Effects of dietary baker's yeast extract on the growth, blood indices and histology of Nile tilapia (*Oreochromis niloticus* L.) fingerlings

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Effects of dietary baker's yeast extract on the growth, blood indices, and histology of Nile tilapia, *Oreochromis niloticus* L, fingerlings

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Abstract

Nile tilapia, Oreochromis *niloticus* (average initial weight, 5.91 ± 0.04g) were fed four isonitrogenous and isolipidic diets for 84 days. The diets contained four levels of yeast extract (CW-I) rich in nucleotides and β-glucan: 0 (control), 5, 10, and 15 g kg^{-1} diet. Weight gain increased linearly while the feed conversion ratio decreased linearly with increasing levels of yeast extract. The diet containing 15g kg^{-1} yeast extract resulted in significantly better ($P<0.05$) specific growth rates and protein efficiency ratios. No significant ($P>0.05$) differences were found in dry matter, protein, lipid, or ash contents or in hematocrit, hemoglobin, or total protein contents among the treatment groups. Blood sample profiles showed an increase in white and red blood cells in fish fed 15g kg^{-1} yeast extract in comparison with the other treatment groups. The fish fed the diets with 10 and 15 g kg^{-1} yeast extract had significantly higher albumin and globulin levels than did the control group, while decreased levels of cholesterol and triglycerides, aspartate aminotransferase, and alanine aminotransferase were noted in fish fed the diet with 15g yeast extract kg^{-1}. Histological analysis of the liver and intestine in fish fed control diet showed substantial damage and even necrotic lesions. Only in fish fed diets supplemented with the highest amount of yeast extract was the structure of the hepatocytes and villi almost unchanged, which indicated that the yeast nucleotides could improve hepatic function and promote liver and gut restoration.

Keywords: Yeast extract, nucleotides, growth, hematology, histology, *Oreochromis niloticus*

Introduction

One of the main challenges in achieving productive, feasible, sustainable aquaculture is to develop alternative prophylactics that could help to maintain high animal welfare standards that foster better production and higher profits. Fish diets should not only provide the essential nutrients that are required for normal physiological functioning, but they should also serve as the medium by which fish receive other components that affect their health (Li and Gatlin 2004). Baker's yeast, or *Saccharomyces cerevisiae* yeast, is a particularly important natural bio-product since it contains immunostimulating compounds such as nucleotides, β-glucan, mannan oligosaccharides, and chitin, and it has been proved to influence the fish immune response and to promote growth (Abdel-Tawwab 2012). On the other hand, commercial brewer's yeast is an inactive yeast (dead yeast cells) that is a by-product of brewing. The cell wall, which can comprise 20–25% of the dry weight of the cell, consists of about 85–90% polysaccharide. The polysaccharide component consists of a mixture of mannan, glucan, and small amounts of chitin (Nguyen *et al.* 1998). Numerous studies have focused on the effect of mannan oligosaccharides, glucans, and chitin on the immune response in different fish species, and indicate that these compounds strongly stimulate fish immune systems (Couso *et al.* 2003, Torrecillas *et al.* 2007). Yeast extract is the product of the enzymatic digestion of the yeast cell constituents by endogenous and exogenous yeast enzymes (Bekatorou *et al.* 2006). Yeast extract is considered an important source of nucleotides in the form of nucleic acids (Ferreira *et al.* 2010). Nucleotides are low molecular weight biological compounds that play important roles in essential physiological and biochemical functions (Carver and Walker 1995). Nucleotides are synthesized *de novo* in most tissues, but some immune and intestinal cells lack or cannot execute this process and depend on exogenous dietary supply (Quan 1992). Hence, the administration of pure nucleotides guarantees increased availability to the body at times of high demand for various

physiological activities (Biswas *et al.* 2012). High dietary concentrations of nucleotides can also compromise growth and protein accretion (Peres and Oliva-Teles 2003, Oliva-Teles *et al.* 2006). It has been demonstrated that nucleotides added to basal diets can affect positively fish growth (Li *et al.* 2005), innate and adaptive immune responses (Sakai *et al.* 2001, Li *et al.* 2004, Li and Gatlin 2004) and disease resistance (Barros *et al.* 2013). However, most experiments on the effect of baker's yeast on the growth and physiological condition in different fish species have focused on investigating the effects of whole yeast cells, or of bioactive components that were isolated from whole yeast cells, such as nucleotides or β-glucan. To the best of the authors' knowledge, there is little information regarding the effect on fish immune responses of baker's yeast extract that contains both nucleotides and β-glucan. Therefore, this study was designed to evaluate the efficacy of baker's yeast extract (CW-I) supplementation on the growth, feed utilization, hematological, and histological and biochemical blood parameters of Nile tilapia, *Oreochromis niloticus* L.

Materials and methods

Experimental design and culture technique

Nile tilapia, *Oreochromis niloticus* fingerlings were collected from the Fish Research Station, El-Kanater El-Khayria, National Institute of Oceanography and Fisheries, Cairo, Egypt and held for two weeks in indoor fiberglass tanks for acclimation. Prior to the beginning of the experiment, the fish were acclimatized to experimental conditions and manually fed a commercial diet (300 g kg^{-1} crude protein) twice daily to apparent satiation for seven days. After acclimatization, 600 Nile tilapia fingerlings with an average initial body weight of 5.91 ± 0.04 g were stocked into 12 concrete ponds (0.5 m^3). Each pond was stocked with 100 fish and maintained in freshwater at 26 °C (± 2.0) under a natural photoperiod. All dietary treatments were tested in triplicate, and each pond was considered to be an experimental unit. During the experiment, the fish were fed manually two times daily to

apparent satiation at 09:00 and 15:00. The total fish weight in each pond was determined every two weeks to check their growth. Feeding was stopped 24 h prior to weighing. A volume of 30% of the fresh water in each pond was renewed through the outlet at the bottom of the ponds daily before feeding. They were provided with continuous aeration to maintain the dissolved oxygen level near saturation, and the fish were held under natural light. Water temperature and dissolved oxygen were measured every other day using a YSI 58 oxygen meter (YSI Company, Yellow Springs Instrument, Yellow Springs, Ohio, USA). Total ammonia and nitrite were measured twice weekly with a DREL 2000 spectrophotometer (Hash Company, Loveland, CO, USA). Total alkalinity and chloride were monitored twice weekly by titration; pH was monitored twice weekly using a pH meter (Orion pH meter, Abilene, Texas, USA). All tested water quality criteria (temperature, DO, pH, total ammonia and nitrite) were estimated according to standard methods as described elsewhere (Hassaan *et al.* 2014).

Experimental diets

Four isonitrogenous and isolipidic diets were formulated (Table 1). Soybean meal contributed the major portion of dietary protein. The proximate composition of the experimental diets was within the desired formulated values with about 300 g kg^{-1} crude protein and 19.45 MJ kg^{-1} gross energy. The control diet contained no added yeast extract. Three diets were supplemented with 5, 10, and 15 g kg^{-1} yeast extract per diet, respectively, (Mark Co., Ltd., Tokyo, Japan (CW-I). The final product was in the form of a fine powder, containing nucleotides (104.4 g kg^{-1}) and β-glucan (70.3 g kg^{-1}). The ingredients were ground into fine powder through 200 μm mesh. The quantities of extract were mixed with 6 ml of distilled water and added to the base ingredient, all the ingredients were thoroughly mixed with soybean oil, and then the mixture was passed through a laboratory pellet mill (2-mm die; California Pellet Mill, San Francisco, CA, USA) at the National Institute of Oceanography and Fisheries, Cairo Governorate, Egypt, and stored at −20 °C until used.

Growth parameters

At the end of the feeding trial, 24 h following the last feeding, all the fish were counted and weighed to determine final body weight (g), weight gain (WG), specific growth rate (SGR, % day^{-1}), feed conversion ratio (FCR), protein efficiency ratio (PER), and feed intake. The growth response parameters were calculated as follows:

Weight gain (WG) = final body weight (g) – initial body weight (g)

Specific growth rate (SGR) =100× (Ln *W2* - Ln *W1*)/T

Where: Ln = natural log; W1 = initial body weight; W2 = final body weight and T = study period (84 days). Feed conversion ratio (FCR) = Feed intake (g)/WG (g). Protein efficiency ratio (PER) = WG (g)/Protein intake (g).

Hematological and biochemical blood analysis

At the end of the experimental trial, ten fish were collected randomly from each of the treatment and control groups. The fish were anesthetized with benzocaine (50 mg l^{-1}) (Sigma–Aldrich) before blood was drawn. Blood samples were collected from the caudal vein of the fish from all treatments and were divided into two portions. The first portion was collected with anticoagulant 10 % EDTA (ethylenediaminetetraacetate) to measure hematocrit (Htc), hemoglobin (Hb), red blood cells (RBCs), and white blood cells (WBCs). Htc was determined and described by (Reitman and Frankel 1957), hemoglobin (Hb) was determined with hemoglobin kits, which is the standard procedure for the cyanomethemoglobin method. RBCs were counted under a light microscope using a Neubauer hemocytometer after blood dilution with phosphate-buffered saline (pH 7.2), the WBCs were determined according to (Barros *et al.* 2009). The second portion of the blood sample was allowed to clot overnight at 4ºC, and then it was centrifuged at 3,000 rpm for 10 min. Non-hemolyzed serum was collected and stored at -20 ºC until analysis. Levels of serum aspartate aminotransferase (AST), alanine aminotransferase (ALT) according the method described by Reitman and Frankel (1957),

while serum creatinine was measured with the colorimetric method and enzymatic determination methods and described by (Henary *et al.* 1974). In addition, serum total protein, albumin, and globulin were determined spectrophotometrically using methods described by Doumas *et al.* (1981).

Histological analysis

On day 84 of the experiment, the livers and digestive tract mid-sections of five fish from each treatment were excised carefully and fixed in 10% formalin, dehydrated in ascending grades of alcohol, and cleared in xylene. The fixed tissues were embedded in paraffin wax, and 5 μm sections were cut with a Euromex Holland microtome (Arnhem, The Netherlands). The sections were stained with the Harris hematoxylin and eosin (H&E) method. Next, these sections were examined microscopically, and photographs were taken with a microscope camera (Bernet *et al.* 1999).

Chemical composition

At termination of the trial, a random sample of five individual fish were sampled from each pond, oven-dried at 105 ºC for 24 h, ground, and stored at -20 ºC for subsequent analysis. Proximate analysis was conducted on both diet and fish samples. Dry matter, total lipids, crude protein, and ash contents were all determined with standard methods (AOAC 1995). Dry matter was determined after drying the samples in an oven (105 ºC) for 24 h. Ash was determined by incineration at 550 ºC for 12 h (AOAC 1995); according to method number 942.05). Crude protein was determined with the micro-Kjeldhal method, N × 6.25 (using a Kjeltech 1030 auto analyzer, Tecator, Höganäs, Sweden) according to method number 984.13, and crude fat by Soxhlet extraction with diethyl ether (40–60 ºC) (AOAC 1995); according to method number 920.39). Total carbohydrate was computed by subtracting the sum of the crude protein, crude lipid, and ash contents from 100.

Statistical analysis

171 Data were analyzed statistically with ANOVA using the SAS ANOVA procedure
172 (Statistical Analysis System 2004). The data were submitted to one-way classification
173 variance analysis. Duncan's multiple range test was used to compare differences among
174 treatment means when significant F values were obtained (Duncan 1955) at a level of
175 significance of $P < 0.05$. A linear model was performed with Sigma Plot version 8 (SPSS Inc.
176 Chicago, IL, USA) for the response variable using means ± SE. All percentage data were arc-
177 sin transformed prior to analysis (Zar 1984); however, the data are presented untransformed to
178 facilitate comparisons.

179 Results

180 *Growth parameters*

181 The positive water quality criteria were associated with good growth performance
182 since there were no mortalities in any of the treatments throughout the experiment. The
183 growth performance of *Oreochromis niloticus* fed the experimental diets is presented in Table
184 2. There were no significant differences in initial weights among the treatment groups;
185 however, after 84 days the group fed the diet containing 15 g kg^{-1} yeast extract had the highest
186 final body weights and specific growth rates (SGR). Figure 1 shows that weight gain (WG)
187 increased linearly as dietary supplementation increased. Feed intake in the present study
188 increased significantly with increased levels of yeast extract. Figure 1 showed that the feed
189 conversion ratio (FCR) decreased linearly as dietary supplementation increased. The addition
190 of yeast extract to the feed also produced a better protein efficiency ratio (PER) with values
191 significantly ($p<0.05$) higher than those in the control, more specifically in the groups treated
192 with 15 g kg^{-1} yeast extract. There was no significant difference in the final body weight,
193 SGR, or PER between groups 5 and 10 g kg^{-1} yeast extract.

194 Chemical composition of whole fish

195 According to the body analysis composition data at the end of the experiment,
196 supplementing the feed with yeast extract did not have a significant ($P > 0.05$) impact on dry
197 matter, lipid, crude protein, or ash contents of the fish (Table 3).

198 Hematological parameters

199 Table 4 shows the effect of yeast extract on Nile tilapia hematological indexes including
200 hematocrit (Htc), hemoglobin (Hb), and the red blood cell (RBC), and white blood cell
201 (WBC) counts. No significant differences were noted in Hct or Hb levels among all the
202 treatments. RBC and WBC counts were significantly ($P<0.05$) higher in the fish fed the
203 highest level of yeast extract (15 g kg^{-1} diet) in comparison with other treatment groups.

204 Biochemical blood parameters

205 According to the results of the analysis, the fish that received the highest concentration of
206 yeast extract (15 g) in their diets exhibited significantly ($P<0.05$) lower AST and ALT activity
207 in comparison with the values noted in the other treatments (Table 5). No significant ($P >$
208 0.05) differences were noted in the total protein levels in any of the treatments. Fish fed diets
209 containing 10 and 15 g kg^{-1} yeast extract had significantly higher albumin and globulin levels
210 than did the fish fed control diet (Table 5). Some of the other recorded parameters, such as
211 cholesterol and triglyceride levels, in the fish supplemented with yeast extract were
212 significantly lower ($P<0.05$) than those in the control group. The lowest cholesterol and
213 triglyceride levels were recorded in fish fed diets with 15 g kg^{-1} yeast extract (Table 5).

214 Histology

215 The liver and intestine histology of Nile tilapia fed diets with control and/or different
216 levels of yeast extract are illustrated in Figure 2. The histological changes in fish liver and
217 intestines were assessed with light microscopy, which revealed that the fish fed the control
218 diet exhibited some changes in these organs. Changes in the liver included degeneration and
219 necrosis in the hepatocytes with congestion in the blood sinusoids of fish fed control diet

220 (Figure 2a), while the intestine showed degeneration in mucosa and necrosis in submucosa layers in
221 fish fed the control diet (Figure 2c). Fish fed diet supplemented with (10 or 15 g kg^{-1}) exhibited an
222 almost normal hepatocyte structure (Figure 2b) and intestinal layers (Figure 2d).

223 **Discussion**

224 The diet supplemented with high levels of yeast extract (15g kg^{-1}) increased the growth
225 rate and feed utilization of Nile tilapia. The yeast extract used in the present study contained
226 nucleotides (10.44 g kg^{-1}) and β-glucan (70.3 g kg^{-1}), which facilitated fish growth (Carver
227 1994). Supplemented diets with 0.1% β-glucan improved Nile tilapia weight gain (Welker *et*
228 *al.* 2012). Diets containing β-glucan and mannan oligosaccharides (MOS) have also
229 previously been found to improve the growth performance of Nile tilapia and Beluga, *Huso*
230 *Huso* (Abdel-Tawwab *et al.* 2008, Selim and Reda 2015, Ta'ati *et al.* 2011). In our experiment,
231 feed intake increased significantly with increasing levels of *Saccharomyces cerevisiae* extract
232 in the diet. This could have been because the extract nucleotide content of adenosine
233 monophosphate, inosine monophosphate, uridine monophosphate, and adenosine diphosphate
234 are proven palatability enhancers and feed attractants (Li and Gatlin 2006, Oliva-Teles *et al.*
235 2006). Furthermore, dietary nucleotide supplementation has also been shown to enhance
236 growth in other fish species such as Atlantic salmon (Burrells *et al.* 2001), grouper,
237 *Epinephelus malabaricus* (Lin *et al.* 2009) and rainbow trout, *Oncorhynchus mykiss*
238 (Tahmasebi-Kohyani *et al.* 2011). However, JarmoŁowicz *et al.* (2012) reported that
239 supplementing diets with yeast extract (NuPro®) did not significantly impact the growth rates
240 of juvenile European pikeperch, *Sander lucioperca*. The reasons for the differences among
241 these studies could stem from the differences in species, physiological conditions, and the
242 type of basal ingredients in the diets.

243 No significant ($P>0.05$) differences were noted in the analysis of the proximate
244 composition of Nile tilapia fed the experimental diets. JarmoŁowicz *et al.* (2012) observed

that brewer's yeast extract supplementation did not interfere with the metabolism or deposition of nutrients in juvenile pikeperch tissues. The present data was confirmed by the observations of Peres and Oliva-Teles (2003), who supplemented fish diets with nucleotides. Lunger *et al.* (2006) noted that increasing levels of *Saccharomyces cerevisiae* extract did not affect nutrient deposition in Nile tilapia. On the other hand, Ebrahimi *et al.*(2012) demonstrated that a combination of β-glucan and MOS added to diets in the amount of 2.5 g kg^{-1} improved the crude protein content in common carp fingerlings.

No significant differences in hemoglobin or hematocrit levels were observed among the fish groups fed diets with yeast extract. Similarly, yeast RNA supplementation had no effect on hematological values of *Labeo rohita* or *Catla catla* Choudhury *et al.* (2005) and Jha *et al.* (2007). Brewer's yeast extract in doses of 15 g kg^{-1} diet significantly enhanced the WBC count in Nile tilapia blood, which concurs with the study by (Jha *et al*. 2007), who found that there was an increase in leukocyte count when *C. catla* fingerlings were treated with nucleotides. Dietary yeast extract activated other functions of carp leucocytes, including phagocytosis that resulted in an increased phagocytic index value (Biswas *et al*. 2012). Other research has also shown that exogenous nucleotides can influence both the humoral and cellular components of the innate immune system of common carp (Sakai *et al*. 2001) and hybrid striped bass (Li *et al*. 2004). The dietary yeast extract used in the present study caused elevated albumin and globulin levels in serum. Albumin and globulin are essential for a healthy immune system (Tahmasebi-Kohyani *et al*. 2011). The tilapia diet yeast extract supplement elevated the serum albumin and globulin contents in Nile tilapia. The highest globulin values were noted in *C. catla* fed diets supplemented with yeast RNA, and an increasing trend was noted along with increases in nucleotides (Jha *et al*. 2007). On the other hand, El-Boshy *et al.* (2010) noted a significant increase in cellular and humoral immunity in Nile tilapia that received β-glucan at 0.1% of the diet for three weeks. In contrast, (Barros *et*

al. 2013) proved that plasma total protein, globulin, and albumin in Nile tilapia were not affected by nucleotide levels. JarmoŁowicz *et al*. (2012) also reported that dietary yeast extract had no significant effect on total protein in juvenile pikeperch.

ALT and AST transaminases are important liver enzyme indicators of liver health that control the transfer of amino groups from alpha-amino acids to alpha-keto acids. Thus, high levels of ALT and AST are mostly released into the blood when there is liver cell damage Racicot *et al. (*1975). In the present study, lower levels of AST and ALT were noted in fish fed diets supplemented with the highest amount of yeast extract (15 g kg^{-1}), which might indicate improved liver function (Metwally 2009). Similarly, juvenile pikeperch that received yeast extract (40 and 60 g kg^{-1} diet) in their diets exhibited significantly lower AST and ALT activity in comparison with the control group JarmoŁowicz *et al*. (2012). Histological analysis corresponded with the lower liver transaminases noted in the groups that received 15 g kg^{-1} yeast extract, which might also indicate improved liver function. Microcopy observations revealed there was little liver or intestine damage after yeast extract diet supplementation. Meanwhile, in other analyzed variants (even in the control group) significant damage was noted in these organs including degeneration, necrosis in hepatocytes, and degeneration in the hypodermis layer and villi, which often occurs after feeding of high soybean diets or in intensive fish farming conditions. A histological analysis of the liver of sea bass fed different levels of yeast extract showed steatosis with fat degeneration, while liver morphology was considerably improved with yeast extract supplementation (Panagiotidou *et al.* 2009). Moreover, nucleotide supplementation significantly increased distal intestine fold height, enterocyte height, and microvillus height in juvenile turbot, *Scophthalmus maximus*, compared to the control diet (Peng *et al.* 2013). In turn, Cheng *et al.* (2011) noted that dietary nucleotide supplementation significantly improved intestinal structure in red drum. JarmoŁowicz *et al*. (2012) reported that changes in intestinal

morphology result in greater cell absorption activity and better digestion of nutrients in the intestine, which usually leads to improved growth performance and feed utilization. The beneficial effects of dietary nucleotides on hepatocytes and the gastrointestinal tract have been more widely investigated in mammals, and nucleotides have been found to improve hepatic function and to promote earlier restoration of nitrogen balance following liver injury (reviewed by (Sauer *et al.* 2009). Dietary nucleotides have also been noted to repair intestinal mucosa after chronic diarrhea induced by a lactose enriched diet in weanling rats fed AMP, GMP, IMP, CMP, and UMP (50 mg 100 g^{-1}each) (Bueno *et al.* 1994). Nucleotides are partly absorbed in the gut as nucleosides trough active transport and Na^{+} cotransport and incorporated into body tissues, mainly the liver, spleen, bone marrow, and gut (Bueno *et al.* 1994). Dietary sources of nucleotides might be conditionally essential nutrients. Rapidly growing tissues such as intestinal epithelium or lymphoid cells lack significant capacity for *de novo* synthesis of nucleotides and require exogenous sources of purine and pyrimidine bases (Uauy *et al.* 1994).

The present study is the first report on the triglyceride and cholesterol parameters of Nile tilapia fed diets supplemented with yeast extract, and these levels were significantly lower in comparison with the control group. In another 8-week study rainbow trout fed a diet supplemented with 1–2g kg^{-1} nucleotides exhibited significant decreases in low-density lipoprotein (LDL)-C and triglycerides in comparison with the control fish (Mohebbi *et al.* 2013). In recent years, dietary nucleotides have been shown to influence lipid metabolism and fatty acids, but the mechanisms by which dietary nucleotides affect circulatory lipids concentrations are not clear. Some researchers believe that dietary nucleotides might increase the synthesis of long-chain polyunsaturated fatty acids possibly by influencing the activity of intestinal and hepatic desaturase enzymes (Gil *et al.* 1988). For example, feeding a

nucleotide-supplemented diet resulted in a significant increase in plasma polyunsaturated fatty acids in mammals (Gil *et al.* 1986, Boza *et al.* 1992, Jiménez *et al.* 1992).

Generally, brewer's yeast is a particularly important natural bio-product since it contains immune-stimulating compounds such as β-glucan, nucleotides, mannan oligosaccharides, and chitin, and it has been proven to influence the immune response (Abdel-Tawwab 2012, Li *et al.* 2004, Bidhan 2011). The results of our study indicate that the diets supplemented with yeast extract improved growth, and have beneficial effects on hematological and biochemical blood parameters, lipid profiles, and the histological structure of liver and gut of Nile tilapia. It can also be used as a source of nucleotides and β-glucan.

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TABLE 1 Composition and proximate analysis of the basal diet (g kg^{-1} dry matter)

Ingredients	Control	5g kg^{-1} yeast extract	10g kg^{-1} yeast extract	15g kg^{-1} yeast extract
Fish meal	100	100	100	100
Soybean meal	460	460	460	460
Yellow corn	295	295	295	295
Wheat bran	100	95	90	85
soybean oil	30	30	30	30
Vitamins and minerals[1]	15	15	15	15
Yeast extract (CW-I)	0	5	10	15
Proximate analysis (g kg^{-1} dry matter basis)				
Crude protein	300.50	298.80	298.00	297.30
Lipids	56.91	57.20	56.71	57.21
Ash	54.30	54.12	53.81	53.21
Total carbohydrate[2]	5883	589.88	591.84	592.28
Gross energy (MJ kg^{-1})[3]	19.45	19.44	19.42	19.43

[1]Vitamins and minerals mix: MnSO4, 40 mg; MgO, 10 mg; K2SO4, 40 mg; ZnCO3, 60 mg; KI, 0.4 mg; CuSO4, 12 mg; Ferric citrate, 250 mg; Na2SeO3, 0.24 mg; Co, 0.2 mg; retinol, 40000 IU; cholecalciferol, 4000 IU; α-tocopherolacetate, 400 mg; menadione, 12 mg; thiamine, 30 mg; riboflavin, 40 mg; pyridoxine, 30 mg; cyanocobalamin, 80 mcg; ;nicotinic acid, 300 mg; folic acid, 10 mg; biotin, 3 mg; pantothenic acid, 100 mg; inositol, 500 mg; ascorbic acid, 500 mg.
[2]Total carbohydrate =100-(crude protein + lipid + ash).
[3]Calculated using gross calorific values of 23.63, 39.52 and 17.15 KJ/ g for protein, fat and carbohydrate, respectively according to (Brett 1973)

TABLE 2 Growth indices and nutrient utilization of *O. niloticus* after 84 days of feeding yeast extract supplemented diets

Items	Control	5g kg^{-1} yeast extract	10g kg^{-1} yeast extract	15g kg^{-1} yeast extract	P value
Initial body weight (g $fish^{-1}$)	5.89±0.56	5.84±0.49	5.84±0.54	5.87±0.45	0.875
Final body weight (g $fish^{-1}$)	34.40±1.56^{c}	40.12±1.71^{b}	40.45±1.15^{b}	42.99±1.78^{a}	0.014
Specific growth rate (% per day)	1.95±0.12^{c}	2.12±0.11^{b}	2.13±0.09^{b}	2.31±0.13^{a}	0.012
Feed intake (g $fish^{-1}$)	52.88±1.13^{c}	54.78±1.88^{b}	55.39±1.90^{b}	56.33±1.18^{a}	0.023
Protein efficiency ratio	1.82±013^{c}	2.12±011^{b}	2.12±013^{b}	2.23±0.12^{a}	0.017

Results were presented as means ± SE of triplicate observations. Means in the same row with different superscript letters were significantly different ($p < 0.05$).

TABLE 3 Chemical composition of *O. niloticus* after 84 days of feeding yeast extract supplemented diets (g kg^{-1} wet basis)

Items	Control	5g kg^{-1} yeast extract	10g kg^{-1} yeast extract	15g kg^{-1} yeast extract	P value
Dry matter	272.17±1.89	277.02±2.01	278.34±1.87	279.46±2.10	0.084
Crude protein	158.25±1.23	159.21±1.52	159.98±2.11	162.02±1.15	0.781
Lipid	63.23±1.00	65.89±1.17	65.23±1.12	67.24±1.12	0.332
Ash	31.22±1.12	31.98±0.98	32.10±0.90	33.02±0.91	0.416

Results were presented as means ± SE of triplicate observations. Means in the same row with different superscript letters were significantly different ($p < 0.05$).

TABLE 4 Hematological parameters of *O. niloticus* after 84 days of feeding yeast extract supplemented diets

Items	Control	5g kg^{-1} yeast extract	10g kg^{-1} yeast extract	15g kg^{-1} yeast extract	P value
Hematocrit (%)	14.57±0.89	14.27±0.99	14.68±0.79	14.80±0.78	0.780
Hemoglobin (g dl^{-1})	10.31±0.65	10.45±0.50	10.65±0.52	11.00±0.46	0.452
WBCs ($\times10^{-3}mm^{-3}$)[1]	$35.67±0.95^{d}$	$37.00±0.87^{c}$	$38.33±1.01^{b}$	$40.00±1.00^{a}$	0.018
RBCs ($\times10^{-3}mm^{-3}$)[2]	$1.81±0.26^{b}$	$1.83±0.26^{b}$	$1.85±0.16^{b}$	$1.91±0.11^{a}$	0.007

Results were presented as means ± SE of triplicate observations. Means in the same row with different superscript letters were significantly different ($p < 0.05$). [1](WBCs) = white blood cell count, [2](RBCs) = red blood cell count.

TABLE 5 Biochemical blood parameters of *O. niloticus* after 84 days of feeding yeast extract supplemented diets

Items	Control	5g kg^{-1} yeast extract	10g kg^{-1} yeast extract	15g kg^{-1} yeast extract	P value
ALT (U l^{-1})[1]	90.33±2.18^{a}	87.33±2.14^{b}	85.30±2.56^{c}	84.66±2.16^{c}	0.043
AST (U l^{-1})[2]	17.63±0.56^{a}	16.83±0.35^{b}	15.87±0.58^{c}	15.83±0.45^{c}	0.0.32
Total protein (g dl^{-1})	3.10±0.41	3.47±0.35	3.67±0.43	3.88±0.55	0.781
Albumin (g dl^{-1})	1.20±0.11^{b}	1.28±0.10^{b}	1.42±0.09^{a}	1.59±0.12^{a}	0.034
Globulin (g dl^{-1})	1.90±0.18^{b}	2.19±0.13^{b}	2.25±0.12^{a}	2.29±0.14^{a}	0.012
Cholesterol (mg dl^{-1})	95.00±3.13^{a}	82.30±2.17^{b}	82.33±2.59^{b}	79.32±2.22^{c}	0.011
Triglycerides (mg dl^{-1})	97.67±2.98^{a}	87.33±3.13^{b}	82.30±2.18^{b}	78.33±2.13^{c}	0.012

Results were presented as means ± MSE of triplicate observations. Means in the same row with different superscript letters were significantly different ($p < 0.05$).
[1](ALT) = Alanine aminotransferase, [2](AST) = Aspartate aminotransferase

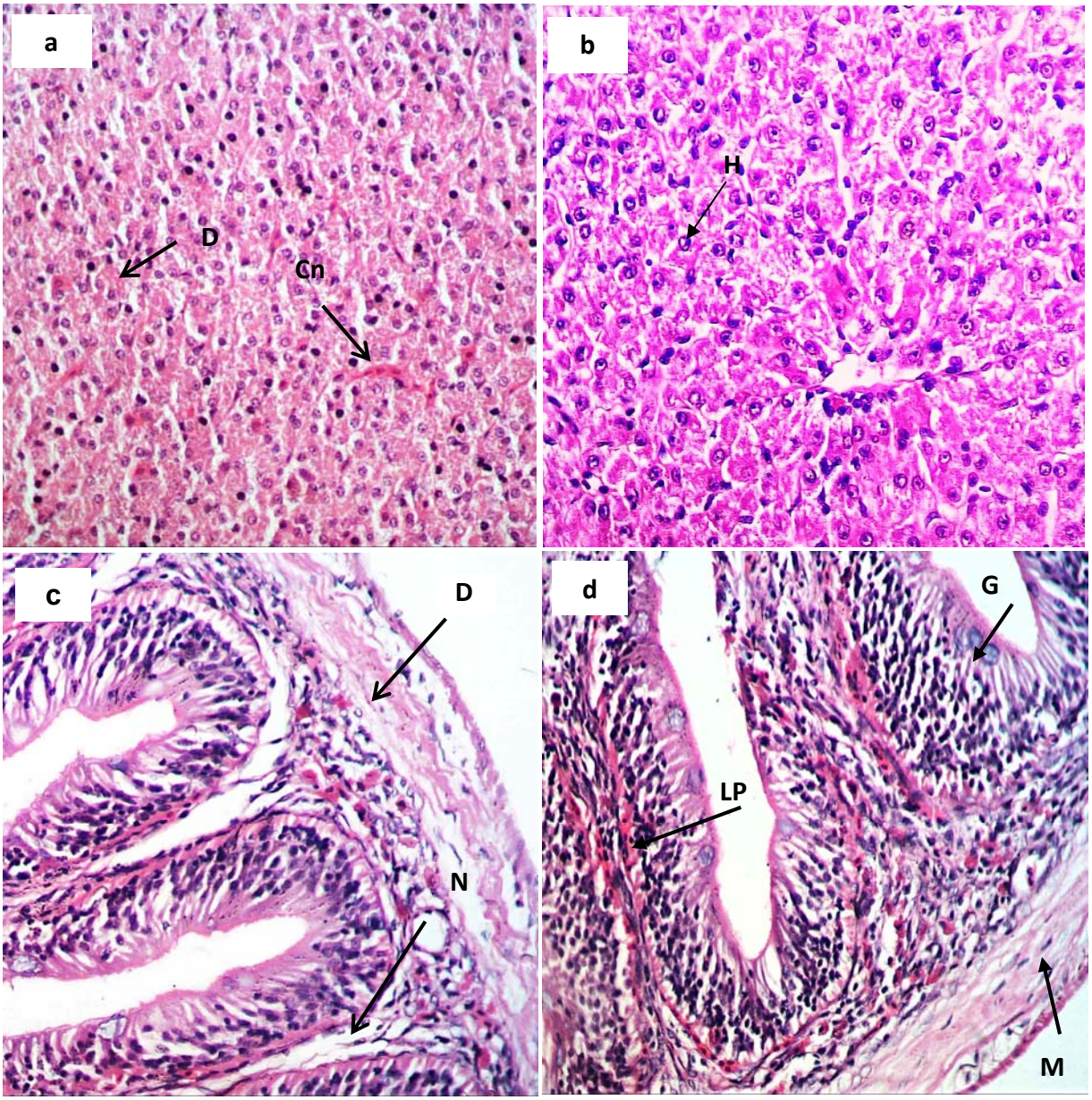

Fig.2. Histoarchitecture of liver and intestine tissues of Nile tilapia fed the control diet and diets supplemented with yeast extract: (a): show congestion (Cn) in blood sinusoids and degeneration (hypotrophy) (D) of hepatocytes of fish fed the control diet; (b): show normal and denser liver morphology of tilapia fed a diet supplemented with yeast extract; (c): shows degeneration (D) and necrosis (N) in sub-mucosal and mucosal morphology respectively of mid-sections of intestine of Nile tilapia fed the control diet; (d): shows a healthier intestine of fish fed a diet supplemented with yeast extract with regular distribution of goblet cells (G) and normal (unbroken) mucosal fold structure and more developed lamina propria (LP) and muscularis (M) layer.