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ORIGINAL ARTICLE

Trends in the use of feed and water additives in Egyptian tilapia culture

Wasseem Emam[1] | Mohamed N. El-Rewiny[2] | Attia A. Abou Zaid[2] | Wael F. El-Tras[2] | Radi A. Mohamed[2]

[1]Institute of Aquaculture, University of Stirling, Stirling, UK

[2]Department of Aquaculture, Faculty of Aquatic and Fisheries Sciences, Kafrelsheikh University, Kafr El-Sheikh, Egypt

Correspondence
Wasseem Emam, Institute of Aquaculture, University of Stirling, Stirling FK9 4LA, UK.
Email: wasseem.emam@stir.ac.uk

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Abstract

This study reports the outcomes of a survey on the use of additives in 120 Egyptian grow-out farms carried out between 2018 and 2019. The survey focused on farms rearing Nile tilapia (*Oreochromis niloticus*) in the biggest tilapia farming region in Egypt (Kafr El-Sheikh). Results were analysed to explore whether any type of additive was used, whether they were feed- or water-based and the frequency of use. A range of farm characteristics and farm management practices were used as independent variables to explain observed additive use patterns reported by farmers. The survey also gathered production data to explore a potential relationship between the use of additives and total marketable yield or mortality. The results of this survey display very low use of any sort of additive in this tilapia farming region (<33% of respondents) which is likely representative of practices in other production regions throughout the country. The most commonly reported additive classes were antibiotics, disinfectants and probiotics with the former two primarily used for treating disease after detecting mortalities in the ponds. Feed-based additives were used more frequently than water-based ones amongst which antibiotics were the most prevalent. There was no association between the use of additives and reported fish survival or total farm production. However, this is likely constrained by the small number of farms found to be using additives relative to the overall number of surveyed farms. Given the increasing trend in the use of additives in small-scale aquaculture, further efforts are needed to establish their cost-benefit and to promote their correct use where appropriate. Moreover, clear regulations are needed to prevent misuse of antimicrobials and minimise potential food safety concerns.

KEYWORDS

antimicrobial resistance, Egyptian aquaculture, farm survey, feed additives, Nile tilapia farming, *Oreochromis niloticus*

1 | INTRODUCTION

The Egyptian aquaculture industry has seen substantial growth in recent decades, and Egypt is now the top producer in Africa (FAO, 2021). As the sector has undergone intensification with larger numbers of fish being cultured, farmers have reported more frequent outbreaks of infectious diseases (Ali et al., 2020). Such outbreaks typically necessitate the use of therapeutic treatments such as antibiotics (and disinfectants which are incorrectly used as therapeutants). In many countries, the use of natural and synthetic chemicals such as antibiotics and probiotics are used to prevent and treat diseases, improve water quality and promote growth (Desbois et al., 2021).

It is now standard practice during feed production for manufacturers (and fish farm operators that formulate their own feed) to add 'sensory' additives to improve palatability, 'technological' additives such as antioxidants or emulsifiers or zootechnical additives such as enzymes and microorganisms (Flachowsky, 2018). The latter group in particular has grown in popularity with numerous studies demonstrating improved growth performance of reared animals where live cultures (so-called 'probiotics') are added to feed or in culture water (Taoka et al., 2006; Wang et al., 2008; Kesarcodi-Watson et al., 2008). Although such practices were initially developed and introduced into more intensive aquaculture systems in industrialised nations, this trend now seems to have expanded into the small-scale fish farming sector in developing countries (Elsabagh et al., 2018; Welker & Lim, 2011).

Egypt is the world's eighth largest aquaculture producer, producing over 1.6 million tonnes in 2019 of which the vast majority (66%) is Nile tilapia (*Oreochromis niloticus*; FAO, 2021). Anecdotal evidence collected during a survey of Egyptian fish farmers in 2016 by some of the same authors of this study (*unpublished*) suggested that a number of small-scale fish farmers were purchasing additives such as probiotics and applying it to feed and culture water themselves (Ali et al., 2020; Desbois et al., 2021). However, it was not known how widespread this practice had become across the country, what sort of additives were commonly used, and whether or not they were used correctly. Given the absence of clear regulations and of centralised government censuses to monitor such trends, there was a need to better understand the current state of water and feed treatment in Egyptian tilapia culture. Amongst other benefits, understanding such trends could mitigate against potential poor productivity caused by the incorrect use of additives, reduce the risk of propagating antimicrobial resistance and help benchmark the sector against typical best management practices.

This study reports the results of a survey on the use of additives in Egypt's largest fish farming region, Kafr El-Sheikh governorate. The majority of Egyptian fish production (>85%) is based on earthen ponds situated within and around the Nile Delta and its associated lakes (Shaalan et al., 2018). The objectives of this survey were to describe the use of additives in the Egyptian aquaculture sector and explore potential relationships with production.

2 | MATERIALS AND METHODS

The survey was conducted in Kafr El-Sheikh governorate in the Egyptian Nile Delta given its prominence in the Egyptian tilapia production sector (>55% of the total national production of farmed fish; Macfadyen et al., 2012). Kafr El-Sheikh is located at the north end of the Nile Delta, bordering the Mediterranean Sea and the brackish Lake Burullus to the north. Locations of surveyed farms are mapped in Figure 1.

2.1 | Data collection

Interviews were carried out between March 2018 and April 2019 in order to cover both production and marketing seasons. The main bulk of the production cycle typically takes place in the warmer months (March to October) and the market supply peaks between September and December. The survey was conducted by asking a series of questions to 120 active tilapia farms in the study area. This number of farms was selected by reviewing an inventory of the number of documented farms in the area held by Kafr El-Sheikh University. During the interviews, farmers were asked about various feed and water additives used as well as production metrics and farm management practices. The fish farms were selected by proximity wherein interviewers walked from one farm to another (within a distance of 1–5 km). If selected fish farmers opted not to take part in the survey, they were thanked by the interviewers who then moved on to the next farm.

A pilot run of the questionnaire was carried out on 12 fish farms in Kafr El-Sheikh which were previously visited in a 2016 survey. Data were collected in the field on smartphones and tablets and were directly uploaded into a database for future downloading and aggregation as necessary. Where smartphones or tablets were unavailable during the survey, hard copies of the questionnaire were used. The Google Form used to enter data was programmed to refuse submission of a form without complete information thereby reducing mistakes in data collection. All data were checked for validity by the principal researcher before being analysed to generate the results presented in this paper.

A total of five interviewers were used to carry out the survey. To standardise the data collection process, all interviewers were trained in the interview protocols by the lead researcher. Interviews were carried out on the farm face to face either with the farm owner or one of the senior staff employed at the farm. To reduce the risk of bias, farmers were interviewed separately.

2.2 | Ethics approval

The protocol and conduct of the present study was reviewed and approved by the Committee of Aquatic Animal Care and Use in Research, Faculty of Aquatic and Fisheries Sciences, Kafrelsheikh

FIGURE 1 Locations of the Nile tilapia (*Oreochromis niloticus*) farms surveyed in Kafr El-Sheikh governorate, Egypt

University, Egypt (approval number: IAACUC-KSU-21-2018) and the University of Stirling's General University Ethics Panel (GUEP546).

2.3 | Data analysis

Statistical analysis was conducted and figures were produced using the software GraphPad Prism 6 (Graph Pad Prism v6.0). Data were tested for distribution and normality was confirmed. Where data were not normally distributed, they were transformed and analysed using standard non-parametric tests. All percentage data were subjected to arcsine square root transformation before analysis. Results were reported in mean ± standard deviation (SD). One-way ANOVA was used for comparison and Tukey's multiple comparison was used as a *post hoc* test where appropriate. Differences were considered significant at $p < 0.05$.

3 | RESULTS

3.1 | Farm characteristics

On average, the size of the surveyed farms was 11 hectares (±10 SD; 27 feddan in local units). The majority (~72%) of respondents practised polyculture stocking mostly Nile tilapia fingerlings (typically >90% of stocked fish) alongside a small number of grey mullet (*Mugil cephalus*) and thinlip mullet (*Mugil ramada*; Risso, 1827) fingerlings. Mean stocking density of the surveyed farms was around 4.16 (±2.04 SD) fish per square metre. Surveyed farms had one of five sources of water used for culturing: (1) agricultural drainage water; (2) irrigation canal water; (3) water pumped from the nearby Lake Burullus; (4) ground water; and (5) 'mixed water' — a mixture of two or more water sources. The most common source of water was agricultural drainage water (>71%), followed by water from irrigation canals (10%), lake water (8.3%), mixed water (6.7%) and groundwater (~4%). Farmers reported carrying out between 5 and 50% water exchanges on a daily basis (25% ± 12 SD on average). A general overview of the key characteristics of the farms surveyed is available in Table 1.

3.2 | Farm performance

Farms typically stocked Nile tilapia fingerlings weighing an average of 6 g (±11 SD) and produced an average of 1.6 (±0.97 SD) metric tonnes (t) of Nile tilapia per hectare. The survival rate of fish during the previous production cycle as reported by the surveyed farmers was on average 76% (±9 SD).

There was no significant association between the source of water used in the farm and the survival rate.

Similarly, there was no significant difference between the use of agricultural drainage water and the use of other water sources in terms of total marketable yield. The majority (>83%) of respondents reported 'significant' fish mortalities in the previous

TABLE 1 Summary of key characteristics of Nile tilapia (*Oreochromis niloticus*) farms surveyed throughout Kafr El-Sheikh governorate, Egypt

	Minimum	Maximum	Average (±SD)
Farm size (hectares)	0.6	57	11 (±9.6)
Size of largest pond in farm (hectares)	0.32	44	5.6 (±4.9)
Total number of ponds in farm	1	38	6 (±5)
Stocking density (fish/m^2)	1.67	11.19	4.16 (±2.04)
Reported total marketable yield in previous production cycle (t)	2	7	3.7 (±0.97)
Weight of fingerlings stocked (g)	2	47	6 (±11)
Reported survival rate in previous production cycle (%)	40	100	76 (±9)
Daily water exchange in ponds (%)	5	50	25 (±12)

Note: All numbers are as reported by survey respondents and not directly collected or validated by the authors themselves. Stocking density and weight of stocked fingerlings refers to Nile tilapia (*Oreochromis niloticus*) whereas reported survival rate and total marketable yield refers to all stocked species including grey mullet (*Mugil cephalus*) and thinlip mullet (*Mugil ramada*; Risso, 1827); however, the latter two are typically stocked in very minor quantities relative to *O. niloticus*.

production cycle. However, this does not correspond with the average survival rate of 76% estimated in this study. The highest mortality rates were reported during the warmest months of summer (45%). Farmers frequently mentioned (although this was not officially recorded) that their perception was that mortalities had been particularly high in the previous 5–7 years. Just over half (51%) of the respondents attributed the mortalities in their farm to (perceived) disease outbreaks. However, most of those farmers (79%) did not send samples of dead fish to a veterinarian or to a laboratory for analysis.

3.3 | Use of additives

Additives were separated by those added to the culture water and those added to feed. No relationships were observed between the use of additives and the size of the farm, the species stocked or the source of water used. Fish farmers in Egypt generally resort to the use of pharmaceutical additives in a reactive manner during disease outbreaks or at times of high mortality. These additives are manually mixed into manufactured feed on the same day it is used.

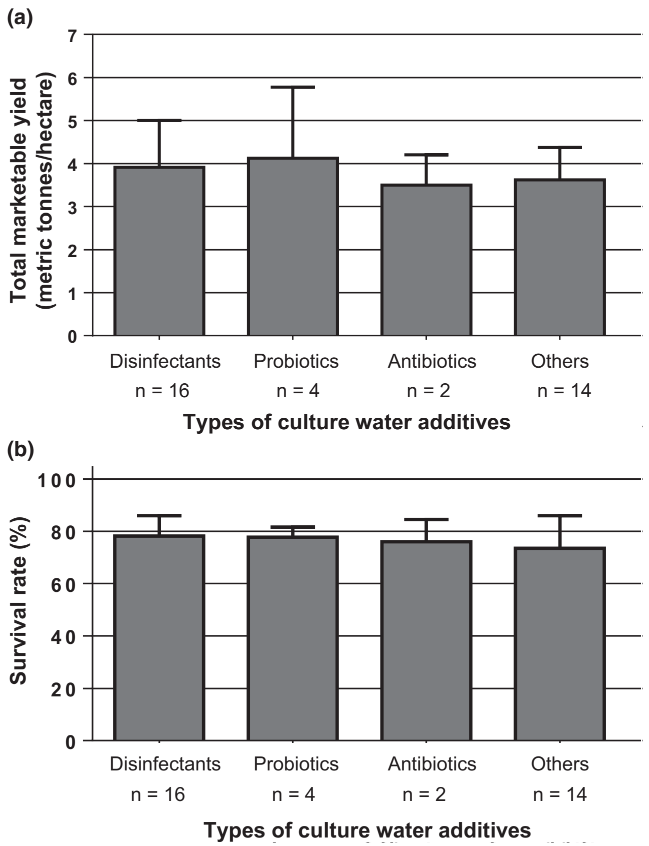

FIGURE 2 Effect of different types of culture water additives on: (a) total marketable yield; and (b) survival rate of cultured Nile tilapia (*Oreochromis niloticus*) in surveyed farms. Values are expressed as mean ± SD (one-way ANOVA, $p > 0.05$)

3.3.1 | Water additives

Only 30% of surveyed farms used in-water additives. Amongst that 30% of farmers that used in-water additives, the most commonly used type of in-water additive was a form of disinfectant (*e.g.* limestone) which was most frequently used alone and added before restocking. Probiotics were the most common additive used during the actual production cycle followed by antibiotics. No significant association was observed between the use of in-water additives and total marketable yield (Figure 2a). Similarly, no significant association was observed between the use of in-water additives and reported fish survival rates. Reported survival rates in farms that used disinfectants before stocking were not significantly different to those in farms that did not use disinfectant (Figure 2b).

Farmers that reported using in-water additives were significantly more likely to have experienced an apparent disease outbreak in the previous production cycle (67% versus 51% of those who did not use additives).

3.3.2 | Feed additives

Only 33% of surveyed farms used additives in feed. The majority of those farms (82% of 33%) reported using antibiotics either alone

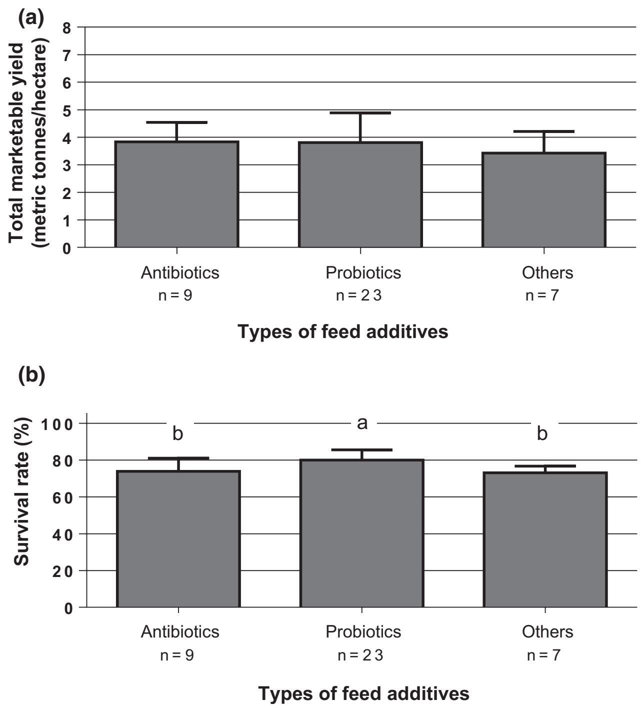

FIGURE 3 Effect of different types of feed additives on: (a) total marketable yield; and (b) survival rate of cultured Nile tilapia (*Oreochromis niloticus*) in surveyed farms. Values are expressed as mean ± SD (one-way ANOVA, $p < 0.05$)

(23%) or in combination with probiotics (59%). No significant association was observed between the different types of feed additives and total marketable yield (Figure 3a). However, a significant difference was observed between the type of feed additives used and the reported survival rates (Figure 3b). In contrast to water additives, there was no association between the use of feed additives and farmers having experienced an apparent disease outbreak in the previous production cycle.

Although these data were not officially collected (since farmers were either unable or unwilling to recall specific details), a number of farms (11%) reported adding vitamins and minerals to their formulated feed of which zinc and selenium were the most commonly mentioned.

4 | DISCUSSION

The range of farms covered by this survey can be considered representative of the typical semi-intensive tilapia farms occurring throughout the Egyptian Nile Delta. The average farm sizes, stocking densities, type of aquaculture practiced (*i.e.*, light polyculture) and typical sources of water (*i.e.* predominantly agricultural drainage water) reported in this survey are in line with what is generally known about the Egyptian tilapia farming sector (Soliman & Yacout, 2016). Similarly, the rates of farm productivity and fish survival rates reported by respondents in this study are consistent with the average yields and mortality rates observed by the authors of this study in their general farm veterinary consultation work.

A relationship may have been expected between the source of water used by the farm and fish survival rates given that the perceived low quality of agricultural drainage water is commonly cited by farmers as a reason for the high mortality rates they have been experiencing in recent years (Shaalan et al., 2018). However, the inability to detect such a relationship could be attributed to the fact that the majority of surveyed farms relied on agricultural drainage water or other 'dirty' sources such as lake water as opposed to cleaner sources such as ground water. In addition, the phenomenon of higher fish mortality during the warmer summer months as reported by a large number of respondents in this study is a well-documented phenomenon within tilapia semi-intensive aquaculture both in Egypt and elsewhere (Abu-Elala et al., 2016; Ali et al., 2020; Elsheshtawy et al., 2019). Egyptian fish farmers typically mention that they have noted higher rates of mortalities in recent years and many speculatively attribute this to diseases although hardly any farmers send samples for analysis.

In general, small landholders were more open to using additives than larger landholders since the small pond size meant that it was more cost-effective and the impact of financial loss through disease and mortality on these farmers was generally greater so they were more eager to minimise mortalities. The reported low use of both feed and water additives was surprising given that anecdotal evidence suggested such use was rather widespread. It may have been expected that farms with perceived 'dirtier' sources of culture water such as agricultural drainage water would be more inclined or incentivised to use water treatment. However, neither of these was detected in the survey. Instead, the survey did detect a greater tendency (albeit non-significant) for the use of water additives amongst farmers who had reported (perceived) disease outbreaks in their previous production cycle.

The use of disinfectants by tilapia farmers has been previously documented (Ali et al., 2020) as has the recent increase in the use of probiotics in Egyptian aquaculture (Elsabagh et al., 2018).

It is interesting that a number of respondents mentioned the addition of vitamins and minerals to their feeds since this has not been documented previously. However, it is difficult to analyse or evaluate this further given that the farmers in question were unable to provide specific details.

5 | CONCLUSIONS

The limited use of manually mixed feed and water additives reported in this study suggests that it was not such a widespread practice in the Egyptian tilapia sector as of 2019. Where their use was reported, it was mostly reactive, in the context of responding to a perceived disease outbreak or a mass mortality event. It is particularly reassuring that relatively low levels of antibiotic use were reported. This will help allay common misperceptions about rampant overuse of antimicrobial agents in the aquaculture sector and its role in fuelling antimicrobial resistance.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

The first two authors contributed to the acquisition, analysis and interpretation of the survey data whilst the first and last authors contributed to manuscript drafting and revision. The other named authors either contributed to the conception of the study or facilitated data acquisition.

DATA AVAILABILITY STATEMENT

All relevant data are available from the authors upon request.

ORCID

Wasseem Emam https://orcid.org/0000-0002-4574-0921
Radi A. Mohamed https://orcid.org/0000-0003-2538-404X

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