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Effect of replacing soybean meal by slaughterhouse poultry by-products meal on nutrient digestibility coefficiency and accumulation of elements in the Nile tilapia (*Oreochromis niloticus* L.) under aquaponics system conditions

Mostafa A. M. Soliman[1], Khaled Fahmy El-Kholy[1], Mostafa Abd El-fatah El-helaly[2], Ashraf Soluma[3]

[1]Utilization of by-Products Department, Animal Production Research Institute (APRI)·, Agricultrure Research Center, ElDokki, Giza, Egypt

[2]Vegetable Crops Department, Faculty of Agriculture, Cairo University, Giza, 12613, Egypt

[3]Fish Nutrition Laboratory (FNL), Animal Production Department, Faculty of Agriculture, Cairo University, Giza, 12613, Egypt

[*]Corresponding Author: mostafa.soliman242@gmail.com

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ABSTRACT

The present study was carried out to investigate the impact of substituting soybean meal with slaughterhouse poultry by-products meal on the Nile tilapia composition, mineral content, apparent digestibility co-efficiency, and basil yield composition under aquaponics system conditions. In an 84-day feeding experiment and 30-day digestibility trial, three isonitrogenous and isocaloric diets (control, SPBM50%, and SPBM100%) were formulated to contain 30% CP. As result, neither the carcass content of moisture nor the CP was affected by the experimental diets. On the other hand, the fish fed $SPBM^{100\%}$ content showed high significant ash content, while those fed $SPBM^{50\%}$ content recorded high significant EE and GE contents. The differences were notably not significant among the different treatments. The fish group fed $SPBM^{50\%}$ diet recorded significantly higher concentrations of minerals than those fed control and $SPBM^{100\%}$ diets. The concentration of heavy metals in fish muscles was within the permissible limits for human health protection. The $SPBM^{50\%}$ treatment recorded the highest levels in DM, CP, EE and CF contents. No significant difference was observed in ADC of DM, CP, CF, NFE, and GE kcal/g (%) in fish fed the experimental diets. The ADC of EE content of diets was higher in the $SPBM^{100\%}$ diet that exhibited significant differences with the control treatment. In conclusion, the $SPBM^{100\%}$ has a positive effect on basil composition under aquaponic system conditions as a good source of minerals that are more available, Moreover, it has no impact on the accumulation of heavy elements in fish muscles.

INTRODUCTION

Aquaponics has various environmental and financial advantages; the scientists and fish farmers all over the world are interested in this method. The aquaponics system combines hydroponics (plant growing in water) and conventional aquaculture in a symbiotic setting (**Jayaprakash *et al*., 2022**). When aquaponic systems are activated, fish should be first introduced and fed for a few weeks before adding plants. This is done to release all the nutrients to fish feed, which are eventually used for plant growth, in addition to allowing the time to accumulate the minimum levels required for optimal plant growth **(Lennard, 2017)**.

In order to ensure a successful aquaponics system, appropriate fish and plant species should be selected. Tilapias are a commercially important species in the world due to the high market value attributed to its good taste **(Amin *et al*., 2019; Magouz *et al*., 2020)**. The Nile tilapia (*Oreochromis niloticus*) is an economically significant species and the world's second most cultured species, contributing remarkably to global food security **(Dawood, *et al*., 2019; Van-Doan *et al*., 2019)**. The Nile tilapia is a tropical fish that can be efficiently reared in warm water at temperatures ranging from 25 to 30°C **(ElSayed, 2019; Dawood *et al*., 2020)**. According to **Yep and Zheng (2019)**, the Nile tilapia is the most successful fish species in aquaponics, followed by carp and the African catfish.

The sweet basil (*Ocimum basilicum* L.) is a commercially important herb, widely cultivated for the production of essential oil (EO) as a medicinal and ornamental plant and as a fresh-market herb. Basil has been used as an ethnobotanical plant or as an ingredient in various dishes and beverages since ancient times, particularly in the Mediterranean cuisines. It is high in natural plant chemicals such as monoterpenes, sesquiterpenes, and phenylpropanoids, all of which have antioxidant properties promoting human health **(Szymanowska *et al*., 2015; Onofrei *et al*., 2017)**. Furthermore, basil extracts contain antibacterial and insecticidal properties; therefore, they have numerous uses in the culinary, pharmaceutical, fragrance, cosmetic and aromatherapy industries **(Stefan *et al*., 2013)**.

To avoid nutrient deficiencies, some aquaponic systems add synthetic salts (e.g., potassium hydroxide) to the water system **(Rakocy, 2003)** or use a foliar spray **(Roosta, 2014)**. Although aquaponic systems aim to use as little synthetic fertilizer as possible for plant growth, it is possible to compensate for nutrient deficiencies and significantly increase yield with minimal synthetic fertilizer application **(Yep & Zheng, 2019)**. Tailoring aquafeeds for aquaponic systems is more difficult than developing conventional aquaculture feeds since the nature of aquaponic systems requires that the aquafeeds not only provide nutrition to the cultured animals but also to the cultivated plants and the microbial communities that occupy the system **(Yep & Zheng, 2019)**. Thus, the use of non-traditional feed ingredients as sources of minerals is the most promising goal for aquaponics. The poultry by-product meal (PBM) over the last two decades has been recognized as one of the most promising candidate fish meal substitutes in aquatic diets **(Rossi & Davis, 2012)**. Generally, the poultry by-product meal PBM is created by processing raw segments of poultry remains such as feet, necks, heads and intestines **(NRC, 2011; Luo *et al*., 2012)**. PBM is a highly palatable that is made from poultry slaughterhouse and poultry processing plant by-products with high protein content (58-65%) **(Galkanda-Arachchige *et al*., 2020)**. Mineral availability in feed derived from plants is lower than in feed derived from animals **(Kumar *et al*., 2012)**. **Suloma *et al*.,**

(2013) postulated that, the meat and bone meal (MBM) can be successfully used as a phosphorus (P) source in plant-protein-based diets, with positive effects on the Nile tilapia growth and P utilization. The high element concentrations in diet ingredients have no recognized harmful effects. **Watanabe *et al*. (1997)** indicated that, when too much amounts of elements are consumed and absorbed, toxicity can exceed the harm caused due to insufficiency. Fish and other vertebrates maintain a precise equilibrium of micromineral levels in their bodies via combining several factors of absorption, storage and excretion. Consequently, even in diets with higher levels of minerals supplementation, the saturation capacity of metals seems to point to the existence of at least a regulatory mechanism to protect tissues from excessive metal deposition and its potential harm **(Pierri *et al*., 2021)**. The removal of nutrients by plants improves the water effluent's quality and might increase fish productivity **(Endut *et al*., 2010)**. Therefore, the current study was designed to evaluate the effect of replacing soybean meal with slaughterhouse poultry by-products meal (SPBM) as an alternative protein source on the chemical composition, mineral accumulation, apparent digestibility coefficient of the Nile tilapia (*Oreochromis niloticus* L.) and the chemical composition of sweet basil (*Ocimum basilicum* L.) under aquaponics system conditions.

MATERIALS AND METHODS

1. Location and the experimental facilities

The present study was conducted at the Fish Nutrition Laboratory (FNL), Faculty of Agriculture, Giza, Cairo University, Egypt. The experiment extended from the 2nd of March till the 27th of May 2021, covering a period of 84 days.

The experimental tanks were set in a greenhouse, with an area of 60m^2 (length: 9.5m^2, width: 6m^2 and hight: 5.25m), lined with concrete floor, surrounded by steel trusses and covered with polyethylene sheet (200 microns thick). Six aquaponics independent recycling systems with identical water treatments were used to replicate the experimental treatments. Each aquaponic unit was connected with fiberglass fish tank, mechanical filter, biological filter, hydroponic unit and sump (Fig. 1).

Each aquaponic unit contained fish tank with a size round of 1m^3; the opaque white fiberglass tank had a 90cm- water column, with water volume of 700 liters. To prevent fish samples from jumping out, a plastic haba net (3 mm) was placed over the tank. Associated with the mechanical filter, five filters were fixed, supplying water column about 60cm with 195L volume; a sixth filter was added containing water column of ≈ 82cm with volume of 402L. This part was connected to 6 circular biological filters, five of which had water column of about 58cm and filled with water volume of 92L; whereas, the sixth one contained water column of ≈ 67cm, with volume of 328L. The biological filter was equipped with a source of airlift diffuser to provide suitable condition for bacterial growth.

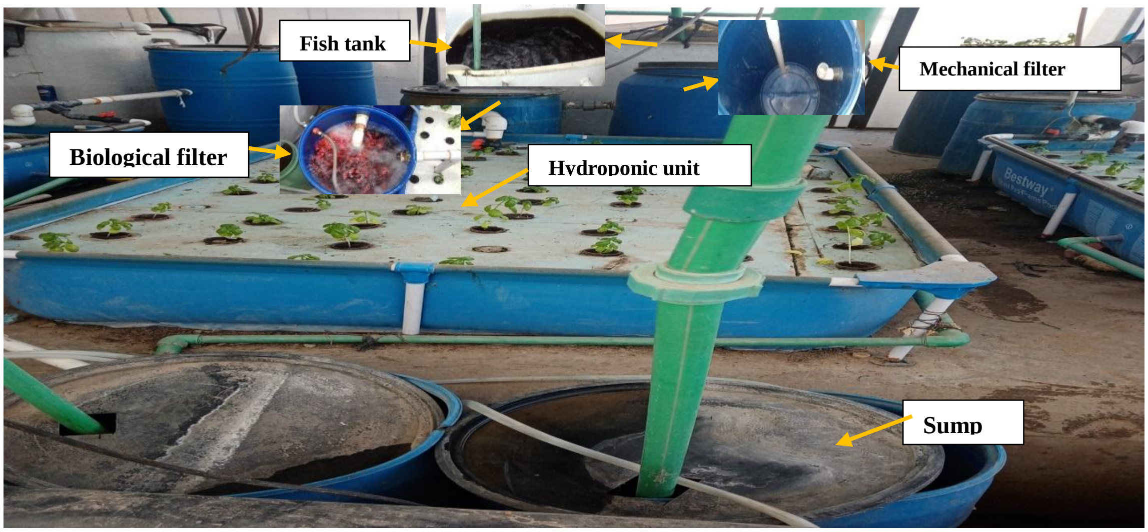

Fig. 1. A photograph of an independent aquaponic system unit

The floating raft hydroponic unit was associated with the system, four of which possessed water column of about 25cm, with a surface area of $3.25m^2$. The other two hydroponic units possessed water column of about 30cm with surface area of $1.64m^2$. Water was received from the hydroponic unit in a sump consisting of a circular tank with the following dimensions: length: 70cm and diameter: 45cm. Blue foam sheets with 20cm thick, length of 130cm and width of 90 cm were used to fix the plants in the hydroponic unit through holes at a distance (25cm) between the holes. The water was transferred from the fish tank to the mechanical filter, then the biological filter and to the hydroponic unit through the siphon process with the effect of gravity through PVC pipes with a diameter of 1.5 inches. The PVC pipes from the hydroponic unit to the sump and from there to the fish tank with a diameter of one inch.

Fish tanks were supplied with ventilation using 2 air blowers with a power of 1.5 HP each through PVC pipes with a diameter of one inch, from which 2 air diffusers were suspended inside the tank. A submersible motor was fixed in the sump with a power of 1 horse to return the collected water to the fish tanks through PVC pipes with a diameter of one inch. The flow rate was about 6.1m/ min.

2. Experimental diets formulation

As the primary sources of protein and energy in the diets, soybean meal, corn, gluten, wheat bran, and slaughterhouse poultry by-products meal were used to formulate the experimental diets (Table 1). The experiment included three diets: control, 50%, and 100% SBM replacement with SPBM. The experimental diets were formulated isonitrogenous 30%±0.06 crude protein (CP), and isocaloric 477.52±1.46 kcal/GE as showed in Table (2). The treatments were randomly assigned with duplicates for each treatment. Diets were manufactured in the Fish Nutrition Laboratory (FNL), all ingredients were purchaed from local market; ingredients were grinded, mixed in a plastic dish and pelleted; afterward, the diets were solar dried and stored in the refrigerator at 5°C throughout the experimental period.

Table 1. Approximate analysis of the ingredients used in the experimental diets (%; on DM basis**)**

Composition (%)	Ingredients				
	SBM	SPBM	Gluten	Corn	Wheat bran
Dry matter	94.21	96.38	98.33	93.55	95.72
CP	44.00	62.07	62.51	9.39	16.04
EE	3.19	6.26	8.91	4.18	1.60
Ash	6.18	12.87	1.40	1.18	3.91
CF	3.40	6.46	0	1.63	2.89
[1]NFE	43.23	12.34	27.18	83.62	75.56
[2]GE kcal/g	472.33	485.64	548.34	450.11	434.38

[1]NFE, nitrogen free extract = 100 – (CP % + EE % + CF % + Ash %).

[2]GE, gross energy content was calculated from their chemical composition using the factors 5.65, 9.45, 4.0 and Cal/GE/g DM for crude protein, ether extract, and nitrogen free extract, respectively (Jobling, 1983).

Table 2. Composition and proximate analysis of the experimental diets (% on dry matter basis**)**

Ingredient (%)	Control	$SPBM^{50\%}$	$SPBM^{100\%}$
[1]Soybean meal	37	18.5	0
[2]Poultry by-products meal	-	13	26
[1]Gluten	16.49	15.99	15.49
[1]Corn	19.5	22.5	25.5
[1]Wheat bran	19.5	22.5	25.5
[3]Vit&Min. Premix.	1.5	1.5	1.5
[1]Corn oil	6	6	6
[4]BHT	0.01	0.01	0.01
Total	100	100	100
Chemical composition (%)			
Dry matter	94.21	94.19	93.60
CP	30.97	30.91	30.78
EE	7.03	7.74	8.73
Ash	6.22	6.86	7.19
CF	4.07	4.69	5.54
[5]NFE	51.71	49.80	47.76
[6]GE kcal/g	475.55	476.65	480.37

[1]Local market. [2]Cairo Poultry Company (CPC) slaughterhouse, Ten of Ramadan City, Sharkia, Egypt. [3]Vit A, 10000000 IU; Vit D3, 3000000 IU; Vit E, 10000 mg; Vit K3, 2000 mg; Vit B1, 1000 mg; Vit B2, 5000 mg; Vit B6, 1500 mg; Vit B12, 10 mg; niacin, 30000 mg; biotin, 50 mg; folic acid, 1000 mg; pantothenic acid, 10000 mg; zinc , 50000 mg; manganese, 60000 mg;; copper, 4000 mg; iodide, 1000 mg; cobalt, 100 mg; selenium, 100 mg, calcium carbonate, 3kg, Malti Vit. Company, Cairo, Egypt. [4]Algomhuria Pharmaceutical Chemical Co. Cairo, Egypt; BHT - Butylated Hydroxytoluene.

[5]NFE (nitrogen free extract) [100-(CP+EE+Ash+CF)]. [6]Gross energy content was calculated from their chemical composition using the factors 5.65, 9.45, 4.0 and Cal/GE/g DM for crude protein, ether extract, and nitrogen free extract, respectively (Jobling, 1983).

3. Plant germination

Sweet basil (*Ocimum basilicum*) seeds were obtained from the Horticultural Research Institute- Agricultural Research Center. The seeds culturing were performed in trays of foam (containing 209 holes). A mixture of peat moss and vermiculite was used for the culture process in a ratio of 2: 1. Three to five seeds of sweet basil were placed in each hole to ensure a reasonable germination rate. The trays were irrigated for 23 days until the plants bore three leaves during the period from the 5th of Feb. to the 1st of March 2021. After that, the grown plants were transferred to the hydroponic unit. The plants were harvested only once at the end of the experiment.

4. Experimental fish

A total of 180 mono-sex Nile tilapia (*Oreochromis niloticus*) weighing about 109.88g±0.46 were randomly distributed and placed in six aquaponics independent identical systems (700L fibreglass tanks) in a greenhouse at a density of 30 fish, corresponding to tilapia biomass ranging from 4.709±0.02 kg/m^3¬¬. The recommended feed ratio for hydroponic raft system is about 56g/m^2/day; this biomass was used to cover the nutrient requirements. The fish were purchased from an Egyptian commercial farmer in the Baltim, Kafr El-Sheikh Governorate and kept for one month in a polyethylene tank with a water volume of approximately 3m^3 and fed on the commercial diet (30% CP). Fish were fed the experimental diets at a rate of 2% of the live biomass for six days during the study period. Feed was provided three times per day until the fourth week of the trial, when it was increased to four times each day at 9:00, 12:00, 14:00 and 16:00. Due to the increased feed amount for the tanks, the number of feed offered was increased to ensure that fish didn't lose feed as a waste. Every two weeks, the fish in each tank were collectively weighed, and the given diet quantity was changed.

5. Proximate analysis of fish carcass, diets, sweet basil and feces

The moisture content was determined using the **Sidwell *et al*. (1970)** method**.** Protein was measured using macro-Kjeldal **(APHA, 2000)**. Ether extract was determined by the standard method reported in **AOAC (1990)**. The ash was determined by burning the samples (1g) in a muffle furnace for 5 hours at 550°C, and the difference in weight (g) was calculated before and after ignition **(Sidwell *et al*., 1970)**. The crude fiber was determined through the method of **Holst (1982)**. While, nitrogen free extract was calculated by differences.

6. Mineral content in fish tissues

Six samples were used for mineral determination. Five grams of fresh fish muscle were dried at 105°C for 24 hours then ignited at 500°C for 5 hours. The ash was digested with 2ml of concentrated HNO_3. It was allowed to evaporate until complete dryness; then, it was placed in a muffle for half an hour at 500°C. An approximate volume of 10ml of HCl (1N) was added to a crucible and put on a heater to evaporate until dryness. The crucible was thoroughly washed with distilled water until it reached 50ml and then stored until it was measured according to **AOAC (1990)**.

7. Mineral determination by ICP-MS apparatus

Disposable 0.2m Polytetrafluoroethylene (PTFE) syringe filters were used to filter the fish sample extracts (DISMIC-25HP, Advantec, Tokyo, Japan). Inductively coupled plasma-mass spectroscopy (ICP-MS) was used to determine the metal contents in these extracts (iCAP, Thermo, Germany). The analyses included certified reference materials (Merck, Germany). Metals were recovered within the certified limits. The average and relative standard deviation were calculated using Qtegra programme **(Lambers *et al*., 2008; APHA, 2017)**.

8. Digestibility trial

A digestibility trial was conducted at the end of the experimental period, and the apparent digestibility coefficients of nutrients (ADC) were determined using insoluble ash as an internal marker, following the guidelines of **Jones and De Silva (1998)** and **Sales and Janssen (2006)**. The (ADC %) of nutrients was calculated using the following equation:

ADC (%) = 100 – [100×(%marker in feed/ %marker in feces) ×(%nutrient in feces/ %nutrient in feed)]

To carry out the digestibility trial, 48 fish were assigned (8 from each replicate). Six polyethylene tanks (55L/ tank) were used for the trial. For a week, the fish were acclimated for feeding in the tank with a partial water change. The fish were fed the experimental diets at a daily rate of 1% of tank fish biomass. Feces were collected by siphoning daily at 9:00 am before feeding. The experimental diets were offered once daily at 10:00 am. Feces were kept in a deep freezer at -4°C after collection to avoid the fermentation according to the method of **AOAC (1990)**. The digestion trial lasted for 30 days after the adaptation period.

9. The statistical analysis

Data of the experiment were subjected to one-way analysis of variance (ANOVA). The level of significance was chosen at $P<0.05$, and the results were presented as the mean ± SE (standard error). Duncan's multiple range test was conducted among group means. All statistical analyses were performed using the **SPSS (2007)**.

RESULTS

1. Chemical composition of the fish carcass

The effect of the experimental diets on the whole fish carcass composition at the end of the experimental period is shown in Table (3). The moisture and crude protein content ranged from 70.89 to 71.79 and 16.46 to 16.60, respectively; the experimental diets did not influence these variables significantly ($P> 0.05$) in the final fish carcass. The group of fish fed the $SPBM^{100\%}$ diets showed significantly ($P< 0.05$) higher ash content than those fed the control and $SPBM^{50\%}$ diets. The highest significant ether extract and GE content ($P< 0.05$) were recorded by the fish fed the $SPBM^{50\%}$ diet, while the lowest significant value ($P< 0.05$) was registered by the control and $SPBM^{100\%}$ diets.

Table 3. Effect of the experimental diets on the chemical composition of the whole body of the Nile tilapia under aquaponics system (on wet weight)

Treatment	Control	SPBM$^{50\%}$	SPBM$^{100\%}$
Moisture (%)	71.79±0.23	70.89±0.16	71.35±0.55
Ash (%)	5.47±0.13^{b}	5.71±0.11^{b}	6.13±0.31^{a}
Crude protein (%)	16.46±0.07	16.54±0.12	16.60±0.62
Ether extract (%)	5.52±0.41^{b}	6.19±0.50^{a}	5.66±0.33^{b}
GE (Kcal/g)	144.30±4.26^{b}	151.10±4.04^{a}	146.39±6.59^{b}

a,b… means in the same row with different superscripts are significantly different (*P*< 0.05).

Mineral elements concentration in fish tissue

The effect of experimental diets on mineral elements concentrations in fish muscles at the end of the experiment is displayed in Table (4). The macro and micro-elements of the fish group fed diet containing SPBM$^{50\%}$ replacing SBM recorded the highest concentrations, followed by the fish group fed the control diet. Adversely, the fish group fed diet containing SPBM$^{100\%}$ showed the lowest level content of macro and micro-elements, except Cd, Pb and Ga that recorded the highest levels. The differences were notably not significant (*P*>0.05) among the different treatments, except for the Cu, I and Bi which showed the highest significant (*P*<0.05) concentrations in fish fed SPBM$^{50\%}$ diet.

Table 4. Effect of the experimental diets on the nutritional elements concentration in fish muscles fed the experimental diets.

Treatment	Control	SPBM$^{50\%}$	SPBM$^{100\%}$
Macroelements (mg/kg)			
P	0.814±0.062	0.847±0.100	0.715±0.022
K	9.130±3.02	9.474±1.30	8.919±0.06
Ca	2.117±0.07	2.223±0.78	2.089±0.17
Mg	2.14±0.83	2.37±0.57	2.15±0.21
Na	37.78±12.55	48.17±16.35	37.23±3.83
Microelements (µg/kg)			
Fe	2.44±0.495	2.82±0.563	2.35±0.471
Mn	0.003±0.0002	0.004±0.0002	0.003±0.0003
Zn	1.050±0.205	1.246±0.417	0.861±0.016
Cu	0.247±0.018^{b}	0.374±0.002^{a}	0.189±0.010^{c}
I	0.055±0.004^{b}	0.084±0.001^{a}	0.043±0.003^{c}
Cr	0.007±0.00	0.007±0.001	0.006±0.001
B	0.189±0.013	0.215±0.059	0.149±0.005
Ba	0.262±0.05	0.311±0.104	0.214±0.004
Bi	0.005±0.002^{b}	0.012±0.001^{a}	0.005±0.001^{b}
Co	0.007±0.001	0.007±0.001	0.008±0.002
Li	0.156±0.049	0.246±0.116	0.163±0.026
Sr	0.068±0.004	0.081±0.003	0.066±0.005
Cd	0.010±0.002	0.009±0.000	0.013±0.004
Pb	0.562±0.061	0.503±0.025	0.455±0.066
Hg	0.002±0.000	0.003±0.001	0.002±0.001
Al	0.887±0.043	1.035±0.028	0.787±0.128
Ni	0.006±0.0003	0.007±0.0008	0.005±0.0006
In	0.026±0.00	0.031±0.003	0.023±0.002
Ga	0.071±0.015	0.060±0.015	0.061±0.011

a,b… means in the same row with different superscripts are significantly different (*P*<0.05).

3. Chemical composition of sweet basil.

Table (5) represent the effect of the nutritional content of the experimental diets on the chemical composition of basil. The DM, ash, EE, CF, and GE (kg/g) contents in basil shoots did not show significant differences (*P*>0.05) among treatments, however they showed numerical differences The highest value of CP was recorded by the SPBM$^{50\%}$ and followed by the SPBM$^{100\%}$ treatments (*P*>0.05), however the lowest (*P*>0.05) value was recorded by the control treatment. On the other hand, the NFE observed in the control treatment recorded the highest significant (*P*<0.05) value, while the SPBM$^{50\%}$ and SPBM$^{100\%}$ treatments recorded the lowest significant (*P*<0.05) values. Generally, the SPBM$^{100\%}$ treatment recorded the highest values, followed by the SPBM$^{50\%}$ treatment, while the control treatment recorded the lowest value in all chemical composition, except the NFE (%) and GE (kg/g), in which the control treatment recorded the highest values followed by the substitution treatments. Concerning the chemical composition of the basil roots, there were no significant (*P*>0.05) differences in DM, CP, EE, CF, NFE, and GE (Kg/g) contents among different treatments. However, the SPBM$^{50\%}$ and SPBM$^{100\%}$ treatments exhibited the highest significant (*P*<0.05) content of ash, whereas the control diet possessed the lowest ash content (*P*<0.05). The SPBM$^{50\%}$ treatment recorded the highest levels of DM, CP, EE, and CF contents. On the contrary, the control treatment recorded the highest NFE and GE contents , while the SPBM$^{100\%}$ treatment showed the lowest contents, except for the ash content that recorded the highest value.

Table 5. Effect of the experimental diets on the chemical composition of sweet basil (on dry matter basis).

Treatment	Shoots			Roots		
	Control	SPBM$^{50\%}$	SPBM$^{100\%}$	Control	SPBM$^{50\%}$	SPBM$^{100\%}$
[1]DM (%)	94.38±0.42	94.50±0.25	94.70±0.38	93.48±1.78	94.49±0.24	93.97±1.18
Ash (%)	11.32±0.04	12.56±1.35	13.66±0.41	12.51±0.01^{b}	13.86±0.22^{a}	14.08±0.40^{a}
[2]CP (%)	10.03±0.04^{b}	12.02±0.17^{a}	12.28±0.21^{a}	9.82±0.04	11.07±0.03	10.73±0.66
[3]EE (%)	2.45±0.16	2.48±0.10	2.56±0.38	1.09±0.12	1.56±0.05	1.29±0.30
[4]CF (%)	19.04±0.21	21.14±1.13	21.46±0.49	21.90±1.88	24.36±0.51	22.48±0.88
[5]NFE (%)	57.17±0.30^{a}	51.81±0.29^{b}	50.05±1.06^{b}	54.69±1.79	49.17±0.32	51.43±1.64
[6]GE (kcal/g)	399.35±0.96	397.12±5.94	393.26±0.03	387.16±0.58	385.78±1.12	382.88±2.37

a,b… means in the same row with different superscripts are significantly different (*P*<0.05).
[1]DM= dry natter. [2]CP= crude protein. [3]EE= ether extract. [4]CF= crude fiber. [5]NFT= nitrogen free extract. [6]GE= gross energy.

4. Effect of the experimental diets on apparent digestibility coefficiency (ADC%)

The apparent digestibility coefficients of dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE), and gross energy (GE kcal/g) by used insoluble ash method as a natural indicator, are shown in Table (6). No statistical differences were observed in ADC (%) of DM, CP, CF, NFE, and GE kcal/g in fish fed the experimental diets. The ADC of EE content of diets was higher with the SPBM$^{100\%}$ diet than other treatments, it exhibited asignificant (*P*<0.05) difference with the control treatment, whilst there were no significant differences (P>0.05) between SPBM$^{50\%}$ treatment and other treatments.

Table 6. Apparent nutrient digestibility coefficient (ADC %) of the experimental diets fed to Nile tilapia.

ADC (%)	Treatment		
	Control	**SPBM$^{50\%}$**	**SPBM$^{100\%}$**
[1]**DM**	**90.59±1.40**	**87.69±1.67**	**88.20±0.44**
[2]**CP**	**79.55±0.56**	**78.47±1.01**	**79.53±1.69**
[3]**EE**	**81.54±0.14^{b}**	**85.00±1.06^{ab}**	**89.55±2.16^{a}**
[4]**CF**	**84.80±2.76**	**79.45±3.20**	**81.16±3.44**
[5]**NFE**	**59.92±2.09**	**52.26±2.81**	**57.44±1.47**
[6]**GE (Kcal/g)**	**70.52±1.17**	**67.48±1.51**	**71.58±0.26**

a,b… means in the same row with different superscripts are significantly different (*P*<0.05).
[1]DM= dry natter. [2]CP= crude protein. [3]EE= ether extract. [4]CF= crude fiber. [5]NFT= nitrogen free extract. [6]GE= gross energy.

DISSCUSION

1. Chemical composition of the fish carcass

The highest ether extract and GE content were observed in fish fed the SPBM$^{50\%}$ diet. Whereas the high ash content in fish fed diet containing SPBM$^{100\%}$ due to the high content of bone (heads, legs, and wings) that causes an increase in their mineral elements content. According to **Sathishkumar *et al*. (2021)** there were no significant differences in the whole-body composition in GIFT tilapia fed control, poultry by-product meal (PBM) 33.33, 66.67, 100% diets, and bio-processed poultry by-product meal (BPBM) 33.33, 66.67, and 100% diets. Whereas, the PBM 66.67 treatment recorded the highest level of EE compared to the other treatments. **Suloma *et al*. (2014)** reported that there is no significant effect of the different dietary levels of hydrolyzed feather meal on the composition of the whole-body of the Nile tilapia fish. Whereas the SBM$_{66\%}$ treatment recorded the highest level of EE and ash compared to the control, SBM$_{33\%}$ and SBM$_{100\%}$ treatments. **Palupi *et al*. (2020)** observed that the chemical composition of the Nile tilapia whole body was unaffected by the different levels of PBM replaced fish meal in diets. Moreover, the high level of EE and ash was recorded to the PBM10 treatment compared to the other treatments. While **Ha *et al*.(2021)** illustrated that the diets containing SPBM replaced fish meal have no effect on the whole-body olive flounder composition (P>0.05).

2. Chemical composition of sweet basil.

It is clear from the obtained results that the SPBM$^{100\%}$ treatment shoots recorded the highest levels in DM, ash, CP, EE and CF, except for NFE and GE, which recorded the highest levels in the control treatment. On the contrary, noted that the SPBM$^{50\%}$

treatment root was recorded the highest levels in DM, ash, CP, EE and CF, except for NFE and GE, which recorded the highest levels in the control treatment.

It is worth mentioning that no attention was paid to the chemical composition of basil in terms of crude protein and ash...etc. in the researches conducted on basil using aquaponic neither hydroponic systems. However, other researches studied some other components in basil in terms of total soluble solids (TSS), colorimetric indexes, nitrate content and antioxidant activity (**Raimondi *et al.*, 2006**), chlorophyll content, the antioxidant capacity, and the total phenol contents (**Prinsi *et al.*, 2020**), total phenolics content (TPC) and total flavonoid content (TFC) (**Mahmoudi *et al.*, 2020**). Plant morph-physiology and the quality of essential oil of basil (**Burducea *et al.*, 2019**). Recently, investigates concerning the chemical composition of plants have been carried out; **Jayaprakash *et al*. (2022)** reported that the maximum protein content of millet was estimated to be 11.63% in the Nutrient Film Technique (NFT) system and 8.8% in the control system. The NFT had a higher carbohydrate content (9.9%) and a lower fat content (6.8%) than the control. Whereas, compared to the control, mustard had a higher protein level of 10.60% and a lower carbohydrate content of 7.30%. The NFT exhibited a high carbohydrate content (9.36%) in comparison to the control (7.2%).

2. Mineral elements concentration in fish tissue fed the experimental diets

In the current study there were no significant differences ($P>0.05$) in the mineral concentrations among the treatments. The concentration of macro minerals (P, K, Ca, Mg and Na) in fish muscles were within the permeissible limits for the human health protection. According to **USAD (2018)** the safe concentrations for human consumption of P, K, Ca, Mg and Na, are 204, 380, 14, 34 and 56 mg/100g in tilapia fillets, respectively. Moreover, **Ling *et al*. (2013)** reported the safe limit of Mg in fish fillets is 13.3 mg/kg for human health. Concerning the concentration of trace elements, the current study was within safe ranges for consumers and fish. The Fe acceptable concentration established by **WHO (1996)** ranged between 20-150 mg/kg in fish muscles for the human health. Whereas the Iodine (I) safe limits in fish fillets varied between 200 to 1000 mg/kg (**WHO, 2020**). In addition, **FAO (1983) and WHO (1989)** reported that the permissible limits in fish fillets of Pb, Zn, As, Cr and Cd are 2.0, 100, 0.05, 0.05 and 1.0 mg/kg, respectively. Moreover, **Ling *et al*. (2013)** illustrated that the acceptable concentration of Cu and Mn are 3.17 and 0.24 mg/kg in fish muscles without causing harm to human health. The As concentration in tilapia fillets in current study was below permeation limits for human consumption which recommended by the USEPA being 1.3 mg/kg (**USEPA, 2007**). The Hg levels in the tilapia fillets in the current study were lower than those reported in **U.S. FDA (2000)** for human consumption being 1.0 mg/kg.

In the current study under the aquaponics system conditions both plant and animal protein sources did not represent any burden on the concentration of the elements in the water and fish muscles. While the previous studies conducted under the recirculation aquaculture system (RAS) condition, indicated that there is a large accumulation of heavy metals in the water and the fish muscles according to (**van-Bussel *et al*., 2014)**. In addition, increasing water re-use increases the accumulation of dissolved metals, such as As, Ba, B, Cu, Fe, Li, Mn, Ni, Sr, and Zn in fresh water RAS (**Davidson *et al*., 2011; Martins *et al*., 2011**). Numerous studies, both in freshwater and saltwater, have found that increased re-use of water in RAS resulted in increased metal concentrations in the fish body. Lead (Pb), Cr, and Mn levels were found to be higher in the muscle or liver of Nile tilapia (*Oreochromis niloticus*) freshwater (**Martins *et al*., 2011**). Therefore, compared to the RAS system, aquaponics has a lower accumulated heavy metal level, allowing it more welfare for fish and produced healthy fish for human consumption.

3. **Effect of the dietary SPBM on apparent digestibility coefficiency (ADC %) of nutrients**

There were no significant (P>0.05) differences in digestibility coefficiency (ADC%) of all components among different diets fed to Nile tilapia, except for EE, in which the SPBM$^{100\%}$ treatmentrecorded the highest significant value (P<0.05).

According to **Poolsawat *et al*. (2021)** the decreased growth and apparent digestibility efficiency (ADC's) of fish fed a diet containing feather meal was due to poor digestibility, palatability, and imbalanced amino acids in feather. Moreover, the hard structure of keratin of feather meal. On the other hand, **Mendoza *et al*. (2000)** demonstrated that the nutritional value of feather meal was enhanced by the hydrolysis of protease, which may conect with the degraded keratin in feather meal by enzyme to suitable forms for fish absorption, and the remaining enzyme may perform some functions in the intestine for enhancing digestion and growth. Whereas, **Adelina *et al*. (2021)** illustrated that the diets containing fermented feather meal (FFM) by *Bacillus subtilis* bacteria fed to silver pompano, *Trachinotus blochii* had higher protein digestibility than the control diet. However, there were no significant differences among different treatments for lipid and carbohydrate digestibilities. In addition, **Poolsawat *et al*. (2021)** reported that the substitution of fish meal with enzymatic feather meal (FeM) considerably decreased the apparent digestibility of dry matter and protein, since fish cannot directly digest the keratin in feather meal. **Palupi *et al*. (2020)** observed that the apparent digestibility co-efficiency (ADC) of all dietary treatments containing PBM were significantly lower in ADC of all components compared to the control treatment in juvenile Nile tilapia fed a PBM-based diet replaced of fish meal in fish feed. On the other side, the ADC of lipid in the PBM inclusion groups was significantly higher than in the control diet.

In the present study, the reason for decline ADC's of ether extract in the control diet, which contained 100% SPBM was explained by many investigator in a variety of fish, including Atlantic salmon (*Salmo salar* L) (**Olli and Krogdahl, 1995**) and rainbow trout (*Onchorynchus mykiss*) (**Romarheim *et al*., 2008; Iwashita *et al*., 2009**). The reduction in soybean meal inclusion level in diets, which replaced PBM, could explain the decreased of dietary crude lipid digestibility. Soybean meal proved tolower bile salt concentration, lowering lipid digestibility.

CONCLUSION

The use of SPBM as a 100% replacement of soybean meal in the Nile tilapia (*Oreochromis niloticus*) diets had no negative effects on carcass composition or ADC. Whereas, the complete replacement has a positive effect on basil proximate composition under aquaponic system conditions, as a good source of minerals that are more readily available, helping in increasing plant growth in an organic form without using of external nutrient solutions. In addition, it hasno impact on the accumulation of heavy elements in fish muscles. The concentration of heavy metals in fish muscles were within the permissible limits for the human health protection. The aquaponics system has a relative advantage in removing heavy metals through use in plant growth, leading to reducing their accumulation in fish muscles and the system itself.

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