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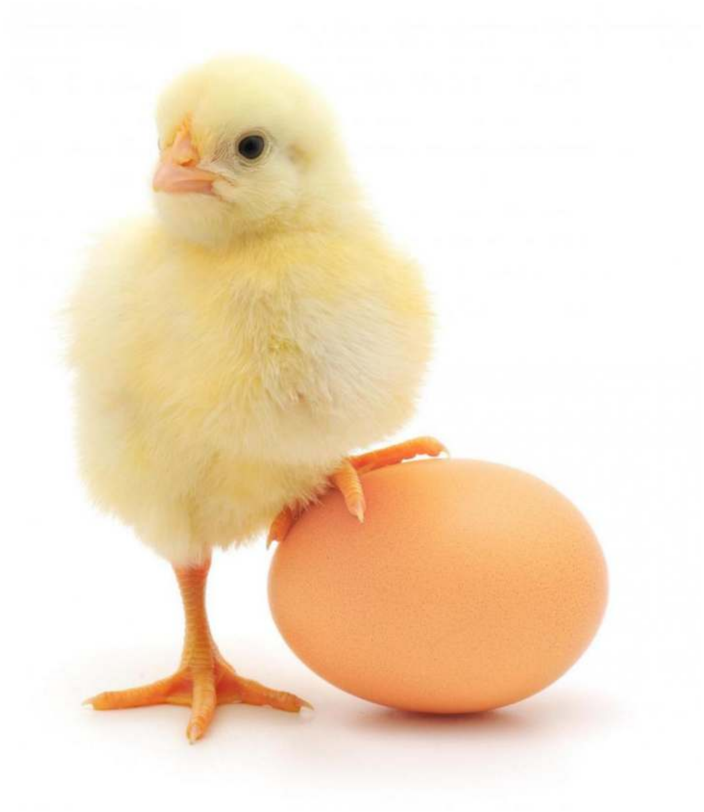

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Nutritional and Biological Evaluation of Marine Seaweed as a Feedstuff and as a Pellet Binder in Poultry Diet

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Abstract: The aim of this research was to evaluate the nutritional value of seaweed as a feedstuff for poultry and evaluate the use of seaweed as pellet binder in duck diets. Chemical analyses of dried marine red seaweed (*Polysiphonia SPP)* showed reasonable amounts of protein (32.4%); ether extract (17.7%), crude fiber (14.9%), ash (6.0%) and nitrogen free extract (23.4%). Seaweed contained appropriate amounts of minerals required by poultry. Leucine and lysine were the most abundant amino acids in seaweed protein. The content of each amino acid in seaweed protein is lower than the whole egg protein. Methionine is the first limiting amino acid (with chemical score 50.0%), valine and arginine were the second and third limiting amino acids in seaweed protein (with chemical score 71.63 and 74.33%, respectively). The estimation of Essential Amino Acid Index (EAAI) was 63.34% and the average of Total Protein Efficiency (TPE) value is 1.26. Thus seaweed is an intermediate source of protein for growing chicks. The metabolizable energy value of marine seaweed was 3518 kcal/kg. Seaweed up to 3% as a pellet binder did not adversely influence growth performance of ducks. Also, the physical test showed some improvement in pellet hardness quality. The inclusion of seaweed meal in the diet for ducks had no significant effects on all of carcass traits. In conclusion, seaweed is a valuable feed resource for poultry feeding and can be utilized as a pellet binder in duck diets.

Key words: Seaweed, protein quality, ducks performance, pellet binders

INTRODUCTION

Seaweeds had been used for many years directly for human consumption and animal feed. It is also an ingredient for the global food and cosmetics industries and is used as fertilizer and as an animal feed additive. Also, seaweeds are valuable sources of food, micro nutrients and raw materials for the pharmaceutical industry. Seaweed has plenty of essential nutrients, especially trace elements and several other bioactive substances. That explains why today seaweeds are considered as the food supplement for 21st century as source for proteins, lipids, polysaccharides, mineral, vitamins and enzyme (Rimber, 2007). Interestingly, the best known component of the seaweed-derived industry is that of the phycocolloids, the gelling, thickening, emulsifying, binding, stabilizing, clarifying and protecting agents known as carrageenans, alginates and agars (Chopin, 2007). Total annual value of seaweed production is estimated at almost US$ 6 billion of which food products for human consumption represent US$ 5 billion. Total annual use by the global seaweed industry is about 8 million tones of wet seaweed (FAO, 2003).

Few studies have been undertaken on the quality of seaweed proteins because the extraction of protein from seaweed is difficult due to presence of phenolic compounds and large amounts polyanionic cell wall mucilages (Fleurence *et al*., 1995a,b). Several researches investigated the nutritional potential value of seaweeds as a feedstuff for poultry. The nutritive value of green algae (*Predominatly Chlorella SPP.)* has been the subject of several investigators. Castro-Gonzalez *et al*. (1991) indicated that unwashed and washed dried seaweed meal (*Macrocystis pyrifera*) contains 46.27 and 46.67% nitrogen free extract and 36.67 and 34.22% ash, respectively. Washing significantly increased the content of some minerals in the seaweed. Although protein percentage was low (8.8%), it had a good amino acid balance.

Tannin was only detected at a low level (34.20 mg/g). *In vitro* and in situ DM digestibility were high (90.34 and 83.24%, respectively). It is concluded that *Macrocystis pyrifera* can be included in animal feeds, and that prior washing is not necessary. Lahaye *et al.* (1994) reported that seaweeds had total dietary fiber contents ranged between 32.7 and 74.6% (on a dry weight basis) of which 51.6 to 85.0% were water soluble. Also, Ventura *et al.* (1994) found that proximate composition of seaweed was 33 nitrogen, 17 crude fiber, neutral detergent fiber 312, acid detergent fiber 153, pentosans 13 and ash 228 g/kg DM. Robledo and Freile (1997) showed that the ash contents of *Gracilaria cornea*, *Eucheuma isiforme*, *Caulerpa racemosa*, *Codium isthmocladum*, *Padina gymnospora* and *Sargassum filipendula* ranged from 29.06 to 55.93%. *E. isiforme* had the highest protein content (12.10%), while lowest value was in *C. isthmocladum* (3.50%). Fat content was highest in

Codium isthmocladum and *Gracilaria cornea* (0.48 and 0.26%, respectively). Crude fiber varied from 1.01 to 9.07%. *E. isiforme* and *G. cornea* had the highest carbohydrate contents (25.89 and 36.29%, respectively). This indicates that the nutritive value of seaweed depends on the variety. Wong and Cheung (2000) found that total dietary fiber ranged from 50.3 to 55.4% Dry Weight (DW) and ash ranged from 21.3 to 22.8% DW were the two most abundant components in these seaweeds but their crude lipid contents were very low (ranged from 1.42 to 1.64% DW). Moreover, the swelling capacity, water holding capacity and oil holding capacity of the seaweeds had a high positive correlation with their total amount of fiber and protein.

Wong and Cheung (2000) indicated that although the crude protein content of the red seaweeds was significantly higher than that of the green, the red seaweeds (*Hypnea charoides* and *Hypnea japonica*) and green seaweed (*Ulva lactuca*) proteins contained all essential amino acids, the levels of which were comparable to those of the FAO/WHO requirement. Mohd *et al.* (2000) determined that *G. changgi* (*C. changii*) contained a higher composition of unsaturated fatty acids (74%), mainly omega fatty acids and 26% of saturated fatty acids (mainly palmitic acid) and also relatively high levels of calcium and iron.

Wong and Cheung (2001) demonstrated that protein extract ability and *in vitro* protein digestibility of the red seaweed (88.7 to 88.9%) were significantly higher than those of green seaweed (85.7%).

Major amino acid constituents were glycine, arginine, alanine and glutamic acid. Among the Essential Amino Acids (EAAs), lysine with a chemical score of 53% was the most limiting when compared with the EAAs pattern of egg protein. The total EAAs was high (36.2 to 40.2% of total amino acid content). All three seaweeds were rich in leucine, valine and threonine but poor in cystine. However, except for sulfur containing amino acids and lysine, the levels of all EAAs were higher than those of the FAO/WHO requirement pattern.

David (2001) stated that 100 g dry matter of *Ulva sp* content of vitamins A (retinal), B_1, B_2, B_3, B_{12}, folic acid and C were 960 IU, 0.06, 0.03, 8.0, 6.3, 11.8 mg and 10.0 mg, respectively and 100 g dry matter of *Gracilaria* content of vitamins B_1, B_2, B_3, B_{12}, folic acid and C were 0.4, 0.4, 14.4, 2.8 and 1.1 mg, respectively.

Okumura *et al.* (1973) showed that apparent digestibility of *Chlorella* and depigmented *Chlorella* was 74% and 75%, respectively. Also, depigmentation of *Chlorella* decreased the biological value of its protein. Metabolizable energy values of 10 and 5% *Chlorella* protein diets were 3.11 and 3.83 kcal/g and 2.54 and 2.47 kcal/g for *Chlorella* and depigmented *Chlorella*, respectively. Lipstein and Hurwitz (1983) found large variation in the ME content (from 900 to 2782 kcal/kg) and nitrogen absorption and retention (from 41.7 to 80.4% and 31.6 to 45.6%, respectively) for eight algae samples using young chick.

Poultry feed is usually manufactured in pelleted form. Pelleting of feed tend to reduce wastage, usually improves Feed Conversion Ratio (FCR) and may increase the body weight of meat type birds (Moran, 1987). Consequently feed manufactures increased the use of pelleted feed. However, pellets often disintegrate especially when high proportion of corn and fat are included in the diets (Reece *et al.*, 1986). To increase the durability of pellets, manufactures have used various types of pellet binders, methods of conditioning and different sizes of diets.

Colloidal binders, molasses and fat have been used for many years and their effect on pellet durability and pelleting efficiency has been reported (Young and Pfost, 1962). The material used as a binder may or may not add nutritive value to the diet. Lignosulfonates are by-products of the paper industry and used as pellet binders. These binders were available as sodium, calcium, or ammonium salts and contain high percentages of various wood sugars and hemicelluloses (Association of American feed control official incorporated, 1989). Takemase and Hijikuro (1984) added seaweed at 2 or 5% to basal diet for non-steam pelleted poultry diet and reported that the seaweeds tested improved pellet quality in terms of productive efficiency, bulk specific weight, hardness and durability.

The aim of this research was to evaluate the nutritional value of seaweeds as a feedstuff for poultry and to evaluate the use of seaweeds as pellet binder in ducks diet.

MATERIALS AND METHODS

Preparing of dried marine seaweed: Red seaweeds *(Polysiphonis SPP)* were collected freshly from the coast of Mediterranean Sea of Alexandria. Seaweeds were washed using tap water several times in order to get rid of associated salts and sand. The test material was dried at 60°C for 72 h in across flow drier, then grinded and kept in bags until being analyses and used in the preparation of the experimental diets.

Analytical methods: Chemical analysis for moisture, crude fiber, crude protein, ether extract, ash and minerals were determined according to the procedures outlined by Association of Official Analytical Chemists (A.O.A.C, 1985).

Determination of amino acids: Total amino acids, except tryptophan, were determined according to the method described by Duranti and Cerlletti (1979) using a Beckman amino acid analyzer Model 118/119CL.

Biological evaluation of marine seaweeds

Total protein efficiency method: The method of Woodham *et al.* (1972) was employed in this study. The composition of the basal ration was modified using available feedstuffs. Forty five one-day old commercial broiler chicks were used in this experiment. All chicks were raised in battery brooder and placed in a temperature-controlled room. During the first two weeks of age, chicks were given a standard chick starter diet. At 14 days of age, birds were individually weighed to the nearest gram and randomly divided into two groups equal in number and had proximately similar initial body weight. Chicks in each group were subdivided into three replicates. Basal diet (Basal diet 1) and tested diet (Tested diet 1) are containing 18.4% protein and 3000 kcal/kg (Table 1). The experimental diets were fed *ad libitum* from 14 to 28 day of age. The birds in each group were weighed at the end of the experiment and feed intake was also recorded. T.P.E. is the weight gain of all birds in each group divided by the protein consumed by the same group during the period from 14 to 28 days of age.

Metabolizable Energy (ME): Fourteen day-old Hubbard chicks were used as experimental birds. The chicks were reared in individual metabolic cages, which were located in the center of heated room. Four replicates of 5 chicks each were assigned to each of the dietary treatments. The chicks were given water and seaweed diet (Table 2) *ad libitum* during three days pre-experimental period. The experimental diets were formulated by adding the test ingredients at the expense of a portion of the basal diet 2. The rate of substitution was 25 % of the basal diet.

Feed intake was measured and the excreta were collected over the following three days period. The excreta samples were dried and grinded for determination of ME value.

The samples of diets and excreta were assayed for GE using Gallaenkamp Ballistic Bomb Calorimeter. Nitrogen was determined by the method of Kjeldahl (A.O.A.C., 1985). In addition, the samples were analyzed for dry matter content.

Feeding trial: This experiment was conducted to determine the effects of varying levels of seaweed in the growing duckling diet as a pellet binder on the growth, feed intake and feed conversion ratio and the physical trait of the pelleted diet.

A total number of 60 one-day old ducklings were weighed; wing banded and randomly distributed into three treatments groups each consisting of 4 replicates of 5 ducks each. The ducks were fed a starter (1 day to 5 wks of age) then finisher (6 to 8 wks of age) practical diets contained 0, 1.5 and 3% seaweed Table 3. The experimental diets were offered *ad-libitum* in pelleted form. Individual body weight, body weight gain, feed intake and feed conversion ratio were evaluated weekly. Moreover, at the end of the experiment (8 wks of age), twelve ducks from each treatment were used to study slaughter traits. The ducks were weighed, then

Table 1: Composition of the basal (1) and tested (1) diets used in determination of the total protein efficiency

	Composition			Calculate analysis	
Ingredient	Basel diet (1) (%)	Tested diet (1) (%)	Items	Basel diet (1) (%)	Tested diet (1) (%)
Wheat	48.00	48.00	Crude protein (%)	18.40	18.40
Soybean meal (44%)	27.30	13.70	ME (kcal/kg)	3003	3000
Yeast	0.40	1.50	C/P ratio	163	163
Seaweed	-	26.40	Calcium (%)	1.13	1.13
Oil	9.30	2.00	Avi. Phosphorus (%)	0.64	0.64
Bone meal	2.90	1.80			
Limestone	0.70	0.60			
Vitamin and minerals*	0.50	1.00			
NaCl	0.50	5.00			
Sand	10.40	-			
Total	100.00	100.00			

Vitamin and minerals*: Vit A 10,000,000 IU, Vit D_3 100,000; Vit E 10,000 mg, Vit K_3 1,000 mg, Vit B_1 1,000 mg, Vit B_2 4,000 mg, Vit B_6 1,500 mg, Vit B_{12} 10 mg; Niacin 20,000 mg; Pantothenic acid 10,000 mg, Folic acid 1,000 mg, Selenium 100 mg, Choline chloride 500, 000 mg, Cu 3,000 mg, Iodine 300 mg, Fe 30,000 mg; Mn 40,000 mg, Zn 45,000 mg

Table 2: Composition of the basal diet (2) used for determination of the metabolizable energy

	Composition		Calculated analysis
Ingredient	Basel diet (2) (%)	Items	Basel diet (2) (%)
Yellow Corn	70.00	Crude protein (%)	20.00
Soybean meal (44%)	20.00	ME (kcal/kg)	3022
Concentrate(52% CP)*	10.00	C/P ratio	151.1
Total	100.00		

*Concentrate analysis: 52%CP, 2440 ME kcal/kg, 2.0% EE, 3.0%CF, 7.5% Ca and 3.5% P

Table 3: Composition of experimental diets used thought the starter and finisher period

	Seaweed in starter diet			Seaweed in finisher diet		
Ingredient	0.0 (control)	1.5	3.0	0.0 (control)	1.2	3.0
Yellow Corn	66.00	66.00	66.00	74.50	74.50	74.50
Soybean meal (44%)	24.00	24.00	24.00	15.50	15.50	15.50
Concentrate (52%CP)*	10.00	10.00	10.00	10.00	10.00	10.00
Seaweed	-	1.50	3.00	0.00	1.50	3.00
Total	100.00	101.50	103.00	100.00	101.50	103.00
Calculated analysis						
Crude protein (%)	21.50	21.49	21.49	18.50	18.54	18.58
ME (kcal/kg)	3041	3048	3055	3142	3149	3153
C/P ratio	141	142	142	170	170	170
Calcium (%)	0.89	0.90	0.91	0.86	0.87	0.88
Avi.Phosphorus (%)	0.54	0.53	0.53	0.52	0.52	0.52

*Concentrate analysis:- 52%CP, 2440 ME kcal/kg, 2.0% EE, 3.0%CF, 7.5% Ca and 3.5% P

slaughtered and eviscerated weight (gizzard, heart and liver), breast length, breast width and weight of breast (muscles), thigh (muscles) and abdominal fat were weighed. Breast width was measured at the crancaltop of the keel bone, while the length was measured as the keel length.

Statistical analysis: The statistical analysis was conducted using SAS® (2001) software program. One way ANOVA of GLM procedure of SAS was used. Mean differences were tested by Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Approximate analysis: The chemical composition and mineral profiles of the dried marine seaweed (*Polysiphania SPP*) sample is given in Table 4. Crude protein in the seaweed was 32.0% and was higher than that reported by El-Deek *et al.* (1987) who found a value of 19.2% CP, while, ash content was lower than that reported by the same investigator.

Seaweed contained appropriate amounts of minerals except for Mn. The mineral content of seaweed reported by other investigators is some what variable but ours were within the range cited by El-Khimsawy (1983). These differences could be due to differences in species of seaweed and/or differences in season of harvesting the seaweed.

Essential Amino Acid (EAA's) content of seaweed: The EAAs content of seaweed is given in (Table 5). Seaweed protein contained reasonable amount of all EAA's except for methionine. Similarly, Clement *et al.* (1967) stated that the dried algae protein contained all EAA's except for sulphur containing ones.

Leucine and lysine (6.07 and 7.03 g/100g protein, respectively) were the most abundant amino acids in seaweed protein (Table 5). This result is in agreement with the result of Wong and Cheung (2001) who found that seaweed protein is rich in leucine, valine and threonine except for cystine and lysine, the levels of all EAAs in two red seaweeds (*Hypnea charoides* and *Hypnea japonica*) and one green seaweed (*Ulva lactuca*) were higher than those of the FAO/WHO requirement pattern. Also, Kawamata *et al.* (1988) found that glutamic acid and valine were the most abundant amino acids in dried algae. The EAAs in seaweed compared with those in whole egg protein is shown in (Table 5). The content of each amino acid in seaweed protein is lower than that of egg protein. Similarly, El-Khimsawy (1983) reported difference between algae and egg protein in amino acids content (lysine was 10% less in algae protein compared to egg protein). Also, Mohd *et al.* (2000) reported that the major amino acid components of *G. changgi* were glycine, arginine, alanine and glutamic acid but lysine had a chemical score of 53% and was the most limiting in *G. changgi* when compared with the EAAs pattern of egg protein.

The present results are on line with those abovementioned and indicated that methionine is the 1st limiting amino acid (with chemical score 50.0%), valine and arginine were the 2nd and 3rd limiting amino acids in seaweed protein (with chemical score 71.63 and 74.33%, respectively). The estimation of EAAs index (EAAI) was 63.34% using the AA requirement cited by NRC (1994). This value is lower than the most other vegetable protein meals, such as cotton seed meal (80%), linseed meal (79%) and alfalfa meal (86%). El-Khimsawy (1983) reported that seaweed (marine algae) had an EAAI value of 74.0%. The difference in EAAI values may be due to the differences of seaweed species, harvesting and processing methods.

Biological evaluation of seaweed

Metabolizable Energy values (ME): The ME's content for seaweed tested and that of the basal diet was established by biological test are shown in (Table 4). The ME value of marine seaweed was 3518 kcal/kg and higher than that reported by El-Deek *et al.* (1987) who indicated that the ME value of seaweed was 2129 kcal/kg. This difference may be due to the differences in

Table 4: Chemical composition, ash content and ME (kcal/kg) of seaweed

Chemical Constituents,%	Air dry basis %	Ash content	mg/100 g dry matter
Moisture	6.00	Iron (Fe)	1.75
Crude protein	32.00	Zinc (Zn)	7.00
Ether extract	17.70	Manganese (Mn)	-
Crude fiber	14.90	Copper (Cu)	1.00
Ash	6.00	Sodium (Na)	45.00
NFE.	23.40	Potassium (K)	92.50
		Magnesium (Mg)	14.00
Total	100.00		
ME (kcal/kg)	3518.0±2.64		

Table 5: Essential amino acids determined in seaweed compared with those content in whole egg protein and EAA index

	Seaweed		Whole egg	Chicks	
Amino acids	Protein (g/100g)	Seaweed of (%)	g/16g nitrogen*	Requirements (% of CP)	Chemical score
Threonine	4.91	1.04	4.70	3.50	130.06
Valine	3.31	0.70	6.60	4.30	71.63
Methionine	1.076	0.23	3.20	2.00	50.00
Isoleucine	4.16	0.88	5.40	4.00	96.75
leucine	6.07	1.28	8.60	7.00	80.71
Phenylalanine	4.23	0.89	6.00	3.50	112.29
Lysine	7.03	1.98	7.00	5.00	174.80
Arginine	4.79	1.01	6.50	6.00	74.33
EAAI	63.34				

*Oser 1965

Table 6: Performance of chicks used in the Total Protein Efficiency (TPE) experiment

Parameter	Control	Seaweed
Body weight gain (g)	517.7±26.30	228.8±16.50
Feed consumption (g)	1100.1±48.90	1003.4±6.07
Feed conversion ratio (g/g)	2.13±0.15	4.39±0.06
Total Protein Efficiency (TPE)	2.63±0.17^{a}	1.26±0.02^{b}

^{ab}means having different superscript in each column are differ significantly ($p \leq 0.05$)

Table 7: Growth performance of ducks fed diets with two levels of seaweeds as a pellet binder

Treatment	Body weight at 1st day (g)	Body weight at 8 weeks (g)	Body weight gain (g)	Feed Intake (g)	feed conversion ratio (g feed/ gain)
Basal diet	74.5±1.5	2320.0±51.1	2245.5±50.6	6270.8±115.3	2.79±0.09
Basal diet+1.5 %seaweed	73.7±1.4	2290.0±34.9	2216.3±34.6	6162.1±144.7	2.78±0.04
Basal diet+3.0% seaweed	75.1±1.2	2235.5±35.0	2160.6±34.8	6080.6±98.4	2.81±0.85
P. value	NS	NS	NS	NS	NS

NS = Not Significant

Table 8: Carcass characteristics of ducks at the end of experimental period (8 wks of age) and the hardness of tested pellets diets

Parameters	Basal diet	Basal diet+1.5 % seaweed	Basal diet+3.0% seaweed	p-value
Live body weight (g)	2530.0±37.9	2411.3±30.6	2428.0±59.9	NS
Dressing (g/100 g BW)	57.2±0.53	57.3±0.63	56.3±0.54	NS
Abdominal fat (g/100g BW)	7.48±0.60	9.12±0.86	6.63±0.43	NS
Liver(g/100g BW)	7.95±0.19	7.65±0.23	8.45±0.69	NS
Heart (g/100g BW)	4.96±0.09	4.53±0.09	4.70±0.17	NS
Gizzard (g/100g BW)	10.06±0.22	9.59±0.18	10.84±0.36	NS
Breast meat (g/100g BW)	27.02±0.41	27.67±0.40	26.70±0.40	NS
Thigh meat (g/100g BW)	22.74±0.37	23.44±0.28	22.44±0.28	NS
Breast width (cm)	20.25±1.31	16.87±0.31	21.62±0.14	NS
Breast length (cm)	17.38±0.24	16.75±0.48	16.75±0.14	NS
Hardness of tested pellets	20.80±1.69	28.33±1.28	23.20±0.74	NS

NS = Not Significant

the drying process, time of harvesting, the variety of seaweed used and/or difference in the experimental animals. Okumura *et al*. (1973) determined ME values of 10 and 5% *Chlorella* protein diets as 3110 and 3830 kcal/kg and 2540 and 2470 kcal /kg for *Chlorella* and depigmented *Chlorella*, respectively. Also, Lipstein and

Hurwitz (1983) found large variation in the ME content (from 900 to 2782 kcal/kg) for eight algae samples using young chickens. Nevertheless this meal showed a reasonable ME value that can be a possible source of available energy for chicks.

Total Protein Efficiency (TPE): The results of body weight gain, feed consumption and feed conversion ratio for broiler chicks throughout TPE experiment showed that the performance of chicks fed diet with seaweed was poorer than those given the control diet (Table 6).

The average of TPE values showed highly significant difference between the seaweed TPE (1.26) and the value (2.63) of the control diet (Table 6). According to Mokady *et al.* (1978) and Becker (1978) TPE of algae meal was in range of 2.2 and 2.6. These differences may be due to differences in species of algae, drying procedure and the time of harvesting.

The present results indicated that seaweed is an intermediate source of protein to growing chicks. Lipstein and Hurwitz (1983) found large variation in the nitrogen absorption and retention (from 41.7 to 80.4% and 31.6 to 45.6%, respectively) for eight algae samples using young chickens.

Utilization of seaweed as a pellet binder: Using of 1.5 and 3% seaweed as a pellet binder did not significantly affect growth performance of ducks (Table 7). However, feed intake from 2 to 4 wks of age showed a significant decrease of groups fed diet contains both levels of the seaweed as compared to those of control diet. These results indicate that up to 3% of seaweed as pellet binders did not adversely influence ducks performance. On the other hand, pelleting of poultry diets reduces wastage, improves FCR and increases body weight (Moran, 1987).

The result of the physical test performed on the pellet produced after the addition of seaweed induced an improvement in pellet hardness quality (Table 8). Similarly Takemasa and Hijikuro (1984) found that the addition of seaweed to the diet improved pellet quality in terms of production efficiency, hardness and durability. Data for carcass quality (Table 8) indicates that inclusion of seaweed meal up to 3% in the diets for ducks had no significant effects on all carcass traits. Similar results were reported by Kienholz *et al.* (1987) and Zatari and Sell (1990).

The results of this study indicated that up to 3% seaweed in diets can be a good pellet binder and source of available nutrients for ducks.

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