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Effect of processed lablab bean (*Lablab purpureus*) meal supplementation on the digestibility and growth response of carp (C*yprinus carpio*)

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Abstract

The effect of processed lablab (PLB) bean meal supplementation in the diet of C*yprinus carpio* was investigated. Soybean was substituted for using raw lablab (RLB) and PLB bean meals on equal nitrogen basis in conventional fishmeal. The diets were subjected to proximate analysis and digestibility studies. Results show that PLB bean diets have comparable crude protein and lipid digestibility coefficients. The carbohydrate digestibility was highest in fish fed fermented LB bean diet and lowest in those fed on RLB bean diet. Crude fiber digestibility coefficients of fish fed on control and PLB bean diets differ significantly from those fed on RLB bean diet. Gross energy of PLB bean diets range from 17.1 to 17.8 kJ/g. Energy retention of 15.0, 12.6 and 12.0% was obtained in fishes fed on cooked, control and fermented diets respectively. The feed conversion efficiency was 166.6 in fish fed the control diet, and differs significantly ($P < 0.05$) from those fed on PLB bean diets (152–159). Fishes fed the control and cooked LB bean diets had the highest specific growth rate and feed conversion ratio. A direct positive linear and quadratic relationship exists between final weight and feeding period in *C. carpio* fed on the test diets.

Key words: *Cyprinus carpio*, processing, lablab beans, growth response.

Introduction

Fish is a nutritious animal protein contributing about 17% of the world's animal protein supply[1,2]. However, the growth and nutritional status of fish depends on the quality and quantity of dietary protein in its meal. Fishmeal, the conventional protein source in fish diets, is expensive and scarce. The acute shortage of conventional feedstuffs for the feeding of livestock in developing countries necessitates the search for unconventional cheaper, high protein and energy feedstuffs for use in fish diets to avoid competition with humans. In recent years, the use of grain legumes in diet formulation has received considerable attention due largely to its ready availability, low cost and high amino acid composition [3-6] compared to the conventional fishmeal which is scarce and expensive. Lablab bean (*Lablab purpureus*), a legume high in crude lignin and protein[7] , has nutrient density comparable to common beans[3] but is grossly under-utilised in Nigeria. Lablab (LB) originated in India[7] has been widely distributed to many tropical and subtropical countries where it is grown as an annual or a short-lived perennial. The seed and immediate pods are used as human food, while the herbage is used as green manure, for erosion control and as feed supplement for cattle grazing. The use of indigenous legumes in diet formulation is generally limited by the presence of anti-nutritional factors – tannin, phytates, saponin and trypsin inhibitor[8]. Consumption of feeds containing these factors reduces nutrient utilisation, feed efficiency and animal productivity. At high levels of intake, toxicity ensues and animal sometimes die[9]. The activity of these compounds can be reduced/removed by dehulling, soaking, cooking, toasting and fermenting[5-7]. The digestibility coefficient of specific components of a diet can be determined by measuring the acid insoluble ash (AIA) in the diets and faeces[10].

Cyprinus carpio (Carp) used in this study was chosen for its rapid growth rate, tolerance of varying environmental conditions, efficient food conversion, ease of spawning, resistance to diseases and good consumer acceptance. The present study aims to evaluate the response of *Cyprinus carpio* to raw, toasted, fermented and cooked LB bean supplementation in fish diet using AIA as markers.

Materials and Methods

Materials: Lablab (LB) beans (*Lablab purpureus*) used for this study were obtained from the Federal University of Technology, Akure Teaching and Research farm. The beans were harvested, screened and were then distributed into four batches. One batch was left raw; the remaining three batches were toasted, fermented and cooked respectively. The other ingredients used, namely: maize, fishmeal, oil, starch, vitamin premix, salt, soybean and bone meal were obtained from a commercial feed store in Akure, Ondo State, Nigeria.

Preparation of meal :

Raw: Raw lablab (RLB) bean was prepared by grinding the mature, dried beans in a laboratory mill, sieved with a 200-mm mesh sieve, put in polythene bags and stored at 4°C. All processed meals were similarly ground, sieved and stored until used.

Toasting: LB beans were put in heated sand (204°C) for 20 minutes. The toasted beans were ground to yield the toasted LB bean meal.

Fermenting: About 200 g of RLB beans were cooked with 2 litres of water in a pressure pot at 15 PSI. After steaming for 20 minutes, it was allowed to cook for additional 10 minutes. The

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water was drained off and the beans were wrapped in banana leaves, placed inside a jute bag and were daily wetted for seven days. The fermented LB beans were oven-dried (40-45°C) until sufficiently dried and ground.

Cooking: About 200 g of RLB beans were cooked with 2 litres of water in a pressure pot at 15 PSI. After steaming for 20 minutes, it was allowed to cook for additional 15 minutes. The water was drained off and the cooked beans oven dried at 40 – 45ºC until sufficiently dried and ground.

Feed formulation: The full-fat soybean content of the control diet was replaced with RLB bean and the three processed LB (PLB) bean meals on an equal-nitrogen basis (Table 1). All diet ingredients were milled to pass through a 3-mm diameter sieve. All other ingredients including premixed mineral/vitamin supplement and table salt were added and manually mixed together before gelatinized corn starch was added as a binder. A diet without LB beans served as reference. All ingredients were mixed thoroughly in a Hobart A-200T pelleting and mixing machine to obtain a homogeneous mass and passed through a mincer to produce 0.8-mm diets, which were immediately oven dried (40–45°C). The diets were then broken up into convenient pellet sizes and frozen (-20°C) until it is required for use in feeding trials.

Feeding trials: *Cyprinus carpio* (average weight 1.04 ± 0.02 g) produced from a commercial hatchery fish farm in Akure, Nigeria were stocked into fifteen 45-L glass aquaria. Fifteen fishes were randomly stocked into each tank, with three replications (i.e. three aquaria) per treatment. Water was supplied to the tanks from a borehole. Continuous aeration was provided by a blower and airstones. Illumination was supplied by fluorescent ceiling lights with an 18:6 h light:dark cycle. The fishes were acclimated to laboratory conditions for 7 days while being fed a 35% crude protein commercial pelleted diet before the experiment. The water in the aquaria was replaced at two days intervals with fresh borehole water. Fish were not fed for 24 hours before the onset of the experiment. Experimental diets were assigned randomly to each aquarium, and each group of fish was fed at 5% body weight/day in two equal portions at 8.00-9.00 and 12.00-13.00 o´clock for seven weeks. All the fishes were removed from each tank every 7 days, batch weighed and the amount of feed adjusted accordingly. Faecal samples were collected twice daily four hours after feeding for 21 days. Droppings from the same tank were pooled together in a bowl, packed in cellophane bags and stored in a freezer. Uneaten diet was siphoned out using a 2-cm pipe 20 minutes after feeding.

Analytical procedures and water quality assessment: The proximate analyses of the diets and fish excreta were carried out as described by the AOAC[11]. Nitrogen was determined by the micro-Kjeldahl method and the nitrogen-free extract estimated by difference. Crude fiber was determined by the methods of Pearson[12]. All chemicals were of analytical reagent grade. Energy content of faeces and diets was determined using an adiabatic bomb calorimeter. Acid insoluble ash (AIA) analyses were carried out on the diets and faeces[11]. AIA was obtained by adding 25 ml of 10% HC1 to the weighed ash content of a sample. This was covered with a watch-glass and boiled gently over a low flame for five minutes. It was then filtered using ashless filters and washed with hot distilled water. The residue from the filter was returned to the crucible, ignited until it was carbon free and then weighed. Percentage AIA was calculated as % AIA = (weight of AIA/weight of ash) 100. Digestibility coefficient was calculated as described by

Table 1. Ingredient and proximate composition (g/kg) of raw and processed lablab bean diets fed to *Cyprinus carpio.*

	Control	RLB	TLB	FLB	CLB
Ingredient					
Fish meal	28.89	28.89	28.89	28.89	28.89
Soybean	34.89	-	-	-	-
Yellow maize	30.02	3.5	3.5	3.5	3.5
Lablab beans	-	61.4	61.4	61.4	61.4
Oil	1	1	1	1	1
Salt	1	1	1	1	1
Corn starch (binder)	1	1	1	1	1
Vit/Min premix*	3	3	3	3	3
Bone meal	0.2	0.2	0.2	0.2	0.2
Proximate composition (g/kg)					
Crude protein (CP)	320.11^{a}	300.32^{a}	306.91^{a}	300.73^{a}	318.12^{a}
Ether extract (EE)	98.62^{a}	90.41^{c}	92.22^{bc}	93.15^{ab}	96.51^{a}
Crude fibre (CF)	56.13	59.25	58.45	57.34	58.13
Ash	72.45^{cd}	81.71^{a}	69.22^{d}	79.12^{b}	76.44^{bc}
Nitrogen free extract (NFE)	301.90^{a}	281.12^{a}	306.63^{a}	282.61^{a}	299.14^{a}
Gross Energy (kJ/g)	17.32	17.64	17.92	17.11	17.84
Acid insoluble ash (AIA)	1.41	1.50	1.45	1.47	1.44

* Composition according to formulation provided by Hoffman La Roche, Basle, Switzerland.
Means within the same row followed by different letters are significantly different ($P < 0.05$)
Means are replicates of three readings
(RLB:Raw lablab bean diet; TLB: Toasted lablab bean diet; FLB:Fermented lablab bean diet; CLB:Cooked lablab bean diet)

Adeparusi and Jimoh[13] as follows:

$$\text{Digestibility (\%)} = 100 - \frac{100\% \text{ AIA in diet x nutrient in faeces}}{\% \text{ AIA in faeces x nutrient in diet}}$$

Water Quality Assessment: Dissolved oxygen (YSI Model 57 oxygen meter, Yellow Spring Industries, Yellow Springs, Ohio), water temperature and pH (electronic pH meter, Jenway, Dunmow, Essex, England) in all tanks were measured weekly.

Evaluation of diet performance: Growth performance and nutrient utilization of fish were determined in terms of final mean fish weight (g), survival (%), specific growth rate (SGR, %day^{-1}), food intake, feed conversion ratio (FCR) and protein efficiency ratio (PER). These growth responses were calculated as described by Olvera-Novoa et al.,[14] as follows:

Weight gain (%) = 100 (final body weight-initial body weight/initial body weight);

SGR (% day^{-1}) = 100 ($\log_e$) final body weight – $\log_e$ initial body weight/time (days);

FCR = [dry weight of feed fed (g)]/[fish weight gain (g)];

PER = [fish weight gain (g)]/[protein fed (g)];

Daily feed intake = [(DFI x 100)/(W_{t+1} + W_t)/2 per g of fish]/ time, where DFI is mean dry food intake; (t, t +1) and W_t, W_{t+1} are the average wet weights at the start (*t*) and conclusion (t +1) of the experimental period[15]

Statistical analyses: Triplicate results of proximate and biological data obtained were subjected to regression analysis and analysis of variance (ANOVA), while means were separatedusing Duncan's Multiple Range Test. These analyses were carried out using GenStat 6.1[16] computer program.

Results and Discussion

The proximate composition of LB bean diets used in this study is shown in Table 1. No significant difference (P > 0.05) was observed in the CP, CF, NFE and AIA contents of raw, toasted, fermented and cooked LB bean based diets. This result suggests that these parameters (CP, CF, NFE and AIA) were not significantly affected by any of the processing techniques employed with the LB beans. The fact that LB bean supplementation gave protein content comparable with the control (where soybean is used) suggests that LB beans is capable of functionally replacing soybeans in the control diet. All the diets agree remarkably with the control with respect to CP, showing that the diets should be capable of meeting the protein requirement of *Cyprinus carpio*. However, only digestibility studies (as shown in Tables 3 and 4) can actually ascertain the level of availability of the protein in the diets for utilisation in growth. Significant difference (P < 0.05) was recorded in the CP, EE, CF and ash of faecal matter of fish fed on the experimental diets (Table 2). The CP level in the faecal matter of fish fed on PLB bean diets is comparable with those fed on the control diet. However, the CP level in the faeces of fishes fed on RLB bean diets was significantly higher (P<0.05). This observation suggests that the CP of RLB beans is not readily bio-utilisable, thus justifying the need for further processing to enhance its digestibility[17]. The AIA of fish fed diets based on RLB and PLB beans based diets were not significantly different (P> 0.05).

Digestibility coefficients of the diets are shown in Table 3. Protein digestibility of PLB beans, which ranged from 85.4 (toasted) to 86.6 (cooked) were not significantly different (P>0.05) from the control. RLB beans based diets had significantly lower (P<0.05) digestibility. The high protein digestibility obtained for heat treated (toasting and cooking) LB beans agree with the report of Jaffe[17] that heat has positive effect on proteins, improves its palatability and make them more liable to enzymatic action. Similarly the carbohydrate portion is made more susceptible to hydrolysis[18]. The CP digestibility

Table 2. Mean of proximate composition (g/kg) of excreta from *Cyprinus carpio* fed on raw and processed lablab bean diets.

Ingredient	Control	RLB	TLB	FLB	CLB
Crude protein	209.10^b	284.92^a	212.35^b	210.93^b	209.71^b
Ether extract	50.11^c	59.84^a	58.42^{ab}	56.62^b	53.15^c
Crude fibre	36.42^b	41.03^a	36.05^b	39.25^{ab}	36.82^b
Ash	67.90^a	53.25^c	60.62^b	65.21^a	68.02^a
Nitrogen free extract	520.54^a	458.75^b	498.45^a	531.23^a	500.42^a
Gross energy (kJ/g)	15.14	16.21	16.37	15.06	15.17
Acid insoluble ash	69.05	69.25	68.75	68.21	68.50

Means within the same row followed by different letters are significantly different (P < 0.05)
Means are replicates of three readings
(RLB: Raw lablab bean diet; TLB: Toasted lablab bean diet; FLB: Fermented lablab bean diet; CLB: Cooked lablab bean diet)

Table 3. Digestibility coefficient (%) of nutrients in the diets of *Cyprinus carpio* fed on raw and processed lablab bean based diets using acid insoluble ash as marker.

Ingredient	Control	RLB	TLB	FLB	CLB
Crude protein	86.65^a	80.15^b	85.39^a	86.25^a	86.56^a
Ether extract	89.86^a	83.65^c	86.53^b	86.60^b	88.86^{ab}
Crude fibre	86.74^a	80.03^b	86.99^a	85.24^a	86.69^a
Ash	85.77^a	86.57^a	84.27^b	84.96^{ab}	81.26^c
Gross energy	2.48^a	1.84^b	2.75^a	2.57^a	2.61^a
Nitrogen free extract	64.78^c	64.74^c	85.65^a	87.99^a	82.70^b

Means within the same row followed by different letters are significantly different (P < 0.05)
Means are replicates of three readings
(RLB:Raw lablab bean diet; TLB: Toasted lablab bean diet; FLB: Fermented lablab bean diet; CLB: Cooked lablab bean diet)

Table 4. Growth performance and nutrient utilisation of *Cyprinus carpio* fed on raw and processed lablab bean based diets (%).

Parameters	Control	CLB	FLB	TLB	RLB
Initial weight (g)	1.04 ± 0.02	1.03±0.02	1.09± 0.03	1.03±0.02	1.08±0.03
Final weight (g)	2.48^{a} ± 0.04	2.40^{a} ± 0.03	2.35^{a} ± 0.05	2.16^{b} ± 0.04	1.88^{c} ± 0.01
Mean weight gain (g)	1.44^{a}± 0.03	1.38^{a} ± 0.03	1.26^{b} ± 0.04	1.13^{c} ± 0.03	0.80^{d} ± 0.02
% Mean weight gain	138.5^{a}	133.0^{a}	115.6^{b}	109.7^{c}	74.1^{d}
Daily mean weight gain (mg)	68.57^{a} ± 0.15	65.71^{a} ± 0.11	60.00^{b} ± 0.1	53.81^{c} ± 0.1	38.10^{d} ± 0.15
Daily Feed Intake (mg)	41.2^{a} ± 0.1	41.3^{a} ± 0.1	39.5^{b} ± 0.1	38.7^{b} ± 0.1	25.5^{c} ± 0.1
Protein Efficiency ratio	5.21^{a}	5.00^{a}	5.05^{a}	4.52^{b}	4.98^{a}
Feed Conversion Efficiency	166.6^{a}	159.3^{b}	153.9^{b}	152.1^{b}	149.5^{c}
Feed Conversion Ratio	0.60^{b}	0.63^{b}	0.66^{ab}	0.72^{a}	0.67^{ab}
Specific Growth Rate (% day^{-1})	4.14^{a}	4.03^{a}	3.66^{b}	3.52^{b}	2.64^{c}
Survival rate (%)	92^{a}	90^{a}	91^{a}	90^{a}	75^{b}
*Total Cost (N)/kg feed	70	55	55	55	50

* Cost of feedstuff at the prevailing market prices in Nigeria (May 2002); 1 US $ = N120
RLB: Raw lablab bean diet; TLB: Toasted lablab bean diet; FLB:Fermented lablab bean diet; CLB: Cooked lablab bean diet

values obtained in this work (85.4–86.6) compare favourably with earlier reports by Adeparusi and Jimoh[13] on protein digestibility of Nile Tilapia (*Oreochromis niloticus*) fed on toasted lima bean diets (84.8%). The high value obtained for fish fed diets based on fermented LB beans may be due to the conversion of insoluble proteins to soluble components, increase in the levels of lysine, vitamins B and C commonly associated with fermentation[19]. Fermentation has been shown to improve bioavailable nutrients in cowpea[20]. The low digestibility recorded in fish fed on RLB based diets could be due to the presence of antinutrients such as tannin, phytates and trypsin inhibitors[21]. The presence of cyanogenic glucosides may also decrease palatability.

There are significant differences ($P< 0.05$) between the digestibility coefficients of lipids in fish fed on RLB and PLB bean diets and the value obtained for fish fed on the control diet was highest but not significantly different from those fed on cooked LB bean diet. The fat digestibility obtained in this study using the tested diets was similar to the values reported for rainbow trout[22] and for Mozambique tilapia fed on some plant protein sources[23]. A range of 76 to 97% fat digestibility for various sources of fat has been reported for channel catfish[24]. Andrew [25] reported that the ability to digest fat appears to be influenced by temperature and the level of fat in the diet. This is reflected in the significantly higher ($P< 0.05$) values obtained for the toasted and cooked LB bean based diets compared with the raw LB based diet. Austreng et al.[26] reported marked differences in the digestibility of fat and fatty acid from various dietary fat sources fed to rainbow trout. Fat digestibility was improved with processing. The digestibility of carbohydrate was significantly different ($P< 0.05$) among fish fed the various diets; the highest value was in fish fed on fermented LB based diet and lowest in those fed on RLB bean diet. The digestibility of carbohydrates has been shown to vary with their complexity, source, treatment and level of inclusion in diet[22]. The digestibility coefficient of the carbohydrate portion in processed LB bean based diets is comparable with that of protein and fat but significantly higher than the digestibility of raw and control diets. This shows that *Cyprinus carpio* does not digest the carbohydrate in raw LB bean diets as much as other nutrients. The high digestibility values obtained for fish fed on PLB bean diets may be due to the breakdown of sugars into simpler, digestible form by heat (during cooking and toasting) and fermentation, making the sugars more readily available for utilisation. In view of this, it is expected that the gross energy of digestibility would be higher in cooked and toasted LB bean diets[27]. The carbohydrate digestibility values obtained in this study for PLB bean diets were higher than the 20% reported in salmonids fed raw corn starch. This is in agreement with the report of Popma[28], that warm water fish like channel catfish, *Ictalurus punctatus,* grass carp, and *Ctenopharyngodon idella* will absorb >60% of raw corn starch. The carbohydrate digestibility in fishes fed on RLB bean based diet and control diets are the least in this study and are not significantly different ($P>0.05$) from each other. This suggests that the carbohydrate fraction of raw LB beans is as digestible to carp as that of the control. Crude fiber digestibility coefficients of fish fed on the control and PLB bean diets were significantly different ($P< 0.05$) from those fed on RLB bean diet. The range in PLB bean diets is 85.2–87.0. This range compare favourably with that reported by Adeparusi and Jimoh[13] for *Oreochromis niloticus* fed on toasted lima bean diet (84.7–85.2). However, crude fiber digestibility was comparably higher than carbohydrate digestibility in *Cyprinus carpio* fed on the control and RLB bean diets. Toasting, cooking and fermentation improved the digestibility of crude fiber. The energy producing value of the PLB bean diets range from 17.1 (fermented LB diets) to 17.8 kJ/g (toasted LB diets). These values are not significantly different ($P< 0.05$) from those obtained for RLB and the control diets. A comparison of the gross energy values in the diets and faecal matter (Tables 1 and 2) shows that the highest energy retention took place in fishes fed on cooked LB diets (15.0%) followed by those fed the control diet (12.6%) and fermented diets (12.0%). The low energy retention values obtained suggests that not all the energy inherent in the diets are available for utilization by the fish. This may be due to the presence of high molecular weight polysaccharides in LB which are not easily broken down for energy purposes. The advantage associated with the use of PLB in diet formulation is further reflected in the high energy digestibility coefficient of PLB based diets (2.57–2.75) compared with RLB diets (1.84). This observation is consistent with the reports of Bressani and Elias[18] that heat improves gross energy digestibility. Fish mortality was low (< 10%) and relatively uniform in all the treatments except those fed on the raw LB bean diets (~ 25%). This suggests that processing (heat and fermentation) significantly improves the mortality of fish fed on diets based on it. All the experimental fish remaining appear to be morphologically normal at the end

Table 5a. Regression equations showing the relationship between weight gain by *Cyprinus carpio* fed on raw and processed LB bean based diet.

Experimental Diets	Linear	R^2	Quadratic	R^2
Control	$y = 0.220x + 0.9102$	0.965	$y = 0.0139x^2 + 0.1225x + 1.0078$	0.981
Cooked lablab bean diet	$y = 0.1989x + 0.9164$	0.965	$y = 0.0167x^2 + 0.0820x + 1.0334$	0.992
Fermented lablab bean diet	$y = 0.1808x + 0.9379$	0.954	$y = 0.0190x^2 + 0.0480x + 1.0708$	0.996
Toasted lablab bean diet	$y = 0.1571x + 0.9497$	0.962	$y = 0.0146x^2 + 0.0547x + 1.0521$	0.996
Raw lablab bean diet	$y = 0.1450x + 0.9117$	0.882	$y = 0.0259x^2 - 0.0362x + 1.0929$	0.994

Where *y* represent the final weight after *x* feeding time (weeks)

Table 5b. Correlation matrix showing relationship between weight gained by *Cyprinus carpio* fed raw and processed lablab bean diet and feeding time (weeks).

	Feeding Period (weeks)	Control	CLB	FLB	TLB	RLB
Feeding period (weeks)	1.000	0.983*	0.982*	0.977*	0.981*	0.939*
Control	0.983*	1.000	0.987*	0.984*	0.985*	0.956*
CLB	0.982*	0.987*	1.000	0.991*	0.991*	0.981*
FLB	0.977*	0.984*	0.991*	1.000	0.994*	0.986*
TLB	0.981*	0.985*	0.991*	0.994*	1.000	0.981*
RLB	0.939*	0.956*	0.981*	0.986*	0.981*	1.000

*Correlation is significant at the 0.01 level (2-tailed).
RLB: Raw lablab bean diet;TLB: Toasted lablab bean diet;FLB: Fermented lablab bean diet;CLB:Cooked lablab bean diet

of the feeding trial. Ranges of water quality characteristics (water temperature 25.4-26.6ºC, pH 7.5-8.6, dissolved oxygen 6.7–7.8 mg l^{-1}) fall within the acceptable range for domesticated fishes[29, 30]. A summary of the growth performance and nutrient utilization of *C. carpio* fed on RLB and PLB bean based diets are presented in Table 4 and Figure 1. The feed conversion efficiency (FCE) was highest in fish fed on the control diet (166.6) and was significantly different ($P< 0.05$) from the values obtained for those fed on PLB bean diets (152–159). Fish fed on toasted LB bean diet had the least FCE (152), followed by those fed on fermented (154) and cooked (159) LB bean diets respectively. However, feed conversion ratio (FCR) was highest in fish fed on toasted LB diets (0.72) and is significantly different from those fed on the control, cooked, raw and fermented LB diets. The lowest % mean weight gain was recorded in fish fed on RLB diets (74%) while those fed on the control (139%) and cooked (133%) had the highest values. This trend is not unexpected since fish fed on the control diet and PLB diets ate more than those fed on RLB bean diets. Of the fishes fed on the test diets, those fed on cooked LB bean diets had the highest daily feed intake, mean weight gain, feed conversion efficiency and specific growth rate. This observation may be due to the conversion of nutrients in RLB beans in bioavailable, palatable and easily digestible form by cooking[17, 18]. The advantages associated with the use of PLB bean was further reflected in the survival rate of the fishes fed on it (90–92%) compared with those fed on RLB diets (75%). The high mortality rate and low digestibility in fishes fed on RLB bean diets might be due to the presence of antinutritional factors like trypsin inhibitor, lectin and tannin[9, 21]. The specific growth rate (SGR) obtained for *C. carpio* fed on cooked LB diet (4.03) is comparably higher than the values reported by Pinto and Rose[31], Rouse and Kahn[32] for redclaw crayfish (1.71 and 1.77 respectively) cultured in outdoor system. The best growth responses were obtained with *C. carpio* fed on the control diet, closely followed by those fed on diets based on cooked and toasted LB bean diets (Figure 1). The observed growth pattern in fish fed the various diets can be described using both linear and quadratic regression equations (Table 5a). These equations makes it easier to describe and predict the growth performance on the basis of weight gain over a given feeding time for each of the diets tested. A direct positive (Table 5b) linear and quadratic relationship (Table 5a) exists between final weight (g), *y*, and feeding period (weeks) *x* in *C. carpio*. However, the quadratic equations appear more appropriate by virtue of their higher R^2 value[33] than the linear equations. The regression

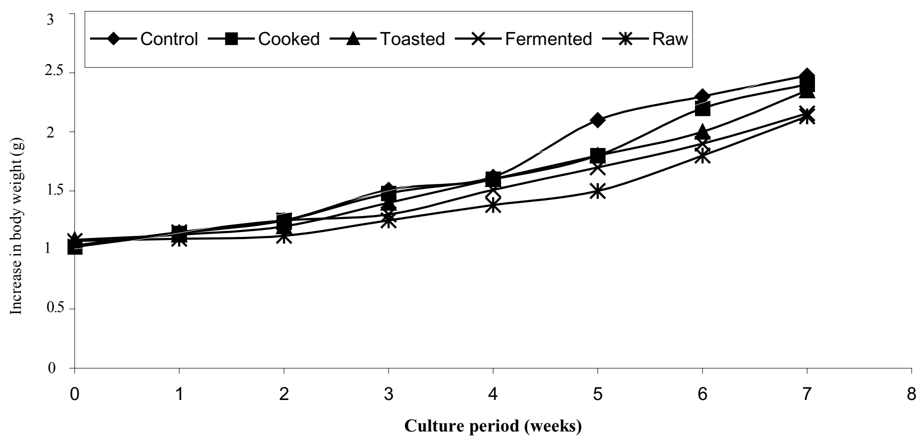

Figure 1. Weekly mean weight increase in body weight of Cyprinus carpio

equation $y = 0.0139x^2 + 0.1225x + 1.0078$ describes the relationship between final weight (y) and feeding time (x) when fed on the control diet, while $y = 0.0167x^2 + 0.0820x + 1.0334$ describes the relationship when fed on cooked LB bean based diets. Weight gained can then be determined by subtracting the initial weight (y_i) from the final weight (y). On the basis of these equations, the growth pattern of *C. carpio* can be simulated over wider feeding period with a good measure of accuracy.

Conclusions

This study showed that heat processing (cooking and toasting) and fermentation can significantly improve the digestibility of LB beans. Significant improvement in the growth performance of *C. carpio* can be obtained by feeding the fishes with cooked LB bean based diets. The observed growth pattern can be fully described using quadratic equations.

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