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Effects of Partial Replacement of Soybean meal with *Mucuna pruriens* Meal in the diet of Common Carp, (*Cyprinus carpio* Linnaeus, 1758) Fingerlings

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ABSTRACT
Feeding trials were conducted to investigate the effect of dietary inclusion of Maize Cob Ash processed *Mucuna pruriens* seed meals in diets fed to *Cyprinus carpio* fingerlings. The processed meals were included in treatment diets as a quantitative substitute for soya bean meal at 10, 20, 30, 40and 50% replacement levels and designated DII, DIII, D1V, DV and DVI respectively. A diet with 0% Mucuna served as the control (D1). The feeding trial was conducted using 12 plastic bowls (25L capacity) for the period of 56 days in three replicates. There was a significant difference (P<0.05) between the treatment means for live weight gain (LWG) and feed conversion ratio (FCR) of the fish fed all the treatment diets. There was no significant difference (P> 0.05) in the feed intake (FI), specific growth rate (SGR%/day), food conversion ratio (FCR), protein, productive value (PPV) and apparent protein digestibility coefficient (APDC %) of fish fed D1, MCAD2 and MCAD3 diets. Analysis of cost effectiveness indicated significant differences (P<0.05) in all the treatment diets which also showed that the soya bean based control diet was not as cost effective as the lower levels (10-20%) of incorporation of MCA diet. The 20% MCA processed Mucuna diet was considered the optimum inclusion level to partially replace soya bean meal to produce a cost effective diet for *C. carpio* without any adverse effect on fish growth.

Key words: Replacement, *Mucuna pruriens* seed meal, Soya bean Meal, diet, Common carp, *Cyprinus capio*

INTRODUCTION

There is greater emphasis on the use of alternative protein feedstuff in fish nutrition due to the high costs of the conventional protein sources such as fish meal and soya bean which are used in other animal feeds (Fagbenro *et al*., 2003; Tacon *et al*., 2009). Although non-conventional plant proteins have their limitations on usage as fish feeds, they have high potential as dietary protein and energy sources (De-Silva and Gunasekera, 1989; 1999; Balogun *et al*., 2008; Naylor *et al*., 2009).

Carps are the most cultured fin fish species all over the world (FAO, 2012). And their production, which is mostly on semi intensive or intensive level is on the increase. In Nigeria, farm production of carp is mostly semi intensive based on the use of natural food from the pond system which provides a source of protein and energy as the cost of formulated fish diet is high (Fagbenro *et al*., 2003).

The genus *Mucuna pruriens* (Velvet bean) is one of the important legumes considered of nutritional value but often neglected crop. It has high protein content of 28-32% (Ukachukwu *et al*., 2002) and sparsely used for human and animal consumption due to its large amount of anti-nutritional factors (Bressani *et al*., 2003; Wanjekeche *et al*., 2003). Previous studies (Francis *et al*. 2001; Vadivel and Pugalethi, 2009) protease inhibitors, tannins, haemaglutamins and cyanogens are among the frequently occurring anti-nutrition factors in velvet bean seed meal. However, processing methods such as de-hulling, aqueous extraction, extrusion, cooking, dry and wet treatments with or without additives (Venou *et al*., 2003; Ramachandran *et al*., 2005; Vadivel and Pugalethi, 2009) could reduce the level and activity of anti-nutritional factors and improve nutrient availability (Tacon, 1997; Davies and Gouveia, 2014). It has been observed by Ramachandran *et al*. (2005) that most anti-nutritional factors (ANFs) are resistant to inactivation by dry heat (toasting) and require the presence of moisture for more

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complete destruction. There is scarce literature on the use of Mucuna seed meals in carp diets and other fish species with the only available information on the use of Mucuna seed meals reported for broilers (Ukachukwu *et al*., 2002; Emenalon and Udedibe, 2005). Similarly, Ramachandran and Ray (2004) also reported that, there is little information available on the effect of indigenous processing methods such as use of local tenderizes on the nutritive value of plant ingredients in compound diets for fish, thus the need to explore processing Mucuna seeds with a maize cob ash solution for possible inclusion as a replacement for soybean meal in the practical diet of Common carp fingerlings.

MATERIALS AND METHODS

Processing of *M. pruriens* seed into feedstuff

Grey variety of *M. pruriens* seed were procured from the National Animal Production and Research Institute, Shika-Zaria in Kaduna State, Nigeria. A sample of Mucuna seeds (500g) was heated (100^0C) and left to boil for 60 minutes in an enamel pot (3 litre capacity) with maize cob ash (MCA) solution while maintaining the solution level by the addition of fresh MCA solution from a standby boiling pot. At the termination of boiling, the MCA solution was drained using raffia basket and the boiled Mucuna seeds washed with distilled water and air-dried for 3 days under shed. The dried sample (500g) was ground to powder, sieved (593µm mesh) and stored in plastic packs at 4^0C prior to analysis and diet formulation.

Experimental diet composition and preparation

Materials used in the diet formulation were purchased locally from commercial livestock feed millers at Vom, near Jos, Plateau State, Nigeria. The proximate analysis and amino acid compositions of the feed ingredients and test diets were determined using standard procedures (AOAC, 2005). Six sets of approximately isonitrogenous and isoenergetic experimental diets (DII- DVI) were prepared using the raw and MCA processed Mucuna seed meals as the main test ingredients, while a no Mucuna diet (DI, 0.00g) served as the control diet (Table 1). The various ingredients were measured and thoroughly mixed at 25°C in a plastic bowl followed by adding vitamin premix and thoroughly mixed by adding warm water, resulting in a semi paste which was manually extruded through 2-mm die to form pellets which were dried for ten hours at a 45°C, sealed and stored at 4°C. The experimental processed Mucuna seed meal based diets were in five different replacement levels of 10, 20, 30, 40 and 50% by substitution of soya bean meal (replacer meal) and designated as D1 (control), DII, DIII, DIV and DV and DVI respectively. One percent chromic oxide was added as an external marker for each of the experimental diets.

Table 1: Composition of treatment diets containing maize cob ash processed Mucuna seed meals fed to *C. carpio* fingerlings

Ingredients (%DM)	**Mucuna beans replacement level (%)**					
	Control D1	**MCAD2**	**MCAD3**	**MCAD4**	**MCAD5**	**MCAD6**
Mucuna meal	-	4.99	9.98	14.87	19.96	24.99
Soya bean meal	49.97	44,98	39.99	35.10	30.01	24.99
Maize flour	35.03	35.03	35.03	35.03	35.03	35.03
Fish meal	10.00	10.00	10.00	10.00	10.00	10.00
Vegetable Oil	3.00	3.00	3.00	3.00	3.00	3.00
Fish Oil	2.00	2.00	2.00	2.00	2.00	2.00
Vitalyte*	2.00	2.00	2.00	2.00	2.00	2.00
Cassava flor	8.00	8.00	8.00	8.00	8.00	8.00
Total	100	100	100	100	100	100
Protein	35.00	32.24	32.16	31.29	31.18	31.16

MCAD = Maize cob ash

Experimental fish

One thousand *C. carpio* fingerlings of weight sizes between 15.10-15.88g, length 13.00-14.50cm were procured from Bauchi State Government Fish Hatchery Complex in Bauchi, North-East Nigeria and transported to Jos in oxygenated plastic (500L) water containers. The fingerlings were acclimated for one week in outdoor (2m x 5m x 1.5m) concrete tank and fed to satiation once daily at 5% body weight on a commercial pelleted diet (Coppens, 35% CP).

Experimental design

The feeding trials were conducted in a Private in-door Fish Hatchery in Jos, Plateau State, Nigeria. The experimental setup consisted of 18 (eighteen) plastic basins (25L capacity) each filled to three-quarters of its volume with water from a bore hole. The system was static and partially aerated for oxygen supply through electric and battery aerators in the in-door hatchery. Prior to commencement of the feeding trials, 180no Common carp fingerlings (mean weight, 15.24 ±0. 01g) were randomly distributed to the 18 basins at a stocking rate of 10 fish per basin. Six (6) experimental diets were randomly allocated to the fingerlings in triplicate per test diet and were fed twice a day between 08.00 - 09.00 hours and 15.00 - 16.00 hours at a feeding rate of 5% body weight per day. Uneaten feed and faeces were removed daily by using a siphon and the water level was maintained to desired level and the entire water changed every week to ensure good and optimal water quality. At the commencement of the feeding trials, fish in each basin were bulk weighed in Sortius Top Electric Loading Balance under benzocaine anaesthesia ($1mgL^{-1}$) and recorded as initial weight. Subsequent weighing was done once a week for 8 weeks and live weight gains of fish in each basin recorded. During the weighing process, faecal samples for nutrient digestibility analyses were collected, oven-dried and stored for nutrient analyses (Cho *et al*., 1982). The experiment lasted eight (8) weeks (56 days) during which the feed ration was gradually adjusted weekly to reflect weight increases recorded. At the start of the experiment, two (2) fish from each of the experimental plastic basin were sacrificed for initial carcass composition (moisture, crude protein, crude lipid, and ash) analysis. At the termination of the experiment, two (2) fish from each replicate basin were similarly sacrificed and analysed for final carcass composition.

Computations of growth and nutrient utilization indices

At the end of the feeding trials, the growth performance parameters of live weight gain (LWG) (Wannigama *et al.*, 1985), feed conversion ratio (FCR), specific growth rate (SGR %) and protein efficiency ratio (PER) (Halver, 1981), protein intake (PI) and protein, productive value (PPV) (Wilson, 1989), apparent net protein utilization (ANPU) and apparent protein digestibility coefficient (APDC) (Windell *et al.*, 1978) were calculated as follows.

(i) Live Weight Gain (LWG) = Final Weight – Initial Weight (g) (Wannigama *et al*., 1985)

(ii) Feed Conversion Ratio (FCR) = $\frac{\text{Feed Intake (g)}}{\text{Weight gained (g)}}$

(iii) Specific Growth Rate (SGR % day $^{-1}$) = $\text{SGR} \quad \frac{100(\log \text{Final Weight} - \log \text{Initial Weight})}{\text{Time (t) in days}}$

(iv) Protein Efficiency Ratio (PER) = PER $= \frac{\text{Fish Weight Gain (g)}}{\text{Protein Intake (g)}}$

(v) Protein Intake (PI) (Wilson, 1989) = PI $= \frac{\text{Food Consume X Percent Protein}}{100}$

(vi) Protein Productive Value (PPV) = PPV=PR2 – PR1÷Pi X 100, where :
PR2 = Total fish body protein at the end of the experiment, PR1= Total fish body protein at the start of the experiment, Pi= Protein intake during the whole experimental period (Wilson, 1989).

(vii) Apparent Protein Digestibility Coefficient: APDC (%) $= \frac{100 - 100 \text{ x C1 x FN}}{\text{FC1 x N1}}$,
Where: C1 = Indicator content of test diet (%), N_1 = Nutrient content of diet (%), FC_1 = Indicator content of faeces of fish fed test diet (%), FN = Nutrient content of faeces of fish fed test diet (%), (Windell *et al*., 1978).

The Hepato-somatic Index (HSI) was determined following the methods described by Ufodike and Matty (1988).

Determination of water quality parameters

The standard analytical methods described by APHA/AWWA/WPCF (1985) were employed in the determination of the various water physico-chemical parameters which included pH (with a pH digital meter model LABTECH), total alkalinity (phenolphthalein with 0.02N H_2SO_4 and methyl orange), free carbon dioxide (phenolphthalein and N/44 NaOH), dissolved oxygen ($MnSO_4$, Sodium Acid and 0.25N Sodium thiosulphate), ammonia (unionized) (using test kit) and temperature (mercury in bulb thermometer in degree Celsius). These parameters were monitored and means calculated weekly for each experimental basin, while water temperature was recorded daily.

Economic evaluation of feed substitution

The economic analyses of substituting soya bean meal with the Mucuna meal in the culture of *C. carpio* fingerlings were determined. Partial enterprise budgets were used to evaluate the economic performance of each dietary treatment as described by Mazid *et al*. (1997). The feed ingredient costs were based on the current market prices.

Statistical analysis

All the data obtained from the experiment were subjected to One-way Analysis of Variance (ANOVA). Standard errors (SE) of the means for each replicate were calculated at 5% probability and means were compared using Duncan's multiple-range test (Duncan, 1955). This was done for the proximate compositions of the raw and MCA processed seeds and growth parameters. The Statistical package, SPSS version 17 was used for the analyses.

RESULTS

Evaluation of *M. pruriens* seeds

Analyses of the test ingredients, proximate composition and amino acid content of processed *M. pruriens* diets fed to *C. carpio* is presented in Tables 2 and 3, respectively.

Table 2: Proximate Composition (% Dry Matter) of Mucuna Diets Fed to *C. carpio* fingerlings for 8 weeks

Nutrients	Mucuna beans replacement level (%)					
	DI	DII	DIII	DIV	DV	DVI
Dry matter	90.09	92.10	93.00	94.00	94.20	95.00
Crude Protein	35.07	30.00	30.50	30.26	30.07	30.00
Crude Lipid	10.90	10.71	11.52	10.20	9.50	10.40
Ash	4.24	4.19	4.21	4.20	4.14	4.25
Crude Fiber	3.78	4.88	4.87	4.86	4.81	4.78
NFE[1]	46.01	45.22	46.90	30.45	51.48	50.57
Gross Energy (Kcal/100g)	403.18	402.40	402.62	403.00	403.10	403.41

At the commencement of feeding trial conducted, the *C. carpio* fingerlings were observed to be receptive to all test diets and feed enthusiastically during the first week. This was followed by a phase of slow response to the test feeds.

The growth responses of *C. carpio* fingerlings fed different replacement levels of processed Mucuna diets and their replacement values for the soya bean meal are shown in Table 4. The highest live weight gains (LWG) of 5.29g were recorded for *C. carpio* fingerlings fed the control diet (DI) followed by DII with mean LWG of 5.06g. The lowest mean LWG of 3.86g was recorded in DVI. There was no significant difference (P>0.05) in the survival rate of fingerlings fed differently MCA processed diets (MCAD). Similarly, there was also no significant difference (P>0.05) in feed intake among all the MCAD diets.

Table 3: Amino Acid (g/16gN) Content of Processed Mucuna Diets Fed to *C. carpio* Fingerlings.

Amino Acid (g/16gN)	**Treatment Diets**					
	DI	**DII**	**DIII**	**DIV**	**DV**	**DVI**
Methionine	1.09	0.99	0.97	0.75	0.48	0.46
Valine	2.03	2.07	1.97	1.98	0.78	0.73
Iso-leucine	1.66	1.74	1.71	1.75	0.87	0.85
Leucine	2.88	3.57	4.09	4.65	3.40	3.05
Phenyl-alanine	1.63	1.86	1.96	2.16	1.55	1.52
Histidine	1.07	1.08	0.97	0.95	0.48	0.45
Lysine	2.73	2.38	1.86	1.57	1.43	1.42
Threonine	2.71	2.57	2.22	2.10	1.05	1.00
Arginine	1.70	1.65	1.50	1.47	1.18	1.04
Tryptophan	0.50	0.65	0.60	0.67	0.28	0.16

Table 4: Growth performance feed utilization efficiency and apparent protein digestibility of *C. carpio* fingerlings fed processed mucuna diets for 8 weeks

Parameter	**Diet designation**					
	DI	**DII**	**DIII**	**DIV**	**DV**	**DVI**
IW (g)	15.10 ± 0.11^c	15.88 ± 0.04^a	15.88 ± 0.04^a	15.40 ± 0.23^b	15.80 ± 0.01^a	15.60 ± 0.11^a
FW (g)	20.30 ± 0.14^a	20.94 ± 0.21^a	20.74 ± 0.09^a	19.77 ± 0.09^b	19.93 ± 0.14^b	19.46 ± 0.16^b
LW G(g)	5.29 ± 0.40^a	5.06 ± 0.30^b	4.86 ± 0.40^b	4.37 ± 0.50^c	4.13 ± 0.10^c	3.86 ± 0.10^c
FI (*)[1]	6.56^a	6.55^a	6.56^a	6.28^b	6.11^c	5.82^d
SGR (%day)	0.91 ± 0.11^a	0.90 ± 0.05^a	0.88 ± 0.03^a	0.86 ± 0.05^b	0.82 ± 0.11^c	0.78 ± 0.02^d
FCR	1.04 ± 0.01^c	1.22 ± 0.01^c	1.36 ± 0.04^c	1.40 ± 0.08^b	1.48 ± 0.67^b	0.66 ± 0.01^d
PER	0.92 ± 0.01^a	0.86 ± 0.02^b	0.85 ± 0.01^b	0.72 ± 0.01^c	0.67 ± 0.02^d	0.66 ± 0.01^d
PPV (%)	29.88 ± 0.14^a	29.56 ± 0.10^a	29.87 ± 0.23^a	28.88 ± 0.10^b	28.65 ± 0.15^b	26.98 ± 0.10^c
ANPU (%)	28.20 ± 0.28^b	27.90 ± 0.27^b	28.48 ± 0.23^a	27.76 ± 0.17^c	26.70 ± 0.21^d	26.50 ± 0.34^c
APDC (%)	88.46 ± 0.42^a	82.10 ± 0.16^b	79.24 ± 0.24^c	78.56 ± 0.11^c	72.65 ± 0.45^c	68.46 ± 0.13^d
HIS	2.48 ± 0.24^a	2.25 ± 0.43^b	2.22 ± 0.41^b	2.20 ± 0.22^c	2.20 ± 0.23^c	2.10 ± 0.42^d
SR (%)	100	98	100	98	95	96

* g per 100g BW of fish per day; Values in the same row with the same superscripts are not significantly different (P<0.05).
[1]Statistical analyses were not possible as determinations were performed on pooled sample.
Key: IW=initial weigh, FW=Final weight, LWG=live weight gain, FI = feed intake, SR= survival rate

The regression equations of the relationship between LWG and graded levels of MCAD diets fed *C. carpio* fingerlings are shown in figure 1. The result showed a negative correlation co-efficient (r = -0.95) in the mean LWG with the graded levels of MCAD diets fed to *C. carpio* fingerlings with regression equation as: Y = 5.340-0.0298X. There was no significant difference (P > 0.05) in specific growth rates (SGR) values among fish fed diets DII, DIII and DIV, with the highest SGR of 0.91 for fish fed DI (control) followed by fish fed DII with SGR of 0.90. The poorest SGR (0.78) value was recorded in fish fed diets DVI. The poorest FCR was recorded in fish fed the 50% (DVI) Mucuna replacement (1.62). The Protein efficiency ratio (PER) was significantly higher (P < 0.05) in fish fingerlings fed the control diet followed by those fed with 10 and 20% replacement with 0.86and 0.85 respectively. Decreases of PER were observed as Mucuna meal levels increased in the fish diets. However, diet D1 had the highest PER of 0.92 while the lowest PER (0.66) was recorded in the DVI diet (Table 3).

The effect of replacing soybean with Mucuna meals on protein utilization and digestibility of *M. pruriens* based diets fed to *C. carpio* fingerlings is shown in figure 2. Digestibility decreased as the level of incorporation of Mucuna seed meal increased. The Protein Productive Value (PPV) differed slightly without significant difference (P>0.05) among DI, DII and DIII. Apparent net protein utilization (ANPU) was least (26.50%) for DVI and significantly (p<0.05) higher (28.20%) on DI. Diet DI showed the best Apparent Protein Digestibility Coefficient (APDC) of 88.46%, followed by DII (82.10%).

Lower APDC values were observed in fish fed diets DIV, DV and DVI which contained higher proportions of *M. pruriens* meal.

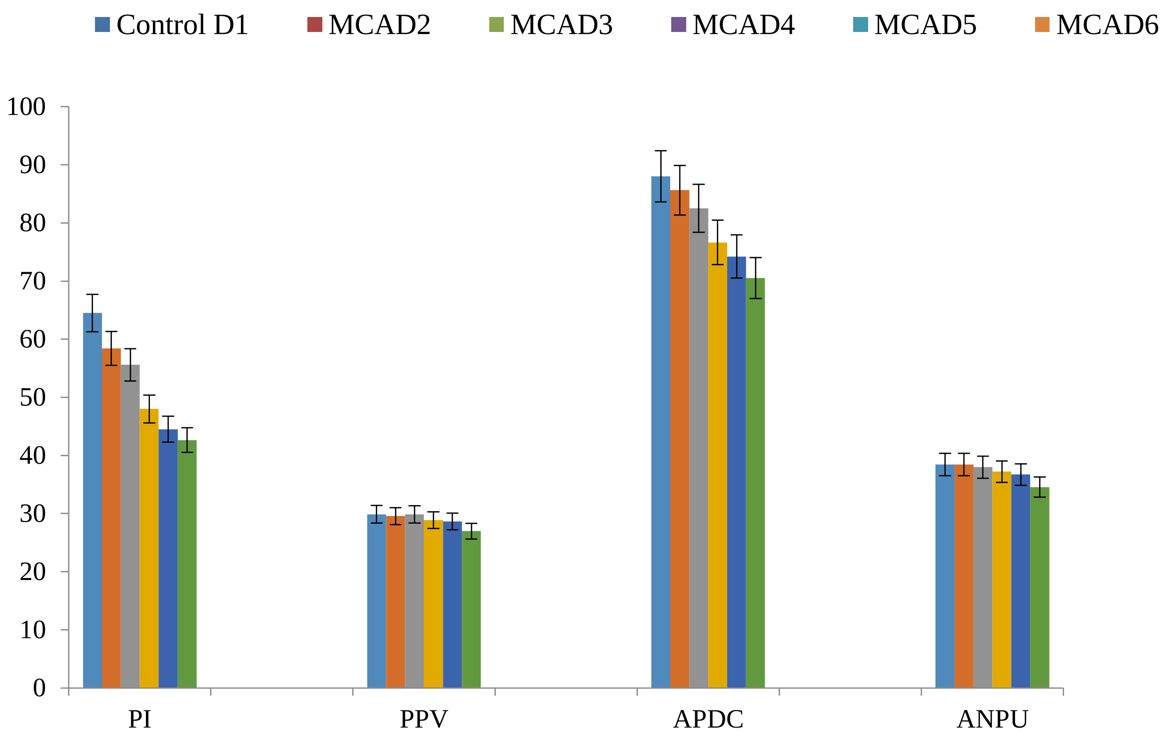


Figure 2: Effect of dietary treatment on protein utilization indices of *c. carpio* fingerlings fed MCA processed diets for 8 weeks. **Key:** PI = Protein Intake (%); PPV = Protein productive value (%); APDC = Apparent Protein Digestibility Coefficient (%), ANPU = Apparent Net Protein Utilization

Carcass composition of *C. carpio* fingerlings fed MCA processed *M. pruriens* diets

The effect of replacement level of the processed Mucuna meal based diets on the carcass composition of *C. carpio* fingerlings is presented in Table 5.

Table 5: Mean (±SEM) proximate carcass composition (% wet weight) of *C. carpio* fingerling fed processed *M. pruriens* diets for 8 weeks

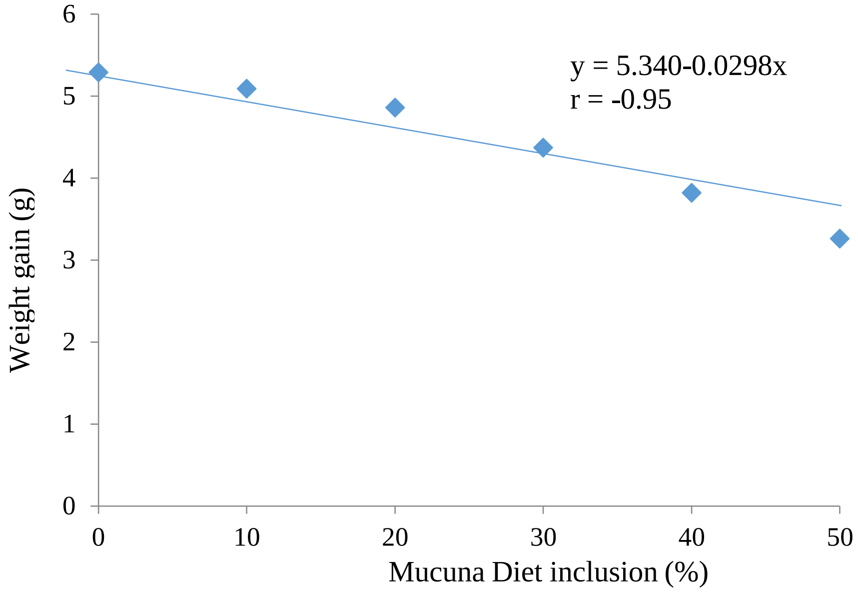
Replacement levels (%)	**Proximate composition (%)**				
	Moisture	**Crude Protein**	**Crude Lipid**	**Crude Fibre**	**Ash**
Initial Fish	79.7±0.54[a]	11.2±0.08[c]	2.0±0.01[d]	1.36±0.03[d]	4.3±0.03[b]
0	75.0±0.51[c]	18.0±0.09[a]	2.1±0.01[c]	1.38±0.03[d]	4.4±0.02[b]
10	75.1±0.5[c]	15.5±0.1[b]	2.0±0.08[d]	1.54±0.03[c]	4.9±0.03[a]
20	74.0±0.51[d]	15.6±0.1[b]	1.98±0.02[d]	1.56±0.03[c]	4.3±0.03[b]
30	76.0±0.50[c]	15.4±0.12[b]	2.1±0.01[c]	1.72±0.03[b]	3.0±0.02[d]
40	77.0±0.52[b]	15.0±0.13[b]	2.6±0.02[a]	1.78±0.03[b]	3.1±0.02[c]
50	77.0±0.51[b]	15.0±0.13[b]	2.3±0.02[b]	1.84±0.03[a]	3.4±0.02[c]

Values in the same horizontal row with same superscripts are not significantly different (P<0.05).

There was no significant difference (P >0.05) between the final carcass protein content values compared to DII-DVI. Crude lipid was higher in DV followed by DVI, DIV and DI and DIII. Ash was significantly (P < 0.05) higher in DII, followed by DI, DIII.

Hepato-somatic index of *C. carpio* fingerlings fed MCA processed *M. pruriens* diets

The Hepato-somatic index (HSI) for *C. carpio* fingerlings fed increasing levels of MCA processed Mucuna meals is as shown in Figure 1. The HSI for *C. carpio* fingerlings fed the diets ranged from 2.10 to 2.48 with the correlation co-efficient equation of Y=2.301-0.286X showing a negative correlation coefficient (r = -0.62).



Regression Graph of Weight Gain of *C. carpio* Fingerlings Fed Graded Levels of MCA Processed *M. pruriens* Seed Diets for 8 Weeks

Cost -benefit analysis of replacing Soybean meal with *M. pruriens* bean meals in the diet of *C. carpio* fingerlings

Cost - benefit analysis of replacing Soybean meal with *M. pruriens* bean meals in the diet of *C. carpio* fingerlings is presented in Table 6. The costs of feed production at each level of replacement of processed Mucuna diet used as compared to the control diet (₦ 450.00) showed ₦ 235.65, ₦ 208.20, ₦ 197.12, ₦ 188.51 and ₦160.20 for the diets containing replacement levels of processed Mucuna diets DII, DIII, DIV, DV and DVI respectively. There were significant reductions in the production costs per kilogramme of diet used. The cost of feed consumed at each level decreased with increase in feed replacement. There was also significant variation ($p < 0.05$) in the cost of feed per weight gain of fish which increased as the percent replacement of soybean with Mucuna meal increased from 10% to 50% in the diets fed to *C. carpio* fingerlings.

Table 6: Cost-Benefit analysis of Fed to *C. carpio* fingerling for 8 weeks

Performance Index	Mucuna meal replacement level (%)						SEM
	DI	DII	DIII	DIV	DV	DVI	
FCR	1.12^{c}	1.22^{c}	1.16^{c}	1.55^{b}	2.24^{a}	2.5^{a}	0.02*
Weight Gain (g)	5.29^{a}	5.06^{a}	4.86^{b}	4.37^{c}	4.13^{d}	3.86^{c}	0.26*
Production Cost/kg of feed (₦)	450.0^{a}	235.65^{b}	208.20^{c}	197.12^{d}	188.52^{c}	160.20^{f}	0.10*
Cost of feed consumed (₦)	1.64^{a}	1.55^{b}	1.34^{c}	1.24^{d}	1.15^{c}	0.93^{f}	0.10*
Cost/kg of weight gain (₦)	310.02^{a}	306.02^{a}	275.72^{d}	283.75^{c}	278.45^{d}	240.93^{c}	0.10*

Mean values in the same horizontal row with different superscripts are significantly different at * ($P<0.05$), Key: FCR = food conversion ratio, g = gram, kg = kilo gram.

Water quality parameters analyzed

The data on water quality parameters in all the experimental basins and control are presented in Table 7. The water temperature varied between different diets (DII-DVI and control) in the range of 22.20 -

22.80°C without being significantly different (P>0.05) within replicate basins of the same diet. There was significant (p<0.05) difference in the dissolve oxygen values with the highest value (5.52mg/L) recorded in the diet DI basin while the lowest (5.26mg/L) was recorded in DVI basin. Free carbon dioxide varied between 4.64 and 5.22 mg/L with the highest value recorded in DVI diet basin and lowest (4.64mg/L) recorded in DI basin, while total alkalinity varied from 24.60 to 24.81mg/L without significant difference (p>0.05). Hydrogen ions (pH) of all the experimental basins was not significantly different (p>0.05) which ranged between 6.94 and 7.10 while unionized ammonia averaged between 0.22 and 0.24µg/L.

Table 7: Mean (±SEM) water quality parameters measured during the 8 week experimental period

Parameter	**Experimental period (weeks)**								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Temp (^{0}C)	22.19±0.20^d	22.22±0.21^d	22.20±0.20^d	23.19±0.20^c	25.20±0.23^c	23.20±0.23^c	22.20±0.20^d	23.20±0.25^c	25.60±0.20^a
DO (mg/L)	6.08±0.32^b	6.42±0.37^a	6.68±0.33^a	5.06±0.30^d	5.62±0.21^c	5.64±0.21^c	6.34±0.10^a	5.16±0.30^d	5.08±0.22^d
CO_2 (mg/L)	7.20±0.99^a	7.04±0.82^a	5.54±0.62^b	4.68±0.66^c	4.80±0.71^c	4.80±0.80^c	4.64±0.54^c	4.88±0.52^c	5.02±0.47^b
Alkalinity (mg/L)	24.10±0.25^c	24.60±0.24^d	24.80±0.08^c	25.60±0.20^a	25.21±0.25^a	24.90±0.12^c	24.86±0.20^c	25.02±0.26^b	24.66±0.07^d
pH	7.00±0.22^a	7.00±0.04^a	7.06±0.03^a	6.96±0.03^b	7.04±0.02^a	7.21±0.01^a	7.10±0.24^a	7.00±0.04^a	6.96±0.01^b
Ammonia	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a	0.22±0.01^a

DISCUSSION

Water quality parameters are known to influence feed availability, feed intake, physiology, growth and development of fish (Boyd, 1979). The results of the physical-chemical parameters monitored during the experiment indicated that the mean water quality parameters studied were within the recommended ranges for Common carp culture (De-Silva and Anderson, 1995). Common carp fingerlings did not show problem adjusting to diets DI, DII and DIII which contained the lower percentages of the Mucuna inclusion. However, the observed decreases in the feed intake at higher levels of Mucuna inclusions could probably be attributed to the low protein quality and effect of residual anti-nutritional factors, which became pronounced as the dietary level of test foodstuff increased for Mucuna (Siddhuraju and Becker, 2003; Akinmutimi and Okwu, 2006); soya bean (Adebayo *et al*., 2004); and canola (Borgeson *et al*., 2006). The results observed could have been due to the presence of residual tannin, cyanogens or trypsin inhibitor content, for instance, tannin was reported to cause poor palatability in high the tannin diet due to its stringent property and its ability to bind with protein of the mucosa membranes (Akinmutimi and Okwu, 2006) and digestive enzymes into complexes that are not readily digestible (Goda *et al*., 2007).

Diets DI, DII and DIII promoted better growth than the other test diets (DIV- DVI) probably due to their ability to meet the essential amino acid requirement of the fish. Cho *et al*. (1982) reported that protein requirements of fish are considered to be the sum of the requirements essential for individual amino acids. The low values of live weight gain observed in this study at dietary levels of processed Mucuna seed meal increased could be due to several factors such as the lower feed intake as well as the effect of toxic components such as cyanogenic glycosides, which on hydrolysis release hydrogen cyanide (HCN) which was reported to have the ability to cause marked weight changes (Siddhuraju and Becker, 2003). The cyanide detoxication route is through cyanide thiocyanate sulfur-transferase (Rhodenase pathway) which generally requires organic sulphur donors in the form of methionine and cystine, thereby precipitating methionine deficiency in an otherwise balanced diet (Davies and Gouveia, 2008) resulting to poor growth.

The replacement of soya bean with processed Mucuna meals at levels below 20%, (which translated to 9.98% inclusion in the diet) significantly enhanced LWG, FCR and PER of *C. carpio* fingerlings. This was attributed to the low levels of residual anti-nutritional factors in processed Mucuna seeds based diets (Francis *et al*., 2001; Olvera- Novoa *et al.*, 2002). Diet DIII (20%) gave the optimum in LWG, SGR, FCR and PER while the poorest SGR, PER and FCR were recorded in fish fed DVI which contained the highest inclusion of the processed Mucuna seed meal. This is in agreement with the findings of El-Saidy and Saad (2008) for the use of feed ingredients containing cowpea seeds (*Vigna sinesis*) meals at 15-20% level rather than at higher and commonly suggested 30% level of inclusion (Cho *et al.*, 1982).

The apparent net protein utilization (ANPU) and apparent protein digestibility co-efficient (APDC) for all diets decreased due to poor digestibility of the test diets with increased levels of Mucuna in the diets. Hossain and Jauncey (1989) reported inclusion of mustard, linseed and sesame seed meals at graded levels in common carp diets depressed net protein utilization compared to the control group. Similarly, De- Silva and Gunasekere (1989), Balogun and Fagbenro (1995), Olvera-Novoa*et al*. (2002), Gaber (2005) reported reductions in protein digestibility with increase in dietary contents of kidney bean, Macandamia press cake, sunflower and canola seed meals respectively.

Among the various treatments, the protein in DI, DII and DIII were efficiently utilized by *C. capio* fingerlings, but less efficient at higher inclusion levels, which could be related to low anti-nutritional factors and fibre levels of in the diets (Emenalom and Udedibie, 2005). The same pattern was observed by Alegbeleye *et al*. (2005), Davies and Gouveia (2008) who independently reported inclusion of toasted lima bean and boiled pigeon pea seed meals at levels of 10-20% and 15-30% respectively without adverse effects or loss in weight in *O. niloticus*. The poorest values of APDC were obtained in fish fed diets DVI which contained the highest proportion of processed *M. pruriens* seed. Similar results were obtained with higher levels of inclusion of pigeon pea meal (De-Silva and Gunasekera, 1989, Abelghany, 2004); lima bean (Alegbeleye *et al*., 2005); peanut (Garduno and Olvera, 2008) and faba bean Azaza *et al*. (2009) in *O. niloticus* diets.

The incorporation of processed *M. pruriens* seed meals did not significantly (P>0.05) affect the carcass protein and proximate components among inclusion levels showing that there was no disparity in the utilization of the test diets which confirms that processed *M. pruriens* protein can replace up to 20% of soybean protein without depressive effects on the production performance and nutrient metabolism. Eyo (2001), Hossain *et al*. (2001), Fagbenro *et al*. (2003), Hasan *et al*. (2006), Davies and Gouveia (2008) observed non-significant differences in the carcass protein contents of diets containing boiled full-fat soybean or defatted soybean meal fed to Nile tilapia and Common carp.

The results of the hepato-somatic index (HIS) showed that incorporation of processed Mucuna as diets (DII-DVI) in replacement of soybean meal in diets fed to *C. carpio* fingerlings had no significant (P>0.05) inflammatory effect on the liver of the test fish. Azaza *et al*. (2009) reported a significant decrease in the hepato-somatic index of Nile tilapia fed faba bean diets at 100% replacement of soya bean meal. El-Hammady (2001) also reported that replacing dietary protein in diets of hybrid tilapia by sesame meals at 40, 60 and 80% levels decreased the hepato-somatic index and that the increase was more pronounced as the level of the replacement increases.

The production cost of the control diet (₦450.00/kg) was the highest because of the very high cost of soybean (₦132.00/kg) compared to *M. pruriens* seed at ₦58.00/kg. Although the production cost of the test diets (DII-DVI) were significantly (P<0.05) lower (₦160.20- ₦ 235.65) than the control diet (₦450.00), the cost of production per kilogram of DIII (₦208.20/kg) was considered to be the most economically viable because the cost of 1kg weight gained by the fish fed on DIII diet had significant savings for inclusion of processed Mucuna diet over the control diet. The MCAD6 diet had the least cost per kg of feed (₦160.20) which also resulted in the lower cost of feed consumed, but encouraged the highest cost per unit weight gain because of its poor feed conversion ratio and nutrient utilization.

Diet DIII had a moderate cost per kg of feed, moderate cost of feed consumed and good weight gain. This cumulatively made the cost/kg weight gain of diet DIII for *C. carpio* the most economically advantageous. The inclusion level of 20% *M. pruriens* in this study had a cost sparing effect, which resulted in the production of cheaper diet and lower cost per unit weight gain than the control diet largely attributable to cost of soybean, which the test ingredient is replacing Similar reports were made Adebayo *et al*. (2004), when evaluating the bio-economics of soya bean and other protein sources in fish feed evaluation.

Conclusion

On the basis of observed results, replacement of processed Mucuna seed meal in the diet of *C. carpio* fingerlings showed no inhibition in feed intake. There was an appreciable growth performance and digestibility index of *C. carpio* fingerlings fed DIII diet. This diet also gave the protein utilization and cost effectiveness and was considered the optimum level of substitution of soya bean in the feeding of *C. carpio* fingerlings with a non-conventional wild plant protein diet.

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