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Growth Performance, Body Composition, Haematological and Serum Parameters to Fish Meal Replacement by Soybean Meal and Cottonseed Meal in Russian Sturgeon (*Acipenser gueldenstaedtii*)

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ABSTRACT

In this study, the effects of replacement of fish meal by soybean meal and cottonseed meal on growth, body composition, blood and serum parameters of Russian sturgeon (*Acipenser gueldenstaedtii*) were investigated. Five experimental diets were formulated to be isonitrogenous (49 % protein) and isolipidic (20 % lipid). Diets were prepared with graded levels (20 % and 40 %) of soybean (*SM*) and cottonseed (*CM*) meals as *SM*20, *SM*40, *CM*20, *CM*40 and a control diet (*FM*, only fish meal with no *SM* and *CM* inclusion). Sturgeon (50.00±0.06 g) were randomly distributed into fifteen 500-L square tanks at 25 fish per tank. Fish were weighed in bulk biweekly after suspending feeding for 1 day. Fish were fed near satiation by hand at 08:00, 12:00 and 16:00 hours for 8 weeks. Sturgeon fed *CM*20 and *CM*40 diets displayed higher specific growth rate (*SGR*) and lower feed conversion ratio (*FCR*) when compared with fish fed *SM*40 and *FM* ($P<0.05$). There were no differences among groups for the percentage of blood cells, including lymphocytes, monocytes and granulocytes of sturgeons. Alkaline phosphatase (*ALP*) of *SM*20 and *SM*40 groups were significantly lower than that of *FM* group ($P<0.05$). The results of this study revealed that dietary cottonseed meal could be used for enhancement in juvenile sturgeon.

Keywords: Aquafeed, dietary replacement, sturgeon feeding, *Acipenser gueldenstaedtii*

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Rus Mersin Balığında (*Acipenser gueldenstaedtii*) Büyüme Performansı, Vücut Kompozisyonu, Kan ve Serum Parametreleri Açısından Balık Unu Yerine Soya Unu ve Keten Tohumu Küspesi Kullanımı

Öz: Bu çalışmada, balık unu yerine soya fasulyesi unu ve keten tohumu küspesi kullanımının Rus mersin balığında (*Acipenser gueldenstaedtii*) büyüme, vücut kompozisyonu, kan ve serum parametreleri üzerine etkileri incelenmiştir. İzonitrojenik (% 49 protein) ve izolipidik (% 20 yağ) olmak üzere beş deneysel yem formüle edilmiştir. Yemler, kademeli seviyelerde (% 20 ve % 40) soya unu (*SU*) ve keten tohumu küspesi (*KU*) ilavesiyle *SU*20, *SU*40, *KU*20, *KU*40 ve bir de kontrol yemi (*SU* ve *KU* ilavesi olmadan sadece balık unuyla (*BU*)) olarak hazırlanmıştır. Deneme başlangıcında, tank başına ortalama 50,00 ± 0,06 g ağırlıktaki 25 balık, 500 L'lik 15 adet kare tanka rastgele dağıtılmıştır. Balıklar iki haftada bir, 1 gün beslemeye ara vermek suretiyle toplu olarak tartılmıştır. Balıklar 8 hafta boyunca 08:00, 12:00 ve 16:00 saatlerinde doyana kadar beslenmiştir. *KU*20 ve *KU*40 ile beslenen mersin balıkları *BU* ve *SU*40 ile beslenenlere göre daha yüksek spesifik büyüme oranı (*SBO*) ve daha düşük yem dönüşüm oranı (*YDO*) göstermiştir ($P<0,05$). Balıkların kan hücrelerinden lenfosit, monosit ve granülositler gruplar arasında bir farklılık yoktur. *SU*20 ve *SU*40 gruplarının Alkalin fosfat (*ALF*) *BU* grubundan önemli derecede düşüktür ($P<0,05$) Bu çalışmanın sonuçları, yavru mersin balığı için yemsel keten tohumu küspesinin kullanılabileceğini göstermiştir.

Anahtar kelimeler: Su ürünleri yemi, yemsel ikame, mersin balığı beslemesi, *Acipenser gueldenstaedtii*

Alıntılama
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Introduction

Aquafeed price comprises almost 40-70 % of total fish farm construction costs and the dietary protein is both an important constituent and is the costliest in aquafeed (FAO 2014). Fish meal has been widely used animal protein source in fish diet due to its high content of protein with well-proportioned amino acids, essential fatty acids, the good source of energy, and high palatability. Recently, the rapid growth of aquaculture production in the world increases the demand for aquatic feeds that depend on fish meal (Hardy 2010). However, the global fish meal production has remained nearly stable for the last time and the increasing demand for fish meal has led to a significant growth and flux in fish meal cost (Tacon and Metian 2008; Gatlin III et al. 2007). As a result, fish nutrition research focused on searching for alternative protein sources for aquafeeds. Numerous researches have utilized plant protein sources, for instance, soybean meal (Viola et al. 1982; Webster et al. 1992; Kaushik et al. 1995; El-Saidy and Gaber 2002; Collins et al. 2012), canola meal (Drew et al. 2007; Collins et al. 2012; Luo et al. 2012), pea protein (Øverland et al. 2009; Hansen et al. 2011; Collins et al. 2012) and corn gluten meal (Tidwell et al. 2005; Li et al. 2012) to partially, totally or mixed substitute fish meal and have accomplished significant progress in different freshwater finfish species. Vegetable proteins have an adequately of protein, sustainability, and low-priced for some fish species (Gatlin III et al. 2007; Sales 2009). However, these proteins have weaknesses as dietary ingredients in aquaculture diets, such as anti-nutritional factors and insufficient amino acids.

Soybean meal and cottonseed meal have been the most usually used plant protein sources because of high protein content, sustainability and reasonable cost-effectiveness (Lim and Lee 2011). Soybean meal is the most produced of protein ingredients in terms of total world production. Soybean as a most common plant protein of fish meal replacer has been used in a variety fish species. However, the high level of dietary soybean meal produced adverse effects on growth performance and health of fish due to it is the presence of some anti-nutritional factors in soybean meal (Pham et al. 2007). Also, low contents of lysine and methionine in soybean meal have also limited its amount of inclusion in the diets (Gatlin III et al. 2007). Cottonseed meal has been used to diets of ruminant livestock and aquatic animals and is cheaper and is a rich source of arginine than fish meal and soybean meal (Li and Robinson 2006; Gatlin III et al. 2007; Lim and Lee 2009; Li et al. 2012). The level of soybean meal and cottonseed meal that can be incorporated in aquafeed diets mainly depends on dietary ingredients are still limited due in part to the presence of anti-nutritional features.

Russian sturgeon is one of the most widely distributed representatives of the genus of *Acipenser*. Russian sturgeon has been cultured in some countries for its flesh and caviar. Little is known about feed formulation and nutrition specific to Russian sturgeon which is becoming the sturgeon of choice for culture in the worldwide. Also, the mixed use of soybean meal and cottonseed meal has not been tested to any sturgeon species. The aim of this study was to evaluate the effects of dietary incorporation of the soybean meal and cottonseed meal on growth performance and some health parameters in diets for Russian sturgeon (*Acipenser gueldenstaedtii*).

Materials and Methods

Rearing systems and fish

The feeding trial was realized at the Kepez Unit of Mediterranean Fisheries Research Production and Training Institute, Antalya, Turkey. Before commencement of the experiment, the fish were acclimatized to experimental conditions for 2 weeks. During the adaption period, fish were fed a sinking extruded commercial rainbow trout diet with 50 % protein and 18 % lipid (Çamlı Yem, İzmir, Turkey). At the start of the trial, fish weighing 50.00 ± 0.06 g were randomly distributed into fifteen 500-L square tanks at 25 fish per tank. Fish were fed near satiation by hand at 08:00; 12:00 and 16:00 hours for 8 weeks. The feed was carefully administered by dropping a few pellets until the feeding activity ceased. The water was exchanged with 20 % twice a week. Water temperature was maintained at 15.01 ± 0.06 °C, dissolved oxygen at 7.86 ± 0.09 mg/L, and pH at 7.91 ± 0.02. Fish were subjected to the natural photoperiod in an indoor system, allowing natural light to enter.

Experimental diets

Five experimental diets (Table 1) were formulated to be isonitrogenous (49 % protein) and isolipidic (20 % lipid). Experimental diets were obtained including, as fed basis, graded levels of soybean (*SM*) and cottonseed (*CM*) meals [*FM* (control diet, with no *SM* and *CM* inclusion, with fish meal), *SM*20 (20 % *SM* inclusion), *SM*40 (40 % *SM* inclusion), *CM*20 (20 % *CM* inclusion) and *CM*40 (40 % *CM* inclusion). Dietary ingredients were mixed in a food mixer (IBT-22; Dirmak Food Equipment, İzmir, Turkey) with warm water until a soft slightly moist consistency was achieved. This was then cold press extruded (*PTM* P6; Yalova, Turkey) to produce a 3 mm in diameter for fish. The moist pellets were then fan-dried and stored frozen at -18 °C until use.

Table 1. Formulation and proximate composition of the experimental diets.

	FM	SM20	SM40	CM20	CM40
Fish meal	55.3	44	33.1	44	33.1
Cotton seed meal	0	0	0	19.7	39.5
Soybean meal	0	18	35.3	0	0
Wheat meal	17	17	17	17	14.1
Starch	15.7	8.3	1.3	6.6	0
Fish oil	4.65	5	5.3	5	5.3
Soybean oil	4.65	5	5.3	5	5.3
Vitamin	0.8	0.8	0.8	0.8	0.8
Mineral	0.9	0.9	0.9	0.9	0.9
Vitamin C	0.5	0.5	0.5	0.5	0.5
Mono ammonium phosphate	0.5	0.5	0.5	0.5	0.5
Proximate Composition(%)					
Protein	49.0	49.1	49.1	49.2	49.2
Lipid	19.8	19.9	20.1	19.9	20.0
Ash	7.8	7.2	7.1	7.5	7.3

Sampling protocols

At the end of the feeding trial, all fish were starved for 48 h to ensure that the digestive tract was devoid of feed. Six fish were randomly taken from the initial pool of fish at the beginning of the experiment and two fish from each tank (six fish per treatment) were sampled at the end of the trial to determine whole body proximate analysis. Samples were kept frozen at -80°C until analysis. Three fish per tank were randomly selected, individually weighed, then dissected to obtain liver for determination of biological parameters; thereafter, the same livers were used for histology observations. Two fish per tank were randomly captured, anesthetized with clove oil, and blood samples were taken from the caudal arch using a 32-gauge needle and 2 mL heparinized syringes for determination of white blood cell (*WBC*) and red blood cell (*RBC*), packed cell volume (*PCV*), and haemoglobin (*Hb*).

Evaluation of growth performance

Growth performance was examined biweekly. Fish were weighed in bulk after suspending feeding for 1 day with an electronic balance. Growth performance, in terms of specific growth rate (*SGR*), feed conversion ratio (*FCR*), and survival rate (*SR*) were determined using the following formulae:

FCR = feed intake / weight gain

SGR = 100 x ([Ln final fish weight] - [Ln initial fish weight]) / experimental days

SR = 100 x (total fish count - dead fish count) / total fish count

Proximate analyses

Analysis of crude protein, moisture, fibre and ash in the whole body of fish and the diets was performed according to standard procedures (AOAC 2000). Dry matter was determined by drying at 105 ℃ until a constant weight was obtained. Ash content was determined by burning in a muffle furnace at 525 ℃ for 12 h. Crude protein (N×6.25) was analyzed by the Kjeldahl method after acid digestion using the Gerhardt system. Dietary and whole-body lipids were extracted according to the procedure of Folch et al. (1957) with chloroform/methanol (2:1 v/v).

Serum analyses

The *RBC* count was obtained with a Thoma hemocytometer using Dacie's diluting fluid. Serum parameters, including calcium (*Ca, mg/dL*), glucose (*GLU, mg/dL*), total protein (*TP, g/dL*), alkaline phosphate (*ALP, U/L*), and phosphorus (*P, mg/dL*) were determined using a semi-auto chemistry analyser (*BA-88A*, Mindray, China).

Statistical analysis

All data were subjected to a one-way analysis of variance (ANOVA), when a significant difference was found among treatments, Duncan’s multiple range test was performed to rank the groups using Statgraphics Centurion XVI (Statpoint Technologies Inc., The Plains, VA) statistical software (Zar 1999). All data are presented as “mean±standard error” of the mean calculated from all replicates. All percentage data were arcsine transformed before being subjected to the analysis. Differences were considered significant at 5 %.

Results

Growth performance of Russian sturgeons fed with experimental diets for 8 weeks were presented in Table 2. The cottonseed meal inclusion instead of fish meal improved the final mean weights (*FMW*) in fish and significant differences were observed (P<0.05). The lowest *FMW*s were found in *SM*40 and

FM groups (P<0.05). On the other hand, soybean meal inclusion was clearly affected to feed intake (*FI*). The highest FIs were observed in groups of *SM*20 and *SM*40, while the FM, *CM*20 and *CM*40 were the lowest (P<0.05). The specific growth rate (*SGR*) was improved by the inclusion of cottonseed meal. The *SGR* values of *CM*20 and *CM*40 were higher than *FM* and *SM*40 (P<0.05). The feed conversion ratios (*FCR*) of *CM*20 and *CM*40 were lower than *SM*40 (P<0.05). The survival rate (*SR*) was found as 100 % for all groups because of no fish died during the study.

The increases in mean weights (*MW*) of experimental fish week-by-week were shown in Figure 1. The lowest weight gain (*WG*) was observed in the *SM*40 group during the experiment. The *MW* of *SM*20 group ran lower than *FM* until the 4th week, but an increment was observed and the *MW* of *SM*20 passed up the *FM* group after that week. The highest weight gains were found in CM groups.

Table 2. Growth performance of Russian sturgeons after 8 weeks of feeding on experimental diets

	FM	SM20	SM40	CM20	CM40
Initial mean weight (g)	50.56±0.08	50.43±0.19	50.37±0.16	50.24±0.09	50.29±0.10
Final mean weight (g)	116.67±4.37[a]	126.79±3.04[ab]	111.91±10.56[a]	137.03±0.82[b]	135.99±3.10[b]
Feed intake (g)	70.57±1.74[a]	76.70±1.30[b]	74.62±1.35[b]	70.70±0.39[a]	68.59±0.65[a]
Specific growth rate (%/day)	1.49±0.07[a]	1.65±0.04[ab]	1.41±0.17[a]	1.79±0.03[b]	1.78±0.04[b]
Feed conversion ratio	1.07±0.05[ab]	1.01±0.03[ab]	1.29±0.22[b]	0.82±0.01[a]	0.80±0.03[a]
Survival rate (%)	100.00	100.00	100.00	100.00	100.00

In the same line, different letters indicate statistical significant differences (P<0.05) among the treatments

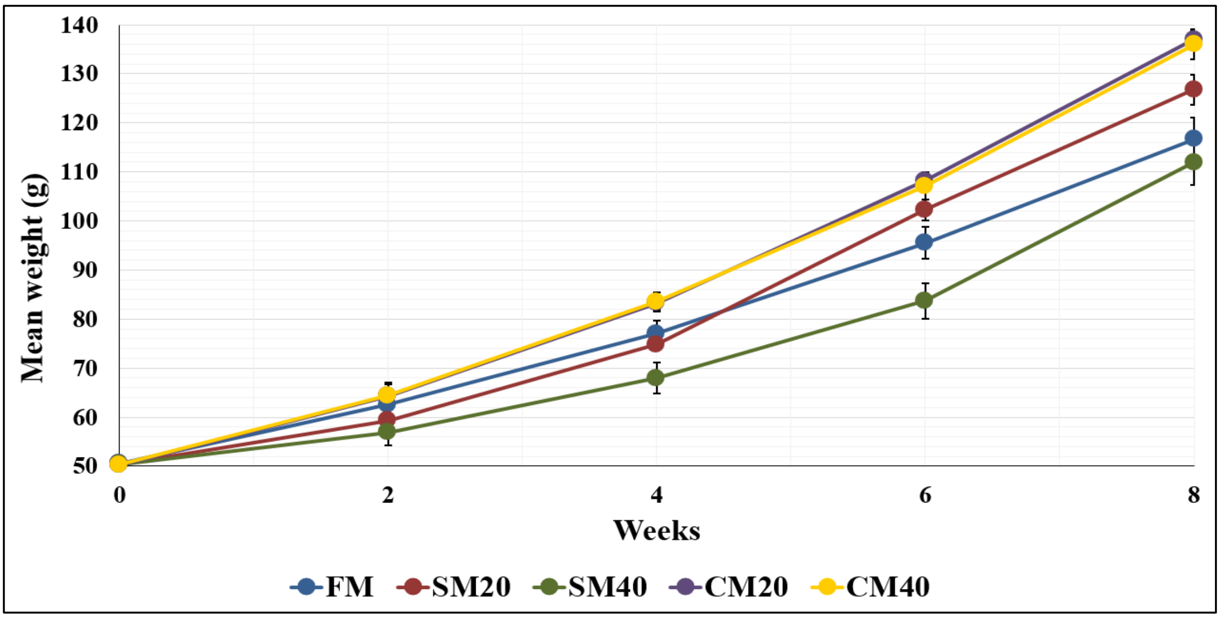

Figure 1. Mean weights of Russian sturgeons during 8 weeks of feeding on experimental diets.

The crude protein, lipid, ash, and moisture compositions of sturgeons fed with control, soybean and cottonseed meal included diets for 8 weeks were given in Table 3. The lowest moisture contents were observed in the *SM*20 and *SM*40 groups (P<0.05). Protein composition of *FM* was found as the highest among all the groups (P<0.05) and the protein ratio of CM40 was significantly different from the *SM*40 (P<0.05). Lipid content of *FM* was recorded as the lowest and *SM*40 and *CM*20 were the highest (P<0.05). The highest crude ash ratio was observed in the *FM* group among all the groups (P<0.05).

The percentage of blood cells, including lymphocytes, monocytes, granulocytes, and thrombocytes of sturgeons were shown in Table 4. The percentages were found between 48.8-62.8 % for lymphocytes, 0.9-1.4 % for monocytes, 31.3-48.0 % for granulocytes and no significant differences were found in these blood cell types of the experimental groups (P>0.05). The thrombocyte percentage of *SM*20 (1.9 %) was significantly different from the *SM*40 (5.2 %) group (P0.05).

Some serum parameters of sturgeons fed with experimental diets detailed in Table 5. Alkaline phosphatase (*ALP*) of *SM*20 and *SM*40 groups were significantly different from *FM* group (P<0.05). No statistical differences were found in glucose (*GLU*), total protein (*TP*), and phosphorus (*P*) of fish amongst the experimental groups (P>0.05). The calcium content of fish serum of *SM*40 was significantly different from *FM* and *SM*20 groups (P<0.05).

Table 3. Whole body composition of Russian sturgeons after 8 weeks of feeding on experimental diets

	FM	SM20	SM40	CM20	CM40
Moisture (%)	80.34±0.17^{c}	78.68±0.10^{a}	78.91±0.01^{a}	79.70±0.08^{b}	80.12±0.10^{bc}
Crude protein (%)	73.49±0.33^{c}	66.97±0.05^{ab}	66.16±0.44^{a}	67.02±0.25^{ab}	68.18±0.46^{b}
Crude lipid (%)	11.61±0.04^{a}	19.25±0.06^{b}	23.19±1.67^{c}	22.60±0.53^{c}	18.17±0.05^{b}
Crude ash (%)	13.30±0.02^{b}	11.83±0.09^{a}	11.23±0.47^{a}	11.21±0.26^{a}	10.81±0.21^{a}

In the same line, different letters indicate statistical significant differences (P<0.05) among the treatments

Table 4. Blood cell percentage of Russian sturgeons after 8 weeks of feeding on experimental diets

	FM	SM20	SM40	CM20	CM40
Lymphocytes (%)	62.78±8.14	49.33±7.91	50.00±4.35	48.78±5.51	49.22±4.74
Monocytes (%)	1.33±0.62	0.89±0.35	0.89±0.26	1.11±0.31	1.44±0.60
Granulocytes (%)	31.33±8.44	47.89±8.20	43.89±4.38	48.00±5.16	46.56±5.07
Thrombocytes (%)	4.56±1.33^{ab}	1.89±0.82^{a}	5.22±1.38^{b}	2.11±0.63^{ab}	2.78±0.72^{ab}

In the same line, different letters indicate statistical significant differences (P<0.05) among the treatments

Table 5. Serum parameters of Russian sturgeons after 8 weeks of feeding on experimental diets

	FM	SM20	SM40	CM20	CM40
ALP (U/L)	76.78±7.67^{b}	37.22±21.62^{a}	39.33±9.66^{a}	59.22±6.87^{ab}	66.33±5.43^{ab}
GLU (mg/dL)	188.05±5.39	141.78±6.32	173.93±3.45	161.22±9.84	150.33±7.10
TP (g/L)	25.72±4.75	28.93±8.39	24.28±6.05	25.97±1.86	26.80±1.73
Ca (mg/dL)	11.82±1.98^{b}	9.24±9.17^{b}	3.88±4.23^{a}	7.24±1.14^{ab}	5.51±0.81^{ab}
P (mg/dL)	16.71±2.77	13.76±5.78	15.61±1.51	14.21±4.30	10.79±2.44

ALP: Alkaline phosphatase, *GLU*: Glucose, *TP*: Total protein, *Ca*: Calcium, *P*: Phosphorus
In the same line, different letters indicate statistical significant differences (P<0.05) among the treatments

Discussion

Growth parameters were clearly showed that the inclusion of cottonseed meal enhanced the *FMW* and *SGR*, while decreased the FI and *FCR*. Toko et al. (2008) carried out a similar experiment with the replacing of soybean and cottonseed meals instead of fish meal on 10 g African catfish (*Clarias gariepinus*). They presented that the beneficial effects of cottonseed meal inclusion on *FMW* and *SGR*. The researchers found that the *FMW* and *SGR* of the control group (117 g and 4.35 %/day) were significantly related to 30 % cottonseed meal included group (116 g and 4.32 %/day). Cai et al. (2011) investigated that the 40 % inclusion of cottonseed meal (among the 20, 40, and 56 % inclusion) instead of fish meal was upgraded the WG and *SGR* on 19.5 g allogynogenetic silver crucian carps (*Carassius auratus gibelio*♀ × *Cyprinus carpio*♂). They declared that the *FCR* was reduced with the further levels of cottonseed meal. Liu et al. (2016) determined that the best growth performance in 761 g grass carp (*Ctenopharyngodon idellus*) was fed with diets included 60 % cottonseed meal among the 20-100 % inclusion groups. Bu et al. (2017) conducted a study on 1.68 g Ussuri catfish (*Pelteobagrus ussuriensis*, formerly *Pseudobagrus ussuriensis*) with the partial replacement of cottonseed meal with the ratios of 10 to 60 % inclusion. The authors stated that the *FMW* and *SGR* were not improved with the increased levels of cottonseed meal. They determined the optimum inclusion level of cottonseed meal as 25.3 % for weight gain in Ussuri catfish. Gui et al. (2010) found no significant differences in *FMW* amongst the 13 g crucian carps (*Carassius auratus gibelio*) fed with 10, 50, and 100 % cottonseed meal protein hydrolysate included diets, while there was a significant interaction between the *SGR* of control and 100 % groups. In contrast, Luo et al. (2006) recorded that the graded decline in *FMW* (101.5 to 95 g), although there were no significant differences amongst the groups of 39 g rainbow trout (*Oncorhynchus mykiss*) fed with 25, 50, and 75 % cottonseed meal included diets. In a study conducted on the similar fish (Jiang et al. 2018), the researchers examined the effects of fish meal replacement by soybean meal, cottonseed meal, and rapeseed meal on 8.6 g hybrid sturgeon (*Acipenser baerii* ♀ × *Acipenser schrenckii* ♂). They reported that they prepared the control diet with the inclusion of 60 % fish meal. The other experimental diets have been formed by decreasing the fish meal ratio of 15 %. The authors stated that the 50 % replacement of soybean, cottonseed, and rapeseed meals (inclusion ratios of these plant-based meals in the recommended diet are 10, 14, and 20 %, respectively) by fish meal were enhanced the growth performance, feed utilization, and body composition of hybrid sturgeon. Additionally, many authors have found the survival rates of 100 % in different studies (Gui et al. 2010; Cai et al. 2011; El-Saidy and Saad 2011; Wang et al. 2014; Bu et al. 2017).

Several studies have been carried out with the replacements of soybean and cottonseed meals with each other. Lim and Lee (2011) reported no statistical alteration in *FMW* and *SGR* amongst the Nile tilapia (*Oreochromis niloticus*) fed with soybean and cottonseed meal mixed diets. El-Saidy and Saad (2011) noted that the lowest *FMW* on the same species was in the 100% cottonseed meal replacement group, while the control, 25, 50, and 75 % groups were significantly similar, and an opposite situation has been recorded in *SGR*. Yue and Zhou (2008) stated that the lowest *FMW* and *SGR* were found in the 100 % soybean meal inclusion group amongst the control, 15, 30, 45, 60, and 100 % experimental feeding groups of hybrid tilapia (*O. niloticus* × *O. aureus*). Zheng et al. (2012) conducted a study with 0, 35, 68, and 100 % inclusion levels of cottonseed meal replacing soybean meal on 7 g juvenile grass carp (*C. idellus*). The authors declared that the inclusion of higher levels of cottonseed meal instead of soybean meal reduced the *FMW* and *SR*, increased the *FCR* in grass carp. Also, they found an optimum inclusion level for cottonseed meal at 35 %.

The whole-body protein, moisture, and ash compositions were decreased with the inclusions of soybean and cottonseed meals in Russian sturgeons. Crude protein and moisture contents of crucian carps fed with 50 % cottonseed meal protein hydrolysate included diet were higher than 0, 10, and 100 % inclusion groups (Gui et al. 2010). Body lipid content increased with the inclusion of soybean meal, while reduced with the inclusion of cottonseed meal in this study. In a different study conducted with the similar method, the whole-body lipid ratio was decreased to 0.7 and 1.6 %, and increased to 2.5 and 0.8 % with the inclusions of 30 and 60 % levels of soybean and cottonseed meals than the control group, respectively. In contrast, no significant differences in whole body compositions among the treatments were reported in numerous previous studies (Luo et al. 2006; Cai et al. 2011; Liu et al. 2016; Zhou et al. 2016).

Health parameters of Russian sturgeons, including blood and serum parameters, were found in moderate levels with the inclusion of cottonseed meal as in outputs of this current study. Gui et al. (2010) declared that the 10 and 50 % inclusion of cottonseed meal protein hydrolysate were reduced the serum glucose. Bu et al. (2017) found that significant differences on plasma *ALP* carried out 0 to 60 % cottonseed meal replacement study on Ussuri catfish. They recorded that the *ALP* of inclusion ratios of 0, 10, 20, and 30 % were higher than 50 and 60 %. Different results in *ALP* were recorded by Wang et al. (2014) with the 9 to 54 % cottonseed meal inclusion with the grade levels by 9 % on common carp (*Cyprinus carpio*). The authors noted that lower levels of *ALP* in 9, 27, and 45 % inclusion groups and higher levels of control, 18, 36, and 54 % groups. They also reported that the white blood cell count (*WBC*) was improved with the 18 and 45 % inclusion levels and red blood cell count (*RBC*) was enhanced with the 54 % inclusion ratio of cottonseed meal. There are no significant differences in *WBC*, plasma glucose, protein, and phosphorus parameters among the experimental feeding groups of Russian sturgeons in this study. No significant differences in plasma parameters among the experimental groups were informed in several previous studies (Cai et al. 2011; Lim and Lee 2011; Zhou et al. 2016).

In conclusion, the replacement of fish meal with the plant-based feed ingredients is a current subject for aquafeed industry and aquaculture sector. The inclusion of the fish meal and fish oil are the main factors that increase the feed costs. The most important situation in this point is to provide a positive feeding by eliminating adverse effects on fish growth and health parameters and animal welfare. For this reason, plant-based meals with high protein content and close to the animal nutrients are preferred. Soybean meal is a raw material that fulfills this task for many years. But now it is known that there are more beneficial plant-based meals on growth and health in fish than soybean meal, and cottonseed meal is one of them. Consequently, the inclusion of cottonseed meal replacing with fish meal is more efficient than the inclusion of soybean meal in Russian sturgeon and it is recommended that the highest amount of cottonseed meal (40 %) might be used in this finfish species. Further studies are necessary about the investigations of valuable plant-based feed ingredients / additives and use of its degraded levels with replacing the fish meal on this species and other commercial fishes.

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