PJN
ISSN 1680-5194
ansinet.com/pjn

PAKISTAN JOURNAL OF NUTRITION

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OPEN ACCESS Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2021.83.89

Research Article
Effect of Inclusion Levels of Maize Bran in Pig Diets on Daily Production, Biochemical Composition and Microbial Quality of Pig Manure

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Abstract

Objective: The aim of this study was to evaluate the effect of inclusion level of varying dietary maize bran on daily production, biochemical quality and microbial quality of pig manure. **Materials and Methods:** A total of 12 castrated pigs with an average weight of 15.08±3.08 kg were randomly selected for a 5-week trial. Pigs were subjected to four dietary treatments with the following maize bran rates: 0, 15, 30 and 45% replicated three times. Faeces were collected to measure parameters such as organic carbon, pH, phosphorous, potassium, nitrogen, ammonia content and total bacterial count. **Results:** Results showed that potassium, phosphorous and organic carbon slightly increased with an increase in maize bran in the diets although they did not show significant difference ($p<0.05$). Concentrations of pH and ammonia decreased while the concentration of nitrogen increased significantly ($p<0.05$) as the level of maize bran increased in the diets. Pigs fed on high-maize-bran diets (30 and 45%) released more manure than those fed on the low-maize-bran diets (15%) and control diets. **Conclusion:** It is concluded that 30% inclusion level of dietary maize bran is the optimum level in order to reduce environmental pollution by reducing ammonia concentration in pig manure while achieving optimum growth performance.

Key words: Fibrous diet, integrated system, manure, nitrogen excretion, pig nutrition, maize bran

Citation: Akilimali Itongwa Justin, Daud Kassam, Joshua Valeta and Daniel Clement Sikawa, 2021. Effect of inclusion levels of maize bran in pig diets on daily production, biochemical composition and microbial quality of pig manure. Pak. J. Nutr., 20: 83-89.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The livestock food chains contribute enormously to greenhouse gas emissions, accounting for about 18% of total anthropogenic CH_4 and NH_3 emissions[1], which leads to a significant acidification and eutrophication of the ecosystems[2]. In addition, the intensive livestock sector releases about 20% of global methane emission resulting from animal wastes storage and handling[1]. In order to overcome this challenge[3], proposed nutrition could be a key factor for reducing environmental pollution. Incorporating high fiber ingredients into pig diets is one of the measures to reduce gas emission[4,5]. Furthermore, the use of diets rich in fiber has been promoted in extensive pig production systems because they facilitate nutrient recycling by reducing urinary nitrogen emission[5,6].

Over the past years, most of the information on dietary fibres in pig nutrition has been generated using purified fibre sources such as pectin, cellulose and guar gum[7] and a few crop by-products. These studies emphasised more on the growth performance[8], nutrients digestibility[9], on the gas emissions[2], behavior and welfare[10] as well as quality of the excreted manure[11,12].

However, fewer studies have focused on the effect of fibre on the quantity of excreted manure in pigs. Furthermore, the effect of maize bran on the daily quantity of manure produced, the changes that occur in the chemical composition and microbial quality of manure are poorly documented. Indeed, maize is an abundant crop in most tropical regions and the common food used by the smallholder farmers especially in Malawi[13]. The maize by-product can contribute up to 30% of energy needs of pigs when it is degraded to volatile fatty acids by microbial enzymes in the intestine[14].

Therefore, understanding the effect of adding maize bran in pig diet on the quantity and quality of manure produced is a good opportunity to avoid waste disposal. In addition, animal manure can be recycled in fish ponds to boost primary production in the context of integrated aquaculture and livestock systems. Integrated agriculture and aquaculture systems are one of the strategies for producing farmed fish at a significant lower cost by reducing fish feeding ingredients which represent approximately 60-70% of aquaculture production costs[15]. Thus, including maize bran in pig diets to increase the quality and the quantity of pig manure can be a strategy used in pond fertilization in order to achieve optimum fish growth performance while reducing environmental pollution. Therefore, within this context, this study aimed at determining the effect of adding varying levels of maize bran in pig diets on growth performance, quantity and biochemical composition as well as on microbial load of pig manure.

MATERIALS AND METHODS

Experimental location: This study was carried out at Lilongwe University of Agriculture and Natural Resources (LUANAR) Fish Farm, in Lilongwe District of Malawi (latitude 14°35S' and longitude 33°50E').

Ethical approval: All the procedures involved in this study were in accordance with internationally accepted guidelines for the use of animals and were approved by the Animal Ethics Committee of Lilongwe University of Agriculture and Natural Resources through the Department of Animal Science. The experimental protocol for the use of animals was in compliance with Malawian Animal Welfare Guidelines, Version 1.0 (2019).

Experimental design, animal and diets: Twelve castrated pigs (Large White) with initial average body weight of 15.08±3.08 kg were selected randomly from the farm of Animal Science Department, Bunda College. First of all the pigs were tagged and dewormed. Based on body weight, pigs were distributed in a completely randomised design (CRD) with 4 treatments and 3 replicates. The treatments were T1 (0% inclusion levels of maize bran as a Control), T2 (15% inclusion levels of maize bran) T3 (30% Inclusion levels of maize bran) and T4 (45% inclusion levels of maize bran). Pigs were housed individually in pens measuring 1.5×1.0 m^2, containing plastic self-feeders and drinker. The 35-day experimental period consisted of a 14-day adaptation period to allow pigs to become accustomed to the pens and to their dietary treatments according to the Jarret *et al.*[2] and followed by a period of 21 days, during which the data and manure were collected.

During the acclimatisation period, the pigs were fed twice a day according to the schedule at 8:00 am and 5:00 pm (3% of body weight) and water was freely available. Feed residues were recorded in order to calculate the rate of feed consumption and dry matter (DM) content. Individual weight and final weight were calculated to determine pigs' performance. The initial weight of each pig was subtracted from the final weight at each data point to determine cumulative weight gain.

The average daily feed intake (ADFI) was determined by calculating the difference between feed allowance and feed residues. Feed conversion ratio (FCR) was calculated as the ratio between feed intake and weight gain.

Proximate analysis of ingredients: The feed ingredients were analysed on a dry matter basis using the standard methods[16] to determine the concentration of Crude fibre, Fat, ash, Gross energy, crude protein, nitrogen and phosphorous. Nitrogen was analysed using the Kjeldahl method, phosphorus and potassium using spectrophotometry. Crude fibre and fat were determined using the procedures stipulated by the Association of Official Analytic Chemistry[16]. Ash content was determined by burning the samples in a muffle furnace at 550°C for 4 h. Diets samples were also analysed for their fat content using petroleum extraction with prior acid hydrolysis. An adiabatic bomb calorimeter was used to determine gross energy content in the diets. The composition and nutrient content of experimental diets are presented in Table 1.

Faecal collection, storage and chemical analyses: Plastic trays were placed underneath of each pen. After two weeks of the adaptation period, faeces were collected once a day from each pen and stored at 4°C for subsequent chemical analysis. During the 21-day collection period, the daily quantity of manure released by each pig was determined by weighing the faeces immediately after defecation. The excreta from each pig receiving the same diet was homogenized, grounded and subsampled for dry matter analysis as well as pH measurements and then freeze-dried for other chemical analyses such as nitrogen, ammonia, carbon, potassium and phosphorous. A nitrogen-carbon analyser (Thermo Delft, The Netherlands) was used to determine carbon organic. The nitrogen content in manure was analysed using the diffusion technique as described by Mpendulo *et al.*[5] related to soil nitrogen fractionation.

Quantification of faecal bacteria: The faecal samples were collected by inserting the cotton swab into the anus of the pig and then transferred into sterile bottles to enumerate total bacterial counts (TBC) following the method reported by Akeredolu and Ekundayo[17]. Nutrient agar and Buffered Peptone water were used as media for total bacterial count. The dilution was prepared by pipetting 1mL of aliquot and mixed with 9 mL of 0.1% peptone water. About 1 g of each faecal sample was serially diluted and 0.1 mL of the appropriate dilutions were spread on plate count agar (Komed, Seongnam, Korea) and incubated at 37°C for 24-48 h. The total number of colonies in each sample were counted according to the method described by Akeredolu and Ekundayo[17] and expressed as colony-forming unit g^{-1} (CFU g^{-1}).

Statistical analysis: Collected data were analysed using the one-way ANOVA. All statistical analyses were performed using the Statistical Package for Social Science (SPSS) version 20.0 for windows (SPSS Inc., Chicago, IL, USA). Differences among treatment means were considered significant at $p<0.05$. Pearson's correlation test was performed to measure the relationship that might exist between the characteristics of pig manure.

Table 1: Composition and nutrient content of experimental diets

	Diets (%)			
Ingredients (%)	0	15	30	45
Maize meal	75.70	62.10	47.35	32.50
Soybean meal	16.20	14.70	14.50	14.30
Wheat bran	5.00	5.00	5.00	5.00
Maize bran	0.00	15.00	30.00	45.00
Monocalcium phosphate	1.40	1.50	1.40	1.40
Limestone	0.65	0.65	0.68	0.63
L-Lysine	0.11	0.13	0.15	0.14
Sodium chloride	0.40	0.40	0.40	0.40
Vitamin and mineral premix	0.50	0.50	0.50	0.50
Analyzed chemical composition (%, as-fed basis)				
Dry matter	88.81	89.61	90.09	91.52
Crude protein	16.50	16.10	15.70	15.20
Ash	4.40	5.50	4.90	5.80
Crude fat	7.44	6.63	7.56	6.12
Total dietary fiber	14.55	21.33	27.87	30.99
Insoluble dietary fibre	9.23	12.48	18.01	19.42
Soluble dietary fibre	5.32	8.85	9.86	11.57
Gross energy (MJ kg^{-1})	14.78	15.13	16.38	17.15
Phosphorous (%)	0.32	0.28	0.36	0.39

RESULTS

Effect of dietary inclusion of maize bran on Average daily feed intake, FCR and growth performance of pigs: Initial pig body weight (BW) was 15.08±3.08 kg. At the end of the experimental period, the final body weight ranged from 22.93 to 27.81 kg among different treatments (Table 2). The growth performance parameters (final and daily gain weight) did not show significant difference in the experimental groups. However, weight gain was slightly improved in pigs allocated to Treatments 2 and 3 ($p<0.05$) compared to those in Treatments 4 and 1. This slight body weight gain pattern can be attributed to the high daily feed intake as shown in Table 2.

Effect of inclusion levels of maize bran in pig diets on daily quantity of manure and dry matter: The daily quantity of manure produced as well as the average dry matter changed significantly among all treatments under experiment ($p<0.05$) (Table 3). Pigs fed on high dietary fibrous (30 and 45%) released more manure while the lowest quantity was recorded from pigs fed on low maize bran diet (15%) and control diet where no maize bran was included.

Effect of dietary inclusion of maize bran on chemical composition of pig manure: The results showed the non-significant effect of dietary inclusion of maize bran on chemical composition of pig manure ($p>0.05$) for some parameters such as phosphorous, potassium and organic carbon. The level of maize bran in the diets significantly affected ammonia and pH concentrations of manure (Table 4). Table 4 shows significant ($p<0.05$) effect of maize bran inclusion on microbial quality of pig manure. The average total bacterial count were 9.708×10^5 CFU g^{-1}, 13.64×10^5 CFU g^{-1}, 19.434×10^5 CFU g^{-1} and 25.407×10^5 CFU g^{-1} for T1, T2, T3 and T4 respectively.

Responses to the increasing levels of maize bran in pig diets: At higher level of maize bran (45%) a linear increase was observed in feed intake, in production of faeces and in the nitrogen concentration as shown in Fig. 1 and 2.

DISCUSSION

The growth performance parameters did not show significant difference in the experimental groups. The present study shows that the inclusion of maize bran in pig diets did

Table 2: Effect of inclusion of maize bran in diets on average daily feed intake (ADFI), final weight and average daily weight gain (ADG) and feed conversion ratio (FCR)

	Inclusion levels of maize bran (%)					
Items	0	15	30	45	SEM	P
ADFI (kg day^{-1})	0.798^{a}	0.869^{ac}	0.906^{bc}	0.839^{ac}	0.014	0.045
Initial weight (kg)	14.500	14.667	15.567	15.233	0.264	0.856
Final weight (kg)	22.930^{a}	25.250^{ac}	27.816^{bc}	25.666^{ac}	1.089	0.006
ADG (kg day^{-1})	0.403^{a}	0.504^{bc}	0.583^{c}	0.496^{b}	0.014	0.000
FCR (kg feed kg^{-1} gain)	1.980^{b}	1.724^{a}	1.554^{a}	1.69^{a}	0.065	0.000

Means with the same superscript in same the row are not significantly different at 5% level of probability ($p>0.05$)

Table 3: Effects of dietary inclusion maize bran on chemical composition of pig's faecal

	Inclusion levels of maize bran (%)					
Parameters	0	15	30	45	SEM	P
Faeces						
Excreted (g pig^{-1} day^{-1})	238.851^{a}	385.037^{b}	596.166^{c}	538.117^{c}	19.023	0.000
Dry matter (%)	46.183^{c}	42.417^{b}	38.083^{a}	35.483^{a}	0.9407	0.000

Means with the same superscript in same the row are not significantly different at 5% level of probability ($p>0.05$)

Table 4: Effects of dietary maize bran on chemical composition of pig's faecal

	Inclusion levels of maize bran (%)					
Parameters	0	15	30	45	SEM	P
Nitrogen (% of DM)	2.315^{a}	2.918^{b}	4.236^{c}	4.814^{d}	0.209	0.000
Phosphorous (% of DM)	0.356	0.334	0.403	0.348	0.011	0.115
Potassium (% of DM)	1.045	1.130	1.249	1.164	0.075	0.835
pH	8.233^{b}	7.967^{b}	7.183^{a}	7.000^{a}	0.122	0.000
NH_3 (% of DM)	3.658^{b}	3.437^{b}	3.050^{ab}	2.665^{a}	0.097	0.000
Organic Carbon (% of DM)	1.120	1.090	1.000	1.480	0.085	0.213
TBC (CFU g^{-1} 10^5)	9.700^{a}	13.600^{b}	19.450^{c}	25.070^{d}	1.230	0.000

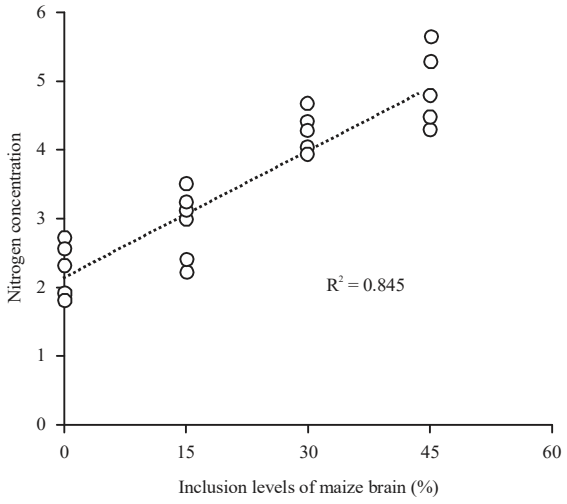

Fig. 1: Linear relationship between nitrogen concentration in pig manure and level of maize bran in the diets

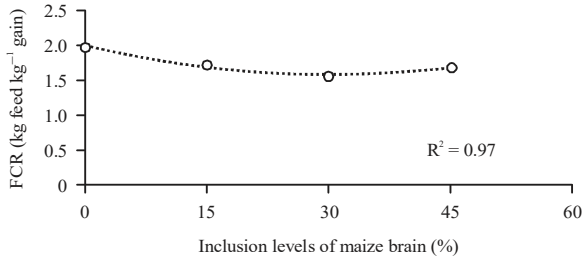

Fig. 2: Curvilinear relationship between growth rate of pigs and level of maize bran in the diets

not significantly affect the growth performance of pig that is in line with a previous study which reported that fibre-rich diets do not always maximise the growth performance of pig[18]. Similar results were reported by Jarret *et al.*[4] who observed a slight decrease in body weight which did not differ significantly among treatments (control diet and High-fiber diet). However, Jarret *et al.*[8] reported a significant increase in weight where pigs were fed with different dietary fibre sources and levels. This difference might be attributed to the age of pigs in their study as suggested by Laitat *et al.*[19]. Moreover, Laitat *et al.*[19] stated that the effect of high dietary fibre on pig growth performance is generally age specific and is limited to the growing period rather than the finishing period. The average daily feed intake (ADFI) increased significantly with inclusion levels of maize bran in all experimental diets ($p<0.05$) (Table 2). Thus, maize bran is a good alternative feed for livestock in Sub-Saharan Africa during feed scarcity faced by small farmers.

Pigs fed on high dietary fibrous released more manure while the lowest quantity was recorded from pigs fed on low maize bran diet and control diet where no maize bran was included. The results agree with a previous study conducted by Jarret *et al.*[4] who observed the significant increase in faeces up to 40% surplus of total fresh faeces per pig/day due to the inclusion of higher-fibre in pig diet compared to animals fed on control diet. However, the quantity of manure reported by these authors[4] was higher compared to that obtained in this study, probably due to the difference in pig weight, age and the sources of fiber[18]. Table 3 shows that 30% inclusion level is as an optimum level to produce high quantity of pig manure which is used to promote algae and zooplankton production, serving as a supplemental nutrient source to the food chain that supports the growth of tilapia[15].

The level of maize bran in the diets significantly affected ammonia and pH concentrations of manure. The types of fibre as well as the inclusion levels in these two studies might explain the difference in ammonia and pH contents[3]. The range of pH reported in this study (7.23-7.00) is lower than the range (8.39-8.11) obtained by Jarret *et al.*[4]. Mpendulo *et al.*[5] reported the reduction in slurry pH in chickens fed on diets containing molasses. They attributed this reduction to the bacterial fermentation of undigested fibre in the large intestine which releases the short chain fatty acid resulting in acidification of faeces[11]. On the other hand, ammonia concentration decreased with the increase of maize bran in the diets and reached the high level at the inclusion level of 45%, this is another opportunity in fertilized fish ponds. Indeed, high concentration of ammonia has sub-lethal effects such as reduced growth, poor feed conversion and reduced disease resistance at concentrations that are lower than lethal concentrations[5].

However, concentration of nitrogen significantly increased as the level of maize bran increased in the diets ($p<0.05$). The high nitrogen level was reported in treatment where pigs were fed diet containing 45% of maize bran. According to Brown *et al.*[15], 70% of input nitrogen accumulates in the tropical fish pond with the application of chicken manure. In agreement with the current results, Brown *et al.*[15] reported that proportion of total nitrogen in faeces ranged from 55-66% when 30% sugar beet pulp was added in pig diets[20]. Availability of nitrogen in the pond soilsystem has a direct impact on primary productivity. Indeed, nitrate uptake by phytoplankton may enhance the productivity of zooplankton and detritus thereby offering more food for the fish[21]. Addition of maize bran in the diets also increased phosphorus concentration which in turn enhances algal growth, thereby causing an increase in ammonia uptake by algae.

The results showed that the TBC was significantly different ($p<0.05$) between treatment 3 and 4 while no differences were observed between treatment 2 and treatment 1 ($p>0.05$). This difference may be due to the high levels of nutrients like nitrogen and phosphorous in treatments 3 and 4. According to Patráš *et al.*[12], microbial populations in the intestine exploit nitrogen from urea and other nitrogen resources thereby decreasing urinary nitrogen. Equally, moisture content in manure provides a favourable environment for survival and re-growth of bacteria[12]. Results in Table 2 and 4 show the relationship between growth performance, bacterial abundance and inclusion levels of maize. This is because some bacteria are favorable to nutrient digestibility as they break down indigestible carbohydrates into short-chain fatty acids which are important energy source[9]. Furthermore, non digestible fibre serves as an energy source for intestinal microbes and supports their proliferation[12]. The highest proportion of bacteria was found in treatment with the highest inclusion level of maize bran (45%). This is another good opportunity in integrated system as microorganisms have major roles in fishpond culture, particularly with respect to productivity and nutrient cycling. Bacteria play a vital role in the mineralization of organic nitrogen and speed up decomposition of organic matter. They also help to adjust algal populations in water bodies so as to avoid unwanted algal bloom and to suppress fish diseases[22]. However, feeding management or sanitary conditions of the farm can also lead to gut microbial abundance although dietary fibre content seems to be the major driver[17].

The feed conversion ratio reported in this study was lower than that reported in previous studies[4,5] probably due to the inclusion levels of dietary fibre as well as the source of fibre (maize bran) incorporated in the diets. However, the average daily weight gain decreased at the highest inclusion level of maize bran in the diets (45%).

On the other hand, the slight reduction in the body weight due to more than 30% inclusion level of maize bran (Fig. 3) can be compensated by the fish production from fertilized ponds. This positive correlation between inclusion level of maize bran in pig diets and good quality of pig manure provides a good opportunity for fish farmers to increase fish pond productivity. Indeed, Minich *et al.*[23] observed the prebiotic effect of livestock manure when used for pond fertilization as it adds organic matter, micronutrients and macronutrients. These nutrients in turn influence the proliferation of bacteria, that is useful for the fermentation of organic matter in the pond. Thus, animal manures can completely replace compound ingredients such as fish oils or fishmeal as well as inorganic fertilizers[1]. According to Minich *et al.*[23], inorganic fertilizers and formulated feeds are expensive and their use by smallholder farmers is limited.

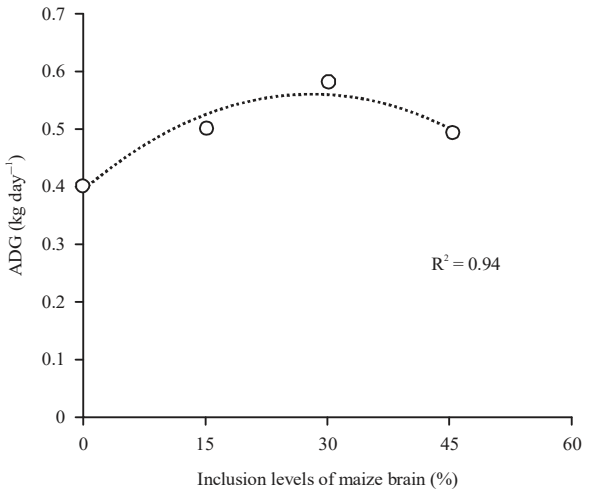

Fig. 3: Curvilinear relationship between feed efficiency and level of maize bran in the diets

CONCLUSION

The inclusion level of maize bran in pig diets affected significantly the average daily feed intake but did not affect the growth performance of pigs. No further improvement in growth rate was observed when more than 30% of maize bran was added in the pig diets. This study also showed that the highest level of maize bran (45%) increased nitrogen and phosphorous excretion in feces but reduced significantly the concentration of pH and uncontrolled ammonia. Incorporating 30% maize bran in pig diets is considered as the optimum level which increased the quantity of excreted manure and improved the growth performance. Microbial analysis of manure also showed the need for proper management of animal fertilizer before use in order to avoid infection. This feeding strategy improved the quantity and quality of pig manure and can be efficiently used in the livestock and fish farming system and solved the problem of limiting feed resources in Sub Saharan Africa.

ACKNOWLEDGMENTS

Funding for this research was provided by the Social and Environmental Trade-offs in African Agriculture (SENTINEL) of the Global Challenges Research Fund (GCRF)-UK through the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

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