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Detoxification of Linseed and Sesame Meal and Evaluation of their Nutritive Value in the Diet of Common Carp (*Cyprinus carpio* L.)

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Abstract

The effect of two processing methods, aqueous extraction and autoclaving (120°C, 1 kg.cm^{-2}, 2 hours) for detoxifying linseed *(Linum usitatissimum)* and sesame meals *(Sesamum indicum)* on their nutritive value as a protein source for common carp was evaluated. Growth and feed utilization of carp fed diets with 25% of the total protein replaced by linseed or sesame seeds, which are either untreated, heat treated or aqueous extracted, were compared to a control diet with fishmeal as the sole protein source. The seven diets were made isonitrogenous (40% protein) and isocaloric (4.4 Kcal.g^{-1}) and were fed to carp initially weighing 3.3 g in three replicate tanks. Both methods of processing did not alter significantly the proximate and amino acid composition of the meals. Phytic acid contents were reduced by 48.2-71.8% and 50.8-74.0% in linseed and sesame meals, respectively with heat treatment resulting in greater reduction. Hydrocyanic acid content in linseed meal was reduced by 34.4-53.1%, with aqueous treatment resulting in the greater reduction. The results of the feeding trial showed that use of detoxified meals in diets significantly ($P < 0.05$) improved growth performance and food utilization of carp compared to those fed untreated meals but not to a level of performance obtained with a fish meal based control diet.

Introduction

Apart from amino acid imbalances, endogenous antinutritional factors are the main factors limiting the use of plant feedstuffs at high levels in animal and fish feeds. Phytic acid is one of the major toxic factors in both linseed and sesame meals (Erdman 1979;

Madhusudhan and Singh 1983). Linseed also contains linamarin or phaseolunatin from which acetone and hydrocyanic acid (HCN) are released by an autoenzyme linamarase (Montgomery 1964). However, reduction in toxicity of such feedstuffs may be accomplished by processing (e.g., water extraction, heat treatment) which inactivate enzymes or volatilize HCN that may have been released.

Several investigators have shown that linseed meal gave poor growth when substituted for protein supplements in chick starter diets. However, "water treatment" of linseed meal with two to three times its weight of water for 12 hours or more markedly improved its nutritive value (McGinnis and Pollis 1946; MacGregor and McGinnis 1948).

Phytic acid (myoinositol 1,2,3,4,5,6-hexakis dihydrogen phosphate) forms strong complexes with protein, calcium, magnesium, zinc and other polyvalent minerals, at pH levels found in intestines of fishes and other monogastrics (Erdman 1979). However, the ability of phytic acid to bind metal ions is lost when the phosphate groups are hydrolyzed through the action of the enzyme phytase (Liener 1977). A 50% decrease in phytate content was observed when whole soybeans were soaked in water for 24 hours at room temperature (Anon. 1976, cited by Cheryan 1980). Joseph (1973) also observed a decrease in phytate in cassava after soaking. Autoclaving of the protein source reduced the requirements of chicks for supplementary zinc when fed isolated soybean protein or sesame diets (Kratzer et al. 1959; Lease et al. 1960). O'Dell (1962, cited by Lease 1966) found that 4-hour autoclaving reduced the phytic acid content of soybean protein from 2.68 to 0.36%.

Considering the poor growth performance observed in carp fed diets containing untreated linseed and sesame meals (Hossain and Jauncey 1989), the present study attempted to detoxify these meals by water extraction and heat treatment and to evaluate their nutritive value in the diet of common carp.

Materials and Methods

Experimental System and Animals

A warm water recirculating system consisting of thirty-two 10-l self cleaning circular tanks was used (Jauncey 1982). Flow rate was at 1 $l.min^{-1}$ for each tank and dissolved oxygen was maintained above

90% saturation by aeration. Water temperature was maintained at 27 ± 1°C by a 3 kw immersion heater placed in the header tank and controlled by a thermistor sensor via a proportional output circuit. A constant photoperiod of 12 hours light and 12 hours dark was maintained. A purpose built experimental fish holding system (Adikwu 1987) was used for feces collection. Water quality in both systems was monitored weekly: temperature 26-28°C; dissolved oxygen 6-8 mg^{-1}; total ammonia 0.1-0.54 $mg.l^{-1}$; and pH 6.6-7.5.

Fry of mirror variety of common carp were obtained from Humberside Fisheries, Cleaves Farm, Driffild, England. Fry were quarantined for 2 weeks before transferring to the Tropical Aquarium Building of the Institute of Aquaculture. Before the experiment fish were maintained for 2 weeks at 28°C in 200-l tanks in a recirculatory system and fed commercial trout pellet (Ewos Baker's Omega No. 3).

Detoxification of Linseed and Sesame Meals

Both linseed *(Linum usitatissimum)* and sesame meals *(Sesamum indicum)* were of Bangladeshi origin. Detoxification of linseed and sesame meals were accomplished by heat and aqueous treatments as follows:

(i) Heat treatment - The ground linseed and sesame meals were subjected to steam autoclaving for 2 hours at 120°C and 1 $kg.cm^2$ pressure in an autoclave. The meals were then dried at 40°C using an electric fan convector heater.

(ii) Aqueous extraction - Aqueous extraction of linseed and sesame meals was carried out according to Ballester et al. (1970). Linseed and sesame meals were soaked in 5 times their weight of water and kept in room temperature (25°C) for 18 hours. After treatments, the meals were filtered and air dried at 40°C using an electric fan convector heater.

All detoxified meals were analyzed for proximate and amino acid composition and the results are shown in Table 1. The available lysine and the antinutritional factors were also analyzed and the results are presented in Table 2.

Experimental Diets

Seven isonitrogenous (40% protein) diets were formulated (Table 3) using fish meal, untreated, heat treated and aqueous treated

Table 1. Proximate and amino acid composition of the dietary protein sources (% dry matter basis).

	Ingredients						
	Fish meal	Untreated linseed meal (UL)	Heat treated linseed meal (HL)	Aqueous treated linseed meal (AL)	Untreated sesame meal (US)	Heat treated sesame meal (HS)	Aqueous treated sesame meal (AS)
Dry matter	92.23	89.65	89.00	92.26	87.60	88.10	94.50
Crude protein	76.95	32.96	32.95	33.35	36.69	36.73	36.91
Crude lipid	10.19	2.81	2.80	2.52	2.48	2.46	2.20
Ash	11.73	11.86	11.80	11.90	13.20	13.21	12.94
Crude fiber	0.55	9.08	9.12	9.14	23.11	23.00	23.20
NFE[1]	0.57	43.29	43.33	43.09	24.52	24.60	24.75
Amino acids							
Arginine[2]	5.06	2.18	2.20	2.18	4.15	4.20	4.23
Histidine[2]	1.60	0.68	0.68	0.70	0.60	0.80	0.78
Isoleucine[2]	3.30	1.31	1.30	1.32	1.19	1.20	1.22
Leucine[2]	5.71	1.84	1.83	1.84	1.92	1.94	1.95
Lysine[2]	5.46	1.28	1.26	1.26	1.24	1.20	1.23
Methionine[2]	2.22	0.26	0.26	0.27	0.28	0.27	0.28
Cystine[2]	0.85	0.38	0.37	0.38	0.56	0.56	0.58
Phenylalanine[2]	2.82	1.52	1.50	1.54	1.55	1.57	1.56
Tyrosine[2]	2.10	0.66	0.65	0.66	0.78	0.76	0.77
Threonine[2]	3.19	1.25	1.26	1.25	1.24	1.23	1.24
Valine[2]	4.02	1.70	1.68	1.72	1.63	1.60	1.62
Alanine	4.65	1.62	1.60	1.61	1.63	1.62	1.64
Aspartic acid	7.60	3.16	3.10	3.14	3.18	3.14	3.20
Glutamic acid	10.35	6.15	6.17	6.17	6.17	6.18	6.21
Glycine	4.46	2.10	2.11	2.12	1.65	1.81	1.64
Proline	3.51	1.34	1.32	1.34	1.60	1.56	1.59
Serine	2.62	1.43	1.41	1.44	1.56	1.55	1.60

[1]Nitrogen free extractives calculated as 100 - (moisture + crude protein + crude lipid + ash + crude fiber).
[2]Essential amino acid (EAA).

Table 2. Effect of different processing treatments on available lysine, phytic acid and hydrocyanic acid contents (% dry matter basis) of linseed and sesame meals.

	Untreated linseed meal (UL)	Heat treated linseed meal (HL)	Aqueous treated linseed meal (AL)	Untreated sesame meal (US)	Heat treated sesame meal (HS)	Aqueous treated sesame meal (AS)
Available lysine	1.06	1.03	1.04	1.00	0.96	0.99
% of total lysine	82.8	81.7	82.5	80.6	80.0	80.5
Phytic acid	2.45	0.69	1.27	2.38	0.62	1.17
% reduction	-	71.8	48.2	-	74.0	50.8
Hydrocyanic acid	0.032	0.021	0.015	-	-	-
% reduction	-	34.4	53.1	-	-	-

linseed and sesame meals as dietary protein sources. Linseed and sesame meals were tested at a level of 25% of total dietary protein. The control diet was prepared with fish meal as the sole source of protein. 0.5% chromic oxide was added to study the nutrient digestibility of the experimental diets. The diets were prepared as described previously (Jauncey 1982). All the diets were analyzed for proximate and amino acid composition and the results are presented in Table 4.

Table 3. Composition of the experimental diets.

Ingredients	Diets 1 (control)	2 (UL)	3 (HL)	4 (AL)	5 (US)	6 (HS)	7 (AS)
Untreated linseed meal		30.04					
Heat treated linseed meal			30.35				
Aqueous treated linseed meal				29.99			
Untreated sesame meal					27.26		
Heat treated sesame meal						27.23	
Aqueous treated sesame meal							27.09
Fish meal	51.98	38.99	38.99	38.99	38.99	38.99	38.99
Cod liver oil	-	1.03	1.03	1.03	1.03	1.03	1.03
Soybean oil	4.70	4.15	4.15	4.25	4.33	4.33	4.40
Mineral mixture[1]	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Vitamin premix[2]	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Binder (CMC)[3]	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Chromic oxide	0.50	0.50	0.50	0.50	0.50	0.50	0.50
α-cellulose	8.00	5.00	5.00	5.00	2.00	2.00	2.00
Dextrin	26.82	12.00	11.98	12.24	17.89	17.92	-

[1]Mineral premix contains ($g.kg^{-1}$ of premix): $CaHPO_4 2H_2O$, 727.78; $MgSO_4 7H_2O$, 127.50; NaCl, 60.00; KCl, 50.00; $FeSO_4 7H_2O$, 25.00; $ZnSO_4 7H_2O$, 5.50; $MnSO_4 4H_2O$, 2.5375; $CuSO_4 5H_2O$, 0.7850; $CoSO_4 7H_2O$, 0.4775; $CaIO_3 6H_2O$, 0.2950; $Cr Cl_3 6H_2O$, 0.1275.

[2]Vitamin premix contains ($g.kg^{-1}$ of premix): thiamine 2.5; riboflavin 2.5; pyridoxine 2.0; pantothenic acid 5.0; inositol 100.0; biotin 0.3; folic acid 0.75; para aminobenzoic acid 2.5; choline 200; niacine 10.0; cyanocobalamin 0.005; retinol palmitate 100,000 IU; α-tocopherol acetate 20.1; ascorbic acid 50.0; menadione 2.0; cholecalciferol 500,000 IU.

[3]Carboxymethyl cellulose (high viscosity)

Table 4. Analyzed proximate, antinutritional factors and amino acid composition of the experimental diets (% dry matter basis).

Components	Diet No. 1 control	2 (UL)	3 (HL)	4 (AL)	5 (US)	6 (HS)	7 (AS)	Requirement for carp[1]
Dry matter	94.59	94.33	94.02	94.80	93.96	94.56	95.14	
Crude protein	39.66	39.87	40.50	40.41	39.83	40.09	41.40	
Crude lipid	10.20	9.85	10.27	10.08	9.87	10.18	9.93	
Ash	10.08	11.92	11.97	11.86	12.10	12.12	11.90	
Crude fiber	7.88	7.52	7.35	7.96	8.19	8.38	8.30	
NFE[2]	32.18	30.84	29.91	29.69	30.01	29.23	28.47	
Chromic oxide	0.49	0.52	0.50	0.50	0.51	0.49	0.49	
Total energy ($Kcal.g^{-1}$)	4.52	4.43	4.47	4.48	4.43	4.42	4.44	
Phytic acid	-	0.73	0.20	0.37	0.66	0.16	0.31	
Hydrocyanic acid[3]	-	0.01	0.006	0.004	-	-	-	
Amino acids								
Arginine	2.64	2.63	2.57	2.66	3.12	3.12	3.20	1.52
Histidine	0.85	0.83	0.80	0.86	0.83	0.84	0.86	0.56
Isoleucine	1.72	1.69	1.70	1.74	1.64	1.62	1.69	0.92
Leucine	3.10	2.79	2.86	2.75	2.72	2.75	2.80	1.64
Lysine	2.91	2.52	2.61	2.48	2.46	2.51	2.54	2.12
Methionine	1.19	0.93	0.92	0.96	0.94	0.92	0.96	0.64
Cystine	0.44	0.45	0.45	0.43	0.47	0.44	0.49	-
Phenylalanine	1.54	1.56	1.51	1.54	1.51	1.49	1.55	1.16
Tyrosine	1.15	1.02	1.07	1.00	1.01	1.00	1.08	-
Threonine	1.68	1.62	1.63	1.60	1.58	1.65	1.73	1.32
Valine	2.10	2.09	2.14	2.07	2.02	2.00	2.05	1.16
Alanine	2.41	2.30	2.31	2.35	2.26	2.28	2.33	-
Aspartic acid	3.90	3.92	3.95	3.96	3.78	3.80	3.91	-
Clutamic acid	5.41	5.89	5.81	5.92	5.72	5.70	5.84	-
Glycine	2.36	2.38	2.41	2.40	2.22	2.24	2.30	-
Proline	1.78	1.78	1.80	1.76	1.83	1.80	1.86	-
Serine	1.44	1.45	1.48	1.44	1.47	1.50	1.56	-

[1]EAA requirement of carp from Ogino (1980).
[2]Nitrogen free extractives calculated as 100 - (moisture + crude protein + crude lipid + ash + crude fiber).
[3]Hydrocyanic acid was estimated from its level in dietary linseed meal.

Experimental Procedure

Each treatment had three replicates, 12 fish per replicate, with a mean initial weight of 3.30 ± 0.04 g. The experiment was conducted for 8 weeks. Fish were acclimated to the experimental system for 7 days before the start of the experiment. Fish were fed 3 times daily at 6% of their body weight. At the start of the experiment fish were anesthetized and individually weighed to the nearest 0.01 g. For intermediate weighings, fish were bulk weighed every 7 days. The quantity of food fed was adjusted after each weekly weighing and fed for the subsequent week. At the end of the experiment 12 fish from each treatment, including control, were sampled for histological study of any change in the gill, thyroid, liver, muscle, kidney and intestine.

Analytical Methods

Proximate analysis of feed ingredients, diets and fish carcasses was performed according to AOAC (1980). Energy contents were analyzed using an Automatic Adiabatic Bomb Calorimeter (Gallenkamp and Co. Ltd., Loughborough, England). Chromic oxide was determined using the wet-digestion technique of Furukawa and Tsukahara (1966). Phytic acid was determined by the method of Wheeler and Ferrel (1971). HCN in linseed meal was determined according to the AOAC (1980) method of analysis for content of cyanogenic glucosides in feedstuffs. Amino acid analysis was performed using an LKB 4151 Alpha Plus amino acid analyzer (LKB Biochrom Ltd., Cambridge) according to manufacturer's recommendation for protein hydrolysates. The amino acid tryptophan could not be analyzed because of its destruction during acid hydrolysis. The available lysine content in protein sources was determined by the method of Roach et al. (1967).

Analysis of Experimental Data

Analysis of experimental results was conducted according to Castell and Tiews (1980). Statistical analyses were carried out by the Multiple Range Method of Duncan (1955).

Results

The two processing treatments caused no major change in proximate or amino acid composition (Table 1). Aqueous treatment had no affect on available lysine content. However, heat treatment resulted in slight reduction in available lysine content in both linseed and sesame meals (Table 2). Phytic acid and HCN levels were significantly reduced after processing linseed and sesame meals. Heat treatment resulted in 71.8-74.0% reduction in phytic acid content when aqueous extraction resulted in 48.2-50.8% reduction. The reduction of HCN in linseed meal was at 34.4% after heat treatment and 53.1% after aqueous extraction.

Fish Growth and Feed Utilization

Replacement of 25% of dietary fish meal protein with protein from linseed or sesame meals significantly depressed weight gain, specific growth rate (SGR), food conversion ratio (FCR), protein efficiency ratio (PER) and apparent net protein utilization (ANPU, Table 5, Fig. 1). Inclusion of detoxified linseed and sesame meals in diets significantly ($P < 0.05$) improved growth performance compared to the diets containing untreated meals. The fish meal based control diet produced significantly ($P < 0.05$) the best growth responses whilst diet 2 (UL) produced the poorest growth. However, there were no significant ($P > 0.05$) differences among the SGRs of the control and diets 4 (AL), 6 (HS) and 7 (AS). Both control and diet 6 (HS) produced significantly higher ($P < 0.05$) feed and protein efficiencies as well as ANPU.

Apparent nutrient digestibility values for the experimental diets are presented in Table 6. Apparent protein digestibilities (APD) for all the diets were fairly high (86.4-89.0%) with the control diet having the highest and diet 2 (UL) the lowest.

Proximate carcass composition of fish at the start and at the end of the experiment is presented in Table 7. Fish fed diets 2 (UL) and 5 (US) containing untreated linseed and sesame meal had significantly ($P < 0.05$) the higher moisture and lower lipid content. There was no significant difference in carcass protein content among fish fed the control diet and diets containing detoxified linseed and sesame meals.

Histological examination of the various organs such as gill, liver, muscle, thyroid and intestine of fish from the various dietary treatments revealed no significant difference in the morphology of these tissues among treatments.

Table 5. Growth and feed utilization of common carp fed the experimental diets for 8 weeks.

Components				Diet no.				
	1 (Control)	2 (UL)	3 (HL)	4 (AL)	5 (US)	6 (HS)	7 (AS)	± S.E.[2]
Mean initial weighted (g)	3.33^{a}	3.25^{a}	3.28^{a}	3.28^{a}	3.26^{a}	3.34^{a}	3.35^{a}	0.03
Mean final weight (g)	20.12^{a}	15.86^{f}	16.08^{e}	17.60^{c}	16.63^{d}	19.28^{b}	17.41^{c}	0.06
Weight gain (g)	16.79^{a}	12.61^{g}	12.80^{f}	14.32^{c}	13.37^{e}	15.94^{b}	14.06^{d}	0.03
% weight gain	504^{a}	388^{e}	390^{e}	438^{c}	410^{d}	477^{b}	420^{d}	3.35
SGR (% day)	3.21^{a}	2.83^{bc}	2.84^{b}	3.00^{ab}	2.64^{c}	3.13^{a}	2.94^{ab}	0.09
SGR as % of control	100	88.16	88.47	93.45	82.24	97.50	91.58	-
FCR	1.50^{de}	1.60^{b}	1.65^{a}	1.54^{c}	1.53^{cd}	1.48^{e}	1.56^{c}	0.01
PER	1.69^{a}	1.56^{d}	1.50^{e}	1.60^{c}	1.65^{b}	1.69^{a}	1.55^{d}	0.01
ANPU (%)	25.58^{a}	22.60^{e}	22.43^{e}	24.12^{b}	23.73^{c}	25.55^{a}	23.10^{d}	0.06

[1]Figures in the same row having the same superscripts are not significantly ($P > 0.05$) different.
[2]Standard error of treatment mean calculated from the residual mean square in the analysis of variance.
[3]Hydrocyanic acid was estimated from its level in dietary linseed meal.

Table 6. Apparent nutrient digestibility (%) of the experimental diets.

				Diet No.			
	1 (control)	2 (UL)	3 (HL)	4 (AL)	5 (US)	6 (HS)	7 (AS)
Apparent dry matter digestibility	77.62	65.10	66.66	67.10	65.77	67.54	67.33
Apparent protein digestibility	88.97	86.36	87.09	87.42	86.68	87.76	88.20
Apparent lipid digestibility	93.09	87.60	91.49	89.00	90.81	87.85	88.78
Apparent ash digestibility	39.34	29.88	33.50	34.01	31.26	32.79	30.41
Apparent energy digestibility	82.08	73.45	74.26	75.10	74.19	75.33	74.75

*No statistical analyses were possible as determinations were performed on pooled samples.

Table 7. Proximate carcass composition (% fresh matter basis) of fish samples at the start and the end of the experiment.

Components	INITIAL (all fish)	FINAL Diet no. 1 (Control)	2 (UL)	3 (HL)	4 (AL)	5 (US)	6 (HS)	7 (AS)	± S.E.[2]
Moisture	80.86	77.60^{d1}	78.47^{a}	78.00^{b}	77.91^{c}	78.53^{a}	77.70^{d}	78.04^{b}	0.05
Crude protein	13.18	14.77^{a}	14.23^{bc}	14.62^{a}	14.66^{a}	14.16^{c}	14.74^{a}	14.56^{a}	0.07
Crude lipid	3.27	5.18^{a}	4.48^{d}	4.64^{cd}	4.80^{bc}	4.48^{d}	4.91^{b}	4.71^{c}	0.06
Ash	2.29	2.31^{d}	2.50^{a}	2.44^{ab}	2.38^{bcd}	2.52^{a}	2.34^{cd}	2.40^{bc}	0.03
TOTAL	99.60	99.86	99.68	99.70	99.75	99.69	99.69	99.71	-

[1]Figures in the same row having the same superscripts are not significantly ($P > 0.05$) different.
[2]Standard error of treatment mean calculated from the residual mean square in the analysis of variance.

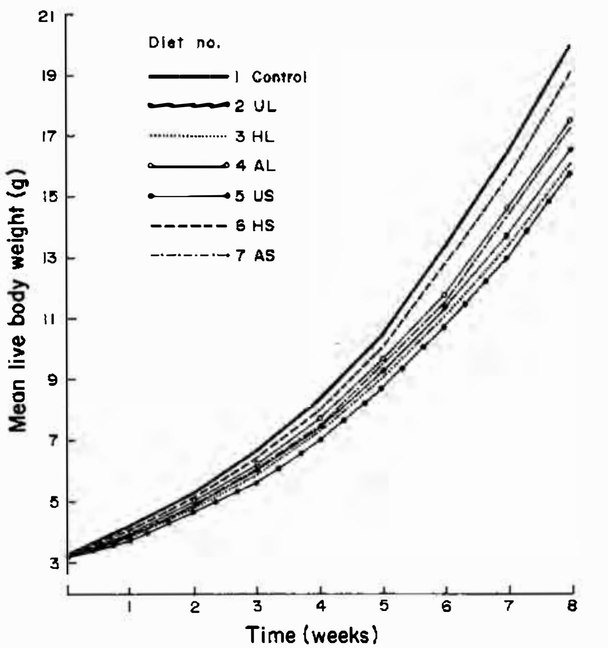

Fig. 1. Growth response of fish fed experimental diets for 8 weeks.

Discussion

In the present study, heat and aqueous treatments did not significantly affect proximate and amino acid composition and available lysine levels (Table 2 and 4). In general, available lysine followed the relative pattern of total lysine values, broadly suggesting no serious effect of processing. Similarly Mandokhot and Singh (1979) reported no effect of processing on the amino acid composition, including lysine content of linseed meal. Abel et al. (1984) also found that available lysine content in full fat soybean was not affected by heat treatment. By contrast, significant reduction (about 22%) in lysine content in rapeseed during heat processing was reported by Mustakas et al. (1965).

Heat treatment was found to be more effective than aqueous extraction in the reduction of phytic acid content while aqueous extraction resulted in greater HCN reduction (Table 2). As mentioned earlier, O'Dell (1962, cited by Lease 1966) found that 4-hour autoclaving resulted in a reduction of 86.56% in the phytic acid content of soybean protein. Although aqueous extraction was less effective in reducing phytic acid levels the decreases were appreciable (linseed 48.16%, sesame 50.84%). Chang et al. (1977) reported that incubation of presoaked beans in water at 60°C for 10 hours lowered phytate content by 90%. Soaking of cassava in water at room temperature has also been reported to reduce the phytate content (Joseph 1973). The reduction in phytic acid observed after aqueous treatment is probably due to the breakdown or partial hydrolysis of phytic acid.

In the present study untreated linseed contained 0.032% HCN which is slightly lower than the other reported values (0.038%; Mani et al. 1949). Aqueous and heat treatment of linseed meal resulted in 34.38 and 53.12% reduction in HCN, respectively. MacGregor and McGinnis (1948) reported that simple water extraction of linseed meal apparently destroyed the toxic factors. Raymond et al. (1941) reported that boiling of cassava reduced the HCN content from 332 $mg.kg^{-1}$ to 10 $mg.kg^{-1}$. Drying of cassava at 60°C was capable of removing up to 90% of the HCN (Charavanapavan 1944, cited by Coursey 1973). The reduction of HCN in linseed meal by processing is likely to be due to volatilization of HCN (Liener 1977).

The results of the present growth trial indicate that the use of detoxified linseed and sesame meals in carp diet improved the growth performance of fish compared to the untreated meals. Abel et al. (1984) reported higher growth performance of carp fed diets containing 50% heat treated soybean meal compared to that obtained with commercially available feeds. Lease (1966) also reported that 4-hour autoclaving of sesame meal led to a significant increase in growth in chicks, no leg deformities and an increase in the zinc contents of the bone ash comparable to untreated meals with 60 ppm of supplemental zinc. Since phytic acid is rather easily hydrolyzed by autoclaving it seems likely that the beneficial effect of heat treatment resulted from destruction of phytic acid (O'Dell et al. 1964).

Among linseed meal containing diets fish fed diet 4 (AL) produced significantly ($P < 0.05$) the highest weight gain, about 85% of that of the control (Table 5). Fish fed diet 7 (AS) also produced higher weight gains than those fed diet 5 (US). Kratzer (1947) and MacGregor and McGinnis (1948) reported increased growth in poultry fed "water-treated" linseed meal compared to untreated meals. Singh and Punia (1979) also used water autoclaved linseed meal at 50% replacement of groundnut meal in poultry feed and found comparable growth to poultry fed groundnut meal. No reports appear in the literature concerning the use of heat treated or aqueous treated linseed or sesame meals in fish feeds. However, the improved growth performance of fish fed diets 4 (AL), 7 (AS) and 3 (HL) compared to diets containing untreated linseed and sesame meals is likely to be due to the lower HCN and phytic acid contents of these diets (Table 4).

In the present study use of detoxified linseed and sesame meals in diets significantly improved both feed and protein utilization compared to the diets with untreated meals (Table 5). The FCRs, PERs and ANPUs obtained here with diets containing detoxified meals were better than those for carp fed the same inclusion levels of untreated linseed and sesame meals (Hasan 1986).

Use of detoxified linseed and sesame did not improve nutrient digestibility (Table 6). Srivastava and Hill (1976) reported that heat treatment did not improve the digestibility of rapeseed meals in rats. The apparent protein digestibility values of diets containing linseed and sesame meals reported here are comparable to those found by Hasan (1986) in common carp fry fed diets containing similar levels of linseed and sesame meals. The apparent energy digestibility values of diets containing linseed and sesame meals are similar to the reported values for canola meal (75%) for trout (Hilton and Slinger 1986); peanut (76%) for channel catfish (Wilson and Poe 1985) and somewhat higher than those for rapeseed meal (65%) and cottonseed meal (64%) for trout (Smith et al. 1980).

Fish fed the control and diet 7(HS) showed significantly ($P < 0.05$) the lower moisture and higher lipid content whilst the diets containing untreated meals resulted in higher moisture and lower lipid levels (Table 7). The inverse relationship between carcass lipid and moisture recorded here has also been reported by other authors (Andrews and Stickney 1972; Atack et al. 1979). There was no variation in the carcass protein content of fish fed the control and diets containing detoxified meals. The lower carcass lipid contents of fish fed the diets containing oilseed meals compared to that of fish fed the fish meal based control diet has also been reported by Tacon and Ferns (1976) in rainbow trout fed single cell protein, Dabrowski and Kozlowska (1981) in carp fed rapeseed meal and Appler and Jauncey (1983) in tilapia fed algal protein.

The results of this investigation revealed that heat treatment was more effective than aqueous treatment in reducing antinutritional factors in linseed and sesame meals. The use of detoxified meals in diets improved the growth performance and feed utilization of carp compared to the untreated meals but not to a level of performance obtained with a fish meal based control diet.

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