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Effects of Replacing Soybean Meal with Jojoba Meal in Sea Bream (*Sparus aurata*) Diets on Fish Performance

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Abstract: The study aimed to investigate the effect of replacing soybean meal (SBM) by treated, either by heat (HJM) or by boiling (BJM), Jojoba meal (JM), to eliminate the negative effects of antinutritional factors, at 10, 20 and 30% replacing levels in diets of sea bream (*Sparus aurata)*) fingerlings on growth performance, nutrient utilization, body biochemical composition, middle intestine morphology and measuring of some hematological parameters of sea bream. Results indicated an enhancement in growth and feed utilization for all fish groups fed boiled followed by heated jojoba meal at 20% inclusion level compared to the control and other tested fish groups. Results of fish biochemical analyses indicate significant increase in crude protein contents in fish fed 10 and 20% HJM and 20% BJM. The present results also showed obvious increment in lipid contents as the level of JM inclusion level increase. Serum total protein, albumin and globulin levels indicated no negative effects when soybean meal was partially replaced by jojoba meal. Also, results indicate pronounced gradual decrease in serum cholesterol levels coincided with an increase in triglyceride. Middle intestine morphology examination showed significant variations in thickness of muscularis layer, villi length and width and also number of goblet cells.

Keywords: Jojoba Meal, Soybean Meal, Growth, Feed Utilization, Body Composition, Serum Constituents, Middle Intestine Morphology

1. Introduction

Feed cost represents almost over 60% to 70% of the production cost in fish culture. There is substantial interest in substituting the expensive dietary ingredients by cheaper cost feed ingredients in sea bream diets with maintaining growth performance as high as possible. Soybean meal is a plant protein, which could substitute fish meal in fish diet, but it is now expensive and its prices are rising due to the high demand on this ingredient. Therefore, it is important to search for other non-traditional available protein sources, which could be incorporated in fish diets without adverse effects on fish growth or efficiency of diet utilization.

Agro-industrial and agricultural by-products can play an important role in animal production in developing countries. Jojoba (*Simmondsia chinensis*) is a native oil seed shrub being grown in the deserts or new lands, is being advocated and developed as a potential cultivated crop for warm, arid regions of the world [1]. It produces highly marketable oil radically different chemical structure from any other known vegetable lipid which is a unique mixture of unsaturated liquid wax esters [2]. According to [3], the liquid wax (about 50% by weight) composed of mono-unsaturated straight-chain acids and alcohols; each with 20 to 24 carbon atoms has characteristics similar to sperm whale oil [4, 5]. Also, jojoba oil has applications in cosmetics, pharmaceuticals, and numerous other products. The residue (meal) that remains after extraction of oil from the seeds contains from 26 to 33% crude protein [6,7] and would increase the economic value of this crop if it could be used as a feed ingredient.

Very little has been published related to the proteins of jojoba seed meal. [8] showed the protein concentration and the composition of essential amino acids of jojoba seed meals after extraction with different solvents. The amino acid composition and protein content of jojoba seed meal was first mentioned by [9] who found methionine to be the limiting amino acid. Practically, the meal is underutilized because it contains 11% anti-nutritional factors (ANF), 5-demethylsimmondsin (DMS), 4,5-didemethylsimmondsin (DDMS), simmondsin (S), and simmondsin 2'-ferulate (SF),

that have adverse effects on animals [10,11,4,12]. Compounds other than simmondsin including poly phenolics, phytic acid and trypsin inhibitors, may be contributing to impaired feed intake and body weight gain of animals fed diets contain Jojoba seeds meal [13,14,1516]. Some authors consider simmondsins to be toxic, probably after metabolism by gut microorganisms [13, 6]. In contrast, The USA Food and Drug Administration approved simmondin as safe for human use and animal feed [17]. From the bright side, [18] reported that elimination of anti-nutritional factors in jojoba seed meal could be done by different methods, including solvent extraction, heat, chemical treatment and microbial fermentation. Jojoba meal, as a by-product of jojoba seeds, is a promising feedstuff after being detoxified [19]. According to [20] defatted jojoba meal contained 31.89±1.12% crude protein, simmondsin 3.33±0.02%, and total phenolic compounds 2.67±0.02%. Phytate content was found to be 2.39±0.05% in the defatted meal. Glutamic and aspartic acids were the most abundant amino acids. The total essential amino acids content was 37.1%.

Very few studies were conducted on potential use of jojoba meal as a waste product for animal feed; broiler chicks [21], rabbits [22], lambs [23, 7], rats [24], cats and other animals [25] and tilapia feed [26, 27, 28]. [26] stated that using JM after being supplemented with methionine and Biogen® at 0.6 and 2 g/kg diet respectively, to replace 25% fish meal in mono-sex *O. niloticus* diet, reduce costs of aquafeeds without any adverse effects on the fish, human health and safety of the environment. More scientific research is needed to maximize the commercial benefit from JM by other fish species.

To our knowledge, No researches were conducted on using jojoba meal in marine fish feeding. Therefore, the objective of the present study aims to evaluate the partial replacement (10, 20 and 30 %) of soybean by either boiled or heated jojoba meal (*Simmondsia chinensis*) as a new plant protein source after being supplemented with methionine and lysine (as a complementary amino acids), and studying its effects on growth performance, feed and nutrients utilization, carcass composition of fish, blood hematological parameters, intestinal morphology of sea bream (*Sparus auata*).

2. Materials and Methods

2.1. Fish and Experimental Management

Five hundred sea bream (*Sparus aurata*) fingerlings were obtained from El-Wafaa Hatchery, Ismaillia governate. A feeding experiment was conducted in the Fish Nutrition Laboratory, (NIOF), Alexandria, Egypt.

After acclimation for a week on the control diet (without Jojoba meal) the fish were divided into seven triplicated groups of 15 fish per replication, with an average weight of 1.1± 0.05 g/fish. They were then randomly stocked in 21 glass aquaria (80 · 30 · 40 cm) (length · width · height) with continuous aeration. The aquaria were daily cleaned before the first feeding and excreta were siphoned. Water quality parameters measured weekly included temperature (via a thermometer), PH (using Jenway Ltd., Model 350-pH-meter) and dissolved oxygen (using Jenway Ltd., Model 970-dissolved oxygen meter). Ambient water temperature, dissolved oxygen and pH through the experimental period were 24.0± 1.0 ^{O}C, 7.6 ±1.0 mg/l and 8.0 ±0.2, respectively. The test diets were fed twice daily, at 09.00 and 7.00 h, for apparent satiation rate for 7 days a week for 60 days and fish were weighed biweekly. During the study period, the total amount of feeds consumed by the fish in each aquarium was determined and the feed consumed for each individual fish was calculated accordingly.

2.2. Dietary Treatments

[29] Recommended that simmondsin should be previously eliminated from the residual Jojoba cake after oil squeeze. Accordingly, Jojoba meal was treated by heating at 100^{o}C for 3 hours [20] or boiled for one hour. Seven experimental diets were formulated (D1 – D7) and D1 is considered as control diet. Boiled (D2-D4) and Heated Jojoba meal (D5-D7) (29% CP) partially (10, 20, 30%) replaced soybean meal. As shown in Table (1) methionine and lysine are the limiting amino acids in jojoba seed meal so they added at the rate of 0.25 g/Kg for both [27]. The diets formulation and chemical composition are shown in Table (2). All the dietary ingredients and additives were purchased from the local market and jojoba meal from The Egyptian Natural Oil Company, Egypt. All ingredients and additives were milled and mixed, then pressed by manufacturing machine.

Table (1). *Proximate analysis, chemical composition and essential amino acids composition of the tested Jojoba meal on (%DM) compared with soybean meal and casein.*

	Jojoba meal	**Soybean meal**	**Casein**
Dry matter	93.17	90.80	-
Protein	26	44	87.20
Ether Extract	4.5	1.1	N.R
Crude fiber	10.5	7.3	N.R
Ash	4.15	6.3	N.R
Nitrogen free extract	54.85	41.3	N.R
Gross energy(Kcal/kg)	4508.25	4533.95	N.R
Arginine	3.45	3.39	4.14
Threonine	1.24	1.78	4.92
Histidine	0.9	1.19	3.19
Isoleucine	1.32	2.03	5.53
Leucine	2.21	3.49	10.32
Lysine	1.2	2.85	9.16
Methionine	0.97	0.57	3.04
Phenylalanine	1.21	2.22	5.69
Tryptophan	N.D*	N.R**	ND*
Valine	2.08	2.02	7.41
Total A.A. %	14.58	19.54	
Chemical score	13.10	18.75	
Essential amino acid index	26.7	35.3	
First limiting amino acid	Lys.	. Met.	

* = Not detected **= Not recorded in N.R.C (1993).
Source (Abd El-Hakim *et al*., 2010)

Table (2). *The composition and Chemical analysis (% on dry matter basis) of the experimental diets.*

Ingredients	Experimental diets composition/kg.						
	CTR	HJM			BJM		
	(J1)	(J2)	(J3)	(J4)	(J5)	(J6)	(J7)
Fish meal (65% CP)	500	500	500	500	500	500	500
Soybean meal	200	180	160	140	180	160	140
Yellow corn	100	60	60	60	60	60	60
shrimp meal	30	30	30	30	30	30	30
Wheat flour	80	80	80	80	80	80	80
Fish oil	60	60	60	60	60	60	60
Jojoba meal	0	60	80	100	60	80	100
Premix[1]	25	25	25	25	25	25	25
Methionine	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Lysine	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	1000	1000	1000	1000	1000	1000	1000
Chemical composition %							
Dry matter (DM)	94.5	93.5	95.1	92.6	93.3	94.4	95.2
Crud protein (CP)	46.30	46.79	46.49	46.19	45.40	46.01	45.99
Ether extract	13.3	13.1	13.5	13.8	14.4	14.1	14
Crude fiber	2.87	2.81	2.86	2.84	3.10	2.90	3.3
Ash	13.9	13.7	13.3	13.2	13.8	13.1	13.1
Nitrogen free extract (NFE)[5]	23.62	23.60	23.85	23.97	23.30	23.89	23.61
Gross energy (MJ/KG DM)[6]	20.28	20.39	20.29	20.33	20.45	20.70	20.53

[1]Danish 999 LT (68.9% protein & 8.1% lipid).
[2]Vit./min. Premix (mg kg_{-1}); p-amino benzoic acid (9.48); D-Biotin (0.38); Inositol (379.20); Niacin (37.92); Ca-pantothenate (56.88); Pyridoxine-HCl (11.38); Riboflavin (7.58); Thiamine-HCl (3.79); L-ascorbyl-2-phosphate Mg (APM) (296.00); Folic acid (0.76); Cyanocobalamine (0.08); Menadione (3.80), Vitamin A-palmitate (17.85); a-tocopherol (18.96); Calciferol (1.14). K_2PO_4 (2.011); $Ca_3(PO_4)_2$ (2.736); Mg SO_4 $7H_2O$ (3.058); NaH_2PO_4 $2H_2O$ (0.795).
[3]Nitrogen-free extract (NFE) = 100 - [% Ash +% lipid +% protein +% Fiber].
[4]GE (kJ/g) = (protein content × 23.6) + (Lipid content × 39.5) + carbohydrate content × 17.2).

2.3. Experimental Procedures

2.3.1. Proximate Analyses

Five fish were netted from each aquarium at the end of the feeding trial. They were then pooled together and homogenized for proximate composition (total of 15 fish per treatment). Moisture, total protein, lipid and ash contents were all determined by Standard Association of Official Analytical Chemist [30] methodology. Triplicates of diet samples were used for proximate analyses (Table 2).

2.3.2. Serum Constituents

Blood samples were collected, transferred to centrifuge tubes and allowed to clot at room temperature. Serum was then separated by centrifugation at 3000 (rpm) for 5 minutes. The serum was stored at -20°C until analysis for total protein, albumin, globulin, triglycerides and cholesterol.

Serum total protein (g/dl), albumin (g/dl) and cholesterol (mg/dl) were determined colorimeterically using Kits supplied by El- Nasr Pharmaceutical Chemicals Co. (Egypt). Serum globulin (g/dl) levels were obtained by differences between total protein (g/dl) and albumin (g/dl). Serum triglycerides (mg/dl) were determined colorimeterically using commercial Kits of *Biodiagnostic* Co. (Egypt).

2.3.3. Histological Examination

Subsamples of fore, mid and distal intestine were carefully separated, fixed in 10% buffered formalin solution, dehydrated in ethanol series, cleared in xylene, embedded in paraffin wax, sectioned at 5-µm and then stained with Hematoxylin and Eosin (H&E). Histological examination was conducted using light microscopy (Nikon E600, Tokyo, Japan).

2.3.4. Evaluation of Growth Performance and Feed Utilization Efficiency

Growth performance and feed utilization including weight gain (WG, g), percent weight gain (%WG), specific growth rate (SGR, %/day), feed conversion ratio (FCR) and protein efficiency ratio (PER) were determined as follows:

WG = FW – IW (g / fish)

%WG = 100 × [(final fish weight (g) - initial fish weight (g)) / initial fish weight]

SGR = 100 × [(ln final fish weight) - (ln initial fish weight)] / experimental days

FCR = feed fed (g) (dry weight)/weight gain (g)

PER = weight gain (g) / protein fed (g)

2.3.5. Statistical Analysis

The collected data were subjected to statistical analysis using general linear models procedure adapted by [31] for users guide, with a one-way ANOVA. Means were statistically compared for the significance ($p \leq 0.05$) using multiple range test [32].

3. Results and Discussion

The growth and feed utilization indices are illustrated in Table (3). The average initial weights are ranged between 1.17 and 1.19 g with insignificant differences ($p<0.05$) among the experimental groups. At terminal of the experiment average percentage weight gain (% wt gain) were ranged between 328 and 482% for 10 and 20% BJM, respectively. The results also revealed that, the highest ($P<0.05$) final weights and specific growth rate were recorded in 20% BJM followed by 20% HJM fish groups and their valued were significantly higher comparing with CTR fish group. Results also showed that incorporation of jojoba meal as soybean replacer does not affect adversely fish feed appetite comparing with CTR group. Values of PER of fish fed J6 diet followed by J3 indicated significant improvement in protein utilization comparing with all tested groups. [27] Concluded that incorporation of Jojoba meal in replacement to SBM protein at 25 and 50% levels had insignificant effects on tilapia feed intake. [33] studied the effect of replacement of soybean meal with Jojoba hexan iso-propanol treated meal JHSO or with Jojoba meal treated with hexan and water JHW at levels 25, 50 and 75% on growth performance of Nile

tilapia fingerlings. The author reported that JHSAO or JHW could replace soybean protein in Nile tilapia diets up to 25% and inclusion of JHSO or JHW in Nile tilapia diets decreased final weight, total weight gain and specific growth rate but increased the average feed intake; crude protein intake and gross energy intake at higher replacement levels. He added that feed conversion ratio (FCR) was elevated negatively, meanwhile, protein efficiency ratio and energy utilization were decreased by increasing the replacement levels of soybean meal with JHSO or JHW. [26] Reported that chemically treated Jojoba meal by isopropanol could be used at 10% of concentrate feed mixtures without any adverse effects on sheep performance. The results of [27] study revealed that, the highest (P<0.05) final weights, specific growth rate, protein and nutrient utilization were recorded by jojoba seed meal (JSM) 25% group followed by the control group and the JSM 50% groups, respectively. The same trend was observed in apparent digestibility coefficients. Therefore, these results suggest that up to 25% of soybean meal can be replaced by treaded Jojoba seed meal protein in Nile tilapia diets without any adverse effect on growth performance, feed and protein utilization, body composition and digestibility of nutrients.

Table (3). *Growth and feed utilization indices of fish at the end of feeding trial.*

	CTR	HJM			BJM		
		10%	20%	30%	10%	20%	30%
Initial wt	1.180±0.02	1.18±0.01	1.18±0.01	1.18±0.01	1.18±0.02	1.17±0.01	1.180±.01
Final wt	5.4±0.03 ^{c}	5.3±0.03 ^{c}	6.2±0.19 ^{b}	5.3±0.45 ^{c}	5.1±0.30 ^{c}	6.8±0.13 ^{a}	5.3±0.12 ^{c}
weight gain	4.20±0.02 ^{c}	4.15±. 02 ^{c}	5.0±0.20 ^{b}	4.2±0.44 ^{c}	3.9±0.30 ^{c}	5.6±0.14 ^{a}	4.11±0.10 ^{c}
%weight gain	356±20 ^{c}	353±10^{c}	424±18 ^{b}	354±35 ^{c}	328± 35 ^{c}	482±15 ^{a}	350±10 ^{c}
SGR	2.39±0.07^{c}	2.37±0.08^{c}	2.68±0.07^{b}	2.36±0.19^{c}	2.24±0.13 ^{c}	2.88±0.04 ^{a}	2.35±0.05 ^{c}
FI	8.2±0.08 ^{ab}	7.8±0.11 ^{ab}	8.7±0.27 ^{ab}	7.9±0.73 ^{ab}	7.4±0.61 ^{b}	8.9±0.38 ^{a}	7.9±0.23 ^{ab}
FCR	1.94±0.02 ^{a}	1.89±0.03 ^{a}	1.75±0.05 ^{b}	1.90±0.02 ^{a}	1.90±0.2 ^{a}	1.57±.05 ^{b}	1. 91±.01 ^{a}
PER	1.22±0.01 ^{b}	1.28±0.02^{b}	1.43±0.04 ^{a}	1.25±0.02 ^{b}	1.25±0.01 ^{b}	1.51±0.05 ^{a}	1.22±0.01 ^{b}

Different letters within the same row indicate significant differences (P< 0.05).

The enhancement in growth in the present study can be interpreted according to [34] who compared jojoba with other plant protein; the amino acid composition of jojoba proteins was lower in methionine, and similar or higher in the other amino acids. The study of [34] on functional properties showed that the albumins and globulins from jojoba showed good solubility, foam ability, gelation, and emulsifying properties. This may recommend their use in foods such as meat, cheese, and yogurt analogs.

Averages of whole body composition including moisture, crude protein (CP), ether extract (EE) and ash contents as affected with the dietary treatments at the start and end of the experimental period are presented in Table (4). Results reveled that CP and EE contents in fish whole bodies, at the end of the experimental period, were significantly (P<0.05) higher in the treated groups compared with the corresponding values at the experimental start meanwhile, moisture and ash contents were significantly decrease in tested groups comparing with starter group. Total protein content values were in parallel trend with growth indices values and highest values were recorded in J3 and J6 groups (17.83 and 17.22, respectively). A gradual increment in lipid contents was pronounced as the level of JM inclusion increase in diets for both treatments. These results are in agreement with the findings of [33] who reported that incorporation of 14.80% of Jojoba meal (in replacement of 25% of soybean meal protein) in Nile tilapia diets increased DM, CP and EE contents in whole fish bodies compared to higher levels (50% or 75%) of Jojoba meal in replacement of soybean protein. Also, According to [27] ether extract (%) in whole fish increased significantly ($P \leq 0.05$) as inclusion levels of JM increased. Moreover, [26] found no significant differences ($P \geq 0.05$) in crude protein, ether extract, ash and energy content in whole body carcass of mono-sex *O. niloticus* with increasing JM replacement level up to 100%.

Table (4). *Biochemical composition of fish at end of feeding trial (wet weight basis).*

	Initial	CTR	HJM			BJM		
			10%	20%	30%	10%	20%	30%
Moisture	73.9±0.1	69.95±.05 ^{a}	69.55±.25 ^{a}	68.55±.15^{b}	68.45±.15 ^{bc}	69.55±0.05 ^{a}	68.0±0.10^{c}	68.15±.05 ^{bc}
CP	15.6±1.5	16.76±0.6 ^{b}	17.25±0.3 ^{a}	17.83±0.1 ^{a}	16.20±0.5^{b}	16.31±0.4 ^{b}	17.22±0.9 ^{a}	16.71±0.2 ^{b}
E.E.	4.1±0.45	7.1±0.2^{c}	7.9±0.6^{b}	8.8±0.4^{a}	9.50±0.45^{a}	8.2±0.5 ^{b}	9.3±0.95^{a}	9.8±0.2 ^{a}
Ash	5.8±0.05	5.1±0.15 ^{ab}	5.4±0.4 ^{a}	4.8±0.2 ^{bc}	4.9±0.75 ^{bc}	4.6±0.5 ^{c}	5.1±0.4 ^{bc}	4.7±0.2 ^{c}

Different letters within the same row indicate significant differences (P< 0.05).

Results represented in Table (5) showed that serum total protein values in fish fed J3 and J7 diets were similar (5.9 g/dl) and significantly elevated comparing with all other fish groups. Albumin values showed no significant variations among treatments except for J5 group where significant depletion was recorded (2.6 g/dl). Additionally, a significant increase in globulin concentration in fish fed JM at 30% replacement level for both treatments was recorded. Results recorded in Table (5) also show gradual decrease in cholesterol level coincided with gradual increase in

triglyceride levels as JM inclusion level increase for both treatments. Blood analysis indicated that no negative effects were recorded on blood parameters when SBM was partially replaced by supplemented JM which may be due to supplementation with both of methionine and lysine in experimental diets. Similarly, [35] reported that canola meal significantly (P<0.01) increased serum total protein, globulin, triglycerides. [36] mentioned that Jojoba oil extracted from seeds, leaves or somatic embryos (artificial seeds) contains Omega-3 fatty acids which provide vitality and reduced cholesterol precipitation in humans as well as several other health benefits and this conclusion may interpreted depletion in cholesterol levels in blood when fish fed diets containing jojoba meal where meal may still contain residues of oil.

Table (5). *Serum constituent of fish blood at end of feeding trial.*

	CTR	HJM			BJM		
		10%	20%	30%	10%	20%	30%
Total protein	5.5±0.09^{b}	4.9±0.21^{c}	5.9±0.13^{a}	5.6±0.12^{b}	5.1±0.10^{c}	5.5±0.21^{b}	5.9±0.11^{a}
Albumin	3.0± 0.13 ^{a}	2.8±0.21^{a}	3.0± 0.20 ^{a}	2.9±0.17^{a}	2.6± 0.19 ^{b}	2.9±0.15^{a}	2.9±0.12^{a}
Globulin	2.5±0.12 ^{b}	2.2± 0.10 ^{c}	2.7±0.05^{b}	2.9±0.13 ^{a}	2.5±0.17^{b}	2.6± 0.09 ^{b}	3.0± 0.07 ^{a}
Cholesterol	232± 6.1 ^{a}	202± 4.4 ^{b}	187.5±2.5^{cd}	167± 3.7 ^{d}	225± 5.3^{a}	196± 2.2^{bc}	181± 5.5^{d}
Triglyceride	229± 3.6^{f}	323±3.2^{e}	346± 4.6^{d}	449±11.1^{b}	353± 3.3^{d}	381.5±5.5^{c}	503± 5.1^{a}
Albumin/globulin	1.20±0.05^{ab}	1.22±0.04^{a}	1.04±0.03 ^{bc}	1.08±0.08 ^{abc}	1.04±0.04 ^{bc}	1.1±0.04 ^{abc}	0.97±0.03 ^{c}

Different letters within the same row indicate significant differences (P< 0.05).

Table (6). *Measurements of mid-gut morphology of sea bream at end of feeding trial*

	CTR	HJM			BJM		
		10%	20%	30%	10%	20%	30%
Thickness of muscularis (µm)	6.5±0.8 ^{b}	4.8±0.3 ^{c}	6.1±0.5 ^{b}	4.8±0.3 ^{c}	5.1±0.3 ^{c}	8.0±0.8 ^{a}	6.8±0.6 ^{b}
Villi length (µm)	55.7± 2.6^{b}	41.2±2.1^{d}	44.2± 2.0 ^{d}	50.0±1.3^{c}	50.8±3.2^{c}	61.3±4.9 ^{a}	54.1±1.4^{b}
Villi width (µm)	8.3±0.5 ^{a}	5.7± 0.6 ^{c}	6.1±0.6 ^{c}	7.0±0.4^{ab}	7.8±0.9 ^{a}	8.0±0.7^{a}	6.7±0.6^{b}
Goblet cells	17.2±1.0 ^{a}	7.7± 1.1 ^{d}	11.0±.7 ^{cd}	10.0±1.0 ^{cd}	11.2± 1.0 ^{cd}	16.0±1.8^{ab}	12± 2.4 ^{bc}

Different letters within the same row indicate significant differences (P< 0.05).

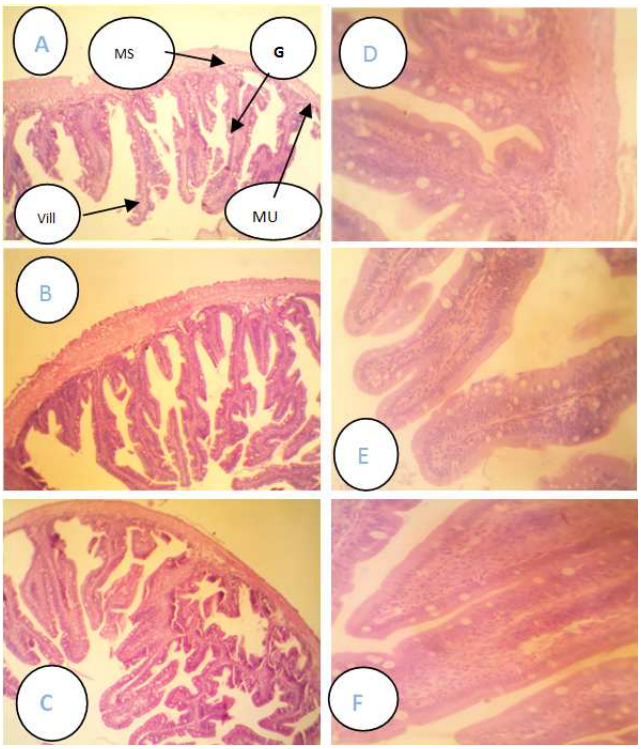

Figure (1). *Photomicrograph of cross sections of intestine of the sea bream. Showing mucosa (MU), Goblet cells (G), villi (V) and muscularis (MS). Hematoxylin and eosin stain (H &E) (A, B, C X100)(D, E, F X400) fish were fed A, D) CTR B, E) J20%heated and C, F) J20%boiled diets for 60 days.*

A healthy digestive system is fundamental for ideal animal growth. Determining alterations that may occur in the intestine is crucial to guarantee the nutritional efficiency of the diet as well as animal health. For this reason, this work studied different parameters related to mid-gut morphology of fish fed experimental diets. Some representative sections are shown in Figure (1). At the end of experiment, the thickness of muscularis layer, the height and width of villi and the number of their goblet cells were measured in the middle part of intestine for each of the control and treated groups. The results are shown in Table (6) and Figure (1).

The present results showed remarkable variations among treatments. Significant increment in thickness of muscularis layer, villi length was recorded in fish fed J6 diet comparing with all tested and control groups (8.0 and 61.3 µm, respectively). Significant reduction in villi length and width in fish fed 10, 20% HJM. The highest number of goblet cells was recorded in control group (17.2) followed by 20% BJM (16.01) meanwhile, rest of tested groups showed significant depletion in goblet cells number. In general, histological analysis showed satisfactory records in fish fed BJM compared to HJM groups. In the intestine, the thickness of the layers differs among diets, with no fixed pattern in terms of statistically significant differences taking in consideration that mid-gut are the area where a great part of the absorption of nutrients occurs, but practically no mechanical processing takes place [37]. The increment in villi length in J6 fish group could be attributed to insufficient digestion of nutrients and it could have occurred to increase surface absorption [38]. The maximum goblet cells count was found in the control group followed by J6 group and significant differences were recorded among diets. These cells are associated to the immune system, and act through the mucus as a lubricant,

containing zymogen granules, an inactive enzyme, involved in protein digestion and this may interpreted the enhancement in protein utilization in J6 fish group. Also, [39] Reported that the number of goblet cells could vary with the food habit or starvation.

4. Conclusion

Based on the obtained results, it is recommended to replace the soybean meal protein with boiled Jojoba meal protein in sea bream (*Sparus aurata*) diets up to 20% without adverse effects on fish growth performance, feed utilization, fish integrity with increasing economic efficiency. More studies are recommended to investigate the long run effects on fish performance. Finishing diets may be recommended for marketable sizes to eliminate fat deposition in fish bodies.

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