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Growth, haematology and serum biochemistry of pigs fed diets containing different levels of crude fibre with or without a probiotic

*Cosmas C. Ogbu[1], Ndubuisi S. Machebe[2], Anthony E. Okafor[2] and Marvin A. Egom[2]

[1]College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike, Nigeria
[2]Department of Animal Science, University of Nigeria, Nsukka, Nigeria

Abstract

The study was carried out to determine the effects of levels of crude fibre (CF), with and without a probiotic (PB) - *Saccharomyces cerevisiae* – on the growth, haematology, and serum biochemistry of weaner pigs. Forty-eight (48) 11 week (wk) old F1 Large White (LW) x Landrace (LR) (LW x LR) crossbred weaner pigs of mean weight 10 kg were used for the study which lasted for 11 wk. The study was a 2 x 4 factorial involving 8 treatments (T_1-T_8) and 3 replications/treatment (6 piglets/treatment, and 2 piglets/replicate) namely: T_1: 5% CF + 0.00g PB; T_2: 10% CF + 0.00g PB; T_3: 5% CF + 0.50g PB; T_4: 10% CF + 0.50g PB; T_5: 5% CF + 0.75g PB; T_6: 10% CF + 0.75g PB; T_7: 5% CF + 1.00g PB, and T_8: 10% CF + 1.00gPB/kg. Two isocaloric and isonitrogenous diets having two CF levels (5 or 10%) were formulated for the experiment. The probiotic was added to the feeds after compounding. Results showed significant (P<0.05) effect of treatment on growth, linear body parameters, and serum biochemical indices of the pigs but not on the haematological indices. It was concluded that the combination of 5 or 10% CF with 0.75gPB/kg diet was found the best to enhance the growth of crossbred weaner pigs. However, some of the blood and serum biochemistry values of the pigs were suboptimal.

Keywords: Crossbred pig; fibre; palm kernel cake; probiotic; *Saccharomyces cerevisiae*

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Introduction

Monogastric diets are characterised by low fibre levels (3-4% in nursery pigs, 6% or less in growers and finishers) (Soren et al., 2003; Kallabis and Kaufmann, 2012; Kerr and Shurson, 2013). Dietary fibres are soluble or insoluble carbohydrates (non starch polysaccharides, NSP) not hydrolyzed by endogenous enzymes in the small intestine (Adrizal et al., 2011; Kerr and Shurson, 2013). Inclusion of high fibre levels (>4% in the diet of newly weaned pigs and >5% in those of grower and finisher pigs) could negatively affect energy and nutrient concentrations, and utilization (Adesehinwa et al., 2008), health, and productivity (Kerr and Shurson, 2013). High levels of fibre have been shown to decrease weight gain (Yen, 2001; Johnston et al., 2003), and depress energy, protein and amino acid digestibility in growing pigs (Adesehinwa et al., 2008; Kerr and Shurson, 2013). Therefore, high dietary fibre has typically been an undesirable component of the diet of growing pigs. However, high cost of conventional feeding stuffs and the need to incorporate non-traditional ingredients to reduce the cost of production drive the interest in inclusion of high fibre ingredients in diet for pigs (Bhar et al., 2001; Soren et al., 2003). There is therefore a need to increase the ability of the pig to utilize the energy contained in high fibre co-products. Supplementation of diets with sub-therapeutic antibiotic growth promoters had helped to enhance nutrient digestibility and utilization by animals fed poor nutritive materials (El Barkouky et al., 2010) but the ban on in-feed antibiotic growth promoters (Yang et al., 2009; Ohimain and Ofongo, 2012) has necessitated the

***Corresponding author:** Cosmas C. Ogbu, College of Veterinary Medicine, Michael Okpara University of Agriculture, Umudike, Nigeria; E-mail: coschi07@yahoo.com

evaluation of other biological feed additives such as probiotics.

Probiotics are mono- or mixed cultures of (live or killed) non-pathogenic bacteria or yeast species that equilibrate intestinal microflora to the benefit of the animal (Ogbe et al., 2009; Willis et al., 2011). Probiotics act by competitive exclusion (Berchieri et al., 2006; Cho et al., 2011), microbial antagonism (Walsh et al., 2004; Mountzouris et al., 2006), and by immune modulation (Le et al., 2005). They exert powerful anti-inflammatory and anti-allergic effects (Soccol et al., 2010). In pig production, probiotics were reported to improved growth rate, and feed efficiency (Alexopoulos et al., 2004; El Barkouky et al., 2010), nutrient digestibility (Chen et al., 2006; Shen et al., 2009), beneficial bacteria in the gut (Huang et al., 2004; Estienne et al., 2005), enzyme activities (Collington et al., 1990), production of short chain fatty acids (Jadamus et al., 2002), and improved health status (Soccol et al., 2010; Adrizal et al., 2011). The probiotic yeasts, *Saccharomyces cerevisiae* has been widely studied (Soccol et al., 2010) and shown to tolerate acidic pH and bile, and protect against bacterial infections through the reduction of the intestinal pro-inflammatory response (Soccol et al., 2010).

In Nigeria, commercial pig production thrives on non conventional feedstuffs (palm kernel cake (PKC), Cassava peel (CP), brewer's spent grain (BSG) etc) (Adesehinwa et al., 2008). PKC, a bye-product of palm kernel oil extraction abound in the Southern zone of Nigeria noted for oil palm production. PKC is a highly fibrous material widely employed in the feeding of poultry and swine because of its abundance, and cheapness. It is low in energy (11.6 MJ/kg DM) and protein (15-16% fermentable N) (Heuze et al., 2012). In swine production, it is considered a source of energy (Heuze et al., 2012) and it is fed sole or mixed in high quantities with other feedstuffs. The nutritive value of these diets has been shown to be poor (Kallabis and Kaufmann, 2012) and results in poor performance of pigs maintained on them (Kallabis and Kaufmann, 2012). It will be beneficial to investigate the effects of probiotic supplementation on the performance of weaned pigs subjected to a high fibre (high PKC) diet. The study was therefore designed to evaluate the effects of a probiotic (*Saccharomyces cerevisiae*) on the growth performance, blood and serum biochemistry of weaned F_1 crossbred (LW x LR) pigs fed diets containing 5 or 10% crude fibre.

Materials and Methods

The study was carried out at the Piggery Unit of the Teaching and Research Farm, Department of Animal Science, University of Nigeria, Nsukka, Enugu State, Nigeria. The experimental animals were forty-eight (48) F_1 Large White (LW) x Landrace (LR) (LW x LR) crossbred weaner pigs aged 11wk and weighed on the average 10kg, obtained from the Piggery Unit of the Department of Animal Science, University of Nigeria, Nsukka. The experiment was a 2 x 4 factorial in a Completely Randomized Design. That is, 2 crude fibre (CF) levels (5% and 10%) and 4 probiotic (PB) levels (0.00g, 0.50g, 0.75g and 1.00g/kg). There were 8 treatments (6 piglets/treatment) namely: T_1: 5% CF + 0.0g PB; T_2: 10% CF + 0.0g PB; T_3: 5% CF + 0.5g PB; T_4: 10% CF + 0.5g PB; T_5: 5% CF + 0.75g PB; T_6: 10% CF + 0.75g PB; T_7: 5% CF + 1.0g PB, and T_8: 10% CF + 1.0g PB. Each treatment was replicated 3 times (2 weaners each). Two rations having 5% or 10% CF level and 18% crude protein (Table 1) were formulated for the experiment. The probiotic was added to the feeds after compounding. The piglets were fed 6% of their weekly body weight as daily ration. Water was provided *ad libitum* throughout the experimental period. The study lasted for 11 wk.

Data collection

Data on weekly body weight (BW), body length (BL), chest girth (CG), length of flank-to-flank (FF), and daily feed intake (FI) were collected according to treatment. Initial and weekly body weights were determined by means of a weighing scale. Daily body weight gain was calculated as the difference between two consecutive weights divided by the number of days in the interval. The linear body measurements were taken with the aid of a tailors tape. Body length (BL) was measured as the distance from the base of the neck to the base of the tail. Length of flank-to- flank (FF) was the distance from the base of one flank over and across the hip bone to the base of the next flank on the opposite side of the animal while chest girth was measured as the circumference of the chest region. Gain in linear body parameters was calculated as per daily body weight gain. Feed intake was measured as the difference between feed given and the left over after 24 h. Feed:gain ratio was calculated as gramme feed consumed per gramme gain in body weight. At the end of the experimental period, blood samples were collected from the ear vein of three pigs per treatment (one/replicate) using sterile needle and syringe. Each blood sample was shared into two portions. The portion for haematological analysis was put into bottles containing an anti-coagulant (EDTA) while the portion for serum biochemical analysis was put into serum collection tubes and allowed to clot. The sample was subsequently centrifuged at 3000 x g for 15 min using a centrifuge to obtain serum. Data were analysed using the General Linear Model of Genstat computer programme (Genstat 13, discovery edition, 2009). Significant means were separated using the Least Significant Different (LSD) option of Genstat.

Results

Final body weight (FBW), BWG, FI, and feed:gain ratio varied significantly (P<0.05) between treatments (Table 2). Pigs fed 5% CF + 0.75g PB, and 10% CF + 0.75g PB surpassed those fed diets without PB in FBW, BWG, and FI.

These groups of pigs also had the least values for feed:gain ratio (better feed efficiency). Feed intake was higher in pigs fed 10% CF compared to those fed 5% CF but was similar in pigs that received PB irrespective of level of CF. Furthermore, pigs fed diets without PB had similar (P>0.05) FBW, BWG, and feed:gain ratio with those fed 0.50 or 1.00g PB irrespective of fibre level.

The results for linear body parameters (Table 3) followed a similar trend as for FBW and BWG except that GBL, GCG, and GLF were highest (P<0.05) in pigs fed 5% CF + 0.75g PB compared to other groups. There were no differences in BW and ADFI of pigs belonging to the various treatments up to the 19 wk of age (Table 4). Pigs fed 5% CF + 0.75g PB had higher BW and ADFI (P<0.05) than those fed diets without PB from 20 to 22 wk of age. Pigs fed diets with lowest and highest PB levels (0.5 and 1.0g PB, respectively) did not differ significantly in these traits and these were generally similar to those fed diets without PB. For ADG, pigs fed 5% CF + 0.75g PB consistently exceeded (P<0.05) those fed diets without PB from 19 to 22 wk of age whereas for feed:gain ratio no particular trend was observed as pigs fed PB supplemented diets generally had similar values as those fed diets without PB.

Significant (P<0.05) treatment effects on linear body parameters were observed for body length (BL) from 20 wk of age, length of flank (LFK) from 18 wk of age, and chest girth (CG) from 19 wk of age (Table 5) and these followed a similar trend as was observed for BW. Pigs fed 5% CF + 0.75g PB consistently exceeded (P<0.05) those fed diets without PB and these were generally similar in these parameters with those fed diets with 0.50 and 1.00g PB. There were significant (P<0.05) treatment effects on gain in linear body parameters across the age periods (Table 6). For most of the age periods, pigs fed 5% CF + 0.75g PB diet gained significantly (P<0.05) higher in linear body traits compared to those fed 5 or 10% CF without PB. Gain in linear body parameters was also mostly the same for pigs fed 10% CF diets without PB and those fed diets with probiotics over the age periods. Generally, the combination of 5 or 10% CF and 0.75g PB/kg diet resulted in the highest gain in linear body traits across the age periods.

The haematological indices namely packed cell volume (PCV), haemoglobin concentration (HbC), erythrocyte (RBC) count, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) evaluated in the present study did not vary significantly between treatments (Table 7). Pigs subjected to the different diets differed significantly (P<0.05) in serum creatinine, urea, alanine amino transferase (ALT), and aspartate amino transferase (AST) but not in total serum protein and bilirubin (Table 8).

The least (P<0.05) serum level of creatinine (127.06±4.32 umol/l) was observed in pigs fed 10% CF+0.75g PB diet. Serum creatinine level was higher and similar in other treatment combinations. Blood urea was highest (P<0.05) in pigs fed 10% CF+0.0g PB diet (14.81±0.77 mg/dl) and this was similar to those of pigs fed diets containing 5% CF+0.0g PB (14.03±1.75 mg/dl) and 5% CF+0.50g PB (11.44±3.62 mg/dl) but significantly (P<0.05) higher than 11.10±0.30 mg/dl obtained in pigs fed 10% CF+0.50g PB diet. Blood urea was statistically similar for other treatment combinations and these displayed the least (P<0.05) values (range, 5.07±0.53 to 7.00±1.77 mg/dl). Serum

Table 1: Percentage and calculated composition of experimental diets

Ingredient	Composition	
	18% CP, 5% CF	18% CP, 10% CF
Maize	40.00	3.00
Wheat offal	20.00	27.00
PKC	16.00	53.00
Groundnut cake	20.00	12.00
Lysine	0.25	0.25
Methionine	0.25	0.25
Bone meal	1.50	2.00
Limestone	1.50	2.00
Salt	0.25	0.25
Vitamin premix	0.25	0.25
Calculated composition		
Crude protein (%)	18.00	18.00
Crude fibre (%)	5.00	10.00
Energy (kcal ME/kg)	2200	2200

Table 2: Growth performance of weaner crossbred pigs (means) fed varying dietary fibre and fibre + probiotic levels

Factor	Parameter			
	FBW (kg)	BWG (kg)	FI (kg)	Feed:gain
5%CF	25.43[b]	0.22[b]	1.06[d]	5.24[a]
10%CF	27.33[b]	0.25[b]	1.14[c]	4.63[ab]
5% CF + 0.5g PB	29.57[ab]	0.28[ab]	1.15[c]	4.09[b]
10% CF+ 0.5g PB	29.77[ab]	0.28[ab]	1.19[bc]	4.20[ab]
5% CF + 0.75g PB	37.00[a]	0.37[a]	1.39[a]	3.75[b]
10% CF + 0.75g PB	35.00[a]	0.34[ab]	1.40[a]	4.06[b]
5% CF + 1.0g PB	29.97[ab]	0.28[ab]	1.22[b]	4.33[ab]
10% CF + 1.0g PB	29.33[ab]	0.27[b]	1.18[bc]	4.36[ab]
SEM	2.83	0.03	0.02	0.37

a, b: Means on the same column with different superscripts are significantly different (P<0.05). S. E. M: Standard error of means.

Table 3: Linear body parameters of weaner crossbred pigs (means) fed varying dietary fibre and fibre + probiotic levels

	Parameter					
Factor	FBL (cm)	FCG (cm)	FLF (cm)	GBL (cm)	GCG (cm)	GFL (cm)
Fibre: 5 %	80.17^{b}	67.77^{b}	52.50^{b}	0.35^{b}	0.26^{b}	0.25^{b}
Fibre: 10 %	78.60^{b}	66.53^{b}	53.47^{b}	0.29^{b}	0.26^{b}	0.23^{b}
5% CF + 0.50 g PB	81.60^{ab}	74.17^{b}	57.77^{b}	0.34^{b}	0.35^{b}	0.34^{b}
10 % CF + 0.50 g PB	81.40^{b}	69.30^{b}	58.10^{b}	0.33^{b}	0.25^{b}	0.29^{b}
5 % CF + 0.75 g PB	92.97^{a}	87.00^{a}	69.67^{a}	0.47^{a}	0.49^{a}	0.48^{a}
10 % CF + 0.75 g PB	82.57^{ab}	75.87^{ab}	61.00^{ab}	0.37^{b}	0.35^{b}	0.34^{b}
5 % CF + 1.00 g PB	83.47^{ab}	71.13^{b}	57.67^{b}	0.39^{b}	0.33^{b}	0.31^{b}
10 % CF + 1.00 g PB	82.00^{ab}	70.13^{b}	56.17^{b}	0.35^{b}	0.26^{b}	0.28^{b}
SEM	3.81	3.76	2.98	0.03	0.04	0.03

a, b: means on the same column with different superscripts are significantly different (P<0.05); S. E. M: Standard error of means; FBL: final body length; FCG: final chest girth; FLF: final length of flank; GBL: gain in body length; GCG: gain in chest girth; GFL: gain in flank length.

Table 4: Age related growth response (mean) of weaner crossbred pigs fed varying dietary fibre and fibre + probiotic levels

	Age (wk)											
Factor	11	12	13	14	15	16	17	18	19	20	21	22
Body weight (kg)												
5%CF	8.33	10.33	11.67	14.00	14.63	15.50	17.27	18.83	20.67	22.33^{b}	24.00^{b}	25.43^{b}
10%CF	8.33	10.00	12.33	13.67	15.00	17.67	19.67	21.00	22.00	24.00^{b}	25.46^{b}	27.33^{b}
5% CF + 0.5g PB	8.33	9.33	11.67	14.00	15.03	16.67	18.67	20.43	22.67	24.87^{ab}	27.33^{ab}	29.57^{ab}
10% CF+ 0.5g PB	8.00	10.33	12.67	14.67	17.00	19.00	20.00	21.33	23.33	25.83^{ab}	27.83^{ab}	29.77^{ab}
5% CF + 0.75g PB	8.33	10.33	12.33	15.33	17.33	19.33	21.67	25.50	28.33	31.33^{a}	34.00^{a}	37.00^{a}
10% CF + 0.75g PB	8.67	11.00	13.33	15.00	17.67	20.50	22.67	25.67	27.67	29.67^{ab}	32.00^{ab}	35.00^{ab}
5% CF + 1.0g PB	8.33	9.33	11.00	13.00	15.67	17.00	19.33	19.75	23.67	25.67^{ab}	27.50^{ab}	29.97^{ab}
10% CF + 1.0g PB	8.33	10.33	12.00	14.67	16.00	18.00	20.00	21.00	22.67	25.00^{ab}	27.33^{ab}	29.33^{ab}
S. E. M.	1.48	1.47	1.80	2.07	2.42	2.56	2.73	2.86	2.79	2.79	2.83	2.83
Av. daily gain (kg)												
5%CF		0.29	0.29	0.33^{ab}	0.09^{b}	0.12^{b}	0.22^{c}	0.26^{ab}	0.24^{b}	0.24^{b}	0.24^{b}	0.21^{b}
10%CF		0.24	0.33	0.19^{b}	0.19^{ab}	0.38^{a}	0.19^{c}	0.14^{b}	0.29^{b}	0.29^{b}	0.21^{b}	0.27^{b}
5% CF + 0.5g PB		0.14	0.33	0.33^{ab}	0.15^{ab}	0.23^{ab}	0.25^{c}	0.32^{a}	0.31^{ab}	0.31^{ab}	0.35^{a}	0.32^{ab}
10% CF+ 0.5g PB		0.33	0.33	0.29^{ab}	0.33^{ab}	0.29^{ab}	0.19^{c}	0.29^{ab}	0.36^{ab}	0.36^{ab}	0.29^{ab}	0.28^{ab}
5% CF + 0.75g PB		0.29	0.19	0.43^{a}	0.29^{ab}	0.29^{ab}	0.56^{a}	0.41^{a}	0.43^{a}	0.43^{a}	0.38^{a}	0.43^{a}
10% CF + 0.75g PB		0.33	0.33	0.24^{ab}	0.38^{a}	0.41^{a}	0.43^{ab}	0.29^{ab}	0.29^{b}	0.29^{b}	0.33^{ab}	0.43^{a}
5% CF + 1.0g PB		0.14	0.24	0.29^{ab}	0.38^{a}	0.19^{ab}	0.41^{b}	0.32^{ab}	0.29^{b}	0.29^{b}	0.26^{ab}	0.35^{ab}
10% CF + 1.0g PB		0.29	0.24	0.38^{ab}	0.19^{ab}	0.29^{ab}	0.14^{c}	0.24^{ab}	0.33^{ab}	0.33^{ab}	0.33^{ab}	0.29^{ab}
S. E. M.		0.11	0.08	0.08	0.08	0.08	0.05	0.06	0.04	0.04	0.04	0.28
Av. daily feed intake (kg)												
5%CF		0.58	0.70	0.80	0.88	0.93	1.04	1.13	1.24	1.34^{b}	1.44^{b}	1.53^{b}
10%CF		0.60	0.74	0.82	0.90	1.06	1.18	1.26	1.32	1.44^{b}	1.53^{b}	1.64^{b}
5% CF + 0.5g PB		0.56	0.70	0.84	0.90	1.00	1.12	1.21	1.36	1.49^{ab}	1.64^{ab}	1.77^{ab}
10% CF+ 0.5g PB		0.62	0.76	0.88	1.02	1.14	1.20	1.28	1.40	1.35^{b}	1.67^{ab}	1.79^{ab}
5% CF + 0.75g PB		0.66	0.74	0.92	1.04	1.29	1.30	1.53	1.70	1.88^{a}	2.04^{a}	2.22^{a}
10% CF + 0.75g PB		0.66	0.80	0.90	1.39	1.23	1.36	1.54	1.66	1.78^{ab}	1.92^{ab}	2.10^{ab}
5% CF + 1.0g PB		0.56	0.74	0.78	1.61	1.02	1.16	1.19	1.42	1.54^{ab}	1.55^{b}	1.80^{ab}
10% CF + 1.0g PB		0.62	0.72	0.88	0.96	1.08	1.20	1.27	1.36	1.50^{ab}	1.64^{ab}	1.76^{ab}
S. E. M.		0.09	0.11	0.12	0.14	0.17	0.16	0.17	0.17	0.16	0.18	0.17
Feed:gain												
5%CF		0.84^{c}	2.10^{b}	2.91^{ab}	8.40^{a}	7.82^{a}	5.25^{b}	4.34^{ab}	6.09^{ab}	5.81^{ab}	6.93^{ab}	9.30^{a}
10%CF		2.66^{ab}	3.01^{ab}	4.69^{a}	5.39^{ab}	3.55^{b}	6.72^{ab}	8.82^{a}	4.62^{ab}	5.04^{ab}	7.80^{a}	6.14^{ab}
5% CF + 0.5g PB		3.92^{a}	2.35^{b}	2.47^{ab}	6.55^{ab}	7.30^{ab}	4.36^{b}	4.42^{ab}	4.39^{b}	4.81^{ab}	4.62^{b}	5.55^{b}
10% CF+ 0.5g PB		2.63^{ab}	2.31^{b}	3.08^{ab}	3.59^{b}	3.99^{b}	6.79^{ab}	4.48^{ab}	3.93^{b}	3.89^{b}	6.04^{a}	6.82^{ab}
5% CF + 0.75g PB		2.31^{ab}	4.41^{a}	2.26^{b}	4.15^{b}	6.07^{ab}	2.45^{c}	3.80^{b}	3.97^{b}	4.39^{ab}	5.58^{ab}	5.60^{b}
10% CF + 0.75g PB		1.98^{bc}	2.61^{ab}	4.62^{a}	5.48^{ab}	2.99^{b}	3.17^{bc}	7.16^{ab}	7.51^{a}	7.93^{a}	6.11^{ab}	5.44^{b}
5% CF + 1.0g PB		3.92^{a}	3.05^{ab}	3.22^{ab}	8.38^{a}	6.02^{ab}	3.30^{bc}	3.72^{b}	4.62^{ab}	5.39^{ab}	4.94^{b}	5.22^{b}
10% CF + 1.0g PB		2.17^{ab}	3.43^{ab}	2.40^{ab}	5.60^{ab}	4.53^{ab}	8.40^{a}	6.80^{ab}	4.27^{b}	4.69^{ab}	5.11^{b}	6.16^{ab}
S. E. M.		0.64	0.83	0.77	1.77	1.70	0.75	1.51	1.26	1.19	0.99	1.34

a, b, c: means on the same column with different superscripts are significantly different (P<0.05)

Table 5: Age related linear body parameters (mean) of weaner crossbred pigs fed varying dietary fibre and fibre + probiotic levels

	Age (wk)										
Factor	12	13	14	15	16	17	18	19	20	21	22
Body length (cm)											
5%CF	53.17	59.17	60.83	62.27	65.00	67.63	71.83	73.83	75.50^{b}	77.50^{b}	80.17^{b}
10%CF	56.17	58.33	61.07	63.83	66.50	70.00	72.67	74.20	75.47^{b}	76.87^{b}	78.60^{b}
5% CF + 0.5g PB	55.17	58.17	59.67	60.93	63.83	66.50	68.50	71.83	75.00^{b}	78.30^{b}	81.60^{b}
10% CF+ 0.5g PB	55.83	60.00	63.50	66.17	68.17	69.50	71.83	74.00	76.57^{b}	78.37^{b}	81.40^{b}
5% CF + 0.75g PB	57.00	59.00	62.83	65.67	71.67	74.93	78.87	83.33	86.67^{a}	90.13^{a}	92.97^{a}
10% CF + 0.75g PB	54.00	57.83	60.50	64.83	67.17	69.67	73.33	75.33	77.57^{ab}	79.93^{b}	82.57^{b}
5% CF + 1.0g PB	53.83	58.67	60.50	63.50	65.60	68.87	71.00	74.33	77.87^{ab}	80.17^{b}	83.47^{b}
10% CF + 1.0g PB	55.00	57.33	60.67	63.87	68.00	70.33	72.33	75.00	77.60^{ab}	80.03^{b}	82.00^{b}
S. E. M.	3.79	3.61	3.68	3.93	3.90	3.84	3.91	3.92	3.81	3.90	3.81
Length of flank (cm)											
5%CF	33.17	36.17	38.83	40.00	41.50	42.97	44.30^{b}	45.83^{b}	48.27^{c}	49.97^{b}	52.50^{b}
10%CF	35.67	37.33	38.83	40.00	44.83	43.27	45.83^{b}	46.97^{b}	48.90^{c}	50.90^{b}	53.47^{b}
5% CF + 0.5g PB	32.00	34.50	36.83	38.80	41.67	44.00	46.13^{ab}	48.73^{b}	51.57^{bc}	55.20^{b}	57.77^{b}
10% CF+ 0.5g PB	36.17	38.50	40.83	43.00	44.50	46.33	47.93^{ab}	50.00^{ab}	52.80^{bc}	55.50^{b}	58.10^{b}
5% CF + 0.75g PB	33.00	38.33	42.00	44.33	48.00	50.40	52.87^{a}	56.27^{a}	61.67^{a}	65.47^{a}	69.67^{a}
10% CF + 0.75g PB	35.00	37.33	40.60	43.00	48.43	48.00	51.50^{ab}	53.00^{ab}	58.83^{ab}	58.33^{ab}	61.00^{ab}
5% CF + 1.0g PB	34.17	36.83	38.83	40.33	41.17	45.17	48.13^{ab}	50.17^{ab}	52.50^{bc}	55.30^{b}	57.67^{b}
10% CF + 1.0g PB	34.67	36.67	40.17	41.07	42.60	44.83	46.33^{ab}	49.10^{ab}	51.53^{bc}	53.27^{b}	56.17^{b}
S. E. M.	2.67	2.39	2.35	2.45	2.67	2.58	2.70	2.87	3.41	2.97	2.98
Chest girth (cm)											
5%CF	47.67	50.00	52.00	53.00	54.00	56.10^{b}	58.53^{b}	60.50^{b}	62.83^{b}	65.20^{b}	67.77^{b}
10%CF	46.50	49.67	51.33	53.17	57.17	59.83^{ab}	62.00^{ab}	62.70^{b}	62.83^{b}	64.70^{b}	66.53^{b}
5% CF + 0.5g PB	47.33	50.00	51.67	53.40	55.50	58.50^{ab}	61.50^{ab}	64.17^{b}	67.33^{ab}	71.13^{b}	74.17^{b}
10% CF+ 0.5g PB	50.33	52.50	54.60	56.67	58.67	61.50^{ab}	64.10^{ab}	66.33^{ab}	67.10^{ab}	69.83^{b}	69.30^{b}
5% CF + 0.75g PB	49.67	54.33	57.00	58.83	62.67	66.00^{a}	68.50^{a}	73.67^{a}	74.50^{a}	85.07^{a}	87.00^{a}
10% CF + 0.75g PB	49.00	51.33	53.83	56.50	60.13	63.00^{ab}	66.00^{ab}	68.17^{ab}	70.57^{ab}	73.27^{b}	75.87^{b}
5% CF + 1.0g PB	45.83	49.00	51.83	54.50	56.50	59.00^{ab}	60.83^{ab}	63.83^{b}	66.33^{ab}	68.87^{b}	71.13^{b}
10% CF + 1.0g PB	50.00	52.33	56.50	58.83	61.00	62.80^{ab}	63.83^{ab}	64.27^{b}	66.27^{ab}	67.97^{b}	70.13^{b}
S. E. M.	2.80	2.94	2.98	3.06	3.14	3.13	3.21	3.51	3.55	4.12	3.76

a, b, c: means on the same column with different superscripts are significantly different ($P<0.05$).

ALT level was highest in pigs fed 10% CF+0.0g PB diet which did not differ significantly from those of 5% CF+0.0g PB, 5% CF+0.50g PB, and 10% CF+0.50g PB diets. The least ($P<0.05$) serum ALT value (5.30±3.25 IU/l) was obtained in pigs fed 5% CF+0.75g PB diet and this was similar to those fed 10% CF+0.75g PB, 5% CF+1.00g PB and 10% CF+1.00g PB diets (7.20±1.41, 8.80±0.57 and 7.60±0.57 IU/l, respectively). For serum AST level, pigs fed 10% CF+1.00g PB diet had the least ($P<0.05$) value of 8.83±0.71 IU/l which was statistically similar to 10.00±0.00 IU/l for pigs fed 5% CF+1.00g PB diet. Other treatment combinations had statistically higher but similar values in this parameter.

Discussion

The present study examined two research questions namely (1) whether a diet having up to 10% CF derived mainly from PKC could support normal growth, haematology and serum biochemistry of growing-finishing crossbred pigs, and (2) whether the addition of a probiotic (*S. cerevisiae*) could improve the growth and the physiological variables of the experimental subjects. The similarity in the growth parameters namely FBW, BWG, and Feed:gain ratio (Table 2) as well as in FBL, FCG, FLF, GBL, GCG, and GLF (Table 3) of pigs fed diets containing 5 and 10% CF without PB indicate that the pigs could tolerate up to 10% CF derived mainly from PKC (56% PKC) without adverse effects on growth and feed efficiency. This is contrary to the report that high (>5%) crude fibre levels significantly depress growth rate, and feed efficiency in growing-finishing pigs (Chimonyo et al., 2001; Kallabis and Kaufmann, 2012). This disparity could stem from the genotype, age and physiological status of the experimental animals, the quality of fibre source, and interaction among feed components all of which influence response to dietary fibre level (Soren et al., 2003). For instance, Chimonyo et al. (2001) reported that crossbred pigs have larger small and large intestines which enhanced crude fibre utilization compared to purebred pigs. Johnston et al. (2003) showed that total gastro intestinal digestibility of NSP increases as the pig matures and that gestating sows tolerate higher fibre diets than non-pregnant animals. The significantly higher FI by pigs fed 10% CF + 0.0g

Table 6: Age related gain in linear body parameters (mean) of weaner crossbred pigs fed varying dietary fibre and fibre + probiotic levels

	Age (wk)								
Factor	14	15	16	17	18	19	20	21	22
Gain in body length (cm)									
5%CF	0.86^{a}	0.24^{b}	0.21^{b}	0.39	0.41	0.57	0.29^{b}	0.24^{c}	0.29^{b}
10%CF	0.31^{b}	0.39^{b}	0.40^{ab}	0.38	0.50	0.38	0.22^{b}	0.18^{c}	0.20^{b}
5% CF + 0.5g PB	0.43^{b}	0.21^{b}	0.18^{b}	0.41	0.38	0.29	0.48^{ab}	0.45^{ab}	0.47^{ab}
10% CF+ 0.5g PB	0.60^{ab}	0.50^{a}	0.38^{b}	0.29	0.19	0.33	0.31^{b}	0.37^{ab}	0.40^{ab}
5% CF + 0.75g PB	0.29^{b}	0.55^{a}	0.41^{ab}	0.86	0.47	0.56	0.64^{a}	0.48^{ab}	0.50^{a}
10% CF + 0.75g PB	0.55^{ab}	0.38^{ab}	0.62^{a}	0.33	0.36	0.52	0.29^{b}	0.32^{bc}	0.34^{ab}
5% CF + 1.0g PB	0.69^{a}	0.26^{b}	0.43^{ab}	0.30	0.47	0.31	0.48^{ab}	0.51^{a}	0.33^{ab}
10% CF + 1.0g PB	0.33^{b}	0.48^{ab}	0.46^{ab}	0.59	0.33	0.29	0.38^{ab}	0.37^{ab}	0.35^{ab}
S. E. M.	0.13	0.08	0.12	0.22	0.13	0.13	0.11	0.06	0.07
Gain in length of flank (cm)									
5%CF	0.43^{ab}	0.38^{ab}	0.17^{b}	0.21	0.21	0.19^{c}	0.22^{b}	0.35^{b}	0.24^{ab}
10%CF	0.24^{b}	0.21^{b}	0.17^{b}	0.69	0.22	0.37^{b}	0.16^{b}	0.28^{b}	0.29^{ab}
5% CF + 0.5g PB	0.36^{b}	0.33^{b}	0.28^{ab}	0.41	0.33	0.31^{b}	0.37^{b}	0.41^{b}	0.52^{a}
10% CF+ 0.5g PB	0.33^{b}	0.33^{b}	0.31^{ab}	0.21	0.26	0.23^{bc}	0.30^{b}	0.40^{b}	0.39^{ab}
5% CF + 0.75g PB	0.76^{a}	0.52^{a}	0.33^{a}	0.52	0.34	0.35^{b}	0.49^{a}	0.77^{a}	0.54^{a}
10% CF + 0.75g PB	0.33^{b}	0.47^{ab}	0.34^{a}	0.78	0.06	0.50^{a}	0.21^{b}	0.83^{a}	0.07^{c}
5% CF + 1.0g PB	0.38^{b}	0.29^{b}	0.21^{ab}	0.12	0.57	0.42^{ab}	0.29^{b}	0.33^{b}	0.40^{ab}
10% CF + 1.0g PB	0.29^{b}	0.50^{a}	0.13^{b}	0.22	0.32	0.21^{bc}	0.40^{ab}	0.35^{b}	0.25^{ab}
S. E. M.	0.13	0.08	0.07	0.26	0.25	0.05	0.08	0.18	0.17
Gain in chest girth (cm)									
5%CF	0.33^{b}	0.29^{b}	0.14^{b}	0.14^{b}	0.30^{ab}	0.35^{a}	0.28^{bc}	0.33^{ab}	0.34^{b}
10%CF	0.45^{ab}	0.24^{b}	0.26^{ab}	0.57^{a}	0.38^{ab}	0.31^{ab}	0.10^{bc}	0.02^{b}	0.27^{b}
5% CF + 0.5g PB	0.38^{b}	0.24^{b}	0.25^{ab}	0.30^{ab}	0.43^{ab}	0.43^{a}	0.38^{b}	0.45^{a}	0.54^{ab}
10% CF+ 0.5g PB	0.31^{b}	0.30^{b}	0.30^{ab}	0.29^{ab}	0.41^{ab}	0.37^{a}	0.32^{b}	0.11^{b}	0.39^{b}
5% CF + 0.75g PB	0.67^{a}	0.38^{ab}	0.26^{ab}	0.55^{a}	0.48^{a}	0.36^{a}	0.74^{a}	0.12^{ab}	1.51^{a}
10% CF + 0.75g PB	0.33^{b}	0.36^{ab}	0.38^{a}	0.52^{a}	0.41^{ab}	0.43^{a}	0.31^{b}	0.34^{ab}	0.39^{b}
5% CF + 1.0g PB	0.45^{ab}	0.41^{ab}	0.38^{a}	0.29^{ab}	0.36^{ab}	0.26^{ab}	0.43^{ab}	0.36^{ab}	0.36^{b}
10% CF + 1.0g PB	0.33^{b}	0.60^{a}	0.33^{ab}	0.31^{ab}	0.26^{b}	0.15^{b}	0.06^{c}	0.29^{ab}	0.24^{b}
S. E. M.	0.09	0.08	0.07	0.12	0.07	0.06	0.12	0.17	0.17

a, b, c: means on the same column with different superscripts are significantly different (P<0.05).

PB diet compared to those fed 5% CF + 0.0g PB diet was contrary to the report by Soren et al. (2003) who found decreased feed intake in crossbred gilts fed high fat (11.61%) and fibre (13.26%) compared to low fat (3.46%) and fibre (5.24%) diets and that of Kallabis and Kaufmann (2012) who reported that the feeding rate of fattening pigs fed high (up to 6%) dietary crude fibre is clearly reduced resulting in lower feed intake. Chimonyo et al. (2001) reported no relationship between levels of maize cob (therefore fibre levels) in diets of growing-finishing *Mukota* pigs and average daily feed intake while Zhang et al. (2013) reported only a tendency (P<0.10) for feed intake to decrease as total dietary fibre level increased. The significantly higher FI of pigs fed 10% CF compared to those fed 5% CF in the present study indicates a direct relationship between fibre level and FI probably due to the need to compensate for nutrient (energy) deficiencies (Kerr and Shurson, 2013; Zhang et al., 2013). Pigs fed 5 or 10% CF plus 0.50 or 1.00g PB had essentially similar FI which indicates that the experimental animals accepted (consumed) the diets equally. Pigs fed 5 or 10% CF plus 0.75g PB had overall highest BW, BWG, FI, and least feed:gain ratio probably on account of the effect of PB at this level of inclusion. Beneficial effects of feeding *S. cerevisiae* have been reported widely in literature (Gao et al., 2008; Silva et al., 2009; Price et al., 2010). The authors attributed the positive effects of yeast probiotic to the contents of yeast cell wall (oligosaccharides, peptides, amino acids, and nucleotides) which stimulate appetite, improve feed intake, and stimulate and enhance the development of intestinal villi.

The overall best performance of pigs fed 5% CF + 0.75g PB in BW, BWG, and feed:gain ratio (Table 2) and in GBL, GCG, and GFL (Table 3) could be attributed to the lower CF level and 0.75g PB combination. It could also be that this CF and PB inclusion levels is optimal for growth performance, FI, and feed efficiency for growing-finishing pigs. In a study of the effect of cassava peel based diets supplemented with avizyme$^{(R)}$ 1300 on growth, serum and haematological indices of growing pigs, Adesehinwa et al. (2008) found better performance in average daily gain and FCR with 100g/100kg enzyme inclusion rate compared to 200g/100kg and control.

Table 7: Haematological profiles of weaner crossbred pigs (mean ± SD) fed varying dietary fibre and fibre + probiotic levels

	Parameter					
Factor	PCV (%)	RBC (x 10^{12}/l)	HbC (g/dl)	MCV (fl)	MCH (pg)	MCHC (g/dl)
5% CF	45.00 ± 7.07	4.35 ± 0.11	13.48 ± 1.58	103.40 ± 13.75	30.99 ± 2.89	30.05 ± 1.20
10% CF	30.00 ± 0.00	4.27 ± 0.30	10.85 ± 1.51	70.43 ± 4.90	25.35 ± 1.78	36.17 ± 5.05
5% CF + 0.5g PB	36.33 ± 5.20	3.73 ± 0.18	9.05 ± 0.13	97.85 ± 18.75	24.29 ± 0.86	25.20 ± 3.95
10% CF+ 0.5g PB	38.00 ± 2.83	4.48 ± 0.06	13.08 ± 0.12	84.88 ± 5.12	29.22 ± 0.14	34.49 ± 2.25
5% CF + 0.75g PB	42.46 ± 1.67	4.18 ± 0.61	10.04 ± 0.45	102.96 ± 18.97	24.36 ± 4.63	23.64 ± 0.14
10% CF + 0.75g PB	40.71 ± 0.16	4.87 ± 0.04	11.51 ± 1.80	83.60 ± 0.40	23.65 ± 3.90	28.29 ± 4.53
5% CF + 1.0g PB	36.99 ± 8.31	4.21 ± 0.95	9.33 ± 0.86	92.41 ± 40.53	22.49 ± 3.03	26.13 ± 8.19
10% CF + 1.0g PB	37.98 ± 0.68	3.94 ± 0.73	10.37 ± 3.83	98.04 ± 16.42	25.90 ± 4.94	27.22 ± 9.60
P value	0.16	0.51	0.21	0.66	0.25	0.33

PCV: packed cell volume; HbC: haemoglobin concentration; RBC: red blood cell count; MCV: mean corpuscular volume; MCH: mean corpuscular haemoglobin; MCHC: mean corpuscular haemoglobin concentration.

Table 8: Serum biochemistry of weaner crossbred pigs (mean ± SD) fed varying dietary fibre and fibre + probiotic levels

	Parameter					
Factor	Protein (g/dl)	Creatinine (umol/l)	Urea (mg/dl)	Bilirubin (mg/dl)	ALT (iu/l)	AST (iu/l)
5%CF	4.36 ± 0.44	171.00 ± 39.91^{a}	14.03 ± 1.73^{ab}	2.72 ± 1.02	12.30 ± 2.40^{abc}	14.67 ± 0.47^{ab}
10%CF	4.15 ± 0.78	197.78 ± 7.38^{a}	14.81 ± 0.77^{a}	4.97 ± 2.16	17.00 ± 2.83^{a}	16.50 ± 1.17^{a}
5% CF + 0.5g PB	4.04 ± 0.96	183.56 ± 23.72^{a}	11.44 ± 3.62^{ab}	4.25 ± 1.77	13.20 ± 3.11^{ab}	16.50 ± 6.36^{a}
10% CF+ 0.5g PB	4.10 ± 0.74	189.56 ± 0.00^{a}	11.10 ± 0.30^{b}	3.75 ± 2.47	12.00 ± 2.83^{abc}	19.33 ± 0.00^{a}
5% CF + 0.75g PB	4.53 ± 0.60	210.61 ± 11.55^{a}	7.00 ± 1.77^{c}	3.25 ± 3.89	5.30 ± 3.25^{d}	19.00 ± 0.95^{a}
10% CF + 0.75g PB	4.13 ± 0.53	127.06 ± 4.32^{b}	5.07 ± 0.53^{c}	6.50 ± 0.71	7.20 ± 1.41^{cd}	16.50 ± 0.24^{a}
5% CF + 1.0g PB	4.19 ± 0.48	185.00 ± 6.45^{a}	5.85 ± 1.04^{c}	5.00 ± 2.12	8.80 ± 0.57^{bc}	10.00 ± 0.00^{bc}
10% CF + 1.0g PB	4.15 ± 0.54	184.00 ± 0.00^{a}	6.20 ± 0.78^{c}	3.40 ± 2.51	7.60 ± 0.57^{bcd}	8.83 ± 0.71^{c}
P value	0.97	0.03	0.00	0.76	0.02	0.01

^{a,bc}means on the same column with different superscripts are significantly different (P<0.05). ALT: alanine amino transferase; AST: aspartate amino transferase

The lack of significant differences between experimental groups in BW, and FI until the 20th wk of age (Tables 4) indicate possible age effect on feed intake and growth response of the experimental pigs to the different treatment combinations (Johnston et al., 2003). LeGoff and Noblet (2001) stated that total digestibility of non starch polysaccharides (NSP) increases as the pig matures and that the improvement of fibre digestibility with age is particularly noticeable with feedstuffs that are high in insoluble dietary fibre mainly digested in the hindgut. The observed differences in BWG, and feed:gain ratio of pigs fed diets containing 5 or 10% CF plus 0.75g PB and those fed diets without PB became clearer with age. Similar trends were observed for BL, LFK, and CG (Table 5) and for gain in these linear body parameters (Table 6). It could be that the requisite gastrointestinal environment (such as the intestinal microbiota, intestinal epithelial cells and villi, etc) for fibre digestion and absorption and interaction with probiotics (for enhanced nutrient digestibility and absorption and immunomodulation) become better developed as the animal matures or that the genetic factors that interact with probiotics to enhance fibre digestion and absorption and improved health status become upregulated with age. LeGoff and Noblet (2001) had stated that for most NSP, sows posses higher digestibility coefficients than growing pigs. Also Kerr and Shurson (2013) reported that growing-finishing pigs tolerate higher fibre levels than nursery and weanling pigs while Johnston et al. (2003) stated that the pig's ability to utilize dietary fibre is positively related to age and the weight of the pig.

The haematological parameters studied did not vary significantly between treatments (Table 7) which indicates that the various diets had similar impact on the blood profile of the animals. The range of values for PCV, HbC, and MCHC fell within the range reported for apparently healthy pigs in the same environment and elsewhere by other studies. For instance Eze et al. (2010) found a range of 25.0 to 46.0% for PCV, 6.05 to 13.20 g/dl for HbC, and 24.0 to 37.2 g/dl for MCHC in pigs reared intensively in Eastern Nigeria which considerably agreed with the range reported in the present study. Also Stukelj et al. (2010) reported reference range for PCV, and HbC as 0.32 to 0.50 l/l, and 100 to 160 g/l, respectively. Buzzard et al. (2013) however reported that values of HbC and PCV above 10.5g/dl, and 32.8%, respectively in 28 day old pigs indicate unthriftiness. The range of values obtained for RBC, MCV and MCH were outside the range reported for growing-finishing pigs (Eze et al., 2010; Stukelj et al., 2010; De et al., 2013). Compared to these reports, our values suggest anaemia in the experimental pigs probably due to nutrient deficiencies. The values for MCV were higher than the reference values reported by

Stukelj et al. (2010) and De et al. (2013) which suggests abnormally large RBC and the presence of macrocytic anaemia. It could be that the pigs responded to the low RBC level by the release of immature RBCs (i.e., reticulocytes which are usually larger in size) into circulation. The observed normal values for PCV could hence be due to fewer RBCs of abnormally large sizes. Macrocytic anaemia is attributed to reticulocytosis due to vitamin (folate, or Vit B_{12}) deficiency (Sheridan, 2004; Khanduri and Sharma, 2007), and/or hepatic disease (Sheridan, 2004). High MCV also impute a need for increased oxygen carrying capacity (De et al., 2013). The abnormally high values of MCH compared to Eze et al. (2010) and De et al. (2013) suggest the presence of hyperchromic anaemia (abnormally high haemoglobin per cell) probably following the shortages in RBC number and the need to maintain adequate oxygen supply to body tissues.

The non significant differences in total serum protein (Table 8) indicate that the experimental diets were similar in crude protein level and that the yeast probiotic used in the study did not significantly alter the protein profile of the diets at the levels of inclusion. It had been speculated (Suryanarayana, 2013) that the protein (peptides and amino acid) content of the cell wall of yeast probiotics enhance the protein content of diets leading to enhanced performances. Except for pigs fed 10% CF + 0.75g PB, the serum creatinine of other treatments were higher than the upper end of the range of referral values reported for pigs by other studies (Chmielowiec-Korzeniowska et al., 2012) which indicates impaired kidney function, higher muscle metabolism or nutritional deficiencies in the experimental subjects. We could not understand the biological significance of the significantly lower serum creatinine level of pigs fed 10% CF + 0.75g PB diet. The reduction in serum urea following inclusion of higher levels of PB (0.75, and 1.00g) could mean improved digestion, and utilization of the diets. Urea is a by-product of dietary and endogenous (muscle) protein catabolism. The addition of 0.75 and 1.00g PB to the diets may have enhanced the digestion, and absorption of the nutrients locked up in the fibrous feed stuff hence reducing muscle protein catabolism. The values obtained for ALT were generally below the lower end of the biologically normal range for finisher pigs (15-46 IU/l) while AST values were generally very close (below or above) the lower end of range of values for finishers (16-67 IU/l) (Pig site.com, unpublished). ALT and AST values measure liver enzyme synthetic activities. The very low values of these liver enzymes compared to reported normal values indicate impaired liver function probably because the experimental subjects were not in optimal health condition (Buzzard et al., 2013). This could be attributed to nutrient deficiencies. ALT decreases with weight loss (Johnston, 1999). Furthermore, ALT and AST levels are severely decreased under nutritional deficiencies (e.g., vit. B_6 deficiency) (Johnston, 1999). The severely reduced ALT values indicate that ALT synthesis was more severely affected compared to AST. Deficiency of pyridoxine is for example more critical for ALT synthesis than for AST synthesis. For reasons not available to us, the lowest ALT values were obtained at the highest levels of PB supplementation.

Conclusions

Weaner LW x LR crossbred pigs fed 10% CF diets with and without PB supplementation had comparable growth, haematological and serum biochemical values as those fed 5% CF diets. The addition of PB at 0.75g/kg diet was found best to enhance the growth performance of weaner pigs fed 5 or 10% CF. The finding of unthriftiness and suboptimal health based on some abnormal blood and serum biochemical values of the pigs should be further investigated.

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