of 8 days to allow fermentation. Diet samples were dried and ground in a Wiley mill with 1mm mesh (Thomas Scientific, Swedesboro, NJ, USA) and stored in plastic bags for further chemical analyses. Dry matter (DM), ash, crude protein (CP), crude fiber (CF) ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF) were determined using the AOAC (2006) methods.

Pigs were adapted to experimental diets for a period of 10 days and thereafter remained in the feeding trial until they reached an average weight of 95kg per pen. Diets were offered twice a day (08:00 and 16:00), considering a 5% daily increase. Pig intake was determined by registering weight differences between offered and refused feed. Pigs were individually weighed every 20 days.

At the end of the feeding trial, pigs were deprived of food overnight, and in the next morning were transported to the abattoir. Pigs were weighed immediately before harvest, and hot carcass weight was registered immediately. The non-carcass components: head, skin, feet, liver, heart, lungs, pluck, empty gut, small intestine, large intestine and cecum were individually recorded. In addition, lungs, trachea and heart were weighted as one piece, and designated as pluck.

Carcasses were hanged and refrigerated at 3-5ºC. Carcass pH was measured at 45min post-mortem from the semimembranosus muscle using a portable pH meter. Dorsal fat thickness and chop eye were measured with a ruler at the middle line of the dorsal area at the 10^{th} and 12^{th} thoracic vertebrae. The prediction of the primary cuts was estimated according to the Savelland and Behrends (2005) equation, which uses hot carcass weight, dorsal fat thickness and chop eye in the calculation.

TABLE I
INGREDIENT AND CHEMICAL COMPOSITION OF THE FERMENTABLE LIQUID DIETS WITH TOMATO SILAGE (TS) OR WET BREWER`S GRAIN (WBG)

	Feedingperiod					
	Post weaning		Growing		Finishing	
	TS	WBG	TS	WBG	TS	WBG
Wet brewers grain, g·kg^{-1}	0.0	300	0.0	300	0.0	300
Tomato silage, g·kg^{-1}	300	0.0	300	0.0	300	0.0
Corn grain, g·kg^{-1}	400	400	460	460	480	480
Soybean meal, g·kg^{-1}	250	250	200	200	150	150
Fish meal, g·kg^{-1}	25.0	25.0	15.0	15.0	25.0	25.0
Premix, g·kg^{-1}	20.0	20.0	20.0	20.0	20.0	20.0
Calcium carbonate g·kg^{-1}	5.0	5.0	5.0	5.0	5.0	5.0
Chemical composition						
Dry matter, %	52.7	51.0	49.9	50.4	50.2	51.8
Ash, %	4.1	4.4	4.4	4.6	4.0	4.3
Crude protein, %	23.5	23.3	20.5	20.4	18.4	18.0
Neutral detergent fiber, %	18.1	19.5	16.3	18.6	17.1	18.5
Acid detergent fiber, %	7.2	8.4	7.2	8.2	7.4	7.9
Crude fiber, %	5.8	6.2	5.6	6.1	5.9	6.0
Ether extract, %	2.4	2.4	2.6	2.6	2.9	2.8

WBG: diet served as control.

Statistical analysis

Data were analyzed by using one-way analyses of variance applying the GLM procedure of SAS (2000). Growth performance variables were adjusted for initial weight by covariance analyses. Means were separated by means of the Tukey multiple range test at P<0.05.

Results and Discussion

Weight of pigs differ (P<0.05) among treatments at all feeding periods (Table II). Pigs fed TS diet were heavier (P<0.05) than pigs consuming the control diet (11, 16 and 10% at post-weaning, growing and finishing phases, respectively). Pigs fed TS diet were 9.8% heavier (P<0.02) at 130 days than pigs fed control diet. The average daily gain (ADG) in weight was greater (P<0.01) for pigs fed TS than for pigs fed WBG diet, at the post-weaning (423 *vs* 360 g/day) and growing (763 *vs* 633 g/day) feeding phases; however, it was similar (P=0.46) at the finishing phase, with gains of 810 and 790 g/day for pigs fed TS and WBG diets, respectively.

TABLE II
GROWTH PERFORMANCE OF PIGS FED LIQUID FERMENTABLE DIETS BASED ON 30% OF TOMATO SILAGE (TS) OR WET BREWER GRAINS (WBG)

	TS	WBG	SEM	P<
Weight, kg				
0 - 40 days	8.3	8.4	0.15	0.9
40 - 80 days	25.2	22.8	0.5	0.01
80 - 130 days	55.7	48.1	0.6	0.01
0 - 130 days	96.2	87.6	0.5	0.02
Total gain	87.9	79.2	0.15	0.01
Average daily gain, g/d				
0 - 40 days	423	360	14	0.01
40 - 80 days	763	632	16	0.01
80 - 130 days	810	790	14	0.46
0 - 130 days	676	609	11	0.01
Dry matter intake, g/d				
0 - 40 days	1125	1180	28	0.01
40 - 80 days	1713	1860	27	0.01
80 - 130 days	2315	2520	28	0.01
0 - 130 days	1864	1905	24	0.01
Feed efficiency	2.8	3.1	0.1	0.01
Days to 95kg	136	150	1.5	0.01

Feed efficiency: dry matter intake/average daily gain, WBG: diet served as control, SEM: standard error of the mean.

In agreement with the present results, Caluya *et al.* (2000) added 6% (on DM basis) of tomato pomace to fattening commercial diets and reported an increase on the ADG and final weight of pigs on the tomato feeding diet. In turn, Cilev *et al.* (2007) substituted corn grain with vegetable and fruit by-products in growing pig diets, and reported that during the initial feeding period (50 days), pigs on the tomato diet were lighter than controls; however, after 100 days of fattening the final weight was similar (P>0.05) when fed 0% (96.2kg), 2% (98kg), or 3% (99.5kg) of tomato pomace in the diet.

On the other hand, Imamidou *et al.* (1999) added 4 or 8% of dry tomato pulp to swine diets and reported lower (P>0.05) nutrient digestibility (DM, OM, CP and CF) on animals fed 8% of tomato pulp. Fondevila *et al.* (1994) added 20% of tomato pomace to diets for growing lambs and observed similar ADG (P>0.05) in comparison to soybean meal diets (311 and 333 g/day, respectively). In addition, Abdullahzadeh (2012) reported similar (P>0.05) final weights for goat kids fed diets with 0, 10, 20 and 30% dried tomato pomace. Similarly, Barbieri-Sanz (1993) added 0, 10, 20, 30 and 40% of wet tomato pomace to diets for feedlot steers, and reported similar (P>0.05) performance data among the experimental treatments. However, Yuangklang *et al.* (2010) reported a reduction in the final weight of steers as dried tomato pomace was increased (3.2, 8.0, or 11.2%) in diets.

Pigs on TS diet had a greater (P<0.01) dry matter intake (DMI) than pigs on a WBG diet at all feeding periods (Table II). The difference between treatments was 5% in the post-weaning phase, and 9% in the subsequent feeding phases. Cilev *et al.* (2007) reported reduction of DMI of pigs when tomato pomace was included (at 2 or 3%) in the diets. Yitbarek (2013) observed similar DMI (P>0.05) among growing chicks fed diets with 0, 5, 10, 15 or 20% of dried tomato pomace. However, Lira *et al.* (2010), who included 0, 5, 10, 15 and 20% of tomato waste on broiler diets, reported that DMI was reduced as tomato increased in the diet in the initial 1 to 7 days of feeding, but DMI increased at days 36 to 42 of fattening. Moreover, feed efficiency followed the same pattern as ADG. In the present study, pigs on TS diet required fewer days (P<0.01) to reach target weight (142 *vs* 129 days for pigs fed WBG and TS diets, respectively; Table II).

In this study, carcass and non-carcass components were similar (P>0.05) between treatment diets (Table III). Also, Abo-Omar (2003) re-

TABLE III
CARCASS CHARACTERISTICS OF PIGS FED LIQUID FERMENTABLE DIETS BASED ON 30% OF TOMATO SILAGE (TS) OR WET BREWER GRAINS (WBG)

Concept	TS	WBG	SEM	P<
Days to harvest	130	142	1.9	0.01
Weight at harvest, kg	96	95	2.1	0.6
Hot carcass weight, kg				
With head	74	73	0.6	0.4
Without head	69	68	0.4	0.4
Carcass yield, %				
With head	77	76	0.6	0.6
Without head	72	72	0.6	0.6
pH *post-mortem*				
45min	6.3	6.4	0.2	0.8
24h	6	6	0.2	0.7
Back fat thickness, mm				
10^{th} rib	25	25	2	0.6
12^{th} rib	22	23	2	0.4
Ribeye area, mm^2	97	96	22	0.6
Primary cuts, kg	45	44	1	0.6
Head, g	4830	4780	118	0.8
Liver, g	1580	1530	56	0.6
Heart, g	318	322	18	0.7
Lungs, g	880	865	38	0.6
Pluck, g	1520	1490	54	0.7
Empty gut, g	550	570	33	0.5
Small intestine, g	1280	1310	38	0.8
Large intestine, g	825	860	26	0.6
Cecum, g	162	172	22	0.7

WBG: diet served as control, SEM: standard error of the mean.

ported similar carcass and visceral organ weight when including 0, 15, 30 or 45% of by-product silage to diets of Awassi lambs. Abdullahzadeh (2012) reported similar (P>0.05) hot carcass weight and dressing percentages in goat kids fed diets containing dried tomato pomace; however, this author reported greater CP and ether extract contents in the carcasses of goat kids fed dried tomato pomace at levels of 20 and 30% compared with levels of 0 and 10%. Lira *et al*. (2010) added 0, 5, 10, 15 and 20% of tomato pomace to diets of broilers and reported similar (P>0.05) wings, breast and abdominal weight; however, they mentioned that the relative weights of liver and heart were greater in broilers fed tomato diets.

Conclusion

Tomato silage can be added at 30% DM basis to fermentable liquid diets of growing finishing pigs, as this diet improved growth performance without affect carcass characteristics.

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