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RESEARCH ARTICLE

GROWTH AND REPRODUCTIVE PERFORMANCE OF LAHORE PIGEONS FED WITH *SARGASSUM WIGHTII* AS A DIETETIC SUPPLEMENT

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ABSTRACT

A feed tryout was conducted to estimate the effects of dietary inclusion of *Sargassum wightii,* as a supplement to Lahore pigeons, on their growth and reproductive performance under Indian circumstances. A total of 50 pairs of 2-months old Lahore pigeons were divided into five groups (each with 10 pairs) and the pigeons in the first group were fed only with basal feed while those in the 2nd, 3rd, 4th and 5th groups were fed with the basal feed and 50 mg, 100 mg, 150 mg and 200 mg of *Sargassum* powder respectively per day. Availability of minerals and other dietary components from *Sargassum* powder was appreciably reflected in the body weight gain, feed intake and feed conversion rate of pigeons. The maturation period was shortened from 180±12 to 160±10 days, the egg cycles were increased from 4±1to 6±2 per year, the number of eggs was increased from 8.00±2.0 to 14.0±1/pair/ year, egg interval of brood was reduced from 37±3 to 34±2 hours, the egg weight was increased from 14.44±1.2 to 15.81±1.28 g, the percentage of fertile eggs was increased from 82.7 - 82.2% to 85.3 - 89.0 %, the eggs' hatchability was increased from 85.3 to 89.0%, the embryo death was reduced from 3.3±1. 1 to 2.8±1.2, squab mortality was reduced from 19.4±2 to 10.1±2, the weight gain of young squabs was increased from 492±12.21 to 505±12.30 g/squab and the squab production was raised from 6.0±0.3 to 7.2±0.2 pairs / year. These growth and reproductive performances of pigeons increased with increase in the dosage of *Sargassum* powder from 50 to 200 mg / bird / day. In pigeons fed with 150 and 200 mg of *Sargassum* powder/day, the reproductive potential observed in the third year was higher than that in the control pigeons in the very first year, which implied that no one component of *Sargassum* powder had induced reproductive stress in the experimental pigeons. This study therefore recommends that pigeon growers can give 150 or 200 mg of *S. wightii* powder as a feed supplement to pigeons for improving their growth and vigor.

INTRODUCTION

In the past few decades pigeon production industry has made available some feed formulations, vitamin supplements, vaccines and drugs with which the problems of under nutrition and disease outbreaks can now be managed productively. Even though such products are relatively cheap and indispensable components for pigeon production units, many growers in the rural and urban parts of India cannot grow pigeons profitably because of low productivity and reproductive potential of pigeons while feeding them with basic diets and because of unexpected disease outbreaks in the lofts. Perusals of available literatures make it clear that dietary supplements such as probiotics, herbal powders and algal products have been put in use in the poultry ration for enhancing the growth and reproductive attributes and innate immunity to provide adequate protection to fowls. *Sargassum wightii* is one of the dietary supplements that have increased the growth and reproductive capabilities of fowl, shrimps, ducks and mice. The brown seaweed *S. wightii* is a macroscopic marine alga found attached to rocky bottom of shallow coastal waters of Tamilnadu and many parts of Asia, which has been used as animal feed, food ingredients, fertilizer, medicines and raw materials (Levering *et al*., 1969). This marine alga is a good source of minerals, vitamins (A, B_1, B_2, C, D and E), proteins, essential amino acids, fats, fatty acids, polysaccharides, fibers and flavanoids (Lahaye, 1991 and Darcy-Vrillon, 1993) and its protein and lipid qualities are acceptable for humans and veterinary animals as it contains relatively high proportion of essential amino acids and unsaturated fatty acids (Thillaikkanu Thinakaran *et al*., 2012).

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In addition, it contains some bioactive compounds (Meenakshi *et al*., 2009; Antonisamy *et al*., 2012) responsible for its antiviral, anti-fungal, antioxidant, anti-inflammatory, antiallergenic, anti-thrombic, anti-carcinogenic, hepatoprotective and cytotoxic activities (Jiang *et al*., 2008; Jeyaraman Amutha *et al*., 2013) due to the presence of long-chain fatty acids (Visakh Prabhakar *et al*., 2011), polyphenols (Chandini *et al*., 2008; Ganesan *et al*, 2008), saponins (Rajasulochana *et al*., 2009), alkaloids, sterols (Sanchez-Machado *et al*., 2004; Rajasulochana *et al*., 2009), flavonoids and fucoidan (Yang *et al*., 2008). The unsaturated fatty acids, especially PUFAs, increase the growth and development of many fishes and animals (Nordoy, 1989; Estevez *et al*., 1999; Evans *et al*., 2000) and at the same time decrease the levels of the expression of cytokines necessary for shifting the function of lymphocytes from the cells mediated response to antibody-mediated response (Klasing and Leshchinsky, 1999). Essential amino acids present in the seaweed make it a highly valuable protein in the food (Orr and Watt, 1968).

Dietary supplementation of *S. wightii* has enhanced the weight gain of mice (Yung-Choon Yoo *et al*., 2007), tiger shrimp (Felix *et al*., 2004.2005), ducks (Breikaa, 1993) and poultry (El-Deek *et al*. 2011). In poultry, dietary supplementation of *S. wightii* has increased the feed conversion rate and weight gain but lowered the blood cholesterol levels (El-Deek *et al*., 2011). As this algal powder is rich in acceptable proteins, it has been recommended as a dietary supplement for cattle in China, Thailand, Korea, Japan, Indonesia and Philippines (Kolanjinathan *et al*., 2014). The present study was undertaken to analyze the suitability of the dried powder of *S. wightii* for using as a dietary supplement to pigeons and its pros and cons in pigeon keeping by growing them for a period of three consecutive years.

MATERIALS AND METHODS

Preparation of *Sargassum* powder

Specimens of *S. wightii* (Phaeophyceae) were collected from the coastal village Leepuram near Kanyakumari (Lat 9º11′ N; Long79º 24′E) of Tamilnadu and brought to the laboratory. They were washed repeatedly with tap water for 3 times to remove dust particles, sand and epiphytic microalgae. The whole plants were dried under shade, and then sun dried and ground into *Sargassum* powder. This powder was then stored in a refrigerator.

Chemical analysis of *Sargassum* powder

The protein content of *Sargassum* powder was estimated using the Biurrette method described by Raymont *et al.* (1964). The lipid was extracted using chloroform methanol mixture as a solvent and estimated by using the method described by Folch *et al.* (1956). The method described in the AOAC (1995) was followed for the quantification of minerals in *Sargassum* powder. A 0.2 g of oven dried *Sargassum* powder was taken in a dry conical flask and treated with 10 ml of diacid mixture (2:5 of Nitric acid and Perchloric acid). The content of conical flask was allowed to stand for a few hours for cold digestion. After that, the conical flask was kept on a hot plate to digest the contents under the influence of temperature. The digested content was filtered through a Whatman No.40 filter paper to get a filtrate. The filtrate was suitably diluted and fed into ICP - Perkin Elmer Mayer Optical Emission Spectrophotometer (Optima 2100 DV) as per the procedure given in the Users' Manual for analyzing the amount of Mg, Cu, Mn, Fe and Zn present in the filtrate. Na, K, I and Ca were analyzed with Flame Photometer. For the estimation of methionine, cystine and lysine contents, one gram of *Sargassum* powder was hydrolyzed with 6N hydrochloric acid in evacuated sealed tube for 24 hours at 110ºC and the hydrolyzed sample was analyzed with Waters Pico-Tag HPLC Amino acid Analysis System (Column: Pico-Tag amino acid analysis column, 3.9 (150 mm); detector: Waters 2489 Dual λ absorbance detector).

Experimental Design

Two months old Lahore pigeons (*Columba livia domestica*; family: Columbidae; order: Columbiformes) were chosen as the experimental birds for this study. 50 pairs of pigeons were divided into five groups each with 10 pairs and every group was grown in a separate loft of 5′ x 7′ x 3′ size. The lofts were constructed with wooden frame, steel plated roof and wire mesh floor and lateral sides. These lofts were kept at a height of 2.5′ from the ground level for reducing dampness facilitating the rapid spreading of pathogenic germs. Feed mixture (in Table 1) was given at the rate of 90 grams / pair / day and drinking water was provided at the rate of 120 ml/ pair/day. Vitamins required for the birds were provided along with the drinking water at the rate of 5ml of Vimeral® (vitamin mix)/ 1 liter water. This feed composition was maintained throughout the study period for feed uniformity in the experimental pigeon groups. Pigeons in the first group were fed only with the basal feed and those in the 2nd, 3rd, 4th and 5th groups were fed with the basal feed as usual and 50mg, 100mg, 150mg and 200 mg of *Sargassum* powder respectively per day.

Table 1. Composition of basal feed

Ingredients	Percentage
Wheat grains	35 %
Finger millet	15%
Pearl millet	15%
Green pea	30%
Grid*	4.97%
Vimeral ® **	0.5ml/pair

* Grid: I kg contains 100 g charcoal, 100g egg shell, 75g limestone, 150g table salt and 575g brick powder; ** Vimeral ®: 1ml contains vitamin A -12,000 IU; Vitamin B_{12} – 20 mcg; vitamin D_2 -6,000 IU; and vitamin E -40mg.

Estimation of growth and reproductive changes

All the five pigeon groups were maintained properly for the period of three consecutive years (Jan 2012 – Dec 2015) and their squabs were transferred regularly to other lofts after attaining full flight stage (56th day). Weight of the birds was estimated with a digital electronic balance and feed intake per pair was taken from the difference between the weight of feed provided in the morning and of feed left unconsumed in the evening. Reproductive parameters such as maturation period, number of egg cycles, length of egg cycles (interval between two consecutive laying seasons), interval between the appearance of first and second eggs, total egg production, egg weight, percentage of fertile eggs, hatching percentage, dead embryos in eggs, change in body weight of squabs at weekly intervals, and mortality and livability of squabs were recorded.

Statistical analysis

Data obtained from this experiment was subjected to one-way ANOVA, using SPSS (1997) computer software. The significant differences among the means of different dietary treatments were analyzed with the Duncan multiple range test (Duncan, 1955).

RESULTS

Chemical composition of *Sargassum* powder

Biochemical analysis showed the presence of 6.42±0.38% crude protein and 1.04±0.031% crude fats in the dried powder of *S. wightii*. In addition, this powder had minerals such as Na (690 µg/g), K (182µg/g), P (45mg/g), Ca (80µg/ g), Mg (5892µg/ g), Mn (21.3µg/ g), Zn (73.4 µg/ g), Cu (39.5 µg/ g), Fe (256µg/ g), Al (182µg/ g) and Co (1.2 µg/ g). The essential amino acids methionine (280mg/g), cystine (260mg/g) and lysine (367 mg/g) were also present in the *Sargassum* powder.

Chemical analysis of basic feed

Chemical analysis according to the NRC (1994) shows that a 100 gram of the basic feed contains crude proteins (11.48g), crude fats (5.21g), metabolic energy (291.574 Kcal), calcium (1149mg), phosphorus (562mg), sodium (160 mg), copper (0.42 mg), iodine (0.1mg), zinc (2.53 mg), manganese (2.73mg), methionine (280mg), cystine (260mg) and lysine (362 mg) (Table 2). The basic feed supplemented with *Sargassum* powder had relatively higher amount of all the above said nutrients than the basic feed we used in the experiment.

Growth performance of pigeons

Body weight of pigeons significantly increased with the increasing dosages of *Sargassum* powder (Table 3). There was a gradual increase in the body weight of the birds up to the end of the first year and it slowed afterward up to the end of the second year, which was followed by a steady state in the weight gain in all the experimental groups. At the end of active growth phase (12th month), weight of pigeons was 473±9, 507±13, 507 ±13 and 507±13 grams in response to 50 mg, 100 mg, 150 mg and 200 mg of *Sargassum* powder respectively instead of 467±10 g in the control group. At the end of the second year, weight of pigeons was 501±12, 549±10, 565 ±14 and 573±13 grams in response to 100 mg, 200 mg, 300 mg and 400 mg of *Sargassum* powder respectively instead of 494±12 g in the control.

Table 2. Levels of recommended dietary components in the basal feed and *Sargassum* supplemented test feed (100g each)

Constituents of diet*	Basal feed (Control)	Basal feed + 50mg of S.wightii	Basal feed + 100mg of S.wightii	Basal feed + 150mg of S.wightii	Basal feed + 200mg of S.wightii
Crude protein (g)	11.47	11.54	11.61	11.68	11.75
Crude fibers (g)	5.21	5.26	5.27	5.32	5.39
Fats (g)	3.61	3.62	3.63	3.64	3.65
ME (Kcal/Kg)	2915.74	2916.00	2916.26	2916.52	2916.77
Calcium (mg)	1149	1149.16	1149.32	1149.48	1149.62
Phosphorus (mg)	562	575	584	591	599
Sodium (mg)	160	160.69	161.36	162.07	162.76
Zinc (mg)	2.53	2.60	2.68	2.76	2.84
Manganese (mg)	2.73	2.77	2.81	2.85	2.89
Iodine (mg)	0.1	0.115	0.130	0.145	0.160
Copper (mg)	0.42	0.46	0.50	0.54	0.56
Methionine (mg)	280	283.7	287.4	291.1	294.8
Cystine (mg)	260	262.5	265	267.5	268
Lysine (mg)	362	367	373	378	383

* Calculated according to NRC (1994)

Table 3. Variation in the body weight (g) of pigeons in response to different concentrations of *Sargassum wightii*

Body weight at the end of	Control	Dosages of Sargassum wightii / day			
		50 mg	100 mg	150 mg	200 mg
2nd month	285±9^{a}	286±9^{a}	286±9^{a}	286±9^{b}	286±9^{b}
12th month	467±10^{a}	473±9^{b}	507±13^{b}	507±13^{b}	508±16^{c}
24th month 36th month	494±12^{a}	501±12^{b}	549±10^{b}	565±14^{b}	573±13^{c}
	492±11^{a}	480±11^{a}	558±10^{a}	564±14^{b}	565±13^{b}

Figure after ± represents standard deviation; n=10 pairs; ^{a} $p<0.05$; ^{b} $p<0.025$; ^{c} $p<0.01$.

Table 4. Variation in the mean body weights (g) of male and female pigeons in response to different concentrations of *Sargassum wightii*.

Body weight of	Basal feed (Control)	Dosages of Sargassum powder /day				r-value
		50mg	100mg	150mg	200mg	
Males	494±12	553±18	573±19	579±13	592±12	+0.122*
Females	473±14	492±14	512±17	516±19	528±16	-0.121*
Difference in weights	47±13	61±16	61±18	63±17	64±13	-

Figure after ± represents standard deviation; n=10 pairs; * ($p<0.01$)

At the steady state, the body weight was 492±11g in the control group while it was 480±11g, 558±10g, 564±14g and 565±13g at 50 mg, 100 mg, 150 mg and 200 mg of *Sargassum* powder respectively. Furthermore, the mean weight of male pigeons was significantly higher ($r = +0.122$; $p<0.01$) than that of the female pigeons (Table 4). Data given in the table 5 shows that feed intake of pigeons had increased drastically

Table 5. Feed intake (g/pair/day) of pigeons in response to different doses of *Sargassum wightii*

Feed intake of pairs with	Control	Dosages of Sargassum wightii /day			
		50 mg	100 mg	150 mg	200 mg
Without squabs	90±5^{a}	96±5^{a}	98±3^{a}	99±1^{b}	102±0^{b}
1 day old squabs	101±7^{a}	110±8^{a}	114±7^{b}	104±6^{b}	112±7^{b}
7 days old squabs	127±10^{a}	145±11^{a}	153±9^{a}	160±8^{a}	164±8^{b}
14 days old squabs	136±12^{a}	155±10^{a}	163±10^{b}	168±7^{b}	174±9^{b}
21 days old squabs	155±13^{a}	163±11^{a}	171±11^{b}	174±10^{b}	179±10^{c}
28 days old squabs	163±14^{a}	172±12^{b}	176±11^{b}	181±9^{b}	183±9^{c}
35 days old squabs	163±14^{a}	176±12^{b}	179±10^{b}	182±9^{b}	186±9^{c}
42 days old squabs	165±10^{a}	179±13^{b}	183±10^{b}	185±11^{b}	188±10^{c}
49 days old squabs	168±13^{a}	181±12^{b}	184±11^{a}	187±10^{b}	190±10^{c}
56 days old squabs	176±16^{a}	182±15^{a}	186±14^{a}	188±11^{b}	190±10^{b}

Figure after ± represents standard deviation; n=10 pairs; ^{a} $p<0.05$; ^{b} $p<0.025$; ^{c} $p<0.01$.

Table 6. Changes in the reproductive characteristics of Lahore pigeons in response to different concentrations of *Sargassum wightii*

Items	Control	Dosages of Sargassum wightii / day			
		50 mg	100 mg	150 mg	200 mg
Maturation period (days)	180±12^{a}	178±13^{a}	167±11^{b}	161±12^{b}	160±10^{b}
Number of egg cycles/year					
1st year	2±0^{ns}	2±0^{a}	2±1^{b}	2±1^{b}	2±1^{b}
2nd year	4±2^{a}	4±2^{b}	5±1^{b}	6±1^{b}	6±1^{c}
3rd year	4±2^{a}	5±1^{b}	5±2^{b}	6±2^{b}	6±2^{c}
Total	10±4^{a}	11±3^{a}	12±3^{b}	14±3^{b}	14±3^{c}
Egg cycles length (days)					
1st year	64±7^{a}	61±8^{a}	47±10^{a}	41±11^{a}	41±10^{a}
2nd year	65±6^{a}	63±10^{a}	49±7^{a}	42±8^{a}	42±7^{a}
3rd year	64±9^{a}	63±6^{a}	50±10^{a}	43±8^{a}	43±9^{a}
Number of eggs/ pair					
1st year	4.00±0^{a}	4.0±1^{a}	4.0±1^{a}	5.0±1^{b}	5.0±1^{b}
2nd year	8.00±2^{a}	8.5±1^{a}	10.5±0^{b}	14.0±1^{b}	13.5±1^{c}
3rd year	8.00±2^{a}	10.0±1^{b}	12.0±1^{b}	14.0±1^{b}	14.0±1^{c}
Duration between 1st and 2nd egg (hours)					
1st year	34±3^{a}	34±3^{a}	34±2^{a}	34±2^{a}	34±3^{a}
2nd year	35±2^{a}	34±2^{b}	34±3^{b}	34±3^{b}	34±2^{b}
3rd year	36±2^{a}	35±2^{b}	35±3^{b}	35±2^{b}	34±3^{b}
Egg weight (g)					
1st year	14.44±1. 2^{a}	14.87±1.57^{a}	15.21±1.24^{a}	15.47±1.13^{b}	15.81±1.28^{b}
2nd year	14.41±1. 0^{a}	14.80±1. 32^{a}	14.86±1. 17^{b}	15.2±1.3^{b}	15.13±1.21^{c}
3rd year	14.34±1. 1^{a}	14.76±1. 23^{b}	14.83±1. 1^{b}	14.87±1. 2^{b}	14.96±1. 13^{c}
Fertile eggs %					
1st year	82.7±1. 1^{a}	85.2±1. 3^{a}	85.9±1. 2^{b}	87.6±1. 4^{b}	88.9±1. 2^{c}
2nd year	83.1±1. 2^{a}	85.7±1.4^{a}	86.3±1. 3^{b}	88.6±1. 1^{b}	88.9±1. 4^{c}
3rd year	82.2±1. 2^{a}	84.6±1. 4^{a}	86.3 ±1. 4^{b}	88.9±1. 2^{b}	89.0±1. 2^{c}
Hatching %					
1st year	84	85	86	88	88
2nd year	84	85	86	87	87
3rd year	83	84	85	86	86
Embryo death %					
1st year	3.7±1. 3^{a}	3.5±1. 3^{a}	3.2±1. 1^{a}	3.0±1. 2^{b}	2.7±1. 3^{c}
2nd year	3.5±1. 2^{a}	3.5±1. 2^{b}	3.3±1. 2^{b}	3.2±1. 1^{c}	2.8±1.2^{c}
3rd year	3.3±1. 1^{a}	3.5±1. 3^{a}	3.2±1. 2^{b}	3.1±1. 2^{c}	2.8±1. 2^{c}
Squabs death%					
1st year	20±5^{a}	18±4^{a}	14±4^{b}	14±2^{b}	14±1^{c}
2nd year	19±4^{a}	17±3^{b}	14±3^{b}	11±2^{b}	11±1^{c}
3rd year	20±4^{a}	17±2^{b}	13±2^{b}	10.3±2^{b}	10.1±2^{c}
Squabs production	4.5±0.3^{a}	6.0±0.3^{b}	6.5±0.2^{b}	7.0±0.18^{b}	7.2±0.2^{c}

Figures after ± represent standard deviation; ^{a} $p<0.05$; ^{b} $p<0.025$; ^{c} $p<0.01$.

while increasing the dosage of *Sargassum* powder from 50mg to 200 mg / bird/day. *Sargassum* powder had enabled the pigeons to intake somewhat higher amount of feed compared to control group, which was observed in all the experimental groups irrespective of age difference. Feed intake of adult pair was almost 90g/day but feed supplementation increased it up to 102g/day. Moreover, increase in the weight of pigeons during this experiment was mainly due to gradual increase in

Table 6. Variation in the weight of squabs in response to different concentrations of *S. wightii*

Days	Control	Dosages of Sargassum wightii /day			
		50 mg	100 mg	150 mg	200 mg
1st day	19±2.12 [a]	19±2.18 [a]	19.62±3.29 [a]	19.72±3.14 [b]	19.72±3.28 [b]
7th day	99±8.21 [a]	102±8.28 [a]	112±8.28 [b]	111±10.52 [b]	112±10.63 [c]
14th day	233±11.36 [a]	241±11.96 [b]	252±11.96 [b]	249±11.26 [b]	249±10.16 [c]
21st day	304±9.54 [a]	315±7.74 [b]	324±7.74 [b]	326±12.71 [c]	327±12.76 [c]
28th day	353±11.61 [a]	376±8.67 [b]	386±10.67 [b]	389±12.27 [c]	390±12.26 [c]
35th day	452±12.29 [a]	264±11.42 [b]	270±11.42 [b]	273±12.32 [b]	279±12.12 [c]
42nd day	481±12.45 [a]	492±12.21 [a]	501±12.21 [b]	504±12.32 [b]	505±12.30 [b]
49th day	426±12.4 [a]	431±10.5 [a]	438±8.5 [b]	439±10.8 [b]	439±10. 8 [b]
56th day	314±12.4 [a]	328±12.9 [a]	342±8.8 [b]	367±11.7 [b]	371±11.7 [b]

Figure after ± represents standard deviation; n=25 squabs; [a] $p<0.05$; [b] $p<0.025$; [c] $p<0.01$.

the food intake of squabs and due to higher feed conversion rate. Newly hatched squabs were totally depending on crop milk of both parents up to the 4th day, then the parents started to feed the crop milk along with food grains until 14th day of age and thereafter they feed only on food grains. Hence, feed intake of pigeons increased from the first day to 56th day and it was the maximum at 150 and 200mg dosages of *Sargassum* powder.

Reproductive performance of pigeons

Table 6 clearly shows the changes in the reproductive distinctiveness of Lahore pigeons in response to dietetic supply of 50mg, 100mg, 150mg and 200mg of *Sargassum* powder / bird / day. *Sargassum* powder had shortened the maturation period from 180±12 days (control) to 174±13, 167±11, 161±12 and 160±10 days in response to 50mg, 100mg, 150mg and 200 mg of the herbal powder respectively. The maturation period of pigeon was inversely proportional to the increasing dosages of *Sargassum* powder (up to 200 mg / bird / day). Pigeons fed only with the basal diet produced 4±2 egg cycles per year whilst those fed with *Sargassum* powder had produced 5±1to 6±2 egg cycles/ year. In the first year, the number of egg cycles/pair was remarkably low as the birds needed at least six months to attain sexual maturity but in the subsequent years it was more or less constant in each group of pigeons. In this experiment, the number of egg cycles/pair was higher in the *Sarassum* fed pigeons than the control group and it significantly increased with increasing dosages of this supplement.

The length of egg cycle - the duration between the second egg of a brood and the first egg of the next brood - was also significantly changed while feeding the pigeons with *Sargassum* powder. In all the experimental groups, the length of egg cycle slightly increased from the first year to the third year. However, the length of egg cycles was shorter (61±8 to 42±7 days) in pigeons fed with *Sargassum* powder than that in the control group (66±3 to 66±4 days). Higher doses (150 & 200 mg/day) had the maximum shortening effect on the length of egg cycle. The interval between the first and second egg was also significantly affected while feeding pigeons with different doses of *Sargassum* powder. In the control group the egg interval of broods was increasing from 34±4 (1st year) to 36±2 hours (3rd year), but in *Sargassum* fed pigeons there was no pronounced extension of egg interval in due course of the experiment and the egg interval ranged from 34±3 to 35±2 hours. There was a reduction of 2±2 hours in the egg interval of pigeons fed with 100mg, 150 mg and 200 mg of *Sargassum* powder.

In the present experiment the number of eggs / pair / year was significantly changed by different doses of *Sargassum* powder compared to the control. Pigeon pair fed with the basal feed had laid 4 eggs in the first year and 8±2 eggs in the subsequent years whereas those fed with *Sargassum* had laid 4 eggs in the first year and 8.5-15 eggs in the subsequent years. The number of eggs produced per year was positively correlated with the increasing dosages of *Sargassum* powder. High doses of *Sargassum* powder (150 & 200 mg) had increased the egg productivity by 75% of the total production. The first egg was slightly heavier than the second egg of the same brood and it was observed even in pigeons fed with *Sargassum* powder. In the control group the mean egg weight decreased from 14.44±1.2 g (1st year) to 14.34±1.1g (3rd year) while in pigeons fed with *Sargassum* powder the mean egg weight was ranged from 14.76±1.23g to 15.81±1.28g in the first year and from 14.76±1.23 to 14.96±1.13 g in the third year. The egg weight of *Sargassum* fed pigeons in the third year was greater than the egg weight of controls in the first year, which indicated that it was a suitable feed supplement to increase the egg weight. The percentage of fertile eggs laid by pigeons fed with *Sargassum* powder was relatively higher than that in the pigeons of control group. *Sargassum* powder had increased the fertility percentage up to 85.2 – 89.0% instead of 82.7 - 82.2% in the control. In this experiment slight increase in egg fertility was observed even at the 50 mg dose of *Sargassum* (3rd year) and it was the maximum at 150 and 200 mg/day. The fertile eggs of *Sargassum* fed pigeons in the third year were more in number than those of controls in the first year. In the control hatching success was found to be 84% while *Sargassum* powder had raised the hatching percentage to 85-88% depending on the dosages. There was no significant change in the hatchability of eggs in the control group during the course of experiment. Higher hatching percentage was observed in pigeons fed with 150 and 200 mg of *Sargassum* powder/day. The egg hatchability of *Sargassum* fed pigeons in the third year was beyond the egg hatchability of controls in the first year, which showed that *Sargassum* had some positive effects on the egg hatchability of pigeons. *Sargassum* powder had reduced the embryo death in eggs during incubation from 3.7% (control) to 2.8% at the higher (150 & 200 mg/day) doses. Mortality percentage of squabs before full-flight stage (56th days) in pigeons fed with *Sargassum* powder significantly differed from that in the pigeons of control group. The mortality percentage of young squabs was ranged from 10.1±2 to 18.4±4 in the *Sargassum* fed pigeons instead of 19±4 -20±4% in the control group. In *Sargassum* fed pigeons, the annual squab production per pair ranged from 6.0±0.3 to 7.2±0.2 instead of 4.5±0.3 squab pairs in the control.

Further, this data reveals that the squab production had increased with increasing dosage of *Sargassum* powder. Results in the table (6) shows that there were significant differences in the body weight of squabs on the 1st, 7th, 14th, 21st, 35th, 42nd, 49th and 56th days both in the control group and in pigeons fed with 50mg, 100mg, 150mg and 200 mg of *Sargassum* powder per day. In the control group, the weight of squabs increased from 19±2.12 (1st day) to 473±10.61g (42nd day) and then declined to 312±12.4 g (56th day). All the doses of *Sargassum* powder had considerably increased the weights of squabs at all time points of the experiment and the weight gain was the maximum at higher doses (150 and 200mg/day). The weight of squabs on the 42nd day ranged from 492±12.21 (50mg/day) to 505±12.30 (200mg/day) instead of 481±12.45g (control). The weight of squabs at full flight stage (56th day) ranged from 328±42.9 g (50mg/day) to 351±11.7g (200mg/day) instead of 314±12.4 g in the control. It is therefore concluded that *Sargassum* powder has helped the weight gaining of 44.5 -56.3g / squab compared to the control group.

DISCUSSION

Nutritional components in the feed and supplements are the determinants of the growth, weaning, fledging, maturation and reproduction of birds (Levi, 1954). Vogel *et al* (1998) have recommended that the daily diet of a pair of racing pigeons should contain crude protein (10g), crude fiber (5.0g), crude fat (3.5g), methionine (350mg), cystine (300 mg), lysine (800 mg), phosphorus (600mg), calcium (1.0 g), Zinc (5mg), iodine (0.1mg), sodium (0.15g), copper (0.2 mg), manganese (5.0mg), iron (trace amount), vitamin A (200 IU), Vitamin D_3 (20 IU), Vitamin B_1 (0.30 mg), Vitamin B_2 (0.30 mg), Vitamin B_6 (0.30 mg), Vitamin B_{12} (1.0 mg), biotin (6 µg), choline (70 mg), folic acid (0.050 mg), niacin (3.0mg) and panthothenic acid (0.70 mg). The basic feed used in our experiment could provide adequate amount of crude proteins, crude fiber, crude fat, metabolic energy, phosphorus, calcium, iodine, sodium, copper, vitamin A, vitamin D_3, Vitamin B_1, Vitamin B_2, Vitamin B_6, Vitamin B_{12}, biotin, choline, folic acid, niacin and panthothenic acid to pigeons, but it had inadequate amount of zinc, manganese, methionine, cystine and lysine, which have to be supplied in yet other form for effective growth of pigeons. Since *Sargassum* powder had Na (690 µg/g), K (182µg/g), P (45mg/g), Ca (80µg/ g), Mg (5892µg/ g), Mn (21.3µg/ g), Zn (73.4 µg/ g), Cu (39.5 µg/ g), Fe (256µg/ g), Al (182µg/ g), Co (1.2 µg/ g), methionine (280mg/g), cystine (260mg/g) and lysine (367 mg/g), it could also enrich the diet with all these minerals and enabled the diet to have adequate quantity of manganese and zinc.

Essential amino acids present in the seaweed make it a highly valuable protein in the food of animals and man (Orr and Watt, 1968; Kanazawa *et al*., 1979; Bell *et al*., 1986; Qasim 1991; Vinoj Kumar and Kaladharan, 2007). *Sargassum* powder contains aspartic acid (1.80%), glutamic acid (1.15%), serine (0.54%), glycine (0.45%), histidine (0.45%), arginine (0.60%), threonine (0.71%), alanine (0.44%), proline (0.38%), tyrosine (0.49%), valine (0.50%), methionine (0.37%), cystine (0.25%), isoleucine (0.55%), leucine (0.55%), phenilealanine (0.63%), tryptophan (0.21%) and lysine (0.50%) (Vinoj Kumar and Kaladharan, 2007), of which methionine, cystine and lysine are the essential amino acids for pigeons (Vogel *et al*., 1998). Powder of *S.wightii* contains fatty acids like caproic acid, caprylic acid, capric acid, lauric acid, tridecylic acid, myristic acid, pentadecyclic acid, palmitoleic acid, margaric acid, stearic acid, oleic acid, linoleic acid, γ-linolenic acid, α-linolenic acid, arachidic acid, dihomo-γ-linolenic acid, arachidonic acid, heneicosylic acid, eicosapentaenoic acid, behenic acid, docosahexaenoic acid and lignoceric acid (Vasanthi *et al*., 2003; Visakh Prabhakar *et al*., 2011), of which unsaturated fatty acids (UFAs) like myristic acid, palmitoleic acid, oleic acid, γ-linoleic acid, α-linolenic acid, arachidonic acid and eicosapentaenoic acid are found in larger proportions. Since these UFAs are essential fatty acids for animals, they increase the growth and development of many fishes and animals (Nordoy, 1989; Estevez *et al*. 1999; Evans *et al*. 2000) and at the same time decrease the levels of the expression of cytokines necessary for shifting the function of lymphocytes from the cells mediated response to antibody-mediated response (Klasing and Leshchinsky, 1999). It is therefore concluded that *Sargassum* powder could improve the dietary values of the basic diet and its effect was increasing with increase in the dosage from 50 mg to 200 mg / day. Growth of pigeons has been reflected both in the body weight and size, and the body weight of pigeons is directly proportional to the body size and vice versa (Levi, 1954). The pigeons kept in lofts are somewhat heavier than those living in the natural habitats because of the supply of adequate amount of healthy feeds, supplements, vitamins and proper disease managements, which together favor the fast growth of individuals (Mariey *et al.,* 2013; Kazal Krishna Ghosh, 2013). As has been reported by Mariey *et al* (2013), who had demonstrated that yeast supplementation has increased the body weight of pigeons, *Sargasssum* powder had increased the body weight of pigeons due to its dietary supplementing property that is associated with rich minerals and vitamins (Meenakshi *et al*., 2009; Antonisamy *et al*., 2012), long-chain fatty acids (Visakh Prabhakar *et al*., 2011), essential amino acids (Chandini *et al*.,2008; Ganesan *et al*, 2008; Rajasulochana *et al*., 2009), sterols (Sanchez-Machado *et al*., 2004) and fucoidan (Yang *et al*., 2008).

Although male and female of a particular race of *Columba liva* are similar in their shape and plumage (Baker and Inglis, 1930), their body weight differed considerably depending on the genders (Johnston, 1984). As a rule, the males are larger and heavier than the female birds as they consume little large amount of feed every day (Vogel *et al*., 1998): the male is 30-36 cm in length while the female measures 29-35 cm length (Williams and Corrigan, 1994); likewise, the males attains 369 g weight while the females attain 340 g (Johnston 1990). This study makes out a clear point that *Sargassum* powder had boosted up the weight gain of pigeons irrespective of gender preference but the males were forever heavier than the female pigeons, which agreed with the reports of Vogel *et al* (1998) and Johnston (1990). The rate of increase in the body weight of fowls and veterinary animals is determined by feed intake and subsequent conversion of the feed into various metabolites and body tissues (Golflus *et al*., 1997; Shanawany, 1988; Kuan *et al*., 1990; Beg *et al*., 1994; Tangendjaja and Yoon, 2002). The feed intake of birds generally varies greatly depending on the genetic race of bird, age group and the type of feed provided to them (Iscan *et al*., 1996; Thind and Ambrosen, 1998). However, it is further altered by nutritional supplements added to the feed (Youssef *et al*., 2001).

Dietary supplementation of *Sargassum* extract had enhanced the feed intake and body weight gain in poultry (El-Sayed, 1982; El-Deek *et al*., 1987; Gu *et al*., 1998; Wong and Cheung, 2001; Sim *et al*., 2004; El-Deek and Brikaa, 2009; EL-Deek *et al*., 2011), ducks (Breikaa, 1993) and aquaculture fishes and shrimps (Chin, 1998; Felix *et al*. (2004). This was also found to be true with pigeons. Pigeons attain sexual maturity in the 6th or 7th month (Sturtevent and Hollander, 1978; Kazal Krishna Ghosh, 2013). The results of present study agreed with the earlier reports. Nevertheless, *Sargassum* powder had helped the early maturation of pigeons and hence the maturation period was shortened while increasing the dosage of *Sargassum* powder. Minerals, vitamins, essential amino acids and long-chain fatty acids in the *Sargassum* powder might have increased the vegetative growth that was necessary for sexual maturity of pigeon squabs.

Young squabs took nearly six months to attain sexual maturity so that the number of egg cycles produced in the first year was two, rarely three, in the first year. But, in the subsequent years, pigeons fed only with the basal feed gave 4±2egg cycles/year while those fed with the *Sargassum* powder gave 4±2 to 6±2 egg cycles/year. There was an increase of 1 -3 egg cycles in the 2nd and 3rd years due to the positive effects of higher doses (150 & 200 mg/day) of *Sargassum* powder. Levi (1974 has stated that if nutritious feeds and adequate supplements are given and the birds are maintained under suitable growing conditions, *Columba livia* may even produce up to twelve broods in a year, but such a high brood number has hardly been achieved in Lahore pigeons (Johnston and Janiga, 1995). AbouKhashaba and Mariey (2009) have proved that the number of egg cycles/pair varies depending on the age of pigeon pairs, feed composition and genetic race of the birds. In this context, the results of the present investigation agreed with the reports of AbouKhashaba and Mariey (2009). According to Abed Al-Azeem (2005), egg cycle of healthy pigeons is within the range of 45¾ -54½ days. AbouKhashaba and Mariey (2009) had observed that dietary supplementation of 1to 5 g of vitamin and minerals premix/kg of diet had shortened the length of egg cycle from 56.62 to 45.62 days, which points out that rich nutrients have a tendency to reduce the length of egg cycle in pigeons. Also, the duration of egg cycle depends on the activity of parents to nurse their squabs and warmth (Mariey, 2013). As the length of egg cycles was reduced, pigeons started to lay eggs before the squabs of the previous brood had attained full flight stage, which resulted in clutch overlapping in the loft. *Sargassum* feed supplement was little more powerful to shorten the length of egg cycles than the yeasts and vitamin supplementation to pigeons because of the presence of methionine, cystine, lysine, long chain fatty acids, minerals and vitamins.

Johnston (1998) states that the second egg of pigeon appears about 40 hours after laying the first egg while Hagg (1991) reported that the second egg was laid 30-34 hours after laying the first egg of the brood. Mariey (2013) concluded that yeast supplement has shortened the interval between the first and second egg. Likewise, *Sargassum* powder has appreciably shortened the duration required for the emergence of the second egg after the appearance of the first egg of the clutch, which might be due to the maintenance of pigeon's health by essential amino acids, fatty acids and minerals present in this powder.

The clutch size of a pigeon pair is two, of which the first egg usually hatches into a male squab and the second one hatches into a female squab (Johnston, 1998). Therefore, pigeons provided with the basal diet had produced 8-10 eggs in 4 -5 broods, but the birds which received the *Sargassum* powder had laid 2 or 3 more broods per year. Proteins, lipids, essential amino acid, fatty acids and mineral present in the *Sargassum* powder might have improved the growth attributes that could enhance the number of broods per year. There was no drop in the egg production up to the third year, which showed that constituents of *Sargassum* powder not at all produce reproductive stress in pigeon. Ibrahim and Sani (2010) found that the egg length of pigeon is 14.7cm while Darwati *et al.* (2010) demonstrated that the egg weight ranged from 10.7 to 23.2 gm. The egg weight of pigeon is directly proportional to the egg size (Levi, 1954). Dietary supplementation of yeasts (Mariety, 2013) and vitamins and minerals (AbouKhashaba and Mariey, 2009) give large-sized eggs compared to control. According to Pingel and Jeroch (1997), the egg quality varies depending on the genetic traits of pigeons and nutrition provided to them. The egg size of birds is mainly determined by the volume of egg white which is in fact affected by the nutritive value of feeds consumed (Tazawa and Whittow, 2000). Fatty acids profile of yolk lipids does not vary in pigeons depending on the type of nutrition (Gugolek *et al*., 2013). Therefore, it is concluded that nutrition type can alter the volume of egg white to determine the size and weight of eggs. Proteins, lipids, essential amino acid, fatty acids and mineral present in the *Sargassum* powder might have improved the growth attributes capable of increasing the egg weight of pigeons due to higher rate of metabolic activities during the formation of the eggs. Further, *Sargassum* powder had corrected the decline of egg weight due to ageing of pigeons to certain extent because of its dietary supplementing properties. In fowls and pigeons, egg infertility appears due to the failure of the male and female nuclei to fuse into a viable diploid zygotic nucleus that can take part in the stages of early embryo development.

Meleg (1997) reported that 4.6 – 6.3% of the laid eggs were found to be infertile. The percentage of infertile eggs was high during the summer and winter because of extreme heat and cold respectively (Levi, 1963). Dietary yeasts, which are capable of increasing the growth and reproductive attributes, improve the quality of semen in pigeons to increase the fertility percentage of eggs (Mariety, 2005) and it is also confirmed in quail hens (Abdel- Azeem *et al*. 2005). Here, the increase in fertility percentage of egg is related to higher sexual efficiency and better semen quality of males (Mariety, 2005). It is therefore concluded that *Sargassum* powder might have improved the fertility of pigeon to produce more number of fertile egg, and that it has nullified the slight egg-fertility reduction appearing in pigeons due to the effect of ageing. Hatching percentage is within the range of 59.68 - 63.69% in pigeons and is low in spring and high during the summer (Meleg, 1997). Darwati *et al.* (2010) observed 77% hatchability in pigeon eggs. Probiotic yeasts increase the hatchability of pigeon eggs (Mariety, 2005). Dietary supply of vitamins and minerals has also improved the hatchability of the eggs of quail hens (Abdel- Azeem *et al*., 2005). Therefore, it is believed that nutritious feeds can in general improve the hatchability of eggs. *Sargassum* powder might have increased the hatchability of eggs by providing adequate amount of essential amino acids, fatty acids and minerals necessary for the metabolic processes going on during the incubation of eggs. Meleg (1997) reported embryo death as high as 16-19% in eggs during incubation in poorly managed lofts, but Mariety (2005) reported only 2-3% of eggs with dead embryos when pigeons were fed with yeasts. Embryo death was reduced in the present study due to the dietary roles of *Sargassum* powder for the early embryo development. In pigeons early mortality of squabs is relatively higher than the mortality after flight stage (Meleg, 1997). Feed supplements that promote the growth and reproductive attributes of pigeons have enhanced the survivability of squabs (Mariey, 2013). Visual examination of the squabs showed that *Sargassum* powder had enabled the parents to feed relatively larger volume of crop milk to their squabs compared to the pigeons in the control group, which implied that this herbal powder might have increased the level of secretion of crop milk from parents at higher doses (150 and 200mg/day) by accelerating the vital metabolic activities and by improving the beneficial micro flora of intestine of pigeons. The crop milk contains IgY antibodies (Meagan Joy Gillespie 1912) and hence it might have provided sufficient protection to the squabs against various pathogens responsible for death of young squabs. This view was agreed by Vogel *et al*. (1998) and Johnston (1998). Levi (1954), Bokhari (1994) and Sales and Janssen (2003) have reported that in the first six or seven days, the body weight of squabs seems to be doubled and the squabs have reached the peak of its growth weight in 26-28 days.

High growth rate of young squabs was mainly due to the effect of crop milk of parents; the crop milk contains fatty acids, essential amino acids, minerals and soluble sugars (Carr and James, 1931; Reed *et al*., 1932; Davis, 1939; Ferrando *et al*., 1971; Leash *et al*., 1971; Hegde, 1972 &1973; Desmeth and Vandeputte-Poma, 1980; Shetty *et al*., 1990; Shetty and Hegde, 1991; Shetty *et al*., 1992 & 1994; Horseman and Butin, 1995; Meagan Joy Gillespie, 1912) to promote the growth of squabs. The results of weight change in the control group are in the same line of reports made by Levi (1954) and Bokhari (1994). Dietary supplements have enhanced the growth and body weight gain in squabs (Mariey, 2013; Saxena *et al*., 2008). Likewise, *Sargassum* powder had enhanced the body weight of squabs to a considerable extent and the weight gain was increasing with increase in the dosages (50, 100, 150 and 200mg/day) due to the supply of minerals, essential amino acids and fatty acids to various metabolic pathways of growing squabs. According to Mariey (2013) and Saxena *et al*. (2008), dietary supplements have been enhancing the growth attributes of squabs to attain maturity. The present observation agreed with the earlier reports and proved that *Sargassum* powder had increased the number of squabs/pair/year compared to the control. The minerals, essential amino acids and fatty acids present in the *Sargassum* powder might have done their positive roles in growth and reproduction for improving the squab production.

Conclusion

The present investigation makes out that the basic feed we provided to pigeons was substandard to a good feed as it had inadequate amount of manganese, zinc, methionine, cystine and lysine, and that when the powder of *Sargassum wightii* was given as a feed supplement, the basic feed was enriched with little more amount of the above said nutrients necessary for the efficient growth of pigeons. *Sargassum* powder also added certain amount of essential and non-essential amino acids and unsaturated fatty acids that play crucial roles in the metabolic pathways taking part in the body building and reproductive activities. Rising concentrations of these nutritional components while increasing the dosages of *Sargassum* powder from50 to 200 mg / bird / day were the determinants for the efficient growth and reproductive capabilities of pigeons. *Sargassum* powder had enabled the pigeons to consume a little more amount of feed, and to convert the feed into body tissues to show fast growth which is optimistically related to efficient reproductive potential of pigeons. Further, this powder has increased the squab production to raise the earnings of commercial pigeon breeders. As this powder had hardly been producing any reproductive stress in pigeons, it may be recommended as a dietary supplement to pigeons and related birds.

Conflict of interest

The authors declare that they have no conflict of interest.

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