



Farmed fish welfare in Egypt: Surveying current practices and future directions for tilapia culture

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ABSTRACT

This study aimed to map the current status of farmers' knowledge, attitudes, and practices (KAPs) vis-à-vis animal welfare in the Egyptian tilapia farming sector. To this end, a survey was conducted of tilapia farmers across different regions, examining their level of training and knowledge as well as their farming practices including feeding, water changes and biosecurity measures.

We found that just 11 % of the surveyed tilapia farmers had received any sort of training on the importance of animal welfare whilst 76 % said they could benefit from such training. Farmers perceived maintaining good water quality as the most important metric for achieving good tilapia welfare. However, they were significantly less willing and able to intervene on this factor compared to other factors such as changing feeding practices, minimising handling, and carrying out veterinary checks.

In addition, we found evidence of better production outcomes for farmers that had received welfare training, with significantly fewer of them reporting high mortality rates and significantly lower reported frequency of poor growth. Most farmers expected the Egyptian tilapia production sector to continue to grow and intensify. This survey identified a need for establishing minimum animal welfare standards in Egyptian tilapia farming either through regulators or certification schemes. There is also a clear need for establishing training programmes that cover animal health and welfare aspects in aquaculture.

1. Introduction and background

1.1. History and growth of Egyptian aquaculture

The aquaculture sector in Egypt has grown rapidly over the past few decades, with Nile tilapia (*Oreochromis niloticus*) leading the way in terms of species farmed. Modern Egyptian aquaculture began in the 1930s which was mostly extensive with the first semi-intensive commercial farm being built in 1961. In the 1970s and 80s, further investments into the sector were made that almost tripled total production from aquaculture reaching 45,000 metric tonnes (Aquatic Network, 2022).

This gradual intensification established Egypt as one of the world's top producers of farmed fish with the country currently holding the top

spot within Africa and the position of 6th globally (Khairy, 2024). Egyptian wild caught fish production rose steadily between 1980 and 1995 when aquaculture started to take off (see Fig. 1). Since then, aquaculture has continued to expand significantly, accounting for more than three quarters of Egyptian fish production by 2022.

Egyptian aquaculture is dominated by three groups of fish (comprising more than 95 % of total production): (i) tilapias (75.54 %); (ii) mullets (12.74 %); and (iii) carps (6.59 %) (Aquatic Network, 2022). In terms of tilapia production, Egypt is the third largest producer globally after only China and Indonesia (El-Sayed, 2021). As recently as 2023, Egypt's tilapia production was estimated to have exceeded 1.1 million tonnes (Global Seafood Alliance, 2023). Nile tilapia farming accounts for over 9 % of global aquaculture production (FAO (Food and Agriculture Organization of the United Nations), 2022).

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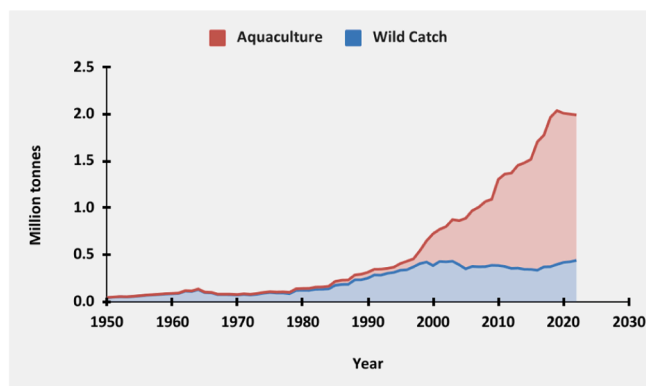


Fig. 1. Fish production in Egypt split into aquaculture and wild capture fisheries, 1950–2022. Source: FAO Food and Agriculture Organization of the United Nations, (2024) FishStatJ data tool.

1.2. Farming practices

Semi-intensive production in earthen ponds is the most commonly used aquaculture system in Egypt, accounting for over 80% of total aquaculture output (El-Sayed & Fitzsimmons, 2023). This method of aquaculture makes use of large, shallow ponds built in natural soil, thereby making it a cost-effective and efficient means of farming tilapia. The ponds are typically filled with water sourced from nearby water bodies or agricultural runoff, and they primarily rely on the natural processes within the pond ecosystem to maintain water quality. Stocking densities vary depending on the desired production intensity. Semi-intensive tilapia farming systems in Egypt are typically stocked at 10,000 – 20,000 fish per hectare (El Sayed, 2017).

1.3. Welfare standards for Nile tilapia

Like all fish, Nile tilapia are sentient and capable of experiencing pain (Sneddon, 2020), however, in contrast with other farmed fish species such as Atlantic salmon (*Salmo salar*) or rainbow trout (*Oncorhynchus mykiss*), there are currently no commercial animal welfare standards for Nile tilapia. As of today, the welfare assessment protocol developed by Pedrazzani et al. (2020) represents the only existing tool for monitoring welfare in farmed Nile tilapia.

1.4. Aims and objectives

This study aims to reinforce existing efforts to improve the welfare of farmed fish in Egypt by reporting the results of a knowledge, attitudes, and practices survey carried out amongst Egyptian tilapia farmers.

By understanding existing practices, developmental concerns, and challenges to adopting improved welfare practices, we aim to promote the adoption of best welfare practices in Egyptian aquaculture.

2. Methods

2.1. Data collection process

This survey employed a knowledge, attitudes, and practices (KAP) approach to assess the farming practices and perceptions towards fish welfare improvements amongst Egyptian tilapia. The survey focused on gathering detailed information on farming practices, health and welfare standards, experience and knowledge levels, and common challenges faced by farmers in adopting high-welfare aquaculture practices (full questionnaire available in Appendix A). Desk research was conducted to inform the structure and content of the survey, and to provide context into the current and projected state of tilapia farming in Egypt.

Survey data collection took place between April 19th, 2024, and

10th June, 2024. The Ethical Seafood Research team facilitated the recruitment of participants using their established networks within the Egyptian aquaculture industry. Enumerators, who were graduates of the Faculty of Fisheries and Aquatic Sciences at Kafr El Sheikh University and who were fluent in Arabic, approached farmers directly on-site at their farms and hatcheries.

Participants were provided with tablets to complete the survey, ensuring accessibility and convenience. In cases where participants needed assistance, enumerators assisted with reading and recording responses to ensure comprehension and accessibility. Pop-up hints with definitions of terms that may be unfamiliar to participants were also programmed throughout the survey. Participation was voluntary, and informed consent was obtained from all respondents prior to the commencement of the survey. Survey participants were also informed that they could withdraw from the study at any time.

All participants were compensated with water testing kits valued at approximately 10 USD each. These kits were provided to farmers upon completion of the survey. Water testing kits were chosen as an incentive because they encourage participation in a way that also contributed positively to the productivity of their business and the welfare of their fish. The authors acknowledge that this incentive, compared to cash, might have introduced some selection bias in favour of farmers who cared about water quality on their farm and who did not already have access to similar tools.

The study received ethical approval from the University of Bath's Ethics Committee. All participants were informed about the purpose of the study and the measures that would be taken to ensure the confidentiality and anonymity of their responses. No personal identifiable information was collected.

2.2. Participants

This study primarily targeted Nile tilapia farmers in Egypt's Kafr El Sheikh governorate as well as the neighbouring governorates, including those working in both farms and hatcheries. A total of **104 farmers and hatchery operators** were surveyed (see locations in Fig. 2). Participants were eligible if they were over the age of 18, residing in Egypt, and currently working in the tilapia farming industry. Full survey demographics are shown in Appendix B.

Participants were recruited by enumerators who visited farms and offered the workers the opportunity to take part in a survey via tablet in exchange for a water testing kit. Participation was non-random, in that (a) it was voluntary, (b) we used an incentive which may have introduced some selection bias, and (c) the location of the farms were all close together due to the logistical ease of accessing the farms.

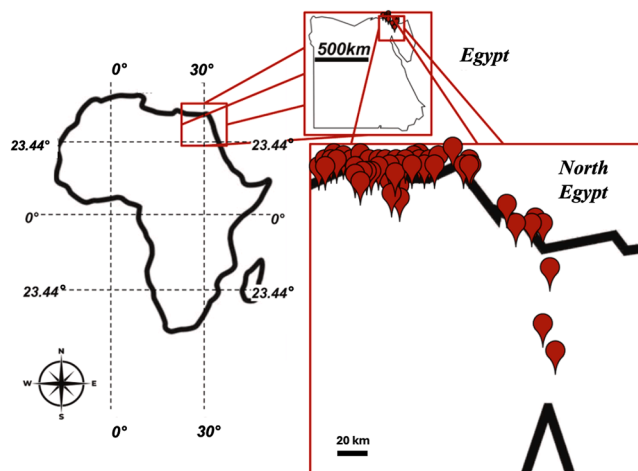


Fig. 2. The locations of tilapia farms and hatcheries that were surveyed in this study.

2.3. Materials

A structured questionnaire was developed based on a comprehensive literature review of tilapia farming practices in Egypt. The survey sections were labelled as follows:

- About your job
- Knowledge levels
- Welfare improvements
- About the industry
- Beliefs and opinions
- Farming practices and problems
- Antibiotics and chemicals
- Demographics

The survey was designed to be completed within approximately 20 minutes. To ensure cultural and linguistic suitability, the survey was translated into Arabic by native speakers from the Ethical Seafood Research team. The full survey instrument is available to view in [Appendix A](#).

2.4. Data analysis

Survey data was analysed using descriptive statistics to summarise the current practices, challenges, and perceptions related to tilapia welfare. Google Sheets and SPSS v26 were used to conduct descriptive analyses and create figures.

Some inferential statistics were performed in order to analyse the impact of welfare training on welfare knowledge and practices. This was also carried out in SPSS v26. Chi-squared tests were used to compare the proportion of farmers with/without welfare training who had encountered a range of welfare issues and *t*-tests were used to compare the mean frequency of encountering these welfare issues between the two groups.

3. Results

The results are divided into four topics: training, welfare, the impact of training on welfare, and broader perceptions of the Egyptian aquaculture industry. The complete sample demographics are available in [Appendix B](#).

3.1. Training

The most common form of training that farmers had reported receiving was on-the-job ([Fig. 3](#)) with 44 % of respondents stating that they had received training at their current farm. The remaining had either received training at another farm (19 %) or were self-taught (30 %) while 4 % had formal scientific training.

When asked about training related to tilapia welfare specifically, just 11 % of our sample reported having received welfare training, while 76 % felt that they could benefit from welfare training. Whereas the

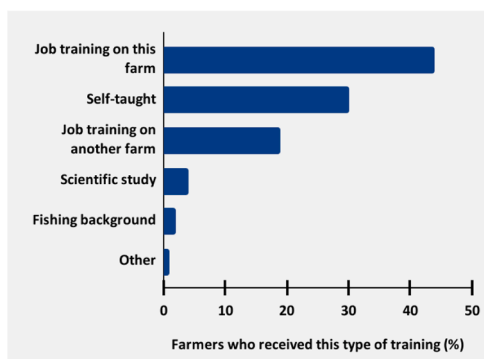


Fig. 3. Forms of training received by Egyptian tilapia farmers.

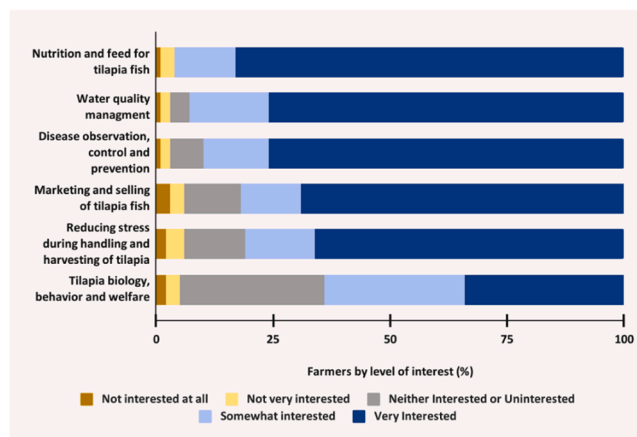


Fig. 4. Levels of interest in different types of further training amongst Egyptian tilapia farmers.

majority (89 %) of respondents said they felt confident or very confident in their knowledge of tilapia farming practices in general, just 42 % said they felt confident or very confident about their knowledge of the welfare of tilapia in particular. This is an indication that animal welfare is not a primary concern for farmers compared to other aspects of aquaculture.

Surveyed farmers were most interested in training related to tilapia nutrition followed by training in water quality management and then disease prevention and control ([Fig. 4](#)). Significantly fewer farmers, though still a majority, were interested in general training about tilapia biology and welfare (just 65 % were somewhat or very interested).

3.2. Welfare outcomes

Most farmers reported implementing some welfare measures such as providing their fish with nutritional feed (88%), removing water pollutants (74%), providing high quality water (65%) and stocking fish at a density that allows them to swim freely (62%) ([Fig. 5](#)).

On average, improving water quality was perceived by surveyed farmers as the most important measure for achieving good tilapia welfare ([Fig. 6](#)). Surveyed farmers, however, did report a lower level of willingness and ability to implement this type of improvement. The aspect that farmers were most willing and able to improve was feed nutrition, which was perceived to be almost as important as water quality.

There was a significant difference between reported willingness and reported ability for both proper handling and regular veterinary checks which indicates that some tilapia farmers would carry out veterinary checks and handle fish in a gentler way if they felt they were able to.

Although reducing stocking density was perceived as a relatively

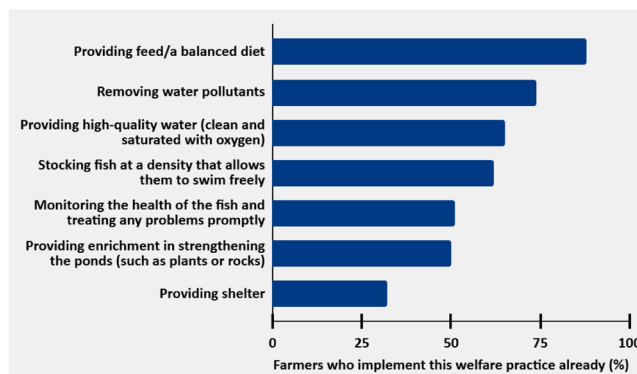


Fig. 5. The proportion of Egyptian tilapia farmers who were already implementing various welfare provisions.

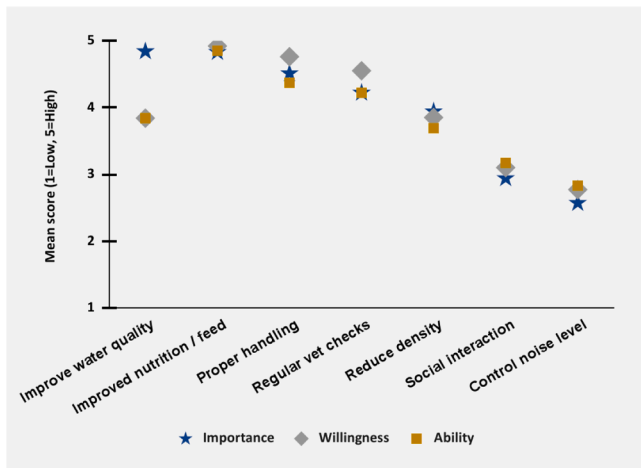


Fig. 6. The perceived importance of, willingness to implement, and ability to implement, various animal welfare enhancing measures amongst Egyptian tilapia farmers.

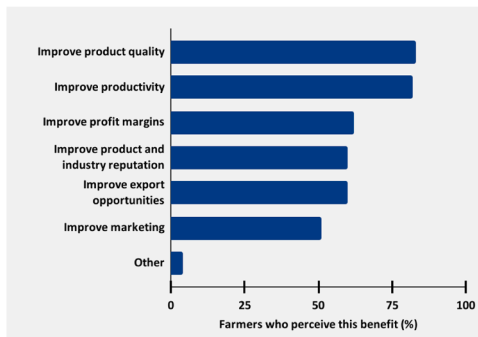


Fig. 7. The perceived benefits of improving fish welfare amongst Egyptian tilapia farmers.

important measure for improving tilapia welfare, farmers reported lower willingness and ability to do so.

Ensuring social interaction and controlling the noise level were both seen as less important measures for improving tilapia welfare.

From the farmers' perspective, the major benefits of improving fish welfare relate to product quality (83%) and farm productivity (82%) (Fig. 7). In addition, farmers mostly (>60 %) anticipated an increased profit margin where fish welfare was improved and expected a better

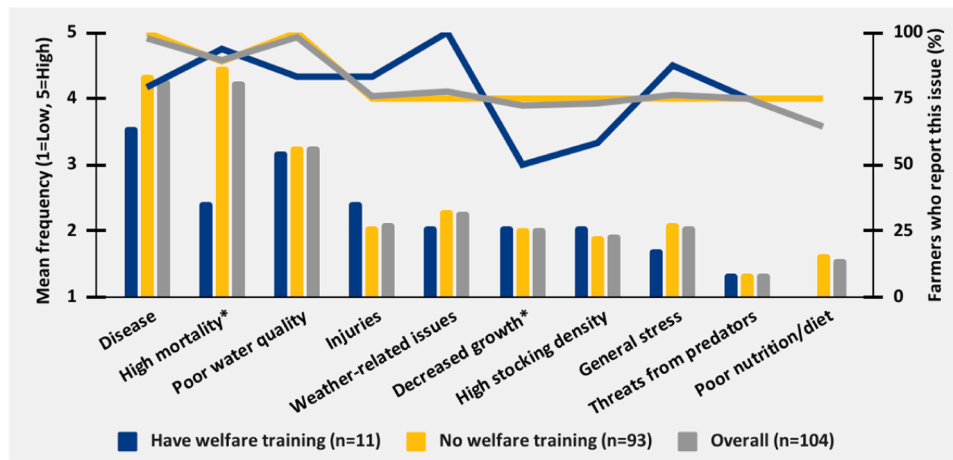


Fig. 8. Frequency of production issues encountered by Egyptian tilapia farmers that had received or not received training in animal welfare. The percentage of farmers reporting each production issue is represented as bars while the lines represent the mean reported frequency of encountering each issue. Farmers who had received welfare training are represented in blue (n = 11) while those that had not received welfare training are represented in yellow (n = 93). The entire sample is represented in grey (n = 104). The asterisks represent significant differences between the groups (p < 0.01).

reputation for the industry as well as increased opportunities for export.

3.3. The impact of welfare training on production outcomes

The impact of training on actual production and welfare outcomes was assessed by dividing the dataset into two groups (Fig. 8).

Of the farmers that had received welfare training, significantly more reported experiencing lower fish mortality rates in their subsequent production cycle compared to those who had received no welfare training ($\chi^2 = 17.19, p < 0.01$). Those same farmers also reported experiencing fewer problems of slower fish growth in their subsequent production cycle ($t = -4.41, p < 0.01$).

3.4. Perceptions of broader issues within the sector

Farmers were asked about their level of concern about four different environmental issues that have been known to occur in the vicinity of tilapia farms: water pollution, disease transmission, use of chemicals and land use (Fig. 9).

Farmers were asked about their level of agreement with different statements about trends in the tilapia farming sector (Fig. 10). Most respondents strongly agreed with the statement that tilapia farming will continue to grow in popularity as a long-term source of fish protein. However, they also felt that tilapia farming will face increasing challenges due to climate change and other factors. The majority of surveyed farmers felt that tilapia culture will become more industrialised and automated (i.e., more intensive) but fewer felt that sustainable practices would spread.

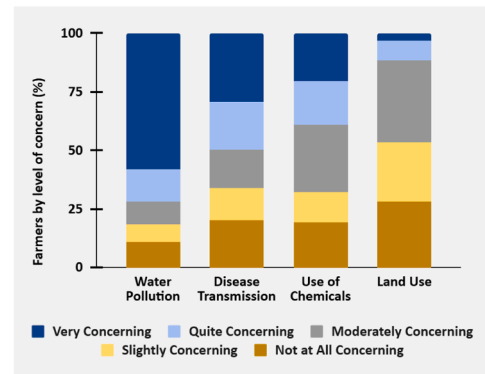


Fig. 9. The extent of concern about different environmental issues related to tilapia culture amongst Egyptian tilapia farmers.

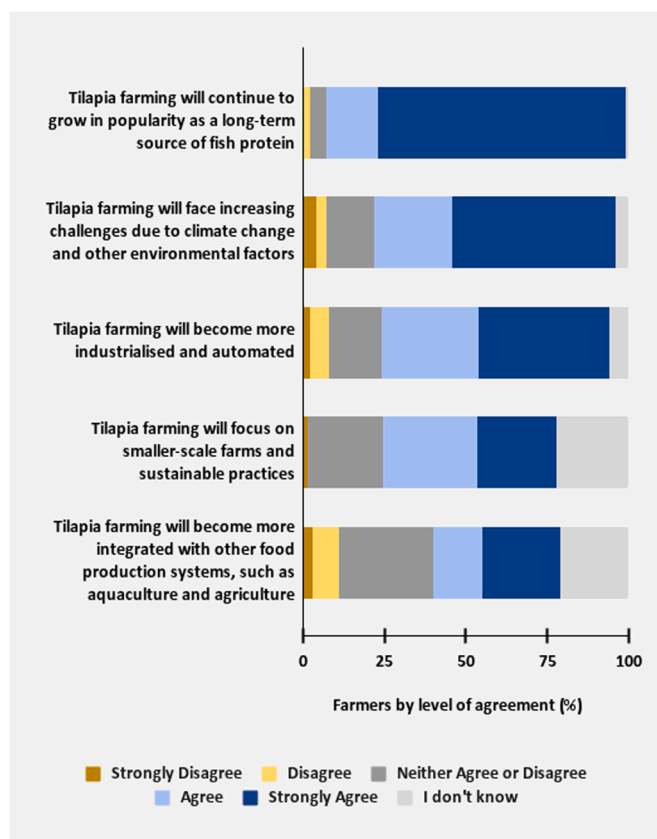


Fig. 10. The extent of agreement with various statements about trends in the tilapia farming sector amongst Egyptian farmers.

4. Discussion

Amongst surveyed tilapia farmers, there was a clear reported desire and need for more training on animal welfare. Farmers were particularly interested in any training that could improve their product quality or productivity, such as training relating to feed management, water quality and disease control.

The gap between perceived importance and ability to improve water quality suggests that farmers could benefit the most from training in this area. Given the importance of water quality to fish welfare, it is also worthwhile to consider other ways to support farmers in improving it, (e.g., through the provision of access to affordable water quality monitoring equipment). Similarly, there were important gaps between farmers' willingness to implement changes related to proper handling and regular veterinary checks, and their ability to do so which indicates that farmers could benefit from training and/or the provision of resources to make useful improvements in this regard.

This survey reported modest evidence of welfare training improving production outcomes in terms of reduced fish mortality and improved growth. Despite our sample being limited in size (only 11 tilapia farmers out of 104 surveyed had received welfare training), the difference was significant.

The issue of stocking density is likely to be a contentious one for tilapia welfare. This is because tilapia are one of the few species which have been reported to display aggressive behaviour when stocked at densities that are too low (Goncalves-de-Freitas et al., 2019). While it is relatively important in terms of health and welfare for all farmed fish to be stocked at densities not increasing a certain threshold, there are clearly economic pressures and incentives for farmers to stock as many fish as they can without compromising fish survival rates (Aly et al., 2023; Global Seafood Alliance, 2018; Goncalves-de-Freitas et al., 2019). This is likely why most surveyed farmers felt less willing and able to

make this change in comparison with other interventions. However, it is important to note that the majority of farmers reported stocking their tilapia at densities which allowed them to swim around freely.

There are several limitations of this study to acknowledge. Firstly, the data was collected in Arabic and while bilingual enumerators facilitated the translation of the survey instrument and responses, there remains a possibility that some nuances and meanings were lost in translation. Measures were put in place to mitigate these risks and improve accessibility and understanding among survey respondents, but the potential for misinterpretation or loss of subtle context cannot be entirely eliminated.

Secondly, very few farmers had received welfare training, with only 11 participants reporting having done so. This limited number reduces the reliability of statistical comparisons between trained and untrained groups. Therefore, the results related to the impact of welfare training should be interpreted with caution.

Third, the analysis relied on self-reported survey data. As with any survey where respondents self-report, answers can be subject to biases such as social desirability bias. Respondents might provide answers they believe are expected or favourable rather than their true practices or beliefs, potentially affecting the accuracy of the data.

There are some limitations in terms of the generalisability of this study. The study focused heavily on tilapia farmers in the Kafr El Sheikh governorate of Egypt with less than 10 respondents from two other governorates, and no other of the major fish-producing governorates represented. As such, the findings may have limited generalisability to aquaculture operations in other parts of the country or even to other countries or to other species. Aquaculture sectors tend to differ greatly between geographical jurisdictions which will limit the applicability of this study's findings.

To the authors knowledge, this study represents the largest survey of Egyptian tilapia farmers and hatchery operators conducted to date on the issue of animal welfare in aquaculture. By engaging 104 farmers across various regions of Egypt, the study provides valuable insights into the challenges and opportunities within the industry vis-à-vis improving animal health and welfare. The data collected not only highlight the significant welfare issues faced by farmed Nile tilapia in Egypt but also underscore the potential for welfare improvements to enhance both the economic viability and sustainability of the sector. As the industry continues to grow, results of this survey can help promote the uptake of high-welfare farming practices, ultimately contributing to the long-term development of ethical and responsible aquaculture in Egypt.

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CRediT authorship contribution statement

Christopher Bryant: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Formal analysis. **Charlotte Flores:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Conceptualisation. **Mohamed Bakr:** Data curation, Investigation, Conceptualisation. **Wasseem Emam:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Data curation, Investigation, Conceptualisation, Resources, Validation, Supervision.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Wasseem Emam reports a relationship with Ethical Seafood Research that includes employment. Ethical Seafood Research aims to improve the welfare of aquatic animals used for food. This organisation has an

interest in the results of the research, however, there is not an interest in finding a specific outcome and/or otherwise biasing the research. For

this organisation, its goals are maximised by conducting accurate and impartial research.

Appendix A. Survey Instrument

Question(s)	Answer Choices
Survey Information:	<p>We are inviting you to participate in a survey to learn more about your job as a tilapia farmer in Egypt, your experiences in your job, and your views on tilapia welfare. The purpose of this study is to gain a better understanding of the lives and work experiences of tilapia farmers in Egypt.</p> <p>Inclusion Criteria In order to be eligible to take part in this survey you must be:</p> <ul style="list-style-type: none"> - A current or former tilapia farmer - Currently living and working in Egypt - Over the age of 18 <p>What is expected of participants? If you agree to participate in this study, you will be asked to complete a short online survey. The survey will take no longer than 25 minutes to complete and will ask you questions about your job, your experiences as a tilapia farmer, and your views on tilapia fish welfare. There are no known risks associated with participating in this study, and you are free to withdraw your participation at any time. If you choose to withdraw after completing the survey, you can do so by contacting the research team (contact information below).</p> <p>Confidentiality All of your responses to the survey will be kept confidential and all data will be anonymized before analysis, meaning that your responses cannot be traced back to you in any published material or presentations. Your name or any other personal identifiable information will not be associated with your responses in any way. The results of the study will be published in scholarly journals and presented at scientific conferences. However, your individual data will not be shared with anyone.</p> <p>Contact information If you have any questions or concerns, you can contact: Researcher: Chris Bryant, C.J.Bryant@bath.ac.uk Biomedical Sciences Research Ethics Committee: biomedical-rec@bath.ac.uk</p> <p>Thank you for your interest in participating in this research Please select 'yes' to each option below to indicate your consent to take part in the study</p>
Consent	
I understand that I am free to withdraw from this study at anytime	(select one only) - Yes - No
I have read and understood the above and I consent to take part in the study	(select one only) - Yes - No
Are you currently employed at a tilapia farm or hatchery?	(select one only) - Yes - No
Are you over the age of 18?	(select one only) - Yes - No
Definitions:	<p>All participants will see these definitions at the beginning of the survey, they will also appear as hints throughout the survey in questions that mention these specific topics.</p> <p>Fish welfare- Fish welfare is the well-being of fish. It describes the condition of living comfortably without additional unnecessary pain or suffering.</p> <p>High/Low welfare practices- Good fish welfare practices include providing fish with clean water, avoiding overstocking, feeding them a balanced diet, and regular monitoring of their health. Bad fish welfare practices include overcrowding fish, keeping them in dirty water, not providing them enough food, and not monitoring them for diseases</p> <p>Welfare- focused training- Welfare focused training would include training on the basic principles of tilapia wellbeing, (e.g. the physical health and behavioural needs of the fish), training on how to identify welfare problems (e.g. signs of stress, disease, or injury), and training on welfare-friendly farming practices (e.g. proper stocking densities, water quality, feeding and handling practices).</p>
About your Job	
How did you first learn how to farm fish?	(select one only) - Self-taught - On the job training at this farm - On the job training at another farm - Formal course - Other (please specify: __)
How satisfied are you with your job as a tilapia farmer?	(select one only) - Very satisfied - Satisfied - Somewhat satisfied - Neither Satisfied or Unsatisfied - Somewhat unsatisfied - Unsatisfied

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Question(s)	Answer Choices
When you first started your job, how prepared did you feel in your ability to carry out the technical tasks (e.g. testing and cleaning water, stocking and harvesting, feeding the tilapia) required in tilapia farming?	<ul style="list-style-type: none"> - Very Unsatisfied (select one only) - Very prepared - Prepared - Somewhat prepared - Not very prepared - Not at all prepared
Prior to or since beginning your job as a tilapia farmer, have you received any training on tilapia-welfare specifically? Program hint to 'fish welfare' definition in question prompt. Do you feel like you would benefit from welfare-focused training in your job? Program hint to 'welfare focused training' definition in question prompt. How interested would you be in each of the following options of additional training to help you take better care of your fish?	<ul style="list-style-type: none"> (select one only) - Yes - No - Yes - No (very interested - not interested at all) - Tilapia biology, behaviour, and welfare - Water quality management - Tilapia feeding and nutrition - Noticing, controlling for, and preventing diseases - Minimising stress in tilapia handling and harvesting - Marketing and sales of tilapia
Knowledge Please indicate how confident you are in your current knowledge of tilapia farming practices ?	<ul style="list-style-type: none"> (select one only) - Very confident - Confident - Somewhat confident - Not very confident - Not at all confident
Please indicate how confident you are in your knowledge of tilapia fish welfare ? Program hint to 'fish welfare' definition in question prompt.	<ul style="list-style-type: none"> (select one only) - Very confident - Confident - Somewhat confident - Not very confident - Not at all confident
Please rate the importance of each of the following measures in benefiting tilapia welfare	<ul style="list-style-type: none"> (Matrix question Very important - Not at all important for each option) - High quality water - Reducing predator threats - More space to swim/reduced stocking density - More social interaction - Reduced noise levels (e.g. reducing vibrations, or loud, sudden, and repetitive noises) - Good feeding practices/diet - Regular health checks (by yourself or a vet) - Gentle handling
Welfare Improvements Do you believe that tilapia farmers have a responsibility to ensure the wellbeing (health, stress, and otherwise) of their fish?	<ul style="list-style-type: none"> (select one only) - Yes - No
How important is your fish's welfare to you? (please answer honestly)	<ul style="list-style-type: none"> (select one only) - Very important - Important - Somewhat important - Somewhat unimportant - Not important
How willing are you to implement various welfare improvements for your tilapia?	<ul style="list-style-type: none"> (select one only) - Very willing - Somewhat willing - Neither willing nor unwilling - Not very willing - Not willing at all
Do you feel like you are restricted in your ability to implement high-welfare practices in your farming?	<ul style="list-style-type: none"> (select one only) - Yes - No
Which of the following do you see as the biggest barrier to implementing high welfare farming practices? Program hint to high-welfare farming practices definition	<ul style="list-style-type: none"> (Matrix Question; not at all important - very important) - Cost - Lack of knowledge - Lack of resources - Lack of support from government - Lack of support from employer/landowner
What welfare improvements would you be most willing to implement for your tilapia?	<ul style="list-style-type: none"> (Matrix Question: Definitely would implement - definitely would not implement) - Improved water quality - More space - Social interaction - Reduced noise levels - Better feeding practices - Regular health checks - Improved handling methods
What welfare improvements would you be most able to implement for your tilapia?	<ul style="list-style-type: none"> (Matrix Question: Definitely would be possible - definitely would not be possible) - Improved water quality

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Question(s)	Answer Choices
	<ul style="list-style-type: none"> - More space - Social interaction - Reduced noise levels - Better feeding practices - Regular health checks - Improved handling methods
About the Industry	
How important do you think tilapia farming is to the national food supply?	(select one only) <ul style="list-style-type: none"> - Very important - Important - Somewhat important - Not very important - Not at all important
How would you rate the long-term sustainability of tilapia farming (the long term ability for tilapia farming to maintain a high level of fish production and quality) as a way to produce food?	(select one only) <ul style="list-style-type: none"> - Not at all sustainable - Somewhat unsustainable - Somewhat sustainable - Sustainable - Very sustainable - Unsure/No opinion
Please indicate your agreement with each of the following statements on the future of tilapia farming in Egypt	(Matrix question answer strongly agree-strongly disagree for each answer option,+ a not sure/no opinion option) <ul style="list-style-type: none"> - Tilapia farming will continue to grow in popularity as a long-term source of fish protein. - Tilapia farming will face increasing challenges due to climate change and other environmental factors. - Tilapia farming will become more industrialized and automated. (e.g. farms will technologically develop and grow in size and production rate) - Tilapia farming will focus on smaller-scale farms and sustainable practices. - Tilapia farming will become more integrated with other food production systems, such as aquaculture and agriculture.
How much of a threat do you perceive imported fish to be to the Egyptian aquaculture business?	(select one only) <ul style="list-style-type: none"> - Not a threat at all - Slightly threatening - Moderately threatening - Highly threatening - Extremely threatening - Unsure/No opinion
Do you think that local consumers are willing to pay more for fish that has been raised in a way that adheres to high animal welfare standards? Program hint to high-welfare farming practices definition	(select one only) <ul style="list-style-type: none"> - Yes - No - I don't know
How promising do you think the foreign export market is for the Egyptian tilapia industry?	(select one only) <ul style="list-style-type: none"> - Very promising - Promising - Somewhat promising - Not very promising - Not promising at all - Unsure/No opinion
Do you think that foreign consumers are willing to pay more for fish that has been raised in a way that adheres to high animal welfare standards? Program hint to high-welfare farming practices definition	(select one only) <ul style="list-style-type: none"> - Yes - No - I don't know
Beliefs	
Do you believe that fish can feel pain?	(select one only) <ul style="list-style-type: none"> - Yes - No - Unsure
Do you believe that fish can suffer?	(select one only) <ul style="list-style-type: none"> - Yes - No - Unsure
Do you believe that there are benefits to improving fish welfare?	(select one only) <ul style="list-style-type: none"> - Yes - No
If yes, what are some of the benefits that you believe improved fish welfare can provide?	(select all that apply) <ul style="list-style-type: none"> - Improved product quality - Improved productivity - Improved opportunities for exporting products to other countries - Improved marketability - Improved reputation of the industry - Improved profit margins
Farming Practices and Problems	
Have you ever had any problems with fish welfare (e.g. disease outbreaks, high mortality rates, injuries, decreased growth, and stress) on your farm?	(select one only) <ul style="list-style-type: none"> - Yes - No

(continued on next page)

(continued)

Question(s)	Answer Choices
Please select all of the following issues related to fish welfare that you or your colleagues have faced on your farm.	If yes to previous question, (Select all that apply) <ul style="list-style-type: none"> - Disease outbreaks - High death rates - Predator threats - Injuries amongst stock - Decreased growth - General stress - Poor water quality/water pollution - Overstocking - Weather-related issues - Poor diet
How often do you or your colleagues experience the following barriers to tilapia welfare on your farm?	Answers will rollover from previous answer choices. Participants will answer this question for each answer choice they checked (Matrix question never - very often) <ul style="list-style-type: none"> - Disease outbreaks - High death rates - Predator threats - Injuries amongst stock - Decreased growth - General stress - Poor water quality/water pollution - Overstocking - Weather-related issues - Poor diet
Please rate your level of concern regarding each of the following environmental problems that can affect communities near tilapia farms.	Matrix question (not at all concerning - very concerning) <ul style="list-style-type: none"> - Water pollution - Land use - Use of chemicals - Disease transmission
Which of the following have you or your employer ever done at your facility to look after your fish?	(Select all that apply) <ul style="list-style-type: none"> - Provide clean, well-oxygenated water - Stock fish at a density that allows them to swim freely - Provide a varied diet - Removing waste and pollution from the water - Providing enrichment in the enclosures (e.g. plants or rocks) - Monitor fish health and treat any problems promptly - Provide shelter
Antibiotics and Chemicals	
Do you use antibiotics in your tilapia farming practices?	(select one only) <ul style="list-style-type: none"> - Yes - No
If yes, which of the following antibiotics do you use in your farming practices?	(Select all that apply) <ul style="list-style-type: none"> - Oxytetracycline - Florfenicol - Chlortetracycline - Trimethoprim-sulfamethoxazole - Enrofloxacin - I don't know - Other (please specify)
Do you use probiotics in your tilapia farming practices?	(select one only) <ul style="list-style-type: none"> - Yes - No
Do you use chemicals in your tilapia farming practices?	(select one only) <ul style="list-style-type: none"> - Yes - No
If yes, which of the following chemicals do you use in your farming practices?	(Select all that apply) <ul style="list-style-type: none"> - Antibiotics - Pesticides - Fertilizers - Disinfectants - I don't know - Other (please specify)
Please indicate your agreement with the following statements about the use of antibiotics and other chemicals in tilapia farming.	(Matrix question; strongly agree - strongly disagree) <ul style="list-style-type: none"> - I believe it is necessary to use antibiotics and chemicals to protect my fish from disease and to promote growth. - I believe the benefits of using antibiotics and chemicals outweigh the risks. - I believe the use of antibiotics and chemicals is harmful to the environment and to human health. - I believe there are safer and more sustainable ways to raise tilapia. - I believe there are both benefits and risks to using antibiotics and chemicals in tilapia farming. - I am not sure how I feel about the use of antibiotics and chemicals in tilapia farming.
Demographics	
How many years have you been farming tilapia?	(Select one only) <ul style="list-style-type: none"> - 0-4 - 5-9 - 10-14

(continued on next page)

(continued)

Question(s)	Answer Choices
What's the highest level of education you have achieved?	<ul style="list-style-type: none"> - 15 + - No educational background - Primary education - Preparatory education - Secondary education - Vocational / trade education - Higher education (university degree or diploma)
Do you lease or own the land where you farm fish?	<ul style="list-style-type: none"> - I lease the land - I own the land - Not Applicable - Other: please specify
What is the size of your farm?	(select one only) <ul style="list-style-type: none"> - Less than 1 feddan - 1–5 feddan - 5–50 feddan - 50–100 feddan - More than 500 feddan
What are the main markets for your tilapia?	(select one only) <ul style="list-style-type: none"> - Local - National - International
Where do you sell your fish?	(select all that apply) <ul style="list-style-type: none"> - Local markets - Wholesalers - Restaurants - Export markets - Online - Supermarkets - Other: please specify
What kind of system do you use for tilapia farming?	(select one only) <ul style="list-style-type: none"> - Earthen ponds - Pond with liner - Small pens - Above ground tanks - Below ground tanks - Recirculating aquaculture systems (RAS) - Cages - Other: please specify
Please indicate your gender	(select one only) <ul style="list-style-type: none"> - Male - Female
Which of the following best describes your current diet?	(select one only) <ul style="list-style-type: none"> - Omnivore (I eat all foods, including meat and animal products) - Flexitarian (I consciously try to reduce my meat consumption) - Pescetarian (I eat fish, but I do not eat meat or poultry) - Vegetarian (I eat dairy and eggs, but I do not eat meat, poultry, or fish) - Vegan (I do not eat meat, poultry, fish, dairy, or eggs)
Please enter your age in years	(write-in numbers only)
Debrief	<p>In this study, we were interested to hear about your experiences and views on tilapia farming and hatchery work.</p> <p>Thank you for your participation in this survey.</p> <p>You may withdraw your submission at any time by emailing the researcher.</p> <p>If you have any questions or concerns, you can contact:</p> <p>Researcher: Chris Bryant, C.J.Bryant@bath.ac.uk</p> <p>Biomedical Sciences Research Ethics Committee: biomedical-rec@bath.ac.uk</p>

Appendix B. Sample Demographics

Gender		
Male	102	100.0 %
Female	0	0.0 %
Total	102	
Missing	2	
Age		
18–29	28	26.9 %
30–39	25	24.0 %
40–49	24	23.1 %
50–59	19	18.3 %
60 +	8	7.7 %
Total	104	
Diet		
Omnivore	101	99.0 %
Flexitarian	1	1.0 %
Pescetarian	0	0.0 %
Vegetarian	0	0.0 %
Vegan	0	0.0 %
Total	102	
Missing	2	
Years farming		
0–4 years	8	7.8 %
5–9 years	16	15.7 %
10–14 years	17	16.7 %
15 + years	61	59.8 %
Total	102	
Missing	2	
Farm size		
1–5 acres	17	16.7 %
5–50 acres	73	71.6 %
50–100 acres	10	9.8 %
500 + acres	2	2.0 %
Total	102	
Missing	2	
Owner status		
Own farm	62	60.8 %
Rent farm	12	11.8 %
Farm worker	28	27.5 %
Total	102	
Missing	2	

Data availability

The data that have been used are confidential.

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