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Effects of Ensiling Total Mixed Potato Hash Ration with or without Bacterial Inoculation on Silage Fermentation and Nutritive Value for Growing Pigs

B.D. Nkosi, A.T. Kanengoni and R. Thomas
ARC-LBD: Animal Production Institute, P/Bag x 2, 0062 Irene, South Africa

Abstract: Total Mixed Rations (TMR) that contained 795 g kg^{-1} (as is basis) of Potato Hash (PH) were formulated and ensiled in 210 L drums (10 drums $treatment^{-1}$) with or without lalsil fresh (heterofermentative lactic acid bacterial inoculant). After 3 months of ensiling, drums were opened and analysed for fermentation characteristics and nutritive value. This was followed by an 8 weeks growth study using forty crossbred pigs (Large white X landrace), twenty males and twenty females weighing 20±3 kg. Inoculating the TMR with lalsil fresh reduced ($p<0.05$) the pH, butyric acid, ammonia-N while increasing the concentration of lactic acid, acetic acid and propionic acid compared to the control. The growth performance of pigs was improved ($p<0.05$) with inoculation compared to control. However, the growth rates of pigs were <120 g day^{-1} which could be attributed to the lower dietary protein (<80 g kg^{-1} DM) and higher fibre contents. Further research is needed to evaluate effects of enzyme addition on the ensiling of potato hash and supplementation of energy and protein on feed intake and growth performance of pigs consuming the silage.

Key words: Crude fibre, growth, inoculation, pigs, silage, South Africa

INTRODUCTION

Semi-intensive and intensive pig production in South Africa is characterised by a high demand and dependence of mixed cereals which are expensive. Cereals may have to be imported, requiring foreign exchange and costs of imported feedstuffs rise steadily especially during times of shortages (Briedenhann, 2008). This makes feed costs to be high, representing 60-80% of the economic inputs in the livestock production system (Henning, 1998). Feed cost and animal competition with humans for feed items suggest strongly that alternative energy sources such as food by-products be used partially or totally to replace cereals in livestock diets to reduce and enhance cheaper meat production (Nkosi *et al*., 2010).

Consequently, the use of by-products from the food processing industry can be a less expensive source of nutrients suitable for animals. Omer and Tawila (2008) reported that feeding potato by-products in growing goat rations saved up to 50% of yellow maize. Furthermore, using these by-products for animal feeding can be an alternative for the food industry to diminish waste discharges and to reduce waste management costs and environmental pollutions. Potato Hash (PH), a potato by-product that derived from the production of chips, snacks, etc., is one of the available by-products which is produced at the rate of 50 ton day^{-1} in South Africa. This by-product contains 150 g Dry Matter (DM) kg^{-1}, 700 g starch kg^{-1} DM, 11.2 MJ Metabolizable Energy (ME) kg^{-1} DM, 105 g Crude Protein (CP) kg^{-1} DM (Nkosi *et al*., 2009a). However, the seasonal nature and high water content of this by-product limit its utilization in animal feeding. If this by-product is not consumed in a short period of time by animals, it gets mouldy and becomes useless as animal feed. To address this concern, the previous studies (Nkosi *et al*., 2009a; Nkosi and Meeske, 2010) reported that potato hash is suitable for ensiling and can be used as animal feed without health risks.

According to some studies (Nishino *et al*., 2003; Wang and Nishino, 2008), it is more advantageous to mix high moisture by-products with other dry feed materials before ensiling. This helps to omit the time of mixing before feeding, minimizes the risk of effluent production and avoids self selection of feeds by animals. The previous study (Nkosi and Meeske, 2010) reported improved silage aerobic stability and better lamb performance with lalsil fresh inoculation to TMR that contained 800 g kg^{-1} at ensiling. In contrast, the previous research (Thomas *et al*., 2010) did not report improvement in pig growth performance with inoculated potato hash silage which was attributed to low protein and energy intake of the silage. Feeding silage to growing pigs has been reported to result in a reduced growth performance (Whittemore and Henderson, 1977; Brooks *et al*., 2001). This may be attributed to the presence of Non-Starch

Corresponding Author: B.D. Nkosi, ARC-LBD: Animal Production Institute, P/Bag x 2, 0062 Irene, South Africa

Polysaccharides (NSP) in forages which are not digested in the alimentary tract of monogastric animals and may have anti-nutritive properties (Li *et al*., 1996).

This anti-nutritive effect can be limited by degrading them with suitable exogenous enzymes (Bedford, 2000). However, some advantages for feeding silage to pigs include; a marked reduction in inflammation of the gastric mucosa in pigs that were fed ensiled forages (Scipioni and Martelli, 2001), a pathology well known and widely spread in intensively reared pigs fed concentrate diets low in fibre indicating that the benefits of feeding ensiled feed may not necessarily all be realised in the direct growth rate of the pigs. In addition, silage may stimulate pancreatic secretion and positively influence villus architecture which may improve digestion and absorption of nutrients (Scholten *et al*., 2001).

There is need to investigate ways to improve the nutritive value of PH silage if the readily available PH by product is to be utilised effectively. The main aim of this study was therefore to investigate the effects of ensiling total mixed potato hash ration with or without bacterial inoculant (lalsil fresh) on silage fermentation and nutritive value for growing pigs.

MATERIALS AND METHODS

Silage fermentation: Potato Hash (PH) was collected from Simba (336 Andre Greyvenstein road, Isando, Gauteng, South Africa), a local food producing factory in South Africa for nutrient analysis, ensiling and *in vivo* growth studies using growing pigs. Totally Mixed Rations (TMRs) that contained 795 g kg^{-1} PH (as is basis) were formulated to meet or exceed the nutrient requirements of growing pigs (National Research Council, 1998) (Table 1) and ensiled with or without a Lactic Acid Bacteria (LAB) inoculant. The inoculant, *Lactobacillus buchneri* NCIMB 40788 (Lalsil fresh LB, Lallemand Animal Nutrition, BP 59, Cedex, France), a heterofermentative LAB was applied at a rate of 2 L ton^{-1} of fresh TMR (10 g of inoculant was dissolved in 2 L water 4 h before application) to obtain at least 3×10^5 cfu g^{-1} in the material as determined by the manufacturer. In order to achieve the same amount of moisture as in the treated TMR, the untreated TMR (U-TMR) was sprayed with 2 L sterilized water per ton of TMR. The treatments (U-TMR and LB-TMR) were ensiled by compacting in 210 L drums (9 drums treatment^{-1}) lined with a plastic bag and closed with a rubber lid to prevent damages to the bags by rodents. A packing density of 966±42.1 kg m g^{-3} was obtained and the drums were stored at 22-25°C. After 3 months of ensiling, drums were opened and sampled weekly for the determination of fermentation characteristics and chemical compositions.

Table 1: Composition (g/kg as fed) of Total Mixed Ration (TMR)

Ingredients	(g/kg)
Maize meal	52.4
Wheat bran	61.8
Molasses	20.4
Soybean oil cake	64.8
Potato hash	795.2
Feedlime*	3.2
Salt	1.6
Premix	0.6

*Contained vitamin A 6500000 iu; D3 1200000 iu; E 40000 iu; K_3 2 g; B_1 1.5 g; B_2 4.5 g; B_{12} 0.03 g; B_6 2.5 g; Niacin 25 g; Calcium pantothenate12 g; Choline 190.5 g; Folic acid 0.6 g; Biotin 0.05 mg; Manganese 40 g; Zinc 100 g; Copper 125 g; Iodine 1 g; Ferrous 100 g and Selenium 0.3 g

Animals and experimental design: About forty crossbred pigs (Large white X landrace), twenty males and twenty females aged 60 days weighing 20±3 kg were used in a growth study that lasted for 8 weeks. All the pigs were housed in pairs in commercial type grower houses under an intensive production system. The forty grower pigs were allocated in a Completely Randomized Design (CRD) to two treatments in a 2×2 (treatment x gender) factorial arrangements. Each experimental unit consisted of two pigs with 20 pigs treatment^{-1} (10 boars and 10 gilts treatment^{-1}).

The pigs were evenly distributed between treatments in such a way that the numbers of litter mates between treatments were equal. The pigs were individually weighed at the beginning of the experiment and continued weekly to determine the Average Daily Gain (ADG). Animals were weighed individually at the start of the trial and continued on weekly intervals using a TAL-TEC® scale calibrated with a 50 kg standard weight. Feed refusals were weighed back weekly for determination of feed intake, Average Daily Gain (ADG), DM intake and Feed Conversion Efficiency (FCE) in animals.

Chemical analysis: A 40 g sample of ensiled TMR was collected from each jar and mixed with 360 mL of distilled water in a stomacher bag, homogenized and left at 10°C for 24 h (Suzuki and Lund, 1980). It was then homogenized for 4 min and filtered through a Whatman no. 4 filter paper (G.I.C. Scientific, Midrand, South Africa) and the extract was used for determination of pH, Water-Soluble Carbohydrates (WSC), Lactic Acid (LA), Volatile Fatty Acid (VFA) and ammonia-N. The WSC were determined by the phenol-sulphuric acid method of DuBois *et al*. (1956) and lactic acid was determined by the colorimetric method of Pryce (1969). The VFAs were determined with a varian 3300 FID detector gas chromatograph (Varian Associates, Inc., Palo Alto, CA, USA) by the procedure of Suzuki and Lund (1980). Ammonia-N was determined by distillation using a Buchi 342 apparatus and a Metrohm

655 Dosimat with a E526 titrator according to AOAC (1990). The Dry Matter (DM) of silage was determined by drying the samples at 60°C to a constant mass and was corrected for loss of volatiles using the equation of Porter and Murray (2001). After drying, samples were ground through a 1 mm screen (Wiley mill, Standard model 3, Arthur H. Thomas Co., Philadelphia, PA, USA) for chemical analyses.

After drying, the samples were ground through a 1 mm screen (Wiley mill, Standard model 3, Arthur H. Thomas Co., Philadelphia, PA) for chemical analyses. Following the procedures of Van Soest *et al.* (1991), the Neutral Detergent Fibre (aNDF) concentration was determined using heat stable α-amylase (Sigma-Aldrich Co. LTD., Gillingham, UK, no. A-1278) with sodium sulfite and the Acid Detergent Fibre (ADF) concentration was determined using the Fibretec system equipment (Tecator LTD., Thornbury, Bristol, UK). Separate samples were used for ADF and aNDF analysis and both included residual ash. Crude protein (ID 968.06), ash (ID 942.05) and EE (ID 963.15) were determined according to the procedure of AOAC (1990). The GE was determined with bomb calorimetry (MS-1000 modular calorimeter, Energy Instrumentation, 135 Knoppieslaagte, Centurion, South Africa).

Statistical analysis: The statistical model used to analyse the data was for a factorial completely randomised design with unequal replication by ANOVA using Payne *et al.* (2005) for an unbalanced design, testing for differences between two diets, two genders and the diet by gender interaction using the model:

$$Y_{ijk} = \mu + t_i + s_j + (ts)_{ij} + \varepsilon_{ijk}$$

Where:

- Y_{ijk} = The individual observations of the ith diet, the jth gender and the kth replicate
- μ = The general effect
- t_i = The effect of the ith diet
- s_j = The effect of the jth sex
- $(ts)_{ij}$ = The interaction between t and s
- ε_{ijk} = The random variation or experimental error

RESULTS AND DISCUSSION

The main objective of using silage additives when making silage is to obtain a lactic acid fermentation which rapid drop in pH that results in a well preserved silage and prevents secondary fermentation (McDonald *et al.*, 1991). At pre-ensiling, the TMR had a pH of 5.93, DM of 395 g kg^{-1}, 60.9 g WSC kg^{-1} DM and 184 g Crude Protein (CP) kg^{-1} DM, respectively. Data on the fermentation characteristics of ensiled total mixed potato hash ration is shown in Table 2. Inoculating the ration with lalsil fresh reduced ($p<0.05$) the pH compared to the control, consistent with our previous study (Nkosi and Meeske, 2010). In contrast, Kristensen *et al.* (2010), reported increased pH and lower lactic acid when maize silage was inoculated with Lalsil fresh compared to the control. A pH range of 3.7-4.2 is ideal for good quality silage (Kung and Shaver, 2001) and that of this study was within this range, indicative of well preserved silage. Water-soluble carbohydrates are regarded as essential substrates for the growth of LAB for proper fermentation (McDonald *et al.*, 1991) and low levels may restrict LAB growth. The WSC concentration of the TMR prior to ensiling was 60.9 g kg^{-1} DM which is crucial for a successful fermentation (Haigh, 1990).

However after 90 days of ensiling, the inoculated silage had lower ($p<0.05$) residual WSC concentrations compared to control, indicating that more WSC was utilized by LAB in the inoculated silage. High quality silage is likely to be achieved when lactic acid is the predominant acid produced as it is the most efficient fermentation acid and reduces silage pH more efficiently than other fermentation products (McDonald *et al.*, 2002). The concentration of lactic acid was increased ($p<0.05$) with Lalsil fresh inoculation compared to the control.

In contrast, there are some studies (Filya, 2003; Kristensen *et al.*, 2010) that reported a reduced concentration of lactic acid with *Lactobacillus buchneri* (heterofermentative inoculant) inoculation to maize silage compared to control. However, Mari *et al.* (2009) and Nkosi and Meeske (2010) did not find a reduced lactic acid concentration in *L. buchneri* inoculated silage compared to the control.

Table 2: The fermentation characteristics and chemical composition of total mixed potato hash silage treated with or without LAB inoculant (n = 3)

Treatments	Control	Lalsil	p-value	SEM
Fermentation characteristics				
DM (g kg^{-1})	363.8^{b}	386.3^{a}	0.050	0.352
pH	4.3^{a}	4.1^{b}	0.001	0.004
WSC (g kg^{-1} DM)	18.7^{a}	16.7^{b}	0.001	0.076
LA (g kg^{-1} DM)	61.0^{b}	69.8^{a}	0.001	0.103
AA (g kg^{-1} DM)	31.8^{b}	36.3^{a}	0.001	0.214
PA (g kg^{-1} DM)	2.6^{b}	4.2^{a}	0.001	0.026
BA (g kg^{-1} DM)	1.2^{a}	0.5^{b}	0.001	0.012
NH_3-N (g kg^{-1})	15.0^{a}	9.4^{b}	0.001	0.003
Chemical composition				
OM (g kg^{-1} DM)	923.2^{b}	932.2^{a}	0.001	0.125
GE (MJ kg^{-1} DM)	15.4	15.4	0.089	0.006
CP (g kg^{-1} DM)	67.7^{b}	83.8^{a}	0.001	0.025
EE (g kg^{-1} DM)	35.9	35.9	0.067	0.231
ADF (g kg^{-1} DM)	132.8^{a}	111.7^{b}	0.001	0.068
aNDF (g kg^{-1} DM)	184.6^{a}	150.5^{b}	0.001	0.154

^{a,b}Means with different letters in row differ significantly ($p<0.05$); LA: Lactic Acid, WSC: Water-Soluble Carbohydrates, AA: Acetic Acid, PA: Propionic Acid, BA: Butyric Acid and TN: Total Nitrogen

The inoculation of Lalsil fresh resulted in an increased ($p<0.05$) concentration of acetic acid compared to the control. This is consistent with other researchers (Taylor *et al*., 2002; Nkosi *et al*., 2009b) who reported increased acetic acid with *L. buchneri* inoculation. According to previous research (Driehuis *et al*., 2001; Taylor *et al*., 2002; Nkosi *et al*., 2009b) inoculation with *L. buchneri* typically results in acetic acid concentrations ranging from 36-50 g kg^{-1} DM, suitable to control yeast during aerobic exposure of silage. Therefore, the acetic acid concentration of 36 g kg^{-1} DM in the Lalsil fresh treated silage in the present was enough to control yeast. Ammonia-N in silage reflects the degree of protein degradation and extensive proteolysis adversely affects the utilization of N by animals. Ammonia can result from several reactions such as deamination of amino acids and oxidation of amines by bacterial amino-oxidases. Well-preserved silages should contain <100 g NH_3-N kg^{-1} TN (McDonald *et al*., 2002). The effects of LAB inoculants on the ammonia-N concentration in silage have been repeatedly demonstrated to reduce ammonia-N content compared to the untreated silage (Rooke *et al*., 1988; Gordon, 1989). Inoculating potato hash ration with Lalsil fresh ensiling reduced ($p<0.05$) the level of proteolysis as indicated by its higher CP and low ammonia-N contents compared to the control.

The fibre fractions (ADF and aNDF) of the silage were reduced ($p<0.05$) with inoculation compared to the control. This supported other studies that reported reduced fibre content with inoculation (Keady and Steen, 1994; Nkosi and Meeske, 2010). In contrast, some researchers (Faber *et al*., 1989; Phillip and Fellner, 1992) did not observe a reduction in cell wall fractions from inoculated silage compared to the control. This could be attributed to lower environmental temperature that inhibited hemicellulose degradation (Faber *et al*., 1989). Data on the performance of pigs fed TMR silage is shown in Table 3. The effect of gender and gender x treatment interactions did not differ significantly ($p>0.05$) in terms of the growth parameters recorded in the present study.

However, the growth parameters of pigs fed on the Lalsil fresh inoculated silage were improved ($p<0.05$) compared to those fed on the control. This is consistent with Canibe *et al*. (2008) who reported improved growth performance of piglets when fed inoculated liquid feed compared with uninoculated feed. In contrast, Scipioni and Martelli (2001) reported a lower growth performance in pigs fed on molassed Sugar Beet Pulp Silage (SBPS) compared to those fed on plain SBPS. According to the National Research Council (1998), an intake of 2320 g day^{-1} is recommended for finishing pigs. However, the daily intake in the study was <700 g day^{-1}

Table 3: Effects of diets on the growth performance of pigs (n = 20)

	Treatments			Significance (p)		
Parameters	Cont	Lalsil	SEM	Trt	G	Trt×G
IBW (kg)	16.83	17.14	0.375	0.478	0.728	0.079
FBW (kg)	19.70^{b}	22.40^{a}	0.698	0.010	0.996	0.064
DMI (g kg^{-1})	577.10^{b}	623.70^{a}	14.900	0.020	0.211	0.072
ADG (g day^{-1})	67.60^{b}	120.30^{a}	15.540	0.018	0.659	0.999
FCR (g $g^{-}{}_{1}$)	8.50^{a}	5.20^{b}	0.034	0.032	0.908	0.923

$^{a, b}$ Means with different letters in row differ significantly ($p<0.05$): DMI: Dry Matter Intake; ADG: Average Daily Gains; FCR: Feed Conversion Rate; IBW: Initial Body Weight; FBW: Final Body Weight; Trt: Treatment; G: Gender: Trt×G: Treatment by Gender interaction

which can be attributed to the lower pH of <4.5 which might have depressed feed intake of the pigs (Lee *et al*., 2004). Nevertheless, inoculation improved ($p<0.05$) feed intake compared to the control, consistent to other studies (Canibe *et al*., 2008; Nkosi and Meeske, 2010). Interestingly, although feeding potato mixed silage decreased the growth performance of finishing pigs, it was reported to increase loin fat contents and meat palatability compared to the control (Shimazawa *et al*., 2007). Although not investigated in this study, it is worth investigating in the future.

Growing pigs reared under commercial conditions can record minimum daily gains of 639 g day^{-1} when fed on concentrate diets (Hoffman *et al*., 2003). However, the present study recorded daily gains <120 g day^{-1} which are lower than those reported in a previous study (Thomas *et al*., 2010) when 400 g kg^{-1} potato hash was included in the diet of pigs. In addition, Shimazawa *et al*. (2007) recorded daily gains of >540 g day^{-1} when pigs were fed on potato mixed silage. The silage used in the latter study had 116 CP g kg^{-1} DM which is higher than that recorded in the present study.

CONCLUSION

Although, there was an improvement in the quality of silage with Lalsil fresh inoculation, this was not sufficient to improve the performance of the pigs sufficiently for the PH by-product to be seen as a viable alternative by pig farmers. The main reason for the poor performance appeared to be low intake and low protein and possibly energy intake. There is a need to evaluate the impact of boosting the energy and protein content significantly before ensiling on subsequent levels of these nutrients in the ration and on voluntary feed intake. The effect of exogenous enzymes on fibre levels during ensiling also need to be investigated.

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