CHEMICAL CHARACTERIZATION, ENERGY AND ZINC BIO-AVAILABILITY OF CASSAVA STARCH RESIDUES FERMENTED WITH RUMEN LIQUOR AND DIFFERENT N-SOURCES

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ABSTRACT

The nutritive potentials of rumen liquor fermented cassava starch residue (RLFCSR) were evaluated with a view to providing basic analytical data which will enhance its use in animal feed. The crude protein (CP) of cassava starch residue increased from 35.62 – 79.4 g/kg, while the crude fibre (CF) decreased from 125.18 – 83.87 g/kg as the levels of N-sources increased from 0 g/kg to 50 – 100g /kg. Increased fermentation period (FP) from 0 hour to 72 – 144 hours led to 21.1 – 21.3 % increment in CP and 8.2 – 9.5 % decrease in CF in RLFCSR. The energy contribution due to fat (PEF) and protein (PEP) increased with N-sources and FP but energy contribution due to carbohydrate (PEC) and utilizable energy due to protein (UEDP) decreased. The molar ratios of K/Na, Na/K, Ca/P and Ca/Mg were affected by N-sources, levels of N-sources and FP. HCN and phytate consistently decreased as the levels of N-sources and FP increased. The levels of Phy:Zn, Ca:Phy and Ca:Phy/Zn were good enough to enhance Ca and Zn bioavailability.

Keywords: Cassava wastes, Animal wastes, Chemical composition, Zinc bioavailability

INTRODUCTION

Cassava tuber and its agro-by products are primarily a carbohydrate source and are potential replacement for maize as energy source for monogastrics. However, the processing and utilization of cassava tubers usually resulted in waste generation in form of cassava peels and cassava starch sievate from the cassava processing industries (Aro *et al*., 2010). For instance in developing countries, cassava starch residue, which constitutes over 17 % of the whole tuber (Tewe, 1996), when allowed to rot could cause environmental pollution and constitute health hazards, social attrition between the cassava processing factories management and their host communities. Whereas, utilization of this cassava waste for livestock production could help in alleviating animal protein shortage in sub-Sahara Africa.

Cassava starch residue has very low protein content of <40 g/kg DM, starch content of between 150 – 500 g/kg and high NDF content of 350 g/kg (Heuze *et al*., 2012). Aro *et al.* (2008) reported the moisture content, crude protein, crude fibre, ether extract and nitrogen free extract of cassava starch residue as 842.2 g/kg, 11.22 g/kg, 192.5 g/kg, 23.7 g/kg and 744.1 g/kg respectively. The major anti-nutrient in cassava; cyanide could be up to 17.88 mg/kg in cassava starch residue (Aro *et al*., 2010) although it is usually less than the quantity found in cassava tuber (Oppong-Apane, 2013).

The use of solid substrate fermentation is envisaged could help in enhancing the nutritive value of cassava starch residues for animal nutrition. Fermentation is known as one of the oldest applied biotechnologies that have been successfully been used in food processing and its preservation for over 6000 years (Oboh, 2006a; Aro *et al*., 2010). It has been implicated as important processing method that can enhance the protein content (Nwafor and Ejukonemu, 2004), flavour (Akindahunsi *et al*., 1999) and detoxification of anti-nutrients (Oboh and Akindahunsi, 2003a) of cassava products. Fermentation can also preserve the final fermented product through acidification and dehydration (Oboh *et al*., 2000); enhance the nutrient content of feed through biosynthesis of vitamins, essential amino acids and protein, and by improving protein quality and fibre digestibility (Oboh, 2006b).

Some microbes being used to ferment cassava waste products with a view to increasing their nutritive value include mixed culture of *Saccharomyces cervisae* and *Lactobacillus* spp. (Oboh, 2006a) which increased the crude protein of cassava peels from 82.0 to 215.0 g kg^{-1}, submerged fermentation with *Trichoderma viride* (ACTC 36316) (Ezekiel *et al*., 2010) which increased the crude protein from 42.1 to 365.2 g/kg and mixed *Aspergillus niger and Lactobacillus rhamnos* increased cassava peel protein content from 55.0 to 244.0 g/kg (Okpako *et al*., 2008). Aro *et al*. (2008) reported that the crude protein of cassava starch residue increased from 11.2 to 70.0 g/kg and fibre content reduced from 192.0 to 147.7 g/kg in a solid state fermentation using mixture of *A. fumigates, L. delbrueckii* and *L. coryneformis.* Abasiekong (1991) reported an improvement in the protein content of spent sorghum grain when fermented with some selected rumen micro-organisms, while Adeyemi *et al*. (2007) reported increase in crude protein content and reduction in fibre content of cassava root meal when fermented with rumen liquor. Fermentation with rumen liquor in a solid state fermentation have advantage because of various kind of microbes such as fungi, bacteria and protozoa present in the rumen liquor. Mixed microbes are believed to utilize low protein quality substrate and non protein nitrogen for synthesis of microbial protein and thus improved the protein quality. However, nitrogen sources have been explained to provide the necessary nutritional requirements for micro-organisms introduced in a solid state fermentation (Noomhorm *et al*., 1992). However, information on the use of different nitrogenous source such as agro-wastes like layer's droppings and rabbit's droppings used in combination with rumen liquor in the fermentation of cassava starch residue with a view to increasing its nutritive value for animal feeding is rare. This study was therefore conducted to assess the chemical composition typified by proximate composition, mineral and energy content of cassava starch residue fermented with different N-sources and rumen liquor for different periods. Also, evaluated are the nutrient inter-relationships and zinc bioavailability in the fermented cassava starch residue.

MATERIALS AND METHODS

Cassava starch residue was collected from Maltna Foods Limited, located in Oke-Odo via Owo, Ondo State, Nigeria. The cassava starch residue was drained out with hydraulic press, sun-dried and ground. Droppings of commercial layers fed layer's mash and commercial rabbits fed grower mash with forages were collected separately from laying unit and rabbitry of the Teaching and Research Farm of the Agricultural Technology Department of the Federal Polytechnic, Ado Ekiti respectively. These droppings were placed in heat resistance conical flasks and autoclaved for 20 minutes; thereafter cooled, sun-dried, milled and kept in a cool dried place until used. Wastes from layer were devoid of feather and broken shell.

The rumen liquor was squeezed out of the rumen content obtained from freshly slaughtered cattle through a sieve in a clean environment and used immediately.

A 2 x 3 x 3 factorial combination of nitrogenous sources (LW and RW), nitrogenous sources inclusion rates (0, 50 and 100 g/kg) and fermentation duration (0, 72 and 144 hours) in a completely randomized design were used in this experiment. Ground cassava starch residue (250 g) was mixed with the various nitrogenous sources (LW and RW) at the rates of 0, 50 and 100 g/kg in air tight black polythene bags. Contents of each polythene bags was sprayed with 250 ml of rumen filtrate, made airtight and fermented for durations of 0, 48, 96 and 144 hours. Thereafter, fermented cassava starch residue was sun-dried for 5 days and analyzed for proximate, anti-nutritive factors and minerals compositions.

Proximate composition and hydrogen cyanide contents were determined as described by AOAC methods (AOAC, 1995) and silver nitrate titration method (Oboh *et al*., 2002) respectively. The phytate content was determined based on the ability of standard ferric chloride to precipitate phytate in dilute HCl extracts of the sample (Preet and Punia, 2000). The gross energy was determined against thermo-chemical-grade benzoic acid using combustion calorimeter (e2k Combustion Calorimeter, Digital Data Systems (Pty) Limited, South Africa). Each sample was analysed thrice. The Na and K contents were determined by flame photometry (Jenway Limited, Dunwow, Essex, United Kingdom) and P by Vanado-molybdate method (AOAC, 1995). The Ca, Mg, Fe, Zn, Cu, Ni, Mn and Cr were determined after wet digestion with a mixture of nitric, sulphuric and hydrochloric acids, using atomic absorption spectrophotometer (210 VGP, Buck Scientific, USA).

Fatty acid was estimated as a product of crude fat content using the conversion factor of 0.08 (Greenfield and Southgate 2003); while the energy values as contributed by protein was reported as percentage proportion of energy due to protein (PEP %) and utilization energy due to protein (UEDP %). The energy values contributed by carbohydrate and fat were reported as percentage proportion of energy due to carbohydrate (PEC %) and as percentage proportion of energy due to fat (PEF %) respectively. The Na/K, K/Na, Ca/P and Ca/Mg mineral ratio were calculated (Nieman *et al*., 1992), while the Phy:Zn, Ca:Phy and [Ca][Phy]:[Zn] were also calculated (Wyatt and Triana-Tejas, 1994).

All data collected were subjected to statistical analysis appropriate for 2 x 3 x 3 factorial design using SPSS (2011) version 20.

RESULTS

The moisture content (MC) of the rumen liquor fermented cassava starch residue (RLFCSR) were significantly ($p<0.001$) affected by N-sources and levels of N-sources (Table 1). Only levels of N-sources + fermentation period, N-sources + levels of N-sources + fermentation period interactions were significant ($p<0.001$). Worthy of note is that moisture content increased with levels of N-sources. Also, the N-sources, fermentation period, levels of N-sources and their interactions had significant effect ($p<0.001$) on the values of crude protein (CP). The CP value increased from 35.62 – 79.4 g/kg as the levels of N-sources increased from 0 to 50 and 100 g/kg, while 21.1 and 21.3 % increment were observed as the fermentation period increased from 0 to 144 hours respectively. The significant effect ($p<0.001$) on the crude fibre (CF) was observed for the level of N-sources, fermentation period and their interactions. The CF value decreased by 24.1 and 33.0 % as the level of N-sources increased from 0 to 50 to 100 g/kg; it decreased with 8.2 and 9.5 % as the fermentation period (FP) increased from 0 hour to 72 and 144 hours, respectively. The crude fat and fatty acid content of the cassava starch residue were only significantly affected ($p<0.001$) by fermentation period.

The effect of N-sources, levels of N-sources and FP on gross energy values and energy as contributed by protein, fat and carbohydrate are as shown on Table 2. Level of N-sources, fermentation period and levels of N-sources + FP were significant ($p<0.001$) for the gross energy. While the PEF % and PEP % increased as the levels of N-sources and FP increased, the PEC % and UEDP % (assuming 60 % utilization) decreased. However, significant interactions ($p<0.001$) were observed at different interaction levels.

The macro-mineral contents of RLFCSR indicated that Ca increased as the FP increased, while Mg content increased as the levels of N-sources increased and P content increased as both the levels of N-sources and FP increased. Levels of N-sources + FP were only significant ($P<0.05$) for K and P, respectively (Table 3).

Table 1: Proximate composition and fatty acid (g/kg) of rumen liquor fermented cassava starch residue

NS	LN (g)	FP (hr)	MC	CP	CF	ASH	FAT	NFE	FA
LW			57.12 ± 0.16[b]	59.67± 0.07[b]	102.11±0.13	67.59±0.07	26.45±0.04	687.04±0.18	21.16±0.03
RW			57.75± 0.16[a]	60.39± 0.07[a]	100.59±0.13	67.57±0.07	26.51±0.04	687.17±0.18	21.21±0.03
	0		52.81±0.198[a]	35.62±0.09[c]	125.18±1.39[c]	66.87±0.09[c]	26.51±0.05	693.02±1.44[a]	21.21±0.04
	50		58.56± 0.19[b]	65.07± 0.09[b]	95.02± 1.39[b]	68.08± 0.09[a]	26.48±0.05	686.79± 1.44[b]	21.19±0.04
	100		60.96± 0.19[c]	79.40± 0.09[a]	83.87± 1.39[a]	67.80± 0.09[b]	26.46±0.05	681.51± 1.44[c]	21.17±0.04
		0	57.19±0.19	50.91±0.09[a]	107.65±0.39[b]	63.60±0.09[c]	21.37±0.05[c]	699.27±0.14[a]	17.10±0.04[c]
		72	57.45±0.19	64.45±0.09[b]	98.94±0.39[a]	69.41±0.09[b]	28.63±0.05[b]	681.09±0.14[b]	22.91±0.04[b]
		144	57.70±0.19	64.70±0.09[b]	97.47±0.39[a]	69.73±0.09[a]	29.40±0.05[a]	680.95±0.14[b]	23.55±0.04[a]
NS x LN									
LW	0		52.73±0.28	35.43±0.13	125.31±1.96	66.90±0.13	26.43±0.07	693.18±2.04	21.14±0.05
	50		58.22±0.28	64.45±0.13	97.51±1.96	68.08±0.13	26.48±0.07	685.24±2.04	21.18±0.05
	100		60.43±0.28	79.68±0.13	83.51±1.96	67.80±0.13	26.45±0.07	682.68±2.04	21.16±0.05
RW	0		52.90±0.28	35.80±0.13	125.03±1.96	66.83±0.13	26.58±0.07	692.84±2.04	21.26±0.05
	50		58.88±0.28	65.68±0.13	92.51±1.96	68.08±0.13	26.48±0.07	688.34±2.04	21.18±0.05
	100		61.48±0.28	79.68±0.13	84.23±1.96	67.80±0.13	26.46±0.07	680.32±2.04	21.17±0.05
NS x FP									
LW		0	56.66±0.28	50.78±0.13	109.05±1.96	63.63±0.13	21.30±0.70	698.56±2.04	17.04±0.05
		72	57.28±0.28	63.68±0.13	99.96±1.96	69.41±0.13	28.63±0.70	681.01±2.04	22.90±0.05
		144	57.44±0.28	64.53±0.13	97.33±1.96	69.73±0.13	29.43±0.70	681.52±2.04	23.54±0.05
RW		0	57.71±0.28	51.05±0.13	106.25±1.96	63.56±0.13	21.45±0.70	699.97±2.04	17.16±0.05
		72	57.61±0.28	65.23±0.13	97.91±1.96	69.41±0.13	28.63±0.70	681.18±2.04	22.90±0.05
		144	57.94±0.28	64.88±0.13	97.61±1.96	69.73±0.13	29.45±0.70	680.37±2.04	23.56±0.05
LN x FP									
	0	0	59.59±0.34	34.25±0.16	124.02±2.41	61.35±0.15	21.51±0.08	706.25±2.51	17.22±0.06
		72	51.81±0.34	36.30±0.16	126.40±2.41	69.45±0.15	28.50±0.08	687.54±2.51	22.80±0.06
		144	54.05±0.34	36.30±0.16	125.10±2.41	69.80±0.15	29.50±0.08	685.25±2.51	23.60±0.06
	50	0	58.88±0.34	58.65±0.16	99.57±2.41	65.10±0.15	21.25±0.08	696.53±2.51	17.00±0.06
		72	59.12±0.34	68.12±0.16	93.02±2.41	69.45±0.15	28.70±0.08	681.57±2.51	22.96±0.06
		144	57.66±0.34	68.42±0.16	92.45±2.41	69.70±0.15	29.50±0.08	682.26±2.51	23.60±0.06
	100	0	60.08±0.34	59.85±0.16	99.35±2.41	64.35±0.15	21.30±0.08	695.01±2.51	17.08±0.06
		72	61.42±0.34	88.95±0.16	77.40±2.41	69.34±0.15	28.70±0.08	674.18±2.51	22.96±0.06
		144	61.37±0.34	89.40±0.16	74.87±2.41	69.70±0.15	29.32±0.08	675.32±2.51	23.46±0.06
NS x LN x FP									
LW	0	0	52.84±0.48	34.35±0.22	124.30±3.41	61.45±0.22	21.30±0.12	705.75±3.54	17.04±0.98
		72	51.56±0.48	36.25±0.22	127.00±3.41	69.45±0.22	28.50±0.12	687.24±3.54	22.80±0.98
		144	53.80±0.48	35.70±0.22	124.65±3.41	69.80±0.22	29.50±0.12	686.55±3.54	23.60±0.98
	50	0	58.40±0.48	58.15±0.22	105.15±3.41	65.10±0.22	21.26±0.12	691.95±3.54	17.00±0.98
		72	58.87±0.48	66.80±0.22	94.15±3.41	69.45±0.22	28.70±0.12	682.03±3.54	22.96±0.98
		144	57.41±0.48	68.40±0.22	93.25±3.41	69.70±0.22	29.50±0.12	681.74±3.54	23.60±0.98

	100	0	58.77±0.48	59.85±0.22	97.70±3.41	64.35±0.22	21.35±0.12	697.99±3.54	17.40±0.98
		72	61.42±0.48	88.00±0.22	78.75±3.41	69.35±0.22	28.70±0.12	682.03±3.54	22.80±0.98
		144	61.12±0.48	89.50±0.22	74.10±3.41	69.70±0.22	29.30±0.12	681.74±3.54	23.60±0.98
RW	0	0	52.34±0.48	34.15±0.22	123.75±3.41	61.25±0.22	21.75±0.12	706.76±3.54	17.00±0.98
		72	52.06±0.48	36.35±0.22	125.80±3.41	69.45±0.22	28.50±0.12	687.84±3.54	22.96±0.98
		144	54.30±0.48	36.90±0.22	125.55±3.41	69.80±0.22	29.50±0.12	683.95±3.54	23.60±0.98
	50	0	59.37±0.48	59.15±0.22	94.00±3.41	65.10±0.22	21.25±0.12	701.12±3.54	17.00±0.98
		72	59.47±0.48	69.45±0.22	91.90±3.41	69.45±0.22	28.70±0.12	681.13±3.54	22.96±0.98
		144	57.91±0.48	68.45±0.22	91.65±3.41	69.70±0.22	29.50±0.12	682.79±3.54	23.60±0.98
	100	0	61.42±0.48	59.85±0.22	101.00±3.41	64.35±0.22	21.35±0.12	692.03±3.54	17.08±0.98
		72	61.42±0.48	89.90±0.22	76.05±3.41	69.35±0.22	28.70±0.12	674.58±3.54	22.96±0.98
		144	61.62±0.48	89.30±0.22	75.65±3.41	69.70±0.22	29.35±0.12	674.37±3.54	23.48±0.98

NS= Nitrogen source, LN= level of N, FP= fermentation period, LW= layer waste, RW= rabbit waste, MC= moisture content, CP= crude protein, CF= crude fat, FA= fatty acid, NFE= nitrogen free extract

Table 2: Gross energy and energy values as contributed by protein, fat and carbohydrate in rumen liquor fermented cassava starch residue

NS	LN (g)	FP (hr)	GE (KJ/g)	PEF%	PEC%	PEP%	UEDP%
LW			15.41±0.00	6.52±0.01	87.06±0.00[a]	6.59±0.00[b]	3.95±0.00[b]
RW			15.40±0.00	6.54±0.01	86.96±0.00[b]	6.67±0.00[a]	4.01±0.00[a]
	0		15.50±0.00[a]	6.50±0.01[b]	89.76±0.02[a]	3.91±0.01[c]	2.34±0.00[c]
	50		15.38±0.00[b]	6.54±0.01[a]	86.44±0.02[b]	7.19±0.01[b]	4.32±0.00[b]
	100		15.34±0.00[c]	6.55±0.01[a]	84.82±0.02[c]	8.80±0.01[a]	5.28±0.00[a]
		0	15.37±0.00[b]	5.28±0.01[c]	89.22±0.01[a]	5.64±0.01[b]	3.38±0.01[b]
		72	15.42±0.00[a]	7.06±0.01[b]	86.01±0.01[b]	7.12±0.01[a]	4.27±0.01[a]
		144	15.42±0.00[a]	7.25±0.01[a]	85.80±0.01[c]	7.14±0.01[a]	4.28±0.01[a]
NS x LN							
LW	0		15.49±0.01	6.48±0.01	89.80±0.02	3.88±0.02	2.33±0.01
	50		15.38±0.01	6.54±0.01	86.51±0.02	7.12±0.02	4.27±0.01
	100		15.34±0.01	6.55±0.01	84.86±0.02	8.76±0.02	5.25±0.01
RW	0		15.49±0.01	6.51±0.01	89.72±0.02	3.92±0.02	2.35±0.01
	50		15.37±0.01	6.54±0.01	86.36±0.02	7.26±0.02	4.35±0.01
	100		15.33±0.01	6.55±0.01	84.78±0.02	8.83±0.02	5.30±0.01
NS x FP							
LW		0	15.38±0.01	5.26±0.02	89.25±0.02	5.61±0.02	3.37±0.01
		72	15.41±0.01	7.05±0.02	86.09±0.02	7.03±0.02	4.21±0.01
		144	15.42±0.01	7.25±0.02	85.82±0.02	7.12±0.02	4.27±0.01
RW		0	15.36±0.01	5.30±0.02	89.18±0.02	5.65±0.02	3.39±0.01
		72	15.41±0.01	7.06±0.02	85.92±0.02	7.21±0.02	4.32±0.01
		144	15.42±0.01	7.25±0.02	85.77±0.02	7.16±0.02	4.29±0.01
LN x FP							
	0	0	15.49±0.15	5.27±0.02	71.10±0.03	3.75±0.02	2.25±0.01

		72	15.51±0.15	6.98±0.02	89.22±0.03	3.97±0.022.39	2.38±0.01
		144	15.48±0.15	7.23±0.02	88.96±0.03	3.98±0.02	2.39±0.01
	50	0	15.32±0.15	5.27±0.02	88.35±0.03	6.50±0.02	3.91±0.01
		72	15.39±0.15	7.08±0.02	85.57±0.03	7.52±0.02	4.51±0.01
		144	15.43±0.15	7.26±0.02	85.38±0.03	7.54±0.02	4.53±0.01
	100	0	15.31±0.15	5.29±0.02	88.19±0.03	6.64±0.02	3.98±0.01
		72	15.35±0.15	7.10±0.02	83.23±0.03	9.85±0.02	5.91±0.01
		144	15.36±0.15	7.25±0.02	83.04±0.03	9.89±0.02	5.93±0.01
NS x LN x FP							
LW	0	0	15.48±0.01	5.22±0.02	91.13±0.03	3.77±0.03	2.26±0.02
		72	15.51±0.01	6.98±0.02	89.23±0.03	3.97±0.03	2.38±0.02
		144	15.48±0.01	7.23±0.02	89.04±0.03	3.91±0.03	2.35±0.02
	50	0	15.32±0.01	5.26±0.02	88.42±0.03	6.45±0.03	3.80±0.02
		72	15.39±0.01	7.08±0.02	85.72±0.03	7.37±0.03	4.42±0.02
		144	15.43±0.01	7.26±0.02	85.38±0.03	7.53±0.03	4.52±0.02
	100	0	15.33±0.01	5.29±0.02	88.21±0.03	6.63±0.03	3.98±0.02
		72	15.35±0.01	7.10±0.02	83.33±0.03	9.75±0.03	5.84±0.02
		144	15.36±0.01	7.25±0.02	83.04±0.03	9.90±0.03	5.94±0.02
RW	0	0	15.50±0.01	5.33±0.02	91.06±0.03	3.74±0.03	2.24±0.03
		72	15.50±0.01	6.98±0.02	89.21±0.03	3.98±0.03	2.39±0.03
		144	15.48±0.01	7.24±0.02	88.98±0.03	4.05±0.03	2.43±0.03
	50	0	15.31±0.01	5.27±0.02	88.29±0.03	6.56±0.03	3.94±0.03
		72	15.38±0.01	7.08±0.02	85.42±0.03	7.67±0.03	4.61±0.03
		144	15.42±0.01	7.26±0.02	85.37±0.03	7.54±0.03	4.52±0.03
	100	0	15.28±0.01	5.31±0.02	88.18±0.03	6.65±0.03	3.99±0.03
		72	15.35±0.01	7.10±0.02	83.12±0.03	9.95±0.03	5.97±0.03
		144	15.35±0.01	7.26±0.02	83.04±0.03	9.88±0.03	5.93±0.03

NS= Nitrogen source, LN= level of N, FP= fermentation period, LW= layer waste, RW= rabbit waste

Table 3: Macro-minerals contents (g kg^{-1}) of rumen liquor fermented cassava starch residue

NS	LN (g)	FP (hr)	Na	K	Ca	Mg	P
LW			4.44±0.05	3.60±0.04	3.44±0.04	3.51±0.01	1.47±0.02[a]
RW			4.47±0.05	3.66±0.04	3.44±0.04	3.41±0.01	1.36±0.02[b]
	0		4.39±0.06	3.61±0.05	3.44±0.05	3.08±0.05[c]	1.11±0.23[c]
	50		4.55±0.06	3.61±0.05	3.41±0.05	3.46±0.05[b]	1.49±0.23[b]
	100		4.42±0.06	3.67±0.05	3.47±0.05	3.83±0.05[a]	1.65±0.23[a]
		0	4.39±0.06	3.65±0.05	3.28±0.05[c]	3.51±0.05	1.22±0.02[c]
		72	4.40±0.06	3.67±0.05	3.50±0.05[b]	3.38±0.05	1.51±0.02[b]
		144	4.57±0.06	3.58±0.05	3.54±0.05[a]	3.49±0.05	1.52±0.02[a]
NS x LN							
LW	0		4.43±0.09	3.49±0.07	3.43±0.07	3.10±0.07	1.14±0.03
	50		4.59±0.09	3.61±0.07	3.44±0.07	3.55±0.07	1.55±0.03
	100		4.36±0.09	3.68±0.07	3.44±0.07	3.86±0.07	1.71±0.03
RW	0		4.41±0.09	3.72±0.07	3.45±0.07	3.05±0.07	1.08±0.03
	50		4.50±0.09	3.61±0.07	3.36±0.07	3.37±0.07	1.42±0.03
	100		4.48±0.09	3.66±0.07	3.48±0.07	3.78±0.07	1.60±0.03
NS x FP							
LW	0		4.36±0.09	3.63±0.07	3.26±0.07	3.53±0.07	1.26±0.03
	72		4.34±0.09	3.61±0.07	3.46±0.07	3.41±0.07	1.54±0.03
	144		4.62±0.09	3.54±0.07	3.58±0.07	3.57±0.07	1.58±0.03
RW	0		4.41±0.09	3.65±0.07	3.29±0.07	3.48±0.07	1.18±0.03
	72		4.450.09	3.73±0.07	3.53±0.07	3.33±0.07	1.47±0.03
	144		4.52±0.09	3.60±0.07	3.48±0.07	3.39±0.07	1.46±0.03
LN x FP							
	0	0	4.32±0.11	3.53±0.08	3.26±0.08	3.13±0.08	1.03±0.04
		72	4.17±0.11	3.59±0.08	3.43±0.08	2.96±0.08	1.14±0.04
		144	4,67±0.11	3.68±0.08	3.62±0.08	3.13±0.08	1.15±0.04
	50	0	4.51±0.11	3.71±0.08	3.29±0.08	3.60±0.08	1.25±0.04
		72	4.64±0.11	3.74±0.08	3.53±0.08	3.45±0.08	1.65±0.04
		144	4.49±0.11	3.37±0.08	3.39±0.08	3.32±0.08	1.55±0.04
	100	0	4.32±0.11	3.68±0.08	3.28±0.08	3.77±0.08	1.38±0.04
		72	4.38±0.11	3.65±0.08	3.52±0.08	3.70±0.08	1.72±0.04
		144	4.55±0.11	3.67±0.08	3.59±0.08	3.99±0.08	1.84±0.04
NS x LN x FP							
LW	0	0	4.32±0.16	3.53±0.12	3.26±0.12	3.13±0.12	1.03±0.05
		72	4.14±0.16	3.48±0.12	3.42±0.12	3.00±0.12	1.19±0.05
		144	4.64±0.16	3.46±0.12	3.61±0.12	3.15±0.12	1.20±0.05
	50	0	4.56±0.16	3.68±0.12	3.30±0.12	3.66±0.12	1.30±0.05
		72	4.55±0.16	3.66±0.12	3.48±0.12	3.46±0.12	1.68±0.05
		144	4.66±0.16	3.51±0.12	3.53±0.12	3.51±0.12	1.65±0.05

	100	0	4.19±0.16	3.70±0.12	3.23±0.12	3.79±0.12	1.46±0.05
		72	4.33±0.16	3.67±0.12	3.48±0.12	3.76±0.12	1.76±0.05
		144	4.55±0.16	3.66±0.12	3.61±0.12	4.04±0.12	1.89±0.05
RW	0	0	4.32±0.16	3.54±0.12	3.26±0.12	3.13±0.12	1.03±0.05
		72	4.19±0.16	3.71±0.12	3.45±0.12	2.92±0.12	1.09±0.05
		144	4.71±0.16	3.90±0.12	3.63±0.12	3.10±0.12	1.12±0.05
	50	0	4.45±0.16	3.75±0.12	3.28±0.12	3.55±0.12	1.21±0.05
		72	4.73±0.16	3.83±0.12	3.58±0.12	3.44±0.12	1.62±0.05
		144	4.31±0.16	3.23±0.12	3.24±0.12	3.13±0.12	1.45±0.05
	100	0	4.46±0.16	3.66±0.12	3.32±0.12	3.75±0.12	1.31±0.05
		72	4.43±0.16	3.64±0.12	3.56±0.12	3.65±0.12	1.68±0.05
		144	4.54±0.16	3.68±0.12	3.58±0.12	3.95±0.12	1.81±0.05

NS= Nitrogen source, LN= level of N, FP= fermentation period, LW= layer waste, RW= rabbit waste

The micro-minerals, Cu, Ni, Mn and Cr contents of RLFCSR significantly increased ($p<0.001$) as the levels of N-sources and FP (except Mn) increased. Also, while N-sources and levels of N-sources were significant ($p<0.05$) for Mn, N-sources and FP were significant ($p<0.001$) for Ni. The levels of N-sources and FP were significant for Cu, Ni and Cr; the N-sources was significant ($p<0.001$) for Mn, while N-sources + levels of N-sources + FP were only significant ($p<0.001$) for Mn (Table 4).

The K/Na, Na/K, Ca/P and Ca/Mg ratios were all significantly affected ($p<0.001$) by the three main factors but their interactions were significant ($p<0.05$) except for Ca/P and Ca/Mg ratios, which were not significantly affected by the N-sources + levels of N-sources and Ca/P which was not significantly affected ($p>0.001$) by N-sources + FP (Table 5).

The values of HCN and phytate in RLFCSR consistently decreased as the levels of N-sources and FP increased (Table 6). Also, while phy:Zn molar ratio and [Ca][Phy]:[Zn] decreased with increased levels of N-sources and FP, the Ca:phy molar ratio increased ($p<0.001$) as the levels of N-sources and FP increased. The N-sources + levels of N-sources and N-sources + FP interactions were significant ($p<0.001$) for Ca:phy molar ratio, while levels of N-sources + FP were significant ($p<0.001$) for the phy, phy:Zn, Ca:phy molar ratios and [Ca][Phy]:[Zn] concentration.

DISCUSSION

One major focus of this study is to provide analytical information for cassava starch residue that has been fermented using rumen liquor, nitrogen wastes from animal origin under different fermentation periods. The observed increase in crude protein content might be due to the bioconversion of some of the soluble carbohydrates in the colonised substrate into mycelia protein or single cell protein by the growing fungus (Iyayi, 2004). It could also be due to possible secretion of some extra-cellular enzymes such as amylases, linamarase and cellulase (Oboh and Akindahunsi, 2003a) into CSR by the fermenting organisms in the rumen liquor in an attempt to make use of the starch as a source of carbon. Furthermore, the crude fibre reduction may be because some fungus could have hydrolyzed the complex carbohydrate into simple glucose and ultimately use it as carbon source to synthesize fungi biomass rich in protein (Oboh and Akindahunsi, 2003b). Similarly, the observed reduction in the NFE content could also be linked with hydrolysis of starch into glucose and its usage of by organism to synthesize fungi and bacteria biomass rich in protein (Oboh, 2006a). These findings clearly showed that nitrogen from poultry and rabbit dung can be veritable N-sources that can be harnessed to provide the much needed nitrogen for the survival of the rumen liquor micro-organisms during the CSR fermentation. It can also be inferred that the 144 hour fermentation period was better than 72 hours. Conceivably from this current study, the rumen liquor might contain sufficient anaerobic micro-organisms that could help to enhance the nutrient quality of CSR when fermented under the conditions reported in this study. The rumen microbial population is known to present rich enzymes among which are plant cell wall polymer-degrading enzymes (e.g., cellulases, xylanases, β-glucananases, pectinases), amylases and proteases. These enzymes play important role in effective digestion of complex substrates (Wood, 1992; Yanke *et al*., 1995). However, the present results with respect to moisture content, crude protein, crude fibre and crude fat are consistent with earlier reports of Adeyemi *et al.* (2007), Lateef *et al.* (2008) and Chumpawadee and Soychuta (2009) on the effect of fermentation on the proximate composition of cassava products and by products. In addition, the interactions between the main factors in this study are in most cases significant for the proximate composition. This suggests that these factors are germane to the improvement of CSR when solid state fermentation is to be used to enhance its nutritive quality.

The energy content of any feed ingredient or diets determines its feed intake. In this study, the level of N-sources and FP were found to be important factors in determining the levels of energy contents of the RLFCSR.

Table 4: Micro-minerals contents (g/kg) of rumen liquor fermented cassava starch residue

NS	LN (g)	FP (hr)	Zn	Fe	Cu	Ni	Mn	Cr
LW			1.78±0.02	2.23±0.03	1.15±0.00	0.11±0.00[a.]	0.03±0.00	0.02±0.00
RW			1.77±0.02	2.23±0.03	1.12±0.00	0.10±0.00[b]	0.03±0.00	0.02±0.00
	0		1.76±0.02	2.21±0.03	0.06±0.00[c]	0.07±0.00[c]	0.02±0.00[b]	0.01±0.02 0[c]
	50		1.75±0.02	2.23±0.03	0.12±0.00[b]	0.12±0.00[b]	0.03±0.00[a]	0.02±0.00[b]
	100		1.80±0.02	2.27±0.03	0.15±0.00[a]	0.15±0.00[a]	0.03±0.00[a]	0.03±0.00[a]
		0	1.59±0.02[b]	2.11±0.03[b.]	0.10±0.00[b]	0.09±0.00[c]	0.03±0.00	0.01±0.00[b]
		72	1.82±0.02[a.]	2.27±0.03[a]	0.11±0.00[b]	0.11±0.00[b]	0.03±0.00	0.02±0.00[a]
		144	1.89±0.02[a]	2.33±0.03[a]	0.12±0.00[a]	0.12±0.00[a]	0.03±0.00	0.02±0.00[a]
NS x LN								
LW	0		1.75±0.03	2.19±0.04	0.06±0.00	0.07±0.00	0.03±0.00	0.01±0.00
	50		1.77±0.03	2.24±0.04	0.12±0.00	0.11±0.00	0.03±0.01	0.02±0.00
	100		1.79±0.03	2.26±0.04	0.15±0.00	0.13±0.00	0.03±0.00	0.03±0.00
RW	0		1.76±0.03	2.21±0.04	0.06±0.00	0.06±0.00	0.02±0.00	0.01±0.00
	50		1.72±0.03	2.20±0.04	0.12±0.00	0.10±0.00	0.03±0.010	0.02±0.00
	100		1.79±0.03	2.28±0.04	0.15±0.00	0.13±0.00	0.03±0.00	0.03±0.00
NS x FP								
LW		0	1.59±0.04	2.10±0.05	0.11±0.00	0.09±0.00	0.03±0.00	0.17±0.00
		72	1.80±0.04	2.25±0.05	0.10±0.00	0.11±0.00	0.03±0.00	0.02±0.00
		144	1.92±0.04	2.34±0.05	0.12±0.00	0.13±0.00	0.03±0.00	0.02±0.00
RW		0	1.59±0.04	2.11±0.05	0.10±0.00	0.08±0.00	0.02±0.00	0.01±0.00
		72	1.83±0.04	2.27±0.05	0.11±0.00	0.11±0.00	0.03±0.00	0.02±0.00
		144	1.86±0.04	2.31±0.05	0.11±0.00	0.10±0.00	0.03±0.00	0.02±0.00
LN x FP								
	0	0	1.55±0.05	2.08±0.06	0.05±0.00	0.06±0.00	0.02±0.00	0.01±0.00
		72	1.79±0.05	2.19±0.06	0.06±0.00	0.06±0.00	0.02±0.00	0.01±0.00
		144	1.93±0.05	2.34±0.06	0.07±0.00	0.07±0.00	0.03±0.00	0.01±0.00
	50	0	1.60±0.05	2.12±0.06	0.12±0.00	0.08±0.00	0.03±0.00	0.02±0.00
		72	1.82±0.05	2.32±0.06	0.13±0.00	0.11±0.00	0.03±0.00	0.02±0.00
		144	1.83±0.05	2,23±0.06	0.12±0.00	0.12±0.00	0.03±0.00	0.02±0.00
	100	0	1.62±0.05	2.11±0.06	0.14±0.00	0.10±0.00	0.03±0.00	0.02±0.00
		72	1.84±0.05	2.28±0.06	0.15±0.00	0.14±0.00	0.04±0.00	0.03±0.00
		144	1.92±0.05	2.40±0.06	0.17±0.00	0.15±0.00	0.03±0.00	0.03±0.00
NS x LN x FP								
LW	0	0	1.55±0.06	2.08±0.08	0.05±0.01	0.06±0.01	0.02±0.00	0.01±0.00
		72	1.78±0.06	2.17±0.08	0.06±0.01	0.07±0.01	0.02±0.00	0.01±0.00
		144	1.92±0.06	2.33±0.08	0.08±0.01	0.08±0.01	0.03±0.00	0.02±0.00
	50	0	1.60±0.06	2.12±0.08	0.12±0.01	0.09±0.01	0.03±0.00	0.02±0.00
		72	1.81±0.06	2.31±0.08	0.13±0.01	0.12±0.01	0.03±0.00	0.02±0.00
		144	1.92±0.06	2.29±0.08	0.13±0.01	0.13±0.01	0.04±0.00	0.02±0.00

	100	0	1.61±0.06	2.09±0.08	0.14±0.01	0.11±0.01	0.03±0.00	0.02±0.00
		72	1.83±0.06	2.28±0.08	0.13±0.01	0.13±0.01	0.04±0.00	0.03±0.00
		144	1.93±0.06	2.40±0.08	0.17±0.01	0.17±0.01	0.03±0.00	0.03±0.00
RW	0	0	1.55±0.06	2.08±0.08	0.06±0.01	0.06±0.01	0.03±0.00	0.01±0.00
		72	1.81±0.06	2.21±0.08	0.06±0.01	0.06±0.01	0.02±0.00	0.01±0.00
		144	1.94±0.06	2.35±0.08	0.06±0.01	0.07±0.01	0.02±0.00	0.01±0.00
	50	0	1.60±0.06	2.11±0.08	0.12±0.01	0.08±0.01	0.03±0.00	0.02±0.00
		72	1.83±0.06	2.33±0.08	0.13±0.01	0.11±0.01	0.03±0.00	0.O2±0.00
		144	1.74±0.06	2.17±0.08	0.12±0.01	0.11±0.01	0.03±0.00	0.02±0.00
	100	0	1.63±0.06	2.12±0.08	0.14±0.01	0.10±0.01	0.03±0.00	0.02±0.00
		72	1.85±0.06	2.29±0.08	0.15±0.01	0.15±0.01	0.03±0.00	0.03±0.00
		144	1.91±0.06	2.40±0.08	0.16±0.01	0.14±0.01	0.04±0.00	0.03±0.00

NS= Nitrogen source, LN= level of N, FP= fermentation period, LW= layer waste, RW= rabbit waste

Table 5: Mineral ratios of rumen liquor fermented cassava starch residue

NS	LN (g)	FP (hr)	K/Na	Na/k	Ca/P	Ca/Mg
LW			0.81±0.00^{b}	1.24±0.00 ^{a}	2.43±0.00^{b}	0.99±0.00^{b}
RW			0.82±0.00^{a}	1.22±0.00^{b}	2.60 ±0.00^{a}	1.02±0.00 ^{a}
	0		0.82±0.00^{b}	1.22±0.00^{b}	3.11±0.02^{a}	1.12 ±0.00^{a}
	50		0.79±0.00^{c}	1.26±0.00^{a}	2.32±0.02^{b}	0.99±0.00^{b}
	100		0.83±0.00^{a}	1.20±0.00^{c}	2.12±0.02^{c}	0.91±0.00^{c}
		0	0.83±0.00^{a}	1.20±0.00^{c}	2.73±0.02^{a}	0.94±0.00^{c}
		72	0.83 ±0.00^{a}	1.20±0.00^{b}	2.40±0.02^{b}	1.04±0.00^{c}
		144	0.78±0.00^{b}	1.28±0.00^{a}	2.42±0.02^{b}	1.03±0.00^{a}
NS x LN						
LW	0		0.80±0.00	1.25±0.00	3.02±0.02	1.11±0.00
	50		0.79±0.00	1.27±0.00	2.25±0.02	0.97±0.00
	100		0.84±0.00	1.18±0.00	2.04±0.02	0.89±0.00
RW	0		0.84±0.00	1.18±0.00	3.19±0.02	1.13±0.00
	50		0.80±0.00	1.25±0.00	2.38±0.02	1.00±0.00
	100		0.82±0.00	1.22±0.00	2.21±0.02	0.92±0.00
NS x FP						
LW		0	0.84±0.00	1.19±0.00	2.64±0.02	0.93±0.00
		72	0.83±0.00	1.21±0.00	2.31±0.02	1.02±0.00
		144	0.77±0.00	1.30±0.00	2.35±0.02	1.01±0.00
RW		0	0.82±0.00	1.21±0.00	2.81±0.02	0.95±0.00
		72	0.83±0.00	1.19±0.00	2.49±0.02	1.07±0.00
		144	0.79±0.00	1.26±0.00	2.49±0.02	1.04±0.00
LN x FP						
	0	0	0.82±0.00	1.22±0.00	3.17±0.02	1.043±0.00
		72	0.86±0.00	1.16V±0.00	3.01±0.02	1.15±0.00

		144	0.79±0.00	1.27±0.00	3.13±0.02	1.16±0.00
	50	0	0.83±0.00	1.21±0.00	2.63±0.02	0.91±0.00
		72	0.81±0.00	1.24±0.00	2.14±0.02	1.02±0.00
		144	0.75±0.00	1.33±0.00	2.18±0.02	1.02±0.00
	100	0	0.85±0.00	1.18±0.00	2.37±0.02	0.87±0.00
		72	0.83±0.00	1.19±0.00	2.05±0.02	0.95±0.00
		144	0.81±0.00	1.24±0.00	1.95±0.02	0.89±0.00
NS x LN x FP						
LW	0	0	0.82±0.00	1.22±0.00	3.17±0.04	1.04±0.01
		72	0.84±0.00	1.19±0.00	2.87±0.04	1.13±0.01
		144	0.74±0.00	1.34±0.00	3.01±0.04	1.14±0.01
	50	0	0.81±0.00	1.23±0.00	2.53±0.04	0.90
		72	0.80±0.00	1.24±0.00	2.06±0.04	1.01±0.01
		144	0.75±0.00	1.33±0.00	2.14±0.04	1.01±0.01
	100	0	0.88±0.00	1.13±0.00	2.22±0.04	0.85±0.01
		72	0.85±0.00	1.18±0.00	1.97±0.04	0.93±0.01
		144	0.81±0.00	1.24±0.00	1.91±0.04	0.89±0.01
RW	0	0	0.82±0.00	1.22±0.00	3.17±0.04	1.04±0.01
		72	0.89±0.00	1.12±0.0	3.15±0.04	1.18±0.01
		144	0.83±0.00	1.21±0.00	3.25±0.04	1.17±0.01
	50	0	0.84±0.00	1.18±0.00	2.73±0.04	0.92±0.01
		72	0.81±0.00	1.23±0.00	2.21±0.04	1.04±0.01
		144	0.75±0.00	1.33±0.00	2.23±0.04	1.03±0.01
	100	0	0.82±0.00	1.21±0.00	2.52±0.04	0.89±0.01
		72	0.82±0.00	1.22±0.00	2.11±0.04	0.98±0.01
		144	0.81±0.00	1.23±0.00	1.98±0.04	0.91±0.01

NS= Nitrogen source, LN= level of N, FP= fermentation period, LW= layer waste, RW= rabbit waste

Table 6: Anti-nutrients and mineral ratios of rumen liquor fermented cassava starch residue

NS	LN (g)	FP (hr)	HCN (g kg^{-1})	Phytate (g kg^{-1})	Phy:Zn	Ca:Phy	[Ca][Phy]:[Zn]
LW			0.02±0.00[a]	19.13±0.20[b]	1.10±0.01[b]	3.35±0.01[a]	0.09±0.00
RW			0.01±0.00[b]	19.99±0.20[a]	1.15±0.01[a]	3.14±0.01[b]	0.10±0.00
	0		0.02±0.00[c]	24.59±0.20[c]	1.41±0.01[c]	2.35±0.02[a]	0.12±0.00[c]
	50		0.01±0.00[b]	18.94±0.20[b]	1.09±0.01[b]	3.13±0.02[b]	0.09±0.00[b]
	100		0.01±0.00[a]	15.15±0.20[a]	0.86±0.01[a]	4.25±0.02[c]	0.07±0.00[a]
		0	0.01±0.00[b]	25.36±0.24[c]	1.58±0.01[c]	2.15±0.02[a]	0.13±0.00[c]
		72	0.01±0.00[a]	17.71±0.24[b]	0.97±0.01[b]	3.53±0.02[b]	0.08±0.00[b]
		144	0.01±0.00[a]	15.61±0.24[a]	0.81±0.01[a]	4.05±0.02[c]	0.07±0.00[a]
NS x LN							
LW	0		0.02±0.00	24.33±0.34	1.40±0.01	2.37±0.02	0.12±0.00
	50		0.01±0.00	18.41±0.34	1.05±0.01	3.28±0.02	0.09±0.00
	100		0.01±0.00	14.65±0.34	0.83±0.01	4.40±0.02	0.07±0.00
RW	0		0.02±0.00	24.85±0.34	1.41±0.01	2.32±0.02	0.12±0.00
	50		0.01±0.00	19.46±0.34	1.12±0.01	2.98±0.02	0.10±0.00
	100		0.01±0.00	15.65±0.34	0.89±0.01	4.10±0.02	0.08±0.00
NS x FP							
LW		0	0.01±0.00	25.16±0.34	1.57±0.01	2.16±0.02	0.13±0.02
		72	0.01±0.00	17.09±0.34	0.94±0.01	3.65±0.02	0.08±0.02
		144	0.01±0.00	15.15±0.34	0.78±0.01	4.34±0.02	0.07±0.02
RW		0	0.01±0.00	25.56±0.34	1.59±0.01	2.14±0.02	0.13±0.02
		72	0.01±0.00	18.33±0.34	0.99±0.01	3.41±0.02	0.09±0.02
		144	0.01±0.00	16.07±0.34	0.85±0.01	3.87±0.02	0.07±0.02
LN x FP							
	0	0	0.02±0.00	28.50±0.42	1.82±0.02	1.88±0.03	0.15±0.00
		72	0.02±0.00	23.59±0.42	1.30±0.02	2.39±0.03	0.11±0.00
		144	0.02±0.00	21.68±0.42	1.11±0.02	2.75±0.03	0.10±0.00
	50	0	0.01±0.00	24.82±0.42	1.54±0.02	2.18±0.03	0.13±0.00
		72	0.01±0.00	17.61±0.42	0.96±0.02	3.31±0.03	0.08±0.00
		144	0.01±0.00	14.37±0.42	0.78±0.02	3.89±0.03	0.07±0.00
	100	0	0.01±0.00	22.76±0.42	1.39±0.02	2.37±0.03	0.11±0.00
		72	0.01±0.00	11.92±0.42	0.64±0.02	4.87±0.03	0.06±0.00
		144	0.01±0.00	10.79±0.42	0.56±0.02	5.50±0.03	0.05±0.00
NS x LN x FP							
LW	0	0	0.02±0.00	28.50±0.58	1.81±0.02	1.88±0.04	0.15±0.00
		72	0.02±0.00	23.43±0.58	1.30±0.02	2.40±0.04	0.11±0.00
		144	0.02±0.00	21.06±0.58	1.08±0.02	2.82±0.04	0.09±0.00
	50	0	0.01±0.00	24.70±0.58	1.52±0.02	2.20±0.04	0.13±0.00
		72	0.01±0.00	16.53±0.58	0.91±0.02	3.47±0.04	0.08±0.00
		144	0.01±0.00	14.01±0.58	0.72±0.02	4.16±0.04	0.06±0.00

	100	0	0.01±0.00	22.30±0.58	1.36±0.02	2.39±0.04	0.11±0.00
		72	0.01±0.00	11.28±0.58	0.61±0.02	5.09±0.04	0.05±0.00
		144	0.01±0.00	10.38±0.58	0.53±0.02	5.72±0.04	0.04±0.00
RW	0	0	0.02±0.00	28.50±0.58	1.82±0.02	1.88±0.04	0.14±0.00
		72	0.02±0.00	23.75±0.58	1.30±0.02	2.39±0.04	0.11±0.00
		144	0.02±0.00	22.30±0.58	1.13±0.02	2.68±0.04	0.10±0.00
	50	0	0.01±0.00	24.94±0.58	1.54±0.02	2.16±0.04	0.12±0.00
		72	0.01±0.00	18.70±0.58	1.01±0.02	3.15±0.04	0.09±0.00
		144	0.01±0.00	14.73±0.58	0.84±0.02	3.63±0.04	0.07±0.00
	100	0	0.01±0.00	23.22±0.58	1.41±0.02	2.35±0.04	0.12±0.00
		72	0.01±0.00	12.55±0.58	0.67±0.02	4.67±0.04	0.06±0.00
		144	0.01±0.00	11.17±0.58	0.58±0.02	5.28±0.04	0.05±0.00

NS= Nitrogen source, LN= level of N, FP= fermentation period, LW= layer waste, RW= rabbit waste

Thus by implication, to obtain a desired GE, these two factors must come into play as can be seen in this study. The present result is however in consonance with the earlier report of Adeyemi *et al*. (2007) who observed a reduction in the gross energy of cassava root meal with levels of nitrogen sources and duration of fermentation in a solid state fermentation with rumen liquor. Furthermore, in this study, the observed highest RLFCSR energy contribution by carbohydrate implies that the main energy source of RLFCSR is from carbohydrate. This finding is in agreement with earlier report of Oloruntola *et al.* (2015) who also reported carbohydrate as the highest contributor of energy in rumen liquor fermented cassava peels.

The present study also showed that the rumen liquor fermented CSR contained both nutritionally needed macro and micro minerals. Increments noticed in micro-minerals as a result of variation in levels of N-sources and FP i that both macro and micro minerals in the CSR could be increased by the processing method adopted in this study. This current finding is consistent with the previous reports of Adeyemi *et al.* (2007) that fermentation of cassava tuber with rumen liquor led to increase in Ca and P content. In addition, Aderemi and Nworgu (2007) observed improvement of Ca, P and sodium as biodegradation of cassava peels and cassava starch residue with *Aspergillus niger* progressed with highest value observed on the 10th day. Thus by implication, the emerged RLFCSR would be an improvement over the CSR, not only with respect to the protein and fibre contents but with enhanced values of macro and micro-minerals. Hence, animals fed on the RLFCSR may not precipitate mineral deficiency symptoms if fed with other farm wastes not rich in minerals. Both Na and K are important minerals in many biochemical activities in the body of animals while the contributions of Ca, P and Mg to the skeletal development can not be underscored. Also, in this study, all the mineral molar ratios were affected by the major factors examined with significant N-sources X levels of N-sources and N-sources X FP interactions, suggesting that all the mineral molar ratios measured are dependent on all the factors measured. The Na/K, Ca/P and Ca/Mg values observed are consistently higher than 0.73-0.76, 0.12-0.17 and 0.72-0.73 reported by Adeyeye (2013) for *Irvingia gabonensis* kernel respectively.

Hydrogen cyanide (HCN) is the major anti-nutritional factor in cassava and cassava wastes. The reduction of HCN level in CSR by FP and levels of N-sources, suggests that RLFCSR will be safe for consumption by the animals when included in their diets. The reduction in phytate content observed in this study also tends to confirms that rumen microbes are capable of degrading cyanogenic glucoside and the breakdown products (Aderemi and Nworgu 2007) and also capable of secreting enzyme phytase which is capable of hydrolysing phytate thereby decreasing the phytate content of the fermented cassava starch residue (Oboh 2006a). It has also been reported that solid state fermentation can successfully reduce cassava cyanide contents (Esser *et al*., 1995). This study further confirms the ruminal microbes' capability of converting toxic ingredients to harmless or even beneficial compounds (Jones and Lowry 1984; Gregg 1995). By implication, rumen liquor could contain cyanophilic micro-organisms that possesses the enzymes linamarase, hydroxynitrile lyase and cyanide hydratase that can catalyze the sequential degradation of cyanogenic glycosides into HCN, which is subsequently converted into formamide which they use as both a nitrogen and carbon source (Adamafio *et al*., 2010).

The interactive effect of FP and levels of N-sources on phytate contents signifies that the quantity of each of N-sources may influence the performance of rumen microbes responsible for the degradation of the phytate in RLFCSR. Thus, the importance of allowing the fermentation to span for 72 hours and 144 hours when animal wastes are being used as N source is evident in this study.

Phytic acid (myo-inositol 1, 2, 3, 4, 5, 6-hexakis dihydrogen phosphate) in food may reduce the bio-availability of dietary zinc by forming insoluble mineral chelates at a physiological pH (Oberleas, 1983). This chelation depends on the relative levels of Zn and phytate and therefore phytate:Zn molar ratio, which may also depends on dietary Ca level is considered a better predictor of Zn bio-availability than total dietary phytate level alone (Ferguson *et al.*, 1988). Phytate:Zinc in this present study decrease with increased levels of N-sources and FP. This further confirmed the potential of using the rabbit and layer's wastes as nitrogen sources in improving the micro-nutrients in CSR during fermentation. In general, the phytate:Zn values observed were far below 10 (Oberleas and Harland 1981), but higher than 0.20 – 0.33 reported by Adeyeye (2013) and similar to 0.3 – 1.3 reported by Oboh (2006b), thus implying the adequacy of Zn in rumen liquor fermented cassava starch residue.

Wise (1983) earlier reported that the solubility of the phytates and the proportion of Zn bound in a mineral complex in the intestine depends on the levels of Ca; and that Phy precipitation is not complete until dietary Ca:Phy molar ratio attain a value of approximately 6:1. The fact that Ca:Phy molar ratio in this study is lower than this critical level of 6:1 further supports the adequacy of this feed stuff, in that Zn bioavailability would not be impaired. The [Ca][Phy]:[Zn] was indicated as a better predictor of Zn availability and that Zn availability will be impaired if the ratio is greater than 0.5 mol/kg (Ellis *et al.*, 1987). However, the [Ca][Phy]:[Zn] in this study is below 0.5 mol/kg (Ellis *et al.*, 1987) but higher than 0.02-0.06 mol/kg reported by Oboh (2006b) for some under-utilized fermented legumes and 0.002 reported by Adeyeye (2013) for *I. gabonensis* kernel indicating high Zn bioavailability in the RLFCSR.

Conclusion: This study showed that rumen liquor could be used to ferment cassava starch residue to enhance its' nutritive value, typified by proximate, energy, minerals contents, some phytochemicals and some calculated indices. Readily available animal wastes (layer waste and rabbit waste) can be used as source of nitrogen in the fermentation process of cassava starch residue. The fermented cassava starch residue could be used as animal feeding ingredient in the diets of non-ruminants and pseudo-ruminants. Judicious use of the feed ingredients is envisaged could help to stem the cost of finished feed for these categories of animals.

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