

Impact of Fermented Liquid Potato Hash Diets on Growth Performance of Grower Pigs

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Received: September 30, 2017

Accepted: January 30, 2018

Online Published: May 15, 2018

doi:10.5539/jas.v10n6p1

URL: <https://doi.org/10.5539/jas.v10n6p1>

Abstract

The study aimed to evaluate growth performance of grower pigs fed fermented liquid potato hash with or without exogenous enzyme. Diets containing either 200 (LFLPH) g/kg potato hash (enzyme treated or not); 400 (HFLPH) g/kg potato hash (enzyme treated or not) or no fermented potato hash (control) were formulated to provide 14 MJ/kg digestible energy (DE), 180 g/kg crude protein (CP) and 11.6 g/kg lysine. Dietary treatments were control (no FLPH), enzyme treated LFPHE and HFLPHE, and untreated LFLPH and HFLPH. The exogenous enzyme was added in treated diets to provide minimum of 560-840 TXU/TDU xylanase per kg feed, at an inclusion rate of 100 g/tonne. Diets were mixed with water at 1:2 ration and fermented for 8 hours at 25 °C room temperature before being fed to pigs. Back-slopping fermentation approach was followed to prepare diets. Twelve pigs (25±2.3 kg) per diet that were individually housed were fed *ad-lib* for eight weeks. Pigs were allocated to diets in complete randomized design. Average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) were measured. The enzyme treated FLPH diets had higher ($P < 0.05$) CP, lower ($P > 0.05$) NDF and ADF concentrations compared to untreated FLPH diets. The LFPHE diet had higher ($P < 0.001$) final weight, ADG and lower ($P < 0.001$) ADFI and FCR compared to LFLPH, HFLPH and HFLPHE. It was concluded that LFPHE diet may be an alternative feed source for growing pigs as indicated by higher gain and lower intake compared to LFLPH, HFLPH and HFLPHE.

Keywords: fermentation liquid feed, potato hash, grower pigs, exogenous enzyme

1. Introduction

In South Africa, the declining grain production and increasing competition with humans for feed ingredients have compelled smallholder pig farmers to use alternative energy sources from agro-industrial by-products to replace cereals in pig diets (Nkosi et al., 2010; Thomas et al., 2010). By-products of industrial potato processing such as potato hash are a potential energy resource, which could replace or be included in traditional pig diets (Thomas et al., 2010). According to Thomas et al. (2010), potato hash is a potato by-product produced during processing of Simba chips in Gauteng province, South Africa. The hash is produced at a rate of ±50 tons per day and is currently dumped (Nkosi & Meseke, 2010) and is polluting the environment. However, this by-product contains 150 g/kg dry matter, 105 g/kg crude protein and 58.5 g/kg crude fiber (Nkosi et al., 2015) and can be useful as pig feed. According to Charmley et al. (2006) and Okine et al. (2005), high moisture content of potato by-products such as potato hash is limiting the utilization of the by-products in pig nutrition. Another setback in feeding potato hash to growing pigs is that it contains high fiber content (Thomas et al., 2010). Kanengoni et al. (2004) and Fevrier et al. (1992) reported that high fiber diets in growing pigs' increases rate of passage. In addition, high fiber diets reduces digestion and rate of nutrients absorption (Wenk, 2001). Fermentation of high fiber by-products and use of exogenous enzymes have been reported to disrupt the fibre matrix structure

enabling further breakdown of fiber components of the diet (Le Gall et al., 2009; Zhang et al., 2010; Urriola et al., 2010). Therefore the study proposes to ferment and feed potato hash as a liquid feed.

Liquid fermented feed (LFF) has been defined as a mixture of feed (dry feed, by-products) with water at a ratio ranging from 1:1.4 to 1.5 and fermented for a minimum of 8 hours before being fed to the pigs (Canibe & Jensen, 2003). Feeding LFF has been reported to reduce several pathogens along gastrointestinal-tract (GI-tract) of growing pigs (Hong et al., 2009). Also, Brooks (2008), and Canibe and Jensen (2003) reported higher growth performances when pigs were fed LFF. Enzymes have been used as additives, and have been incorporated in high moisture by-products to reduce DM losses and improve nutritive value of the diet (Nkosi et al., 2015; Urriola et al., 2010). Addition of exogenous enzymes in the diet degrade fiber to fermentable water-soluble carbohydrates (WSC) for use by LAB (Eun & Beauchemin, 2007). The LAB in the diet will inhibit exogenous enzyme activities against structural carbohydrates in fermented diets (Xing et al., 2009). Therefore, the aim of the study was to evaluate growth performance of Large White × Landrace crossbred pigs fed varying levels of fermented liquid potato hash diets treated with or without exogenous xylanase feed enzyme (Natugrain TS L®).

2. Materials and Methods

2.1 Location and Experimental Area

The study was conducted at the Pig Nutrition Research Unit of Agricultural Research Council (ARC), Animal Production (AP), (ARC-AP: Irene, Pretoria, South Africa). The ARC-AP campus is located at 25°55' South; 28°12' East. The campus is located in the Highveld region of South Africa and situated at an altitude of 1525m above sea level. Potato hash (PH) was collected from Simba (Isando, Gauteng, South Africa), a potato chips factory in South Africa for production of fermented liquid potato hash diet (FLPH). The study was approved by the Agricultural Research Council Animal Ethics committee (Reference Number: APIEC16/005).

2.2 Fermentation Process and Diets

A back-slopping fermentation approach was used to prepare fermented liquid potato hash diets as described by Plumed-Ferrer and Von Wright (2009). Fermented liquid diets were prepared by mixing potato hash diets with water, at a ratio of 1:2. The composition of the potato hash before fermenting is shown in Table 1. Five diets (Table 2) were formulated to be isoenergetic and isonitrogenous containing either 200 (LFLPH) g/kg potato hash (enzyme treated or not); 400 (HFLPH) g/kg potato hash (enzyme treated or not) or no fermented potato hash (control). The diets were formulated to provide 14 MJ/kg digestible energy (DE), 180 g crude protein (CP)/kg and 11.6 g lysine /kg which meet and exceed the requirements of growing pigs (NRC, 1998). The five dietary treatments were: control (no FLPH), enzyme treated LFPHE and HFLPHE, and untreated LFLPH and HFLPH. The exogenous xylanase enzyme (Natugrain TS L®) was added in the diets before fermenting diets to provide a minimum enzyme activity of 560-840 TXU/TDU xylanase per kg feed, at an inclusion rate of 100 g/tonne. The fermented diets were stored in closed 100 L drums under agitation at 25 °C for 8 hours before being fed to the pigs. Pigs were adapted to diets for a period of ten days. The pigs were fed *ad libitum* for eight weeks and water was made available at all times through drinking nipples.

Table 1. Composition of potato hash (g/kg DM) pre-fermentation (n = 3)

Parameter	Mean±SD
Dry matter, g/kg	374±0.92
Crude protein, g/kg DM	192±0.88
Gross energy MJ/kg DM	18.9±0.74
aNDF, g/kg DM	468±0.98
Acid detergent fibre, g/kg DM	129±0.87
Water soluble carbohydrates, g/kg DM	79±0.71
pH	5.05±0.54

Note. aNDF, amylase-treated neutral detergent fibre.

2.3 Pigs, Experimental Design and Housing

Sixty (12 pigs per treatment) crossbred pigs (Large White × Landrace) aged 55 days with an average weight of 25.5±3 kg were randomly selected from the ARC-AP Irene, pig breeding unit. Pigs were allocated to dietary treatments in a completely randomized design. The pigs were housed individually in 1.54 × 0.8 m pens in

environmentally controlled houses with the temperature ranging from 22 to 25 °C. The feeders were checked and adjusted twice each day to ensure constant access to fresh feed and minimize any possible wastage.

2.4 Chemical Composition Analysis

Diets were analysed in triplicate, in the Animal and Poultry Science Laboratory at the University of KwaZulu-Natal, Pietermaritzburg. Dry matter (DM) content was determined by oven-drying the samples at 65 °C for 48 hours. The ash content was determined after incineration of the sample at 550 °C for 4 hours according to method 990.05 (AOAC, 1990). Dry samples were ground through a 1 mm screen (Wiley mill, Standard Model 3, Arthur H. Thomas Co., Philadelphia, PA, USA) for chemical analyses. The neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents were determined following the procedures of Van Soest et al. (1991) using ANKOM Fibre Analyser (Ankom, Macedon, NY, USA). Separate samples were used for ADF and amylase-treated neutral detergent fibre (aNDF) analyses and both included residual ash. The GE was determined with bomb calorimetry (MS-1000 modular calorimeter, Energy Instrumentation, Centurion, South Africa).

2.5 Measurements

During the study, the pigs were weighed individually on a weekly basis to determine daily body weight gain. Daily feed offered and weekly orts were recorded. The orts were dried, weighed and discarded daily. Weights of feed refusals and orts were subtracted from the total weight of the feed allocated to determine feed intake for that week. Weight of the feed consumed each week was divided by seven to determine the average daily feed intake. Feed was supplied *ad libitum* and water was made available at all times through drinking nipples.

Table 2. Composition of varying inclusion levels of fermented liquid potato hash (as-is basis)

	Experimental diets ¹		
	CON	LLFPH	HLFPH
<i>Ingredient, kg</i>			
Hominy Chop	608.7	504.4	400
Molasses	20	15	10
Potato hash	0	200	400
Soybean oilcake	181.4	166.7	152.1
Corn meal	150	75	0
Monocalcium phosphate	5	8.1	11.2
Limestone	18.8	16.3	13.7
Lysine HCl	8	6.5	5
Salt	4	4	4
Vitamin-mineral premix ²	4	4	4
<i>Nutrients, g/kg</i>			
DM	892	605	599
Ash	25	31	37
CP	180	180	180
Crude fibre	57	58	60
Calcium	9.12	9.12	9.12
Phosphorus	5.47	5.46	5.46
Lysine	11.6	11.6	11.6
Methionine	0.67	0.56	0.56
DE, MJ/kg	13.5	13.5	13.5

Note. ¹CON = control (liquid fermented control with and without enzyme); LLFPH = low inclusion of liquid fermented potato hash with and without enzyme; HLFPH = high inclusion of liquid fermented potato hash with and without enzyme. ²Provided the following per kg of diet: 6,500 IU vitamin A, 1,200 IU vitamin D3, 40 IU vitamin E, 2 mg vitamin K3, 1-5 mg vitamin B1, 4.5 mg vitamin B2, 0.03 mg vitamin B12, 2.5 mg vitamin B6, 25 mg niacin, 12 mg calcium pantothenate, 190.5 mg choline, 0.6 mg folic acid, 0.05 mg biotin, 40 mg manganese, 100 mg zinc, 125 mg copper, 1 mg iodine, 100 mg ferrous, and 0.3 mg selenium.

2.6 Statistical Analyses

Data of growth performance of grower pigs fed fermented liquid potato hash diets treated with or without enzyme were analysed for effects of treatment using General Linear Model (SAS Inst. Inc., Cary, NC). All data were tested for normality and homogeneity and comparisons were made to the 95% significance level. The model used was:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha \times \beta)_{ij} + \epsilon_{ijk} \quad (1)$$

where,

Y_{ijkl} is the performance parameter (ADFI, ADG and FCR); μ is the overall mean response common to all observations; α_i is the effect of fermentation (i = treatments); β_j is the effect of enzyme (j = E); $(\alpha \times \beta)_{ij}$ is the interaction between the enzyme and inclusion level and ϵ_{ijk} is the residual error.

3. Results and Discussion

Chemical composition of diets based on varying inclusion levels of fermented liquid potato hash treated with or without enzyme are shown in Table 3. Control diet had a higher ($P < 0.05$) dry matter (DM) and ash concentrations compared to diets containing varying levels of FLPH. The enzyme treated FLPH diets had higher ($P < 0.05$) DM and ash concentrations compared to untreated FLPH diets. Ideal, dry matter content of fermented liquid diets range from 200 to 300 g/kg⁻¹ (de Lange et al., 2006) and the results of this study are consistent with those findings. The DM content influence the quality of the resulting of fermented liquid diets. The enzyme treated FLPH diets had a lower ($P > 0.05$) NDF and ADF concentrations compared to untreated FLPH diets. Reduced fibre content with enzyme treated fermented liquid potato hash compared to untreated fermented liquid potato hash are consistent with previous observations on enzyme-treated fermented potato pulp diet (Li et al., 2011). The reduction in fibre content (NDF and ADF) with enzyme treated fermented liquid potato hash could be attributed to hydrolysis of hemicelluloses (Muck & Kung, 1997). These results, support studies that recorded reduced fiber content with enzyme treatment (Nkosi et al., 2011, 2015). There was no difference ($P > 0.05$) between treated and untreated FLPH diets on gross energy (GE) and ether extract (EE) concentrations. Control had a greater ($P < 0.05$) crude protein (CP) compared to FLPH diets. However, enzyme treated FLPH diets had a higher ($P < 0.05$) CP than untreated FLPH diets. Nkosi et al. (2015) also reported higher CP content on enzyme-treated diets which are consistent with the results of the current study. The CP increase could be due to the disappearance of dietary components (easily fermentable carbohydrates) during fermentation (Scholten et al., 2002; Canibe & Jensen, 2003). In addition, there were no differences ($P > 0.05$) in diet \times enzyme interactions on GE, EE and CP between diets containing varying levels of FLPH diets treated with or without enzyme.

Højberg et al. (2003) and Brooks et al. (2003) reported that fermented liquid diets reduced incidence of diarrhoea when fed to growing pigs. In the current study, pigs fed on fermented liquid potato hash did not have diarrhoea compared to control were three pigs were treated for diarrhoea which is consistent with those studies. Growth performance of growing LW \times LR crossbred pigs fed diets containing varying levels of FLPH treated with or without enzyme are shown in Table 4. There was no difference between LFLPHE and control diets on final weight, ADG, ADFI and FCR. The LFLPHE had higher ($P < 0.05$) average daily gain (ADG) and lower ($P < 0.05$) average daily feed intake (ADFI) and feed conversion ratio (FCR) compared to pigs fed diets containing LFLPH, HFLPH and HFLPHE. The fermented liquid diets treated with enzyme improved ($P < 0.05$) feed intake of grower pigs compared to LFPH, HLPFH and control treatments. There were diet \times enzyme interactions for ADG and FCR in the growing pigs. The current study is in agreement with studies (Kim et al., 2001; Choct et al., 2004; Han et al., 2006), that reported improved growth performance of grower pigs fed fermented liquid diets. Grower pigs when fed concentrates diets can record minimum daily gains of 630 g per day⁻¹ (Hoffman et al., 2003). However, the present study recorded daily gains of > 720 g day⁻¹ which was higher than those reported in a previous study (Thomas et al., 2010) when 200 and 400 g kg⁻¹ potato hash diets were included in the diet of grower pigs. In addition, Nkosi et al. (2010) also recorded lower daily gains < 120 g day⁻¹ when total mixed potato hash ration with or without bacterial inoculation was fed to growing crossbred (Large White \times Landrace) pigs. The current study reported a higher DMI for pigs fed low fermented liquid potato hash diet, which may be the reason for an improved ADG compared with pigs fed the control diet which is consistent with study by Brooks et al. (2003).

Table 3. Chemical composition (g/kg DM feed) varying inclusion levels of fermented liquid potato hash with or without exogenous enzyme (n = 3)

Composition ²	Treatments ¹								
	Control	LLFPHE	LFPH	HLFPHE	HLFPH	SEM	Diet	Enzyme	Diet×Enzyme
Dry matter g/kg DM	904.7 ^a	294.5 ^{bc}	284.7 ^c	260.4 ^d	256.3 ^d	0.189	<.0001	<.0001	<.0001
Ash g/kg DM	62.0 ^a	53.6 ^{bc}	51.1 ^{bc}	41.1 ^c	40.6 ^c	0.209	<.0001	<.0001	<.0001
Gross energy (MJ/kg)	18.1	17.9	17.9	17.9	17.8	0.656	0.326	0.605	0.728
Ether extract g/kg DM	49.0	48.5	44.5	38.9	37.5	4.14	0.048	0.688	0.679
Crude protein g/kg DM	194.0 ^a	193.5 ^a	186.5 ^c	190.0 ^b	178.0 ^d	1.13	<.0001	0.171	0.495
Density(g DM/ ml)	1.4	1.5	1.6	1.6	1.6	1.69	0.445	0.812	0.257
NDF (g/kg DM)	132.1 ^d	202.2 ^d	244.8 ^c	418.1 ^b	465.9 ^a	1.99	<.0001	<.0001	<.0001
ADF (g/kg DM)	39.1 ^c	71.3 ^d	80.1 ^c	98.9 ^b	106.85 ^a	0.085	<.0001	0.002	0.020

Note. ^{abc} Values with different superscripts within a row are different ($P > 0.0001$); ¹CON = Control diet; LLFPHE = Low liquid fermented potato hash with enzyme diet, LLFPH = Low liquid fermented potato hash without enzyme diet, HLFPH = High liquid fermented potato hash with enzyme diet, HLPHE = High liquid fermented potato hash without enzyme diet. ²NDF = neutral detergent fibre; ADF = acid detergent fibre.

Table 4. Growth performance of growing Large White × Landrace (LW × LR) pigs fed varying inclusion levels of fermented liquid potato hash with or without exogenous enzyme (n = 9)

Parameters ²	Treatments ¹								
	CON	LLFPHE	LLFPH	HLFPHE	HLFPH	SEM	Diet	Enzyme	Diet×Enzyme
IW (kg)	24.50	22.98	22.33	21.15	22.37	5.61	0.785	0.991	0.903
FW (kg)	77.55 ^a	75.29 ^a	66.87 ^{bc}	62.06 ^{cd}	56.90 ^d	7.12	0.0001	0.952	0.263
ADFI (kg/DM)	1.75 ^a	1.71 ^a	1.87 ^a	1.59 ^b	1.49 ^b	0.18	<.0001	0.0047	<.0001
ADG (kg)	0.85 ^a	0.89 ^a	0.81 ^{ab}	0.72 ^c	0.71 ^c	0.09	<.0001	0.898	0.192
FCR	2.06 ^d	2.39 ^a	2.25 ^a	2.11 ^c	2.07 ^d	0.21	<.0001	0.045	<.0001

Note. ^{ab} Within a row means with different superscripts differ ($P < 0.001$), ¹CON = Control diet; LLFPHE = Low liquid fermented potato hash with enzyme diet, LLFPH = Low liquid fermented potato hash without enzyme diet, HLFPH- High liquid fermented potato hash with enzyme diet, HLPHE = High liquid fermented potato hash without enzyme diet. ²IW = Initial weight, FW = Final weight; ADFI = Average daily feed intake, ADG = Average daily gain, FCR = Feed conversion ratio.

4. Conclusion

The varying levels of fermented liquid potato hash did not negatively affect nutrient composition of the diets. The use of exogenous enzyme during fermentation reduced the fibre fractions of the fermented liquid potato hash even though it was at the expense of energy content of the diets. The overall performance of pigs fed low inclusion levels of fermented liquid potato hash diets treated with or without enzyme improved growth performance of grower pigs. Therefore, this implies that FLPH might be an alternative feed source for growing pigs. More studies need to determine the optimum inclusion level of LFPH in pig diets, their impact on carcass quality and the cost benefit.

Acknowledgements

The Agricultural Research Council and Gauteng Department of Agriculture and Rural Development funded the study.

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