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Assessment of phytoplankton species in gut and feces of cultured tilapia fish in Egyptian fishponds: Implications for feeding and bloom control

Avaliação de espécies fitoplanctônicas no intestino e nas fezes de tilápia cultivada em viveiros no Egito: implicações para a alimentação e controle da floração

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Abstract: Aim: This study was carried out to determine which phytoplankton species, as a natural food, can be ingested and digested by Nile tilapia (*Oreochromis niloticus* L.). **Methods:** During this study, phytoplankton in the gut contents of Nile tilapia collected from three fishponds in southern Egypt were investigated during the period Oct. 2012-Sep. 2013. Samples of tilapia fish were grown in aquarium containing filtered pond water to detect undigested phytoplankton species in the feces. **Results:** The majority of the phytoplankton found in the gut of Nile tilapia was Cyanobacteria (36-50%) and Chlorophyta (27-38%). Other groups such Diatoms, Euglenophyta and Dinophyta were also found but with lower percentages (<19%). The most important and dominant phytoplankton species found in Tilapia gut were the potentially toxic cyanobacteria, *Anabaena, Anabaenopsis, Cylindrospermopsis, Microcystis* and *Planktothrix*. Only diatoms were recorded in the feces, indicating the ability of Tilapia to digest all phytoplankton except diatoms. **Conclusions:** The data of this study could be useful for biomanipulation of nuisance phytoplankton blooms in eutrophic aquacultures.

Keywords: cyanobacteria; diatoms; digestion; ingestion; tilapia.

Resumo: Objetivo: Nosso estudo visou determinar quais espécies de fitoplâncton, como alimento natural, podem ser ingeridas e digeridas pela tilápia do Nilo (*Oreochromis niloticus* L.). **Métodos:** Durante o estudo, coletamos e analisamos o fitoplâncton nos intestinos de tilápia do Nilo cultivadas em três viveiros de peixes no sul do Egito, durante o período de outubro de 2012 a setembro. 2013. Indivíduos de tilápias foram colocados em aquários contendo água filtrada para detectar espécies de fitoplâncton não digeridas nas fezes. **Resultados:** A maioria do fitoplâncton encontrado no intestino de tilápia do Nilo foi cianobactérias (36-50%) e clorofíceas (27-38%). Outros grupos, como Diatomáceas, Euglenophyta e Dinophyta, também foram encontrados em menores quantidades (<19%). As espécies fitoplanctônicas mais importantes e dominantes encontradas no intestino de tilápia foram as cianobactérias potencialmente tóxicas, *Anabaena*, *Anabaenopsis*, *Cylindrospermopsis*, *Microcystis* e *Planktothrix*. Apenas as diatomáceas foram registradas nas fezes, indicando a capacidade da tilápia de digerir todo o fitoplâncton, exceto espécies deste grupo. **Conclusão:** Os dados deste estudo podem ser úteis para a biomanipulação de proliferação de fitoplâncton em ambientes aquicolas eutróficos.

Palavras-chave: cianobactérias; diatomáceas; digestão; ingestão; tilápia.

1. Introduction

Grazing by higher trophic level organisms including fish and zooplankton can be a major contributor to the reduction of algal and cyanobacterial blooms (Mohamed & Al-Shehri, 2013a). Nile tilapia (*Oreochromis niloticus* L.) is one of the most important tropical and subtropical freshwater fish that can feed on both phytoplankton and smaller zooplankton (Abdel-Tawwab, 2000). Phytoplankton cells could be used as a natural food of Tilapia fish (Fattah et al., 2008; Budihastuti et al., 2013), as they are rich in vitamin precursors, growth promoters and essential fatty acids (Awasthi et al., 2006). However, some phytoplankton groups, particularly cyanobacteria can produce toxins that may negatively affect fish health or accumulate in their tissues posing a risk to human health upon consumption of such contaminated fish (Mohamed et al., 2003; Mohamed, 2016). Therefore, the types of phytoplankton consumed by fish as a food should be determined before selecting them for fish feeds. Analysis of phytoplankton composition in fish gut contents is widely used to ascertain the food and feeding habit of fish (Nath et al., 2015). Furthermore, accurate identification of prey and feeding behavior provide the basis for understanding the trophic interactions in aquatic food webs (Zanden et al., 2000).

Several studies have shown that Tilapia has negative effects on cyanobacteria with high ingestion rates and digestion efficiencies (Lu et al., 2006; Menezes et al., 2010; Salazar Torres et al., 2016). These studies therefore suggested that stocking tilapia is an effective way to control algal blooms in eutrophic waters. Conversely, some studies reported that Tilapia fish are not effective in reducing phytoplankton biomass through direct grazing, and can contribute with nutrient excretion to the increase of phytoplankton biomass in the aquatic systems (Silva et al., 2014). Furthermore, Semyalo et al. (2011) found no significant relationship between the contribution of phytoplankton in tilapia diet and microcystin concentrations in the water.

As phytoplankton is one of the main food items for Tilapia fish, we hypothesized that Nile Tilapia will decrease the phytoplankton biomass and composition in fishponds through direct herbivory (top-down control). We also hypothesized that Tilapia fish would not influence phytoplankton through nutrient recycling (bottom-up control), because our fishponds are eutrophic. The present study was carried out to determine the composition and abundance of phytoplankton species in fish pond waters as well as in the gut contents of Tilapia fish (*Oreochromis niloticus*) collected from these fishponds, to ascertain the preferences of fishes for phytoplankton species as food, and its capability of feeding on nuisance algae.

2. Material and Methods

2.1. Description of study area

This study was conducted in three fishponds located in Sohag governorate during the period Oct. 2012 - Sep2013 (fishponds 1, 2 and 3). Fishpond 1 is located at 26° 27 N, and 31°40 E. It receives water from Nile River and agricultural drains with about 3m depth. Fishpond 2 is located at 26° 27 N, and 31° 49 E). This fishpond receives water from the Nile River with about 4m depth. Fishpond 3 is located at 26°36 N, and 31°43 83 E). It receives water from the Nile River, with about 3.5 m depth. In a parallel study by us, these fishponds were regarded as hypertotrophic (chl. a concentrations exceeded 75 $\mu g\ L^{-1}$) with physico-chemical parameters characterized by high temperature, moderate pH and high nutrient concentrations, particularly during warm months (Mohamed & Bakr, 2018). The fish densities in these fishponds ranged from of 7 to 9 fish/m^3.

2.2. Phytoplankton analysis in gut contents and feces.

Fish pond water and fish samples tilapia (*Oreochromis niloticus*) were collected monthly from three fish farms during the period from October 2012 to September2013 for 12 months except fishpond 1 for only nine months because no water samples collected at that time as the pond was dried up due to the Nile's low water level. The live fish samples were washed with distilled water to remove phytoplankton attached to their surfaces. Fishes were weighed, scarified and dissected. The gut of each fish was removed and fixed with 1 mL of Lugol's solution for microscopic examination. In order to test the digestibility of phytoplankton species by tilapia fish, about 10 tilapias were collected from fishpond 3 on a certain sampling occasion, and introduced into aquarium containing strained fishpond water by filtering through a 20 µm plankton net following the method of Ping & Jiankang (1994).The feces were collected immediately after digestion by means of a pipette, and washed twice carefully in distilled water. They were homogenized with a stirrer for a few minutes, and fixed in Lugol's iodine. Phytoplankton species in fishpond waters, fish gut and feces were identified based on morphological characteristics according to Prescott (1978). The counts of these species were performed using Sedgwick-Rafter under a binocular inverted microscope.

3. Results

The species composition of phytoplankton recorded in fishpond waters and the gut of Tilapia fish caught from these fishponds during the period Oct. 2012-Sep.2013 is shown in tables 1-4. Fifty four species of different groups were identified in Tilapia fish gut during the study period. Of which, 20 species belonging to Cyanobacteria,18 to Chlorophyta, 7 to Bacillariophyta, 4 to Dinoflagellates, 2 to Charophyta and 2 to Euglenophyta. The biomass composition of phytoplankton (based on cell count) in the fish gut varied significantly among fishponds and study months. Cyanobacteria and Chlorophyta constituted the highest percentages of phytoplankton biomass along the study period (36-50% & 27-38%, respectively). Other phytoplankton groups such as Bacillariophyta, Dinophyta, Charophyta and Euglenophyta were found in the fish gut with lower percentages, where they constituted 12-18.9%, 8%, 5-6%, 2-5% of total phytoplankton biomass, respectively (Tables 1-3). The phytoplankton species in the fish gut varied significantly among

Table 1. Phytoplankton species composition (**cells x10^6 L^{-1}**) in fishponds used in the present study.

Algal species	Fishpond 1	Fishpond 2	Fishpond 3
Cyanobacteria			
Anabaena affinis Lemmermann	1-100	-	-
Anabaenopsis circularis (G.S.West)	-	0.1-1	-
Aphanizomenon gracile Lemmermann	-	0.1-0.8	0.3-1
Aphanocapsa rivularis (Carmichael)	-	0.1-0.5	1-2
Chroococcus minimus (Keissler)	2-3	0.2-1.1	0.5-1
Coelosphaerium kuetzingianum Nägeli	1-5	0.1-1	2
Cylindrospermopsis catemaco Komár	-	0.1-1	12-24
C. philippinensis Taylor	-	0.2-1	11-20
Cylindrospermopsis raciborskii (Woloszynska)	-	0.3-1	12-24
Gomphosphaeria aponina Kützing	-	0.01-0.1	14-32
Lyngbya wollei (Farlow ex Gomont)	1-80	-	-
Merismopedia minima G.Beck	20	0.1-0.5	-
Merismopedia tenuissima Lemmermann	0.5-20	0.2-0.5	4-24
Microcystis aeruginosa (Kützing)	0.5-1	0.3-0.5	3-54
Oscillatoria formosa Bory ex Gomon	1	-	-
Oscillatoria limnetica Lemmermann	1	0.1-0.4	2-12
Planktolyngbya limnetica (Lemmermann)	2	-	-
Pseudanabaena catenata Lauterborn	-	0.2-0.7	-
Planktothrix agardhii (Gomont)	1-110	-	-
Spirulina abbreviata Lemmermann	0.5-9	0.5	1-10
Synechocystis aquatilis Sauvageau	-	1-3	1-11
Chlorophyta			
Actinastrum hantzschii Lagerheim	2-56	11-34	8-77
Ankistrodesmus gracilis (Reinsch)	10-76	34-54	4-76
Chlamydomonas reinhardtii P.A.Dangeard	22-55	23	6-76
Chlorella vulgaris Beyerinck	22-88	6-7	88
Chlorococcum lobatum (Korshikov)	11-54	6-90	8-67
Cladophora aegagropila (Linnaeus)	36-98	6-9	3-5
Cosmarium abbreviatum Raciborski	13-76	8-81	4-65
Crucigenia fenestrata (Schmidle)	12-32	4-6	56-76
Eudorina elegans Ehrenberg	32-34	8-89	32
Kirchneriella lunaris (Kirchner)	54	6-9	58
Monoraphidium arcuatum (Korshikov)	10-45	-	4
Ochromonas tuberculata D.J.Hibberd	-	34-65	4-54
Pandorina morum (O.F.Müller)	5	7-70	5-63
Pediastrum duplex Meyen	6-12	8	1-8
Scenedesmus ellipsoideus Chodat	4-98	3-98	2-11
Staurastrum anatinum Cooke & Wills	3-65	5-78	3-54
Tetraëdron minimum (A.Braun)	4-11	1-98	-

Table 1. Continued...

Algal species	Fishpond 1	Fishpond 2	Fishpond 3
Euglenophyta			
Euglena agilis H.J.Carter	6-23	-	4-65
Phacus acuminata Kiss	-	-	10-54
Bacillariophyta			
Cyclotella sp.	7	3-7	2-8
Cymbella sp.	-	-	34
Fragillaria sp.	5-65	5-7	5-65
Melosira sp.	4-14	2-8	4-11
Navicula sp.	6-87	-	1-87
Nitzschia sp.	2-45	3-9	4-89
Tribonema sp.	4-76	-	3-98
Tabillaria sp.	4-45	-	3
Charophyta		-	-
Cloesteruim sp.	7-56	-	12
Spirogyra sp.	45	-	23
Dinoflagellates			
Ceratinum sp.	22	-	-
Gymnodinium sp.	9	-	67
Katodinium sp.	-	-	9
Peridinium sp.	12	-	4-11

Table 2. Analysis of different phytoplankton groups identified in fish gut (cells x10^6 gut^{-1}) from fishpond 1 during the study period Oct. 2012- Sept. 2013.

Algal species	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	April	May	June	July	Aug	Sep.
Cyanobacteria												
Anabaena affinis Lemm	1.3	1	-	-	-	-	0.5	0.8	0.86	1.5	3	4.2
Chroococcus minimus Keissl	3.2	-	-	-	-	-	-	-	-	-	-	-
Coelosphaerium kuetzingianum Näg	4	3	-	-	-	-	-	-	-	-	-	-
Cylindrospermopsis raciborskii Wol	2.2	-	-	-	-	-	-	-	-	-	-	-
Gomphosphaeria aponina Kützing	1.8	2	-	-	-	-	-	-	-	-	-	-
Lyngbya wollei Farlow ex Gomont	-	-		-	-	-	0.07	0.78	0.9	1	1.3	3
Merismopedia minima G.Beck	3.1	3	-	-	-	-	-	-	-	-	-	-
Merismopedia tenuissima Lemm	-	4	1	-	-	-	-	-	-	-	-	23
Microcystis aeruginosa (Kützing)	3	-	-		-	-	-	-	-	-	-	2
Oscillatoria formosa Bory ex Gomon	4	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria limnetica Lemm	5	2	-	-	-		-	-	-	-	-	12
Planktolyngbya limnetica Lemm	-	-	6	-	-	-	-	-	-	-	-	-
Planktothrix agardhii (Gomont)	4	-	-	-	-	-	0.4	0.3	0.7	3	5	7
Spirulina abbreviata Lemm	-	-	-	-	-	-	-	-	1	4	6	8
Synechocystis aquatilis Sauvageau	12	-	-	-	-	-	-	-	-	-	-	-
Chlorophyta												
Actinastrum hantzschii Lagerheim	43	-	-	-	23	43	45	33	-	-	-	-
Ankistrodesmus gracilis (Reinsch)	-	-	43	12	45	56	42	22	-	-	-	-
Chlamydomonas reinhardtii Dangeard	-	-	-	-	-	-	45	31	-	-	-	-
Chlorella vulgaris Beyerinck	-	3	-	67	30	18	19	20	-	-	21	-
Chlorococcum lobatum (Korshikov)	-	-	-	34	55	34	22	18	-	-	-	-
Cladophora aegagropila (Linnaeus)	-	-	-	-	7	4	2	5	-	-	-	-
Cosmarium abbreviatum Raciborski	5	-	3	4	21	4	2	-	-	-	-	-
Crucigenia fenestrata (Schmidle)	3	2	2	-	-	-	-	-	-	-	-	-
Kirchneriella lunaris (Kirchner)	-	-	2	-	-	-	-	-	-	-	-	-
Monoraphidium arcuatum Korshikov	-	11	-	-	-	-	-	-	-	-	-	-
Pandorina morum (O.F.Müller)	-	34	53	-	-	-	-	-	-	-	-	-
Pediastrum duplex Meyen	2	7	44	59	52	65	-	-	-	-	2	-
Scenedesmus ellipsoideus Chodat	3	5	11	-	-	-	2	-	-	1	0.9	-
Staurastrum anatinum Cooke & Wills	-	3	6	-	-	-	-	2	-	-	-	11
Tetraëdron minimum (A.Braun)	2	1	-	21	11	17	10	-	-	-	-	15

Table 2. Continued...

Algal species	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	April	May	June	July	Aug	Sep.
Euglenophyta												
Euglena agilis H.J.Carter	23	11	3	-	-	-	11	-	12	-	2	-
Bacillariophyta												
Cyclotella sp.	22	7	19	-	-	-	21	-	-	-	4	-
Fragillaria sp.	-	-	-	-	-	-	-	-	12	-	-	-
Melosira sp.	-	-	34	-	-	-	23	5	11	-	24	35
Navicula sp.	11	31	33	-	-	-	-	50	45	56	67	51
Nitzschia sp.	21	43	5	-	-	-	39	28	41	53	67	-
Tribonema sp.	23	11	32	-	-	-	-	-	10	-	12	-
Tabillaria sp.	-	23	43	-	-	-	-	-	12	-	9	-
Charophyta												
Cloesteruim sp.	-	-	-	-	-	-	34	-	-	11	-	-
Spirogyra sp.	-	-	-	-	-	-	-	67	34	4	11	2
Dinoflagellates												
Ceratinum sp.	-	-	-	-	-	-	21	-	-	-	-	-
Gymnodinium sp.	-	-	1	-	-	-	-	-	-	-	-	-
Peridinium sp.	21	11	23	-	-	-	41	-	-	-	9	-

Table 3. Analysis of different phytoplankton groups identified in fish gut (cells x10^6 gut^{-1}) from fishpond 2 during the study period Oct. 2012- Sept. 2013.

Algal species	Oct	Nov	Dec	Jan	Feb	Mar.	Apr	May	Jun	Jul	Aug	Sep
Cyanobacteria												
Anabaenopsis circularis (G.S.West)	33	-	-	-	-	-	-	-	-	19	32	52
Aphanocapsa rivularis Carmichael	22	-	-	-	-	-	12	43	65	45	77	78
Chroococcus minimus Keissl	54	-	-	-	-	-	-	-	-	-	-	-
Coelosphaerium kuetzingianum Näg	76	-	-	-	-	-	-	-	-	59	-	40
Cylindrospermopsis catemaco Komárk	60	-	-	-	-	-	-	-	-	-	-	87
C. philippinensis W.R.Taylor	-	-	-	-	-	-	-	-	-	54	45	77
C. raciborskii Wol.	23	-	-	-	-	-	-	-	43	67	98	56
Gomphosphaeria aponina Kütz	66	-	-	-	-	-	-	-	-	-	-	-
Merismopedia minima G.Beck	67	100	57	65	45	33	69	-	-	-	-	87
Merismopedia tenuissima Lemm	39	-	-	-	-	-	-	-	-	-	-	-
Microcystis aeruginosa Kütz	43	56	34	12	-	-	-	-	-	-	-	-
Oscillatoria limnetica Lemm	-	-	-	-	-	-	-	67	-	-	-	45
Pseudanabaena catenata Lauterborn	-	-	-	54	33	23	-	-	-	-	-	55
Spirulina abbreviata Lemm	-	-	-	-	-	-	-	-	-	-	65	-
Synechocystis aquatilis Sauvageau	8	54	45	80	19		-	-	-	-	-	-
Chlorophyta												
Actinastrum hantzschii Lagerheim	-	-	43	-	56	-	-	-	-	-	-	-
Ankistrodesmus gracilis Reinsch	-	12	43	-	66	78	45	55	-	-	-	-
Chlamydomonas reinhardtii Dang			34	-	-	-	-	-	-	-	-	-
Chlorella vulgaris Beyerinck	-	43	-	33	32	-	33	23	-	-	-	-
Chlorococcum lobatum (Korshikov)	-	-	-	-	43	-	12	-	-	-	-	-
Cladophora aegagropila (Linnaeus)	-	-	-	-	-	-	12	-	-	-	-	-
Cosmarium abbreviatum Raciborski	-	43	-	-	-	-	32	43	-	-	-	-
Crucigenia fenestrata (Schmidle)	12	22	32	-	-	19	-	-	-	-	-	-
Eudorina elegans Ehrenberg	-	-	-	-	34	-	-	-	-	-	-	-
Kirchneriella lunaris (Kirchner)	-	-	-	-	-	32	-	-	-	-	-	-
Monoraphidium arcuatum (Korshikov)	-	-	-	-	-	7	-	-	-	-	-	-
Ochromonas tuberculata D.J.Hibberd	-	-	-	-	-	12	-	-	-	-	-	-
Pandorina morum (O.F.Müller)	-	-	-	-	32	-	4	5	-	-	-	-
Pediastrum duplex Meyen	-	31	43	-	-	55	3	5	1	-	-	-
Scenedesmus ellipsoideus Chodat	3	20	4	43	5	0.8	-		-	0.6	-	-
Staurastrum anatinum Cooke & Wills	12	32	11	-	34	43	33	54	-	-	-	20
Tetraëdron minimum (A.Braun)	22	32	23	-	43	4	-	-	-	-	-	5

Table 3. Continued...

Algal species	Oct	Nov	Dec	Jan	Feb	Mar.	Apr	May	Jun	Jul	Aug	Sep
Bacillariophyta												
Cymbella sp.	-	-	-	-	-	-	-	12	-	-	-	-
Fragillaria sp.	-	-	-		100	40	-	-	-	-	-	-
Melosira sp.	28	56	57	40	30	56	23	34	4	-	2	-
Nitzschia sp.	-	23	50	49	-	38	-	56	87	67	72	-

Table 4. Analysis of different phytoplankton groups identified in fish gut (cells x10^6 gut^{-1}) from fishpond 3 during the study period Oct. 2012- Sept. 2013.

Algal species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Cyanobacteria												
Aphanocapsa rivularis Carmichael	-	-	34	34	-	-	-	-	-	-	-	-
Chroococcus minimus Keissl.	23	-	-	-	-	-	-	-	-	-	-	56
Coelosphaerium kuetzingianum Näg.	34	-	-	-	-	-	-	-	-	-	-	-
Cylindrospermopsis catemaco Komár	25	-	-	-	-	-	-	-	45	55	63	40
C. philippinensis Taylor	34	-	-	-	-	-	-	-	-	23	43	30
C. raciborskii Wol.	23	-	-	-	-	-	-	-	24	43	55	20
Gomphosphaeria aponina Kützing	100	-	-	2	-	-	-	-	-	-	-	63
Merismopedia tenuissima Lemm.	200	-	27	-	-	-	-	-	-	-	-	88
Microcystis aeruginosa (Kützing)	34	42	23	7	1	-	2	2	17	54	65	40
Oscillatoria limnetica Lemm	45	-	-	-	-	-	-	-	-	13	17	20
Spirulina abbreviata Lemm	-	-	-	-	-		-	13	-	-	-	21
Synechocystis aquatilis Sauvageau	11	-	-	-	-	-	-	-	-	-	-	23
Chlorophyta												
Actinastrum hantzschii Lagerheim	22	-	-	-	34	55	-	-	-	-	-	3
Ankistrodesmus gracilis (Reinsch)	18	20	30	48	100	87	75	65	-	-	-	40
Chlorella vulgaris Beyerinck	-	-	-	-	-	-	-	-	-	-	-	-
Chlorococcum lobatum (Korshikov)	-	-	-	-	34	-	-	-	-	-	-	-
Cladophora aegagropila (Linnaeus)	-	-	-	-	-	54	-	-	-	-	-	-
Cosmarium abbreviatum Raciborski	-	-	-	-	-	-	-	-	-	-	-	24
Crucigenia fenestrata (Schmidle)	-	-	-	16	51	30	-	-	-	-	-	-
Eudorina elegans Ehrenberg	-	-	-	-	-	33	-	-	-	-	-	-
Kirchneriella lunaris (Kirchner)	-	21	-	-	32	54	-	-	-	-	-	-
Monoraphidium arcuatum Korshikov	12	32	55		52	60	67	32	-	-	-	17
Ochromonas tuberculata D.J.Hibberd	14	3	42	5	30	67	-	-	-	-	-	-
Pandorina morum (O.F.Müller)	5	21	3	55	87	53	77	3	0.7	0.9	0.3	1
Pediastrum duplex Meyen		-	-	-	54	-	-	78	-	-	-	87
Scenedesmus ellipsoideus Chodat	54	-	67	-	-	56	75	45	32	-	-	55
Staurastrum anatinum Cooke & Wills	32	19	-	-	-	56	-	-	-	-	-	-
Euglenophyta												
Euglena agilis Carter	12	34	9	4	11	34	2	-	4	1	4	3
Phacus acuminata Kiss	11	8	-	-	-	-	7	-	-	-	-	-
Bacillariophyta												
Cyclotella sp.	-	54	45	35	65	54	22	11	-	-	-	-
Cymbella sp.	-	-	-	-	-	23	-	-	-	-	-	-
Fragillaria sp.	-	-	-	-	45	56	-	-	-	-	-	-
Melosira sp.	-	11	12	23	13	34	34	20	34	67	-	-
Navicula sp.	8	34	54	2	15	65	24	23	42	-	32	32
Nitzschia sp.	11	32	24	53	11	19	54	23	43	-	2	1
Tribonema sp.	3	4	0.9	_	2	2	-	1	-	4	13	4
Dinoflagellates												
Gymnodinium sp.	3	-	-	-	-	-	-	-	-	-	-	-
Katodinium sp.	2	-	-	-		-	-	-	-	-	-	-
Peridinium sp.	23	34	12	32	22	24	24	-	32	-	-	21

study months, and dominated by the chlorophytes (e.g. *Actinastrum, Ankistrodesmus, Chlamydomonas, Chlorella, Chlorococcum, Pediastrum* and *Scenedesmus)* in winter, the cyanobacteria (*Anabaena, Anabaenopsis, Cylindrospermopsis, Microcystis* and *Planktothrix*) in summer and autumn, the Euglenophyta (*Euglena*) in autumn and winter, the diatoms (*Cyclotella, Melosira, Navicula and Nitzschia*) in spring and the dinoflagellate (*Peridinium)* in autumn. Results of microscopic investigation of phytoplankton composition in fish feces along one week compared to those in gut contents, revealed that all phytoplankton cells of cyanobacteria, chlorophyta, dinophyta, disappeared from the gut and not found in the feces (Table 4,5). In contrast, all diatom species disappeared from the gut and detected in the feces (Table 5).

Table 5. Phytoplankton species in gut contents of tilapia fish collected from fishpond 3, and in feces after growing in aquarium containing filtered pond water for one week.

Phytoplankton species	Gut contents	Feces
Cyanobacteria		
Chroococcus minimus Keissler	+	-
Cylindrospermopsis raciborskii (Woloszynska	+	-
Gomphosphaeria aponina Kützing	+	-
Merismopedia tenuissima Lemmermann	+	-
Microcystis aeruginosa (Kützing)	+	-
Oscillatoria limnetica Lemmermann	+	-
Pseudanabaena catenata Lauterborn	+	-
Spirulina abbreviata Lemmermann	+	-
Synechocystis aquatilis Sauvageau	+	-
Chlorophyta		
Actinastrum hantzschii Lagerheim	+	-
Ankistrodesmus gracilis (Reinsch)	+	-
Pediastrum duplex Meyen	+	-
Scenedesmus ellipsoideus Chodat	+	-
Euglenophyta		
Euglena agilis Carter	+	-
Bacillariophyta		
Navicula sp.	+	+
Nitzschia sp.	+	+
Dinophyta		
Peridinium sp.	+	-

4. Discussion

Consistent with our hypothesis, Tilapia fed and reduced phytoplankton biomass in fishponds. The results showed that most phytoplankton species present in fishpond waters are pre-dominant in the gut contents and preferred food for Tilapia fish. Cyanobacteria and chlorophytes constituted the most phytoplankton groups in Tilapia fish gut during the study period. These results are thus in agreement with those obtained by Turker et al. (2003) reporting that Nile tilapia is more effective for filtering green algae and cyanobacteria from water sources. Salazar Torres et al. (2016) also analyzed tilapia gut contents and confirmed that cyanobacteria were a major component of its diet. More recently, Osti et al. (2018) found that cyanobacterial biomass in fishponds of a Nile tilapia production system in Brazil, was 2 to 3 times more than that in the system without tilapia, indicating the feeding of Tilapia on cyanobacteria. Additionally, euglenophytes and dinophytes and a little bit diatoms, were also detected in Tilapia fish gut in our study. Quite similar results were previously obtained by Abdel-Tawwab & Sweilum (2003) for Nile tilapia (*Oreochromis niloticus)* cultured in earthen ponds. Abdel-Tawwab & El-Marakby (2004) also showed that Cyanobacteria and Euglenophyceae were the most food found in the stomach of Tilapia. In the present study, the most common species found in Tilapia fish gut including the green algae (*Ankistrodesmus, Scenedesmus Actinastrum*), the cyanobacteria (*Anabaena, Microcystis, Oscillatoria*), the diatoms (*Navicula, Nitzschia*), and the euglenophytes (*Euglena, Phacus*) were also recorded previously in Nile tilapia stomachs from the Nile River (Abdelghany, 1993) and fishponds in Egypt (Abdel-Tawwab, 2000; Abdel-Tawwab & Sweilum, 2003).

Potentially toxic cyanobacteria such as *Microcystis* and *Anabaena* were recognized as the most dominant phytoplankton ingested by the Nile tilapia in different lakes (Bwanika et al., 2006; Semyalo et al., 2011). In addition to these species, our study recorded other cyanobacterial species in Tilapia fish gut including *Anabaenopsis*, *Cylindrospermopsis* and *Merismopedia*. These species were previously reported as toxin producers (Mohamed & Al-Shehri, 2009, 2010, 2013b; Mohamed & Bakr, 2018). The abundance of these species in fish gut seems dependant on the density of these species in the environment and the condition of fish (Xie et al., 2001; Abdel-Tawwab & Sweilum, 2003). This could be true for our results, as these species were abundant in Tilapia fish gut and in fishpond waters as well. This means that Tilapia can feed on all cyanobacteria without any avoidance for toxic species. In this respect, Lu et al. (2006) found that stocking Tilapia fish played an important role in reducing the biomass of bloom-forming species such as *Oscillatoria princes* and *M. aeruginosa* and *Merismopedia tenuissima* in Lake Yuehu, Ningbo. Salazar Torres et al. (2016) also provided evidence that Tilapia has the potential to reduce approximately 60% of cyanobacteria community in eutrophic reservoirs.

Interestingly, our study showed that Tilapia could ingest different morphological forms of phytoplankton including filamentous, colonial and single celled forms. This supports the fact that tilapia is a generalist filter feeder, which is capable of efficiently ingesting small and large phytoplankton (Turker et al., 2003). More recently, Rivera Vasconcelos et al. (2018) also reported that the Nile tilapia can suppress phytoplankton biomass in tropical lakes and reservoirs, with higher efficiency at feeding on larger algal and cyanobacterial forms than on small ones. Ingestion of phytoplankton by fish does not imply digestion and assimilation, which usually aided by two mechanisms including physical grinding of phytoplankton cells between two pharyngeal plates of fine teeth, and a stomach pH below 1.5 which lyses algal cell walls (Teichert-Coddingeton et al., 1997; Xie et al., 2001). Here in the present study, we examined the feces of Tilapia fish to determine its ability to digest phytoplankton species ingested. The results showed that except diatoms, all phytoplankton cells detected in Tilapia fish gut were not found in the feces. This indicates that Tilapia fish were able to digest cyanobacteria, green algae, dinoflagellates and euglenophytes, but not able to digest diatom cells. This agrees with the results of many studies reporting that Adult Tilapia fish have a pH of about 1.4 in their digestive organs, so most phytoplankton cells can be digested (Tavera, 1996; Komarkova & Tavera, 2003). Specifically, Lu et al. (2006) showed that Tilapia is among the very few fish species which are capable of digesting cyanobacteria.

Other studies showed the ability of Tilapia to assimilate bioactive compounds produced by cyanobacteria such as microcystin toxins and accumulate them in fish tissues (Mohamed et al., 2003; Deblois et al., 2008). Here in the present study, we did not investigate the cyanotoxins concentrations in fish tissues, but our previous studies reported the presence of microcystins in Tilapia fish tissues at concentrations as high as 102 ng g^{-1} fresh weight (Mohamed et al., 2003). This may represent a risk to human health. Therefore, Nile tilapia fed on toxic cyanobacteria should be continuously monitored for microcystin levels in their tissues to ensure its suitability for human food. On the other hand, the inability of Tilapia fish to digest diatoms has been demonstrated earlier by Ping & Jiankang (1994) and Grubach (2010) who found seventy-seven percent of the diatom taxa in the fish feces. This means that diatoms are more resistant to digestion in the fish gut than other phytoplankton groups. This resistance may be attributed to siliceous frustules which is hardly digested (Hamm et al., 2003), and may mechanically damage the intestinal cells (Giancamillo et al., 2012).

In conclusion, the results of this study along with other studies mentioned above, suggest a Nile Tilapia has high ingestion and digestion efficiencies for different forms of cyanobacteria (i.e. unicellular, colonies, filaments). Therefore, Tilapia may offer opportunities for control of harmful cyanobacteria in eutrophic lakes. However, cyanobacteria can produce cyanotoxins e.g., microcystins, and long-term exposure of Tilapia fish could increase the chances of toxin accumulation in fish tissues with potential transfer to higher trophic levels including human (Mohamed, 2016). Therefore, further studies are needed to determine levels of cyanotoxins in tilapia tissues from these fishponds and make an assessment of the potential health risk posed to humans living off this fishery.

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