



## Impact of Food Values of Dried Orange Peel in Feeding the Nile Tilapia

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### ABSTRACT

The present study was conducted to evaluate the influence of three different levels of yellow corn replacer (dried orange peel) which contained high-quality nutritional compounds for tilapia feeding to enhance fish performance. The inclusion levels of dried orange peel (OP) were 10, 20, and 30 percent besides the control. Fourteen weeks feeding experiment was carried out with mean initial body weight ( $16.83 \pm 0.12$  g). The best growth performance parameters, feed utilization, apparent protein digestibility, and blood measurements were recorded for the fish fed moderate level of OP (20%), followed by the third level (30%). To attain the best fish performance and save about 30% of the yellow corn cost, the dried orange peel powder is recommended to be used in tilapia feed.

### INTRODUCTION

Maize (*Zea mays*) is one of the most important cereal grains used for fish feeding all around the world and it has a relatively high nutritional value, and the energy value of maize may be greater than 1.1 MJ kg<sup>-1</sup> (Song *et al.*, 2004).

Yellow corn contains significant amounts of bioactive compounds providing desirable health benefits beyond its role as a major source of food. The health benefits of corn are not only from basic nutrients such as carbohydrates, vitamins and minerals, but also from their unique phytochemicals such as phenolic acids. A wide range of phytochemicals, such as total phenolics are found at high concentrations in corn bran and germ fractions (Siyuan *et al.*, 2018). Corn has the highest total antioxidant activity (vitamin C) among all common grains such as rice, wheat and oats (Adom & Liu, 2002).

Fresh fruits are important sources of energy, vitamins, minerals and fibers. The nutritional value of fruits depend mainly on the quality of these nutrients as well as their quantity. Citrus is a rich source of vitamins and some minerals (Hornick & Weiss, 2011). Citrus belonging to family Rutaceae (Ladaniya, 2008) is considered a dominant global fruit (Jiang *et al.*, 2014). This family has primary sources of bioactive compounds which are responsible for antioxidant and many other biological activities (Fejzić & Čavar, 2014).

Citrus by-products (seeds, peels and pulp) are considered an annual huge waste load on the environment (Ramful *et al.*, 2011; Nayak *et al.*, 2015). However, they are promising sources of bioactive ingredients. They can be used as ingredients or food additives (O'Shea *et al.*, 2012). During processing, the citrus peels reach about 50- 65% of fruit weight. Citrus peels contain many valuable substances (natural products and bioactive phenolic compounds) that can be turned into raw materials forming natural by-products that can work as a cheap antioxidant source (AbdEl-ghfar *et al.*, 2016).

Sweet orange (*Citrus sinensis*) peel is common by-products (wastes) produced from processing food and juice industry. Orange peels contain flavonoids, essential oils and carotenoids. The use of economic unconventional fish diets and inexpensive feed sources is the main target of fish nutritionists. In Egypt and in many Mediterranean countries, a huge quantity of the citrus peels are left unprocessed, and some efforts were exerted to make use of these by-products in animal feed (Chedea *et al.*, 2010; Farhat *et al.*, 2011). Oranges and their peels are a wide source of thiamin, foliate, vitamin A in the form of betacarotene, potassium and calcium. Orange peels are used in animal feeds because they include a variety of phytonutrient compounds (that combine with the vitamin C contents) that give the fruit many antioxidant properties. Herperidin, for instance, a phytonutrient in oranges, is the most important flavanone that optimizes blood pressure and cholesterol in animals (Oluremi *et al.* 2007; Nwanna *et al.*, 2011).

On a dry matter basis, the nutritional value of orange peels may be comparable with concentrates such as sorghum, barley and corn (Oluremi *et al.*, 2006). The citrus fruit residues (peels), which are generally discarded as waste in the environment, can act as potential nutraceutical resources. Due to their low cost and their availability in great amounts in the form of wastes, the potential of the citrus fruit peels to offer significant low-cost nutritional dietary ingredient is remarkable (Rafiqet *et al.*, 2016).

Agro by-products from fruits can substitute maize and grain as an energy component. Those bioactive substances such as phenolics, flavonoids, alkaloids and many other nitrogenous compounds that are present in fruits and vegetables have been reported to exhibit bioactivities such as antioxidant, antibacterial, antifungal and antiviral activities (Meng *et al.*, 2018). The nutritional value of the peels reported by Oluremi *et al.* (2008) showed that protein and fiber contents are 7.44 -10.0 % and 12.9-14.6 %, respectively depending on the process. This indicates that orange peels could replace maize in fish feeds because the protein content of maize varies from 9.0-10.0 % (Nwanna *et al.*, 2011) Agu (2006) also reported that orange peels replaced 20 % of maize in broiler chicken. Ipinjolu (2000) mentioned that orange peels could be employed in both fish and livestock diets without affecting fish growth.

Thus, the present work aimed to evaluate the influence of partially replacing yellow corn with dried orange peel in fish feed of the tilapia on the growth performance and feed utilization parameters, physiological parameters and body indices.

## MATERIALS AND METHODS

### 1. Experimental design

A 14- weeks experiment was organized to examine the effect of applying orange peel in the feed of the monosex Nile tilapia, (*Oreochromis niloticus*) with initial body

weight of  $16.83 \pm 0.12$  g. The study was conducted in a concrete pond of  $40 \text{ m}^3$  ( $4 \times 10 \times 1.5 \text{ m}$ ), which was divided by using plastic nets into 4 duplicate equal parts. Each part contained 100 fish samples, and the 8 parts represented 4 dietary treatments with orange peel replacing 0 %; 10 %; 20 % & 30 % of yellow corn (control; OP<sub>10</sub>; OP<sub>20</sub> & OP<sub>30</sub>), respectively. The diet formula together with the chemical composition are shown in Table (1).

Fish were acclimatized under optimal conditions for 2 weeks before starting the trial. Fish were fed twice a day at 9:30 am, and 13:30 pm. Fish weight was calculated biweekly in order to adjust feeding rate (3 % of wet weight). Water was changed twice a week.

## 2. Water quality parameters

The mean values of water quality ( $\pm$ SD) were measured once per week at 8 am. The recorded values of water temperature was  $27.9 \pm 0.4$  °C; dissolved oxygen was  $5-6.5 \pm 0.4$  mg/L; pH was  $7.4 \pm 0.3$ . Total ammonia nitrogen values ( $0.022 \pm 0.01$  mg/l) were measured by using a portable colorimeter. The unionized ammonia (UIA) was calculated according to the method of **Zhang *et al.* (2018)**. All water quality parameters were within the acceptable range for rearing the tilapia (**Makori *et al.*, 2017**).

## 3. Orange peel preparation

Orange peels were obtained from the Hero food industries (Vitrac) in Tersa, Qaliubia Governorate. Peels were left to dry at 50°C for 48 h. A fine powder was obtained using a mechanical laboratory grinder and passed through a 24-mesh sieve, then packaged in polyethylene bags and stored at  $4 \pm 1$ °C until further usage as a yellow corn substitute in fish diet.

## 4. Determination of vitamin C content in the orange peel

The powder of orange peel (1 g) was extracted in 4 % oxalic acid, and the solution was imparted to 100 ml ( $V_1$  ml) and centrifuged at 12,000 rpm for 10 min. Then, 5 ml of the supernatant was mixed with 10 ml of 4% oxalic acid and the solution was titrated against the dye ( $V_2$  ml). Ascorbic acid was calculated according to the method of **Nwanna *et al.* (2011)** as follows:

$$\text{Ascorbic acid mg/100g} = 0.5\text{mg}/V_1 \text{ ml} \times V_2/5 \text{ ml} \times 100 \text{ ml/sample weight (1g)} \times 100$$

**Table 1.** Chemical composition of sweet orange peel and yellow corn

Component	Orange peel	Yellow corn
Moisture	83.5	14.0
Crude fiber	40.75	7.3
Protein	7.94	7.5
Ash	3.01	1.1
Fat	0.95	3.5
NFE	47.35	72.9
Vitamin C (mg/100 g)	238.6	167.40

## 5. Fish performance and feed utilization parameters

Fish growth performance and feed utilization parameters were calculated according to the equations in the study of **Cho and Kaushik (1985)** as follows:

- **Body weight gain (BWG, g/ fish)** = [final body weight (g) - initial body weight (g)];
- **Daily weigh gain (DWG, g/ fish/ day)** = [BWG (g) / Experimental period (days)];
- **Specific growth rate (SGR, %g/ day)** = 100 [Ln final weight - Ln initial weight] / Experimental period (days);
- **Feed conversion ratio (FCR)** = feed intake (g) / body weight gain (g);
- **Protein efficiency ratio (PER)** = gain in weight (g) / protein intake in feed (g);
- **Protein productive value (PPV%)** = 100 [protein gain in fish (g) / protein intake in feed (g)];
- **Survival rate%** = 100[Initial fish number stocked - Mortality] / Initial fish number stocked;

Total energy content (gross energy) was measured using the equation of **NRC (1981)**. The Metabolizable energy was determined following the study of **Phillips (1972)** as follows:

- **Gross energy** =  $\{(5.65 \times \% \text{ Protein}) + (9.45 \times \% \text{ Fat}) / 100\} \times 10^3$ ;
- **Metabolizable energy** =  $\{(3.90 \times \% \text{ Protein}) + (8.00 \times \% \text{ Fat}) / 100\} \times 10^3$ ;
- **Protein energy ratio (P/E)** = (Crude protein / Gross energy)  $\times 10^4$  according to the method of **Omar (1993)**.

Apparent protein digestibility (APD) was measured by using the method of **Furukawa and Tasukahara (1966)**. The uneaten diet and feces were collected by siphoning once daily over the last 15 days of the trial. Feed or feces were carefully collected before first feeding. After about 30 min of feeding, uneaten feed was collected. Feces were collected separately after 2 hours then filtered and dried at 60°C and stored for determining the chemical composition.

## 6. Physiological parameters

### 6.1. Blood parameters

At the end of the trial, blood samples were collected from the fish caudal vein. Blood was centrifuged at 1008 xg for 15 min. Samples were subjected to the determination of plasma total protein (PTP) following the method of **Armstrong and Car (1964)**. Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were measured by the method of **Rettman and Frankel (1975)**. Serum cholesterol was determined according to the method of **Stein (1986)**. In addition, glucose values were calculated using the method of **Trainder (1969)**. While, the immunoglobulins (IgM and IgD) were measured by using the method of **Feinstein *et al.* (1985)**

### 6.2. Body indices

At the end of the feeding experiment, liver and gut indices were calculated as follows:

- Hepato somatic index (HSI) = (Liver weight / fish total weight)  $\times 100$ ;
- Gut somatic index (GSI) = (Gut weight / fish total weight)  $\times 100$ .

## 7. Chemical analysis

Chemical analysis of the orange peel (Table 2), the different experimental diets (Table 3) and fish body composition were conducted to measure the dry matter (DM %). Crude protein (CP %), ether extract (EE %), crude fiber (CF %), Ash (%) and minerals of orange peel, all were examined according to the method of **AOAC (2012)**.

**Table 2.** Mineral concentrates in orange peel and yellow corn

Element	Concentration (ppm)	
	Orange peel	Corn
Potassium (K)	157.1	279
Iron (Fe)	123.7	25
Manganese (Mn)	87.2	4.5
Calcium (Ca)	41.6	7.1
Sodium (Na)	22.8	33.45
Zinc (Zn)	13.4	2.18
Magnesium (Mg)	4.43	121.7
Nickel (Ni)	1.48	-
Copper (Cu)	1.11	2.9
Chromium (Cr)	1.23	-
Lead (Pb)	0.24	-
Cadmium (Cd)	0.10	-
Phosphorus (P) %	0.22 %	0.33 %

## 8. Statistical analysis

The data were subjected to analysis of variance (ANOVA) using general linear models (GLM) procedure; the software used was SPSS (Version 16.0) (**SPSS, 1997**). Duncan's multiple range tests (**Duncan, 1955**) was used to compare between means of the control and the treated groups.

The model of analysis was as follows:

$$Y_{ij} = \mu + T_i + E_{ij}$$

$\mu$  = the overall mean,

$T_i$  = the effect of treatment and

$E_{ij}$  = the random error.

**Table 3.** The formula and chemical composition of different experimental diets

Ingredient	Experimental diets			
	Control	OP <sub>10</sub>	OP <sub>20</sub>	OP <sub>30</sub>
Fish meal	15.0	15.0	15.0	15.0
Soybean meal	30.0	30.0	30.0	30.0
Corn gluten meal	3.0	3.0	3.0	3.0
Yellow corn	23.0	20.7	18.4	16.1
Wheat bran	22.5	22.5	22.5	22.5
Sun flower oil	2.0	2.0	2.0	2.0
NaCl	2.0	2.0	2.0	2.0
Vit. and Min. Premix*	2.0	2.0	2.0	2.0
Orange peel dried	0	2.3	4.6	6.9
Cr <sub>2</sub> O <sub>3</sub>	0.5	0.5	0.5	0.5
<b>Chemical composition</b>				
Dry matter	89.65	88.05	86.45	84.85
Crude protein	28.55	28.56	28.57	28.58
Lipid	5.16	5.10	5.04	4.98
Crude fiber	6.02	6.79	7.56	8.33
Nitrogen free extract (NFE %)**	41.26	40.67	40.08	39.49
Ash	6.19	6.24	6.28	6.32
Gross energy	2105.4	2095.6	2090.48	2085.41
Metabolizable energy	1526.3	1521.84	1517.4	1513.0
(P/E) ratio	136	136	136.67	137.05

\*One kg premix contained:

**Vitamins:** 48×10<sup>5</sup> I.U. (A), 6×10<sup>2</sup> mg (B<sub>6</sub>), 20 mg (biotin), 8×10<sup>5</sup> I.U. (D<sub>3</sub>), 144 mg (E), 400 mg (B<sub>1</sub>), 1600 mg (B<sub>2</sub>), 4×10<sup>3</sup> mg (pantothenic acid), 4 mg (B<sub>12</sub>), 4×10<sup>2</sup> mg (niacin), 2×10<sup>5</sup> mg (choline chloride), and 400 mg (folic acid).

**Minerals:** 12×10<sup>3</sup> mg iron, 16×10<sup>3</sup> mg manganese, 12×10<sup>2</sup> mg copper, 120 mg iodine, 80 mg cobalt, 40 mg selenium, and 16×10<sup>3</sup> mg zinc.

\*\*Nitrogen free extract = 100 - (CP% + EE% + CF% + Ash%)

## RESULTS AND DISCUSSION

### 1. Growth performance of experimental fish

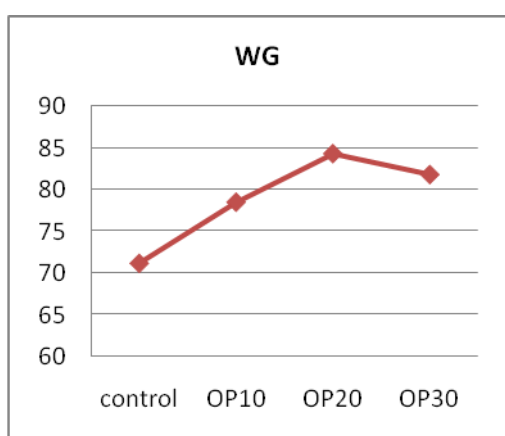
The present results showed that the growth performance of the tilapia improved when fed on the three supplemented diets, especially for those fed on diet 2 (OP<sub>20</sub>) followed by diet 3 (OP<sub>30</sub>) when compared the control (Table 4 and Figs. 1-3).

Those results may be due to the fact that orange peel contains a rich and important content of phenolic compounds which may enhance digestion and intestinal function. Moreover, orange peel contains a huge content of fibers and pectin that improves intestinal function and health due to their physicochemical properties (Chau *et al.*, 2005; Nwanna *et al.*, 2011; Doan *et al.*, 2018). The present data revealed that the three levels of orange peel acted as a direct fish growth promoter.

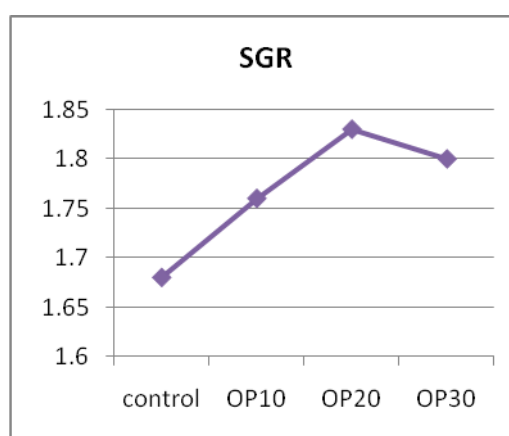
Additionally, the survival rate (Fig. 3) in the present findings increased ( $p < 0.05$ ) in all fish groups fed on the three levels of orange peel compared to the control.

**Table 4.** Growth performance for fish fed the three levels of orange peel

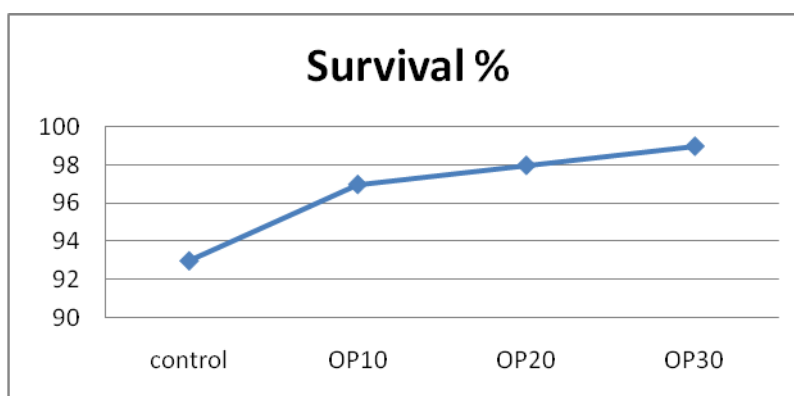
Growth parameter	Experimental diets			
	Control	OP <sub>10</sub>	OP <sub>20</sub>	OP <sub>30</sub>
Initial weight(g)	17.1 <sup>a</sup> ± 0.10	16.4 <sup>b</sup> ± 0.08	16.9 <sup>a</sup> ± 0.2	16.9 <sup>a</sup> ± 0.12
Final weight(g)	88.3 <sup>d</sup> ± 0.5	91.9 <sup>c</sup> ± 0.53	101.2 <sup>a</sup> ± 1.97	98.7 <sup>b</sup> ± 0.54
Body weight gain(g)	71.2 <sup>d</sup> ± 0.5	78.5 <sup>c</sup> ± 0.51	84.3 <sup>a</sup> ± 1.0	81.8 <sup>b</sup> ± 0.53
Daily weight gain(g/day)	0.73 <sup>d</sup> ± 0.01	0.77 <sup>c</sup> ± 0.01	0.86 <sup>a</sup> ± 0.02	0.83 <sup>b</sup> ± 0.03
Specific growth rate	1.68 <sup>c</sup> ± 0.020	1.76 <sup>b</sup> ± 0.010	1.83 <sup>a</sup> ± 0.011	1.80 <sup>a</sup> ± 0.003
Survival rate (%)	93 <sup>c</sup>	97 <sup>b</sup>	98 <sup>a</sup>	99 <sup>a</sup>



**Fig. 1.** Mean weight gain



**Fig. 2.** Specific growth rate



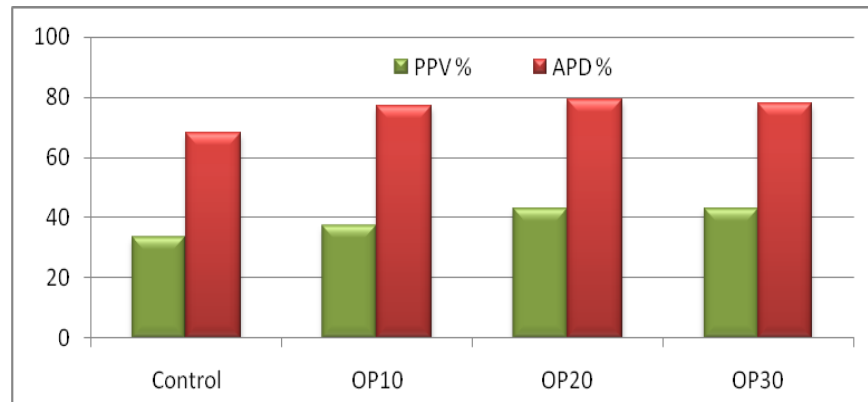
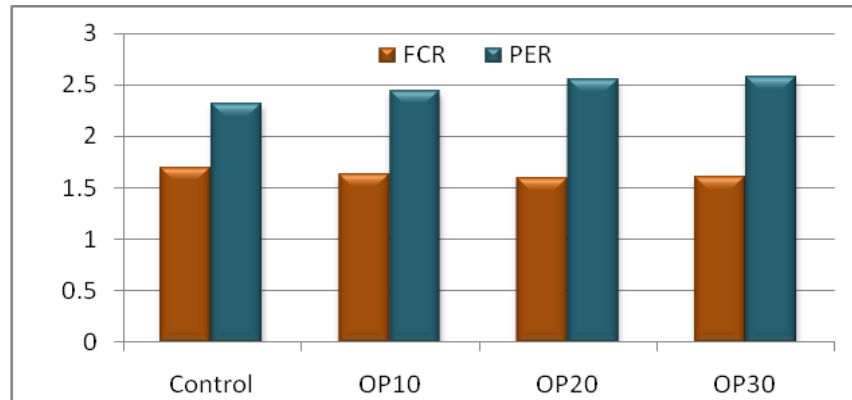
**Fig. 3.** Fish survival rate

## 2. Feed utilization

The best values (79.02 %, 42.96 % and 2.58) of apparent protein digestibility, protein productive value and protein efficiency ratio, respectively, were found for fish fed on OP<sub>20</sub>, accompanied with the optimal values of feed conversion ratio and feed consumed with values of 1.59 & 133.63 g, respectively (Figs. 4 & 5).

**Table 5.** Feed utilization of Nile tilapia fed yellow corn replacer (OP)

Parameter	Experimental diets			
	Control	OP <sub>10</sub>	OP <sub>20</sub>	OP <sub>30</sub>
Final weight	88.3 <sup>d</sup> ± 0.67	91.9 <sup>c</sup> ± 0.53	101.2 <sup>a</sup> ± 1.97	98.7 <sup>b</sup> ± 0.58
Food consumed	119.99 <sup>d</sup> ± 0.5	122.87 <sup>c</sup> ± 1.0	133.63 <sup>a</sup> ± 0.51	130.93 <sup>b</sup> ± 0.53
Feed conversion ratio	1.69 <sup>c</sup> ± 0.01	1.63 <sup>b</sup> ± 0.02	1.59 <sup>a</sup> ± 0.01	1.60 <sup>a</sup> ± 0.03
Protein efficiency ratio	2.32 <sup>c</sup> ± 0.020	2.44 <sup>b</sup> ± 0.011	2.55 <sup>a</sup> ± 0.010	2.58 <sup>a</sup> ± 0.003
PPV %	33.37 <sup>c</sup> ± 0.95	37.20 <sup>b</sup> ± 0.89	42.96 <sup>a</sup> ± 0.94	42.96 <sup>a</sup> ± 0.86
APD	68.03 <sup>d</sup> ± 1.01	77.03 <sup>c</sup> ± 0.99	79.02 <sup>a</sup> ± 1.02	77.8 <sup>b</sup> ± 1.08

**Fig. 4.** Apparent protein digestibility (APD) and protein productive value (PPV)**Fig. 5.** Feed conversion ratio (FCR) and protein efficiency ratio (PER)

The present results cleared that dietary inclusion of orange peel levels improved fish feed utilization, indicating that orange peel acts as a fish appetizer.

The huge fiber content of the yellow corn replacer could improve the nutrient digestibility of the diets. On the other hand, high lipid and carbohydrate levels act as dietary sources (Nwanna *et al.*, 2011). Additionally, Salem and Abdel-Ghany (2018) noted that, the orange peel powder in the tilapia diets (2 %) enhanced the digestion and nutrient absorption.



### 3. Body chemical composition

The results showed that, the lipid content of the fish showed a decreasing trend with the inclusion of orange peels, where the highest protein and lowest lipid content were recorded for the fish fed OP<sub>20</sub> and OP<sub>30</sub>. Therefore, fat reducing in the muscle of fish fed orange peel improved the flesh quality because of the reduction in the cholesterol levels of the fish. This application could fairly be adjusted to produce low cholesterol fishes for people with heart problems (Table 6).

**Table 6.** Effect of different experimental diets on carcass composition of Nile tilapia

Body analysis	Experimental diets			
	Control	OP <sub>10</sub>	OP <sub>20</sub>	OP <sub>30</sub>
<b>Protein (%)</b>	56.1 <sup>c</sup> ±1.05	58.42 <sup>b</sup> ±0.84	60.94 <sup>a</sup> ±1.12	60.6 <sup>a</sup> ±1.06
<b>Lipid (%)</b>	22.4 <sup>a</sup> ±0.80	18.3 <sup>b</sup> ±0.63	17.7 <sup>c</sup> ±0.45	17.83 <sup>c</sup> ±0.47
<b>Ash (%)</b>	18.85 <sup>c</sup> ±0.66	19.5 <sup>b</sup> ±1.01	19.75 <sup>a</sup> ±0.80	19.63 <sup>ab</sup> ±0.12
<b>NFE (%)</b>	2.65 <sup>b</sup> ±0.10	3.78 <sup>a</sup> ±0.11	1.61 <sup>d</sup> ±0.05	1.94 <sup>c</sup> ±0.11
<b>Moisture (%)</b>	74.34 <sup>a</sup> ±1.22	73.94 <sup>b</sup> ±1.06	72.4 <sup>d</sup> ±0.81	72.71 <sup>c</sup> ±0.78
<b>DM (%)</b>	25.66 <sup>c</sup> ±0.84	26.06 <sup>b</sup> ±0.67	27.6 <sup>a</sup> ±0.90	27.29 <sup>a</sup> ±0.75
<b>Gross energy</b>	5286.5 <sup>a</sup> ±2.35	5030.1 <sup>c</sup> ±1.54	5115.8 <sup>b</sup> ±2.11	5108.8 <sup>c</sup> ±2.31
<b>Metabolizable energy</b>	3979.9 <sup>a</sup> ±2.84	3742.4 <sup>d</sup> ±1.83	3792.7 <sup>c</sup> ±2.04	3789.8 <sup>b</sup> ±1.91
<b>(P/E) ratio</b>	106.12 <sup>c</sup> ±1.01	116.14 <sup>b</sup> ±1.24	119.12 <sup>a</sup> ±1.56	118.62 <sup>a</sup> ±1.53

Thus, orange peels could be used to produce low fat fishes that would be beneficial for people with cardiovascular problems (Nwanna *et al.*, 2011). Moisture recorded content fluctuated insignificantly ( $p > 0.05$ ) through the three fish groups. The result cleared that, dry matter and ash content were increased for fish fed OP<sub>20</sub> and OP<sub>30</sub>. High percent of dry matter and ash content may owe to the high mineral content of orange peel powder that may increase mineralization in fish muscles (Nwanna *et al.*, 2011). The high lipid, fiber and carbohydrate contents of orange peel feedstuffs are indications that the peels could serve as a good source of dietary energy in fish feeds.

### 4. Physiological parameters

#### 4.1. Body indices

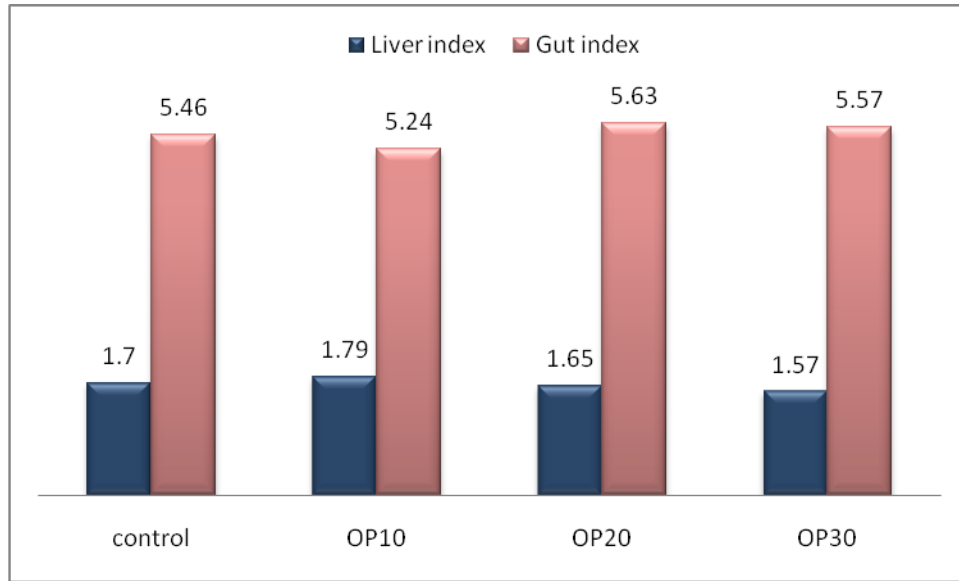
Fig (6) shows that the recorded body indices were affected by the experimental diets; the highest and lowest liver and gut indices were recorded for fish fed diet 1. Those results may be attributed to the fiber content, phenolic compounds, and pectin that may improve intestinal function and fish health (Chau *et al.*, 2005; Doan *et al.*, 2018). In such a case, an increase in the level of replacement would be recorded leading to a decline in the hepatic index.

#### 4.2. Hematological parameters

The present results explained that using orange peel as an additive improved the plasma total protein and optimized liver health (AST and ALT) of the treated fish. Moreover, orange peel additive enhanced the immunity of the tested fish accompanied with the declining trend in plasma glucose and cholesterol. The best plasma total protein value (3.91) was recorded for those fed the OP<sub>30</sub> (Table 7).

Terpstra *et al.* (2002) and Figuerola *et al.* (2005) stated that, some physiological functions of the fiber content in the dried orange peel may reduce blood cholesterol and

glucose level. Furthermore, orange peel essential oil contains terpenes compounds which are effective in reducing plasma cholesterol levels (Dillard & German, 2000).



**Fig. 6.** Body indices of experimental fish

**Table 7.** Hematological condition of the fish fed the replacer

Blood parameter	Experimental diets			
	Control	OP <sub>10</sub>	OP <sub>20</sub>	OP <sub>30</sub>
Glucose (mg/dl)	94.8 <sup>a</sup> ±1.03	81.32 <sup>b</sup> ± 1.10	78.73 <sup>c</sup> ± 1.05	76.0 <sup>d</sup> ± 1.02
Cholesterol (mg/dl)	119.8 <sup>a</sup> ±1.12	108.22 <sup>b</sup> ±1.10	105.13 <sup>c</sup> ±1.03	105.17 <sup>c</sup> ±1.05
Plasma total protein	3.32 <sup>c</sup> ±0.05	3.85 <sup>b</sup> ±0.05	3.89 <sup>ab</sup> ±0.03	3.91 <sup>a</sup> ±0.04
AST	140.2 <sup>a</sup> ±2.01	128.11 <sup>b</sup> ±1.72	123.40 <sup>c</sup> ± 1.82	124.75 <sup>c</sup> ±1.93
ALT	70.8 <sup>a</sup> ±1.55	65.45 <sup>b</sup> ±1.17	61.74 <sup>d</sup> ±0.84	62.17 <sup>c</sup> ±0.77
IgM	10.75 <sup>a</sup> ±0.34	8.94 <sup>b</sup> ±0.31	8.67 <sup>c</sup> ±0.12	8.37 <sup>d</sup> ±0.11
IgD	134.65 <sup>d</sup> ±1.11	145.55 <sup>c</sup> ±1.32	156.52 <sup>b</sup> ±1.41	158.35 <sup>a</sup> ±1.54

The present results revealed that, orange peel enhanced the liver enzyme activities and the immunoglobulins (IgM & IgD). Those findings may be due to the presence of some bioactive components such as phenols, amino acids, essential oils, pectin, carotenoids, flavonoids, and vitamin C in orange peel which have a positive biochemical functional effects as antioxidant agents, (Assini *et al.*, 2013; M'hiri *et al.*, 2015). The essential oils of orange peel have recorded beneficial effects on growth and immune system of the tilapia (Acaret *et al.*, 2015). All those compounds have positively affected the enzymes activities, enhanced nutrients digestibility and food absorption, and thus improved fish growth (Al-Saadi *et al.*, 2009; Immanuel *et al.*, 2009; Citarasu, 2010; Hashemi & Davoodi, 2011; Fadda & Raky, 2021). In addition, these bioactive substances can promote biological activities and act as antistress and appetizer, adding to

their role in enhancing the immunity system and antioxidants (Citarasu, 2010; Yilmaz, 2019; Raky *et al.*, 2021).

The current findings showed that, the different levels in OP as a yellow corn replacer enhanced liver enzyme activities and immunoglobulins' concentrations. Vitamin C in orange peel plays a positively effective role and act as an antioxidant for cell integrity.

### 5. Economic profit.

Orange peels contain some important minerals and also huge amount of vitamin C. This advantage can be used in reducing supplemental minerals and vitamins in the diet, which could reduce the cost of feed production (Nwanna *et al.*, 2011).

Combined with maize, orange peels can reduce the oxidation of dietary protein for energy that has a protein sparing ability, which, in return, would minimize the quantity/cost of dietary protein (Hanley 1991; Nwanna *et al.* 2003).

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