



Effect of Inclusion of Rice DDGS on the Nutrient Digestibility, Energy and Mineral Balance in Crossbred Pigs

A.V. Siva Reddy^{1*}, M.V.A.N. Suryanarayana², A. Ravi¹, G. Gangaraju³, D. Suresh Babu⁴

¹Department of Animal Nutrition, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati Andhra Pradesh, INDIA

²Department of Livestock Farm Complex, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh, INDIA

³Livestock Research Station, Sri Venkateswara Veterinary University, Palamaner, Andhra Pradesh Andhra Pradesh, INDIA

⁴ICAR-All India Coordinated Research Project on Pigs, Tirupati, Andhra Pradesh, INDIA

*Corresponding Author: atlurusreddy9@gmail.com

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Abstract

Four isonitrogenous dietary treatments were evaluated for their effect on nutrient utilization of crossbred (LWY x Desi) male pigs (15.24 kg ± 0.21) during grower and finisher phases in a completely randomized design. The basal diet include corn-soybean meal based diet mixed with 100g Probiotic (*Bacillus*) and 500 g enzyme cocktail per ton feed. The dietary treatments constitute rice dried distillers grain solubles (DDGS) in basal ration (control; T1) at 20% (T2), 30% (T3), and 40% (T4) levels. During grower phase, the digestibility coefficients of DM and EE was higher ($P<0.05$) in pigs fed basal diet and the calcium and phosphorus digestibility (%) was higher ($P<0.05$) for DDGS included rations with highest in 40% DDGS ration. The nitrogen loss (g/d) in urine was lower ($P<0.05$) in T1 fed pigs. The total nitrogen loss (g/d) was higher ($P<0.05$) for 30% and 40% DDGS rations. The total calcium loss (g/d) was not significantly different among the treatments. Phosphorus retention (g/d) was higher ($P<0.01$) in DDGS diets compared to those fed on basal ration. The intake, faecal, and urinary gross energies were not significantly different among the treatments. During finisher phase, none of the nutrient digestibility of the nutrients, except phosphorus was found to be significant. The nitrogen retention (% intake) was higher ($P<0.05$) for basal diets. Phosphorus retained (g/d) was higher ($P<0.05$) for DDGS diets. None of the energy balance parameters was significant. It was concluded that DDGS could replace 30% of protein in the swine diets without any deleterious effects on the nutrient digestibility.

Keywords: Finishers, Growers, Nutrient digestibility, Nutrient balance, Rice DDGS,

Introduction

Pig is the most prolific and fast growing animal mainly reared for meat purpose. Pork contributes 6.5 per cent of total meat production in India (Basic Animal Husbandry and Fisheries Statistics, 2017). Pigs yield higher dressing percentage compared to other meat animals (Jaishankar *et al.*, 2015). The demand for high quality pork and pork-products has recently increased worldwide due to increasing world population and greater consumer expectation (Banik *et al.*, 2013). The relatively high abundance, low price, and high nutritional value of DDGS make it a popular cost-effective alternative feed ingredient for swine producers. Hence, the present study is aimed to evaluate the effect of inclusion of Rice DDGS on the nutrient utilization in crossbred pigs. Corn and Soybean have been the major components of conventional feed for pigs and satisfy the needs for energy and protein. Feed costs account for most of the production costs in almost any animal production system with 65% - 75% in the pig industry (Boggess *et al.*, 2008). Owing to an increased cost of production, use of human inedible and non-conventional protein and energy sources in livestock industry is need of the hour (Reddy *et al.*, 2019a, 2019b).

Indian cereal processing industry is gaining huge importance and hence the production of various beverage-based by-products is constantly rising (Lakshmi *et al.*, 2017). Among those by-products, distillers dried grains with soluble (DDGS) has a relatively high concentration of energy and digestible phosphorus, and a moderate concentration of protein and it can partially replace conventional protein supplements (Reddy *et al.*, 2017). Among various DDGS sources, rice DDGS is an excellent protein source available at judicious price compared to traditional protein sources. Rice DDGS contains yeast enzyme, a probiotic factor, that helps in increasing the production performance of livestock.

The beneficial effects of probiotics and prebiotics on poultry (Munyaka *et al.*, 2016), ruminants (Poonooru *et al.*, 2015) and pigs (Swiatkiewicz *et al.*, 2016) were well discussed. Supplementation of probiotics and prebiotics was known to increase the fibre digestibility. Replacement of SBM with DDGS increases the fiber quantity of diet, and hence, addition of probiotic (*Bacillus*) and Non-starch polysaccharidase (enzyme) cocktail might increase the fiber digestibility, thereby ameliorating the negative effects of cell-wall fractions. Hence, the work involved supplementation of multienzyme and bacillus species, hypothesizing that they will increase the digestibility values and ameliorate the negative effects of high fiber- DDGS. In view of the higher production costs related to corn-soya diets, high and low-cost availability of DDGS, the present study was conducted to assess the effect of rice DDGS on nutrient digestibilities, energy and mineral balance in crossbred pigs.

Material and Methods

Experimental Animals and Diets

The experiment was carried out on 24 crossbred (Large White Yorkshire) male pigs and distributed randomly into four groups with six animals in each group. Four isonitrogenous experimental diets were formulated as per NRC (2012) and fed during grower (15-35 kg body weight) and finisher (35-70 kg body weight) phases. Dietary treatments consisted of corn, soybean meal control (T1) or rice DDGS to contribute 20% (T2), 30% (T3) and 40% (T4) of the total protein of T1. The ingredient and chemical composition (%) of the experimental grower and finisher diets fed to pigs from 15 to 35 kg and 35 kg to 70 kg body weight are presented in Tables 1 and 2, respectively. Synerzyme-P-FS (a combination of Amylase, Hemi-cellulase, Xylanase, Galactosidase, Cellulose, Protease, β -glucanase and Phytase) as Enzyme cocktail and *Bacillus* probiotic were added uniformly to T1, T2, T3, and T4 at 50g and 10g/100 kg of feed, respectively. The ingredient and nutrient composition of the experimental diets are presented in Table 1 and 2, respectively.

Table 1: Ingredient and chemical composition (%) of experimental grower diets

| | T1 | T2 | T3 | T4 |
|-------------------------------|-----|-----|------|------|
| Ingredient composition | | | | |
| Maize | 60 | 59 | 59 | 59 |
| Soybean meal | 20 | 12 | 9.5 | 5.5 |
| Rice DDGS | - | 9 | 12.5 | 16.5 |
| Deioled Rice bran | 18 | 18 | 17 | 17 |
| Mineral mixture # | 1.5 | 1.5 | 1.5 | 1.5 |

| | | | | |
|---------------------------------|-------|-------|-------|-------|
| Salt | 0.5 | 0.5 | 0.5 | 0.5 |
| Lysine (%) | 0.47 | 0.63 | 0.70 | 0.81 |
| Methionine (%) | 0.05 | 0.05 | 0.05 | 0.05 |
| Bacillus (g/100kg) | 10 | 10 | 10 | 10 |
| Multi enzyme (g/100kg) | 50 | 50 | 50 | 50 |
| Cost per 100kg (Rs.) | 2355 | 2238 | 2209 | 2154 |
| Nutrient composition (%) | | | | |
| DM | 91 | 91.2 | 91.1 | 91.1 |
| OM | 89.1 | 89.5 | 89.4 | 89.5 |
| CP | 16.4 | 16.2 | 16.1 | 16.4 |
| TA | 10.9 | 10.5 | 10.6 | 10.5 |
| EE | 1.7 | 1.9 | 1.8 | 1.8 |
| CF | 9.2 | 9.6 | 9.9 | 10.7 |
| NFE | 61.8 | 61.8 | 61.6 | 60.6 |
| NDF | 27.53 | 28.60 | 28.80 | 29.20 |
| ADF | 17.10 | 17.30 | 17.60 | 18.10 |
| Hemicellulose | 10.43 | 11.30 | 11.20 | 11.10 |
| Calcium | 0.67 | 0.62 | 0.66 | 0.70 |
| Phosphorus | 0.30 | 0.30 | 0.31 | 0.32 |
| GE (kcal/g) | 3591 | 3747 | 3856 | 3919 |

Per kg contained - Ca 25.5%; P 12.75%; S 0.72%; Zn 9600mg; Mn 1500mg; Na 5.9mg; K 100 mg; Mg 6000mg; Fe 1500mg; Iodine 325mg; Cu 12000mg; Co 150 mg

Table 2: Ingredient and chemical composition (%) of experimental finisher diets

| | T1 | T2 | T3 | T4 |
|---------------------------------|-------|-------|-------|-------|
| Ingredient composition | | | | |
| Maize | 59 | 59 | 59 | 59 |
| Soybean meal | 15 | 9 | 6 | 2 |
| Rice DDGS | - | 7.5 | 11 | 15 |
| Deioled Rice bran | 24 | 22.5 | 22 | 22 |
| Mineral mixture # | 1.5 | 1.5 | 1.5 | 1.5 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 |
| Lysine (%) | 0.41 | 0.57 | 0.65 | 0.76 |
| Methionine (%) | 0.04 | 0.04 | 0.04 | 0.04 |
| Bacillus (gm/100kg) | 10 | 10 | 10 | 10 |
| Multi enzyme(gm/100kg) | 50 | 50 | 50 | 50 |
| Cost per 100kg (Rs.) | 2205 | 2133 | 2094 | 1939 |
| Nutrient composition (%) | | | | |
| DM | 91.6 | 92 | 91.5 | 91.3 |
| OM | 88.2 | 88.9 | 89.2 | 89.2 |
| CP | 14.5 | 14.3 | 14.4 | 14.2 |
| TA | 11.8 | 11.1 | 10.8 | 10.8 |
| EE | 1.7 | 1.6 | 1.9 | 1.6 |
| CF | 14.5 | 14.8 | 15.2 | 15.9 |
| NFE | 57.5 | 58.2 | 57.7 | 57.5 |
| NDF | 29.7 | 30.1 | 30.4 | 30.5 |
| ADF | 19.4 | 19.1 | 19.0 | 19.2 |
| Hemicellulose | 10.30 | 11.00 | 11.40 | 11.30 |

| | | | | |
|-------------|------|------|------|------|
| Calcium | 0.73 | 0.69 | 0.72 | 0.69 |
| Phosphorus | 0.31 | 0.32 | 0.31 | 0.35 |
| GE (kcal/g) | 3500 | 3625 | 3714 | 3792 |

Per kg contained - Ca 25.5%; P 12.75%; S 0.72%; Zn 9600mg; Mn 1500mg; Na 5.9mg; K 100 mg; Mg 6000mg; Fe 1500mg; Iodine 325mg; Cu 12000mg; Co 150 mg

Housing and Management

The pigs were housed in well-ventilated conventional sheds maintained in good hygienic condition and were stall fed throughout the experimental period. Fresh, clean drinking water was provided to the animals at ad libitum amounts. Two days prior to the collection period, the animals were shifted to the metabolism stalls for adaptation. The pigs were fed with their respective rations at 9.00 AM and 3.00 PM during throughout the experimental period. On 13th day of the preliminary period, the pigs were shifted to the metabolism stalls for adaptation to reach their normal feed consumption. Daily feed intake, feed refusals, if any, as well as faeces and urine voided were recorded daily at 9.00 AM. Twenty-four hour collection of faeces was recorded on every day morning at 9.00 AM for seven days. The faeces were weighed, mixed thoroughly and representative sample (2%) was taken in polythene bag separately for each animal and stored at -10°C in a deep freeze. After completion of each trial, pooled faecal samples were thawed to room temperature mixed properly and they were taken for nitrogen (8-10g) and DM (50-60g) analysis. For further analysis, faeces was dried at 60°C and ground to pass through 1mm screen and preserved in airtight bottles. The urine voided by each animal was measured, mixed thoroughly and representative sample (2%) was taken in glass bottle for each animal and stored at 4°C in a refrigerator after addition of few drops of concentrated sulphuric acid.

Laboratory Analysis

Samples of feed ingredients and faeces were analyzed for proximate composition and urine for N according to AOAC (2007) methods. The crude protein (N x 6.25) was estimated with fresh faeces samples. Nitrogen analysis was done by using Turbotherm and Vapodest (Gerhardt, Germany) analyzer. The crude protein (N x 6.25) of feeds and leftovers were also estimated with fresh material. Cell-wall constituents' viz., neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, acid detergent lignin (ADL) and silica were determined for feeds and faeces by using the methods described by Van Soest *et al.* (1991). Hemi-cellulose was calculated as NDF - ADF. Calcium and Phosphorus in feeds and faeces were determined according to methods described by Talapatra *et al.* (1940). Calcium and Phosphorus in urine samples were determined by Ferro and Ham (1957) and Fiske and Subba Row (1925), respectively.

Statistical Analysis

The data pertaining to digestibility coefficients and nitrogen, calcium, phosphorus and energy balance were analysed statistically (Snedecor and Cochran, 1994) and tested for significance by using Duncan's multiple range test (Duncan, 1955) using SPSS 23.0 version.

Results and Discussion

Nutrient digestibility coefficients

The nutrient digestibility coefficients of pigs fed with rice DDGS at varying levels are presented in Table 3 and 4, respectively. The digestibility coefficients of DM and EE were higher in the grower pigs fed T1 ration, whereas the calcium and phosphorus digestibilities were higher in T4 rations. However, the diets did not affect ($P > 0.05$) any of the digestibility coefficients, except for phosphorus. Previous studies (Thacker, 2006; Feoli, 2008; Avelar *et al.*, 2010) reported a reduced digestibility of DM and energy on feeding the growing-finishing pigs with increasing levels of either wheat, sorghum or corn DDGS. The decreased nutrient digestibility in the present study was attributed to the higher fibre content in DDGS containing diets. It was reported that the dietary fibre, particularly insoluble fibre, enhances DM flow and decreases digesta transit time in the gut leading to the decreased digestibility of energy and nutrients including starch and protein in pigs (Wenk, 2001; Montagne *et al.*, 2003; Owusu-Asiedu *et al.*, 2006). Stein and Shurson (2009) and Yanez *et al.* (2011) have reported that the fibre in DDGS is predominantly

insoluble and they stated that insoluble fraction is almost 6 times greater than the soluble fraction and this could be the probable reason for a decrease in nutrient digestibility. Stein and Shurson (2009) also suggested a decreased DM and energy digestibility on feeding the pigs with DDGS containing diets. They attributed the reduced digestibility to the fibre component of DDGS. A trend of decreased digestibility of nutrients in pigs fed diets containing rice DDGS (T1 to T4) might be due to the higher CF and NDF portions.

Table 3: Effect of rice DDGS on nutrients digestibility in growing pigs (Mean in percentage)

| Nutrient | T1 | T2 | T3 | T4 | SEM | P-value |
|----------------|-------------------|--------------------|--------------------|--------------------|------|---------|
| DM | 82.1 ^b | 80.8 ^{ab} | 78.5 ^a | 79.7 ^{ab} | 0.89 | 0.043 |
| OM | 84.1 | 82.9 | 80.9 | 81.7 | 0.80 | 0.470 |
| EE | 64.1 ^c | 60 ^{bc} | 53.6 ^{ab} | 50.4 ^a | 3.64 | 0.007 |
| CF | 39.7 | 39.2 | 35.9 | 32.3 | 3.14 | 0.421 |
| CP | 81.3 | 80.2 | 78.2 | 75.9 | 1.74 | 0.170 |
| NFE | 88.3 | 85.7 | 82.7 | 86.7 | 0.98 | 0.171 |
| Calcium | 59.8 ^a | 66.3 ^b | 64.7 ^{ab} | 67.6 ^b | 1.68 | 0.049 |
| Phosphorus | 55.6 ^a | 59.1 ^{ab} | 63.7 ^b | 65 ^b | 2.25 | 0.038 |
| Energy | 80.6 | 78.3 | 77.1 | 76.6 | 1.32 | 0.208 |
| ADF | 23.9 | 22.8 | 20.1 | 21.6 | 1.64 | 0.218 |
| NDF | 38.7 | 37.8 | 36.2 | 37.0 | 0.60 | 0.080 |
| Hemi cellulose | 44.7 | 43.7 | 42.1 | 43.3 | 0.55 | 0.091 |

(n=6) P<0.05 for Dry matter, Calcium and Phosphorus; P<0.01 for Ether extract.

Table 4: Effect of rice DDGS on nutrients digestibility in finisher pigs (Mean in percentage)

| Nutrient | T1 | T2 | T3 | T4 | SEM | P- value |
|----------------|-------------------|-------------------|--------------------|-------------------|------|----------|
| DM | 77.0 | 74.6 | 72 | 75.0 | 1.35 | 0.240 |
| OM | 80.5 | 77.7 | 77.3 | 78.7 | 1.19 | 0.303 |
| EE | 63.4 | 65.8 | 61.6 | 57.5 | 3.27 | 0.530 |
| CF | 41.8 | 39.9 | 41.7 | 39.4 | 2.14 | 0.845 |
| CP | 76.9 | 72.2 | 72.6 | 73.3 | 2.09 | 0.439 |
| NFE | 88.2 | 85.7 | 82.7 | 86.7 | 1.15 | 0.089 |
| Calcium | 76.6 | 70.1 | 67.9 | 69.3 | 2.64 | 0.170 |
| Phosphorus | 54.5 ^a | 62.1 ^b | 61.1 ^{ab} | 64.3 ^b | 2.24 | 0.041 |
| Energy | 76.9 | 75.3 | 73.4 | 73.5 | 1.47 | 0.396 |
| NDF | 38.9 | 37.1 | 34.6 | 37.6 | 1.07 | 0.601 |
| ADF | 26.6 | 26.0 | 22.4 | 24.8 | 1.62 | 0.334 |
| Hemi cellulose | 44.5 | 44.1 | 39.8 | 43.3 | 1.13 | 0.102 |

(n=6) P<0.05 for Phosphorus

The lower CP digestibility could be attributed to loss of more nitrogen in faeces of DDGS fed pigs. Significant differences were found (P<0.05) among the treatments with respect to loss of nitrogen in faeces from T1 to T4 in finisher phase (Table 6). The out go in faeces linearly increased from T2 to T4 containing DDGS, though the loss in grower phase was not significant. Since the DDGS has increased concentration of NDF and ADF, the loss of N from urine could have shifted to faeces (Zervas and Zijlstra, 2002). The diets containing Rice DDGS have shown a decrease in (P<0.01) EE digestibility values with lowest value for 40% ration. It was reported that the digestibility of ether extract in DDGS is suppressed because of the high dietary concentration of fiber in DDGS that has a negative impact on the digestibility of ether extract (Noblet and Shi, 1993). High dietary fiber may also increase the endogenous losses of fat because of increased microbial activity in the hindgut, which will reduce the ATTD of fat (Back Knudsen and Hansen, 1991). The relatively high concentration of NDF and ADF in DDGS and low digestibility of these nutrients was likely the reason for the low digestibility of DM and energy in DDGS included in the diets (Stein *et al.* 2009).

The digestibility of calcium tended to increase as the DDGS level increased and in particular at T3 and T4 diets. Similarly, the phosphorous digestibility has increased linearly from T1 to T2 and values were significant. It was reported that available phosphorous in DDGS is higher than phosphorous in the cereal grains from which DDGS was derived (Reddy *et al.*, 2017; Stein and Shurson, 2009) because the fermentation process of ethanol production uses microbial phytase to hydrolyze phytate P in the cereal grains (Cromwell, 1979; Pedersen *et al.*, 2007). This could be the probable reason for an increased P digestibility in current study. In present study, it was observed that calcium digestibility tended to increase with higher levels of DDGS and this could be a probable reflection of P digestibility, since Ca digestibility and retention are influenced by the availability of P in the body (Stein *et al.*, 2006; Widmer *et al.*, 2007). The substantially higher digestibility of phosphorous is due to P content and digestibility in DDGS. The higher digestibility coefficients of Ca and P in livestock could also be positively related to the lowered environmental pollution (Reddy *et al.*, 2019a, 2019b).

Nitrogen, Calcium, Phosphorus and Energy balance

Nitrogen, Calcium, Phosphorus and Energy balance of the grower and finisher pigs fed DDGS diets are presented in Table 5 and 6, respectively. In grower phase, the intake N was higher ($P < 0.001$) for diets containing DDGS at 20% and 30% of the ration. Both the excreted and retained N (g/d) were higher ($P < 0.05$) in DDGS groups compared to control. Although the retained N, in terms of g/d, was higher ($P < 0.001$) for DDGS groups containing 20 and 30 % ration, the retained N, in terms of % of N intake and % of absorbed, were lower ($P < 0.05$) for the pigs fed on diets included with DDGS. The N balance in finisher phase was different from that of grower phase. No differences were observed for N intake, urinary N excretion, and retained N; however, faecal N and total N excreted were higher ($P < 0.05$) in DDGS rations. Higher N intake of pigs fed DDGS containing groups is due to high CP content of DDGS (due to addition of lysine) and was directly related to an increased N excretion in faeces and urine, especially with Rice DDGS. As reported by Widyaratne and Zijlstra (2007), almost 25% of the CP was NPN in wheat DDGS, and is partially responsible for the increased N excretion. Similar trend observed in their study also. The increased urinary N excretion indicates increased AA catabolism, suggesting an imbalanced AA profile or a limitation in one or more limiting AA in DDGS (de Lange 2004). The N retention as a percentage of N intake in present study contradict with results of Widyaratne and Zijlstra (2007) wherein they reported addition of DDGS didn't affect the parameter.

Table 5: Balance studies of Nitrogen, Calcium, Phosphorus & Energy in Grower phase

| | T1 | T2 | T3 | T4 | SEM | p- value |
|---------------------------|--------------------|--------------------|--------------------|--------------------|------|----------|
| Nitrogen balance | | | | | | |
| Intake (g/d) | 28.7 ^{ab} | 36.4 ^b | 34.4 ^{ab} | 25.2 ^a | 1.19 | 0.001 |
| Outgo in faeces (g/d) | 4.2 | 5.3 | 6.5 | 5.5 | 0.61 | 0.115 |
| Outgo in urine (g/d) | 7.2 ^a | 9.80 ^{ab} | 10.8 ^b | 8.10 ^{ab} | 0.94 | 0.048 |
| Total loss (g/d) | 11.4 ^a | 14.9 ^b | 17.4 ^b | 13.5 ^{ab} | 1.20 | 0.018 |
| Retained (g/d) | 17.3 ^b | 21.5 ^b | 17.0 ^b | 11.7 ^a | 1.09 | 0.001 |
| Retained (% of intake) | 60.6 ^b | 58.9 ^b | 49.7 ^a | 46.3 ^a | 5.16 | 0.017 |
| Retained (% of absorbed) | 69.6 ^b | 60.8 ^{ab} | 52.8 ^a | 55.7 ^a | 3.51 | 0.020 |
| Calcium balance | | | | | | |
| Intake (g/d) | 7.3 | 7.2 | 7.3 | 7.0 | 0.25 | 0.848 |
| Outgo in faeces (g/d) | 2.0 | 2.23 | 2.0 | 1.9 | 0.15 | 0.222 |
| Outgo in urine (g/d) | 2.4 | 2.04 | 2.0 | 2.0 | 0.17 | 0.399 |
| Total loss (g/d) | 4.4 | 4.3 | 4.3 | 3.9 | 0.26 | 0.642 |
| Retained (g/d) | 2.9 | 2.9 | 3.0 | 3.1 | 0.18 | 0.927 |
| Retained (% of intake) | 40.4 | 40.6 | 40.7 | 43.9 | 2.43 | 0.711 |
| Retained (% of absorbed) | 52.2 | 58.9 | 59.3 | 60.2 | 3.04 | 0.712 |
| Phosphorus balance | | | | | | |
| Intake (g/d) | 2.95 | 3.28 | 3.18 | 3.00 | 0.13 | 0.198 |
| Outgo in faeces (g/d) | 1.30 | 1.35 | 1.26 | 1.01 | 0.53 | 0.198 |
| Outgo in urine (g/d) | 0.28 | 0.25 | 0.23 | 0.24 | 0.10 | 0.927 |

| | | | | | | |
|--------------------------|--------------------|---------------------|--------------------|--------------------|--------|-------|
| Total loss (g/d) | 1.60 | 1.60 | 1.37 | 1.30 | 0.13 | 0.298 |
| Retained (g/d)* | 1.35 ^a | 1.68 ^b | 1.80 ^b | 1.70 ^b | 0.10 | 0.002 |
| Retained (% of intake)* | 46.30 ^a | 51.30 ^{ab} | 56.60 ^b | 57.40 ^b | 2.08 | 0.047 |
| Retained (% of absorbed) | 83.40 | 86.80 | 88.80 | 87.40 | 2.33 | 0.588 |
| Energy balance | | | | | | |
| GE intake (kcal) | 3970 | 4429 | 4371 | 3757 | 161.50 | 0.059 |
| GE of feces (kcal) | 774.2 | 964 | 1018 | 838 | 81.00 | 0.191 |
| GE of urine (kcal) | 68.1 | 118 | 105 | 136 | 23.25 | 0.281 |
| DE (kcal/ kg DM) | 2895 | 2932 | 2922 | 2978 | 78.50 | 0.705 |
| ME (kcal/ kg DM) | 2833 | 2832 | 2831 | 2836 | 57.25 | 1.000 |

(n=6) $P < 0.05$ for *N* out go in urine, total *N* loss, *N* retained (% intake; % absorbed), *P* retained (% of intake). $P < 0.01$ for *N* intake, *N* retained, and *P* retained.

Table 6: Balance studies of Nitrogen, Calcium, Phosphorus and Energy in Finisher phase

| | T1 | T2 | T3 | T4 | SEM | p- value |
|---------------------------|-------------------|-------------------|-------------------|-------------------|------------|-----------------|
| Nitrogen balance | | | | | | |
| Intake (g/d) | 36.5 | 37.9 | 39.8 | 38.9 | 1.59 | 0.604 |
| Outgo in faeces (g/d) | 7.2 ^a | 10.6 ^b | 10.8 ^b | 10.5 ^b | 0.84 | 0.033 |
| Outgo in urine (g/d) | 10.3 | 12.0 | 12.3 | 13.7 | 0.86 | 0.136 |
| Total loss (g/d) | 17.5 ^a | 22.6 ^b | 23 ^b | 24.2 ^b | 1.40 | 0.030 |
| Retained (g/d) | 19.1 | 15.3 | 16.8 | 14.8 | 1.42 | 0.233 |
| Retained (% of intake) | 52.2 ^b | 40.5 ^a | 42.2 ^a | 37.5 ^a | 3.05 | 0.035 |
| Retained (% of absorbed) | 64.6 | 56.0 | 57.7 | 51.4 | 3.34 | 0.118 |
| Calcium balance | | | | | | |
| Intake (g/d) | 9.2 | 9.0 | 9.2 | 8.5 | 0.73 | 0.911 |
| Outgo in faeces (g/d) | 2.1 | 2.7 | 3.0 | 2.6 | 0.29 | 0.269 |
| Outgo in urine (g/d) | 1.30 | 0.97 | 0.78 | 0.78 | 0.20 | 0.563 |
| Total loss (g/d) | 3.3 | 3.7 | 3.9 | 3.4 | 0.36 | 0.684 |
| Retained (g/d) | 5.9 | 5.3 | 5.4 | 5.1 | 0.44 | 0.723 |
| Retained (% of intake) | 64.5 | 58.9 | 58.5 | 59.9 | 2.04 | 0.274 |
| Retained (% of absorbed) | 84.4 | 83.9 | 86.5 | 86.6 | 2.94 | 0.883 |
| Phosphorus balance | | | | | | |
| Intake (g/d) | 4.1 | 4.6 | 4.9 | 5.5 | 0.29 | 0.066 |
| Outgo in faeces (g/d) | 1.8 | 1.8 | 1.85 | 1.75 | 0.16 | 0.976 |
| Outgo in urine (g/d) | 0.38 ^a | 0.58 ^b | 0.53 ^b | 0.55 ^b | 0.05 | 0.049 |
| Total loss (g/d) | 2.25 | 2.4 | 2.5 | 2.3 | 0.16 | 0.932 |
| Retained (g/d) | 1.8 ^a | 2.2 ^{ab} | 2.5 ^{ab} | 3.2 ^b | 0.31 | 0.045 |
| Retained (% of intake) | 44.0 | 46.6 | 50.6 | 57.8 | 4.38 | 0.238 |
| Retained (% of absorbed) | 79.8 | 76.8 | 81.8 | 85.4 | 4.28 | 0.658 |
| Energy balance | | | | | | |
| GE intake (kcal) | 4453 | 5508 | 5474 | 5697 | 425.00 | 0.243 |
| GE of feces (kcal) | 1017 | 1398 | 1428 | 1319 | 122.25 | 0.156 |
| GE of urine (kcal) | 58.00 | 76.00 | 68.00 | 67.00 | 12.25 | 0.783 |
| DE (kcal/ kg DM) | 2699 | 2708 | 2752 | 2903 | 53.75 | 0.069 |

| | | | | | | |
|------------------|------|------|------|------|-------|-------|
| ME (kcal/ kg DM) | 2646 | 2658 | 2704 | 2858 | 56.50 | 0.086 |
|------------------|------|------|------|------|-------|-------|

(n=6) P<0.05 for N outgo (faeces), total N loss, Retained (% of intake), P Outgo in urine (g/d), and P Retained (g/d).

The diets did not affect (P>0.05) calcium balance of both grower and finisher pigs fed with DDGS fed diets. Although a linear decrease in Ca intake was observed with increased DDGS supplementation, the differences were not statistically non-significant. Bioavailability of calcium in M-SBM based swine is relatively low because these feed stuffs contains high proportions of Phytic acid (NRC, 1998) and their contribution to total dietary calcium content is relatively low (Soares, 2008) compared to supplemental calcium sources. The lack of a significant effect of DDGS inclusion on calcium digestibility and retention was due to the binding ability of phytates or phytic acid.

The experimental rations of grower phase did not affect (P>0.05) any of the phosphorus balance parameters, except for retained P, in terms of g/d and % of intake. Similarly, the finisher rations did not affect (P>0.05) phosphorus balance parameters, except for urinary P and retained N (g/d), which showed an increased trend (P<0.05) with DDGS inclusion. The higher P content in DDGS as compared with control increased P intake of pigs fed diets with DDGS (Reddy *et al.*, 2017). Because of increased P intake with DDGS, more percentage of P is retained in the body. The reasons are attributed due to higher content of bioavailability of P (Hanson *et al.*, 2012) and the addition of enzyme cocktail. In the present study, we hypothesised that increasing levels of DDGS in swine diets would increase P digestibility and decrease in faecal and urinary excretion based on above said two reasons. It is justified that increased P retention is a reflection of significant increase in P digestibility in both growers and finishers.

Both grower and finisher diets did not affect any of the gross energy of feed, faecal, and urine. The DE and ME values in grower and finisher phases had shown a non-significant increase in trend as the level the DDGS increased in the diet. The probable reason may be as the level of DDGS in the diets was increased, the NSP content would have been also increased (Mustafa *et al.* 1999) and in view of supplementation of the enzyme cocktail NSP digestibility would have improved leads to an increased value for both DE and ME. In contradiction, Stein *et al.* (2009) and Pederson *et al.* (2007) were reported that DE and ME in corn is greater than in corn DDGS and DE and ME in DDGS are not different from DE and ME in corn, respectively.

Conclusion

Feeding the pigs with increased levels of Rice DDGS reduces the cost of pig production apart from decreasing the environmental pollution, in terms of nitrogen, calcium, and phosphorus. It was concluded that DDGS could replace 30% of protein in the swine diets without any deleterious effects on the nutrient digestibility.

Conflict of Interests

There is no conflict of interest.

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