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Design and development of IoT and demerit score-based system to assess fresh fish quality

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ABSTRACT

FISHQCheQ, a non-destructive and cost-effective web-based software system has been designed and developed to assess the quality of fresh fish. The developed system works in online platform using internet of things (IoT) and enable consumers/stakeholders for spot quality evaluation of fish in a real time manner. The system uses a demerit score on five general quality characteristics of fish *viz*, appearance of fish, fish eyes, gills, belly and vent, which were integrated using Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS) to evaluate the quality of fish. A modified algorithm has been incorporated for computing the fish quality index using HTML and JavaScript. The user can assess the quality of fish based on five general and their sub-quality characteristics on a demerit scale score and the system automatically calculates the fish quality index score in the range of 0 to 1 with a quality description as output. The quality index score in the range of 0 to 1 represents excellent to worse quality of fish. The developed IoT-based system was validated with real time storage data of Indian oilsardine and tilapia.

Keywords: Consumer perception, Fish quality, Fish storage, HTML, JavaScript

Introduction

The quality of fish is influenced by physical, bio-chemical and microbial changes happening during storage (Ashie *et al*., 1996; Joshy *et al*., 2018). Berdanier (2002) mentioned that these changes affect the sensory characteristics of fish and ultimately the consumer preference. From a consumer point of view *prima facie*, the quality assessment is being done by evaluating the sensory characteristics of fish. Sensory evaluation is a rapid, reliable and non-destructive method to assess the quality of fish (Hyldig *et al*., 2007). The most commonly used sensory evaluation method to assess the quality of fish is Quality Index Method (QIM), where demerit score is used by a panel of experts on different quality attributes to assess the quality. There were several studies in the past where normal QIM was used to assess the quality of different species of fish (Dalgaard, 2000; Huidobro *et al*., 2000; Nogueras *et al*., 2003; Van-pires and Seixas, 2006; Bonilla *et al*., 2007; Sant Ana *et al*., 2011; Abdullah and Ismail, 2018). All these studies have taken the cumulative total of demerit scores obtained for different quality attributes and produced a wide range of quality index scores, which brought redundancy in the index score. Another drawback is that different quality attributes considered in the QIM were given equal importance and treated differently by giving different range of demerit scores.

To overcome the above mentioned drawbacks of normal QIM, Joshy *et al*. (2020) developed a modified Fish Quality Index (FQI) method to assess the quality of fish by giving different weightages to the different quality attributes by Delphi method. The final FQI score ranged from 0 to 1 with a range of quality description of fish starting from excellent to bad quality. The modified FQI method provides an efficient method to evaluate the quality of fish offline or in labs, but the consumer needs to do computational procedure manually. The consumer or stakeholder might prefer an onsite evaluation of the quality of fish either at fish markets or at fish farms before purchasing the fish. At present no such system is available for the consumers or stakeholders for onsite evaluation of fish even when internet-assisted applications are widely available in the modern era. The integration of modified FQI into an internet of things (IoT) assisted platform is the immediate solution. Keeping this in view, a web based dynamic and non-destructive system was designed and developed to assess the quality of fresh fish (FISHQCheQ) using Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS) and JavaScript. The system provides background information on how to evaluate the quality of fish by examining different quality attributes. Demerit scores on different quality attributes were embedded into the system as an input database for the consumers or stakeholders to choose. Finally, the system automatically computes the FQI score with a quality description using the modified algorithm described by Joshy *et al*. (2020). The developed system was validated with real time storage data of Indian oilsardine (*Sardinella longiceps*) and tilapia (*Oreochromis mossambicus*).

Materials and methods

Design and development of web pages

The entire application was divided into three web pages *viz*, introduction to FQI, instructions to FQI and assessment of FQI. The web pages were designed using HTML and CSS and responsiveness of the system was achieved through the bootstrap framework. Bootstrap framework was implemented to deliver a responsive web page layout, so that the application can be accessed on any device (Powel, 2017). The management of input data and evaluation of fish quality for the web page assessment of FQI was implemented using JavaScript (Yehuda and Tomer, 1998). The design of the developed system is depicted in Fig. 1.

A very general outline about the system is provided in the web page "Introduction to FQI" using HTML. The web page "Instructions for FQI" states the guidelines (FAO, 1999) for the selection criteria of demerit score for different sub-quality attributes to be followed by the user or stakeholder while assessing the quality of fish using this system. These instructions were integrated into this web page for the user to easily follow while assessing the quality of fish using HTML codes. The major and sub-quality attributes mentioned by Joshy *et al*. (2020) were integrated into the web page "Assessment of FQI" by HTML and CSS codes. Different levels of each sub-quality attributes under each major attribute was assigned a demerit point. The user has to select the appropriate demerit score after evaluating the quality of the fish with respect to the particular quality attribute. The selection of demerit score has to be done for all the five factors *viz*. appearance of the outer surface, conditions of eyes, gills, belly and vent.

The computational procedure developed by Joshy *et al*. (2020) was adopted and integrated into the web page "Assessment of FQI" by developing computer codes in JavaScript to get the final FQI score and linked into the

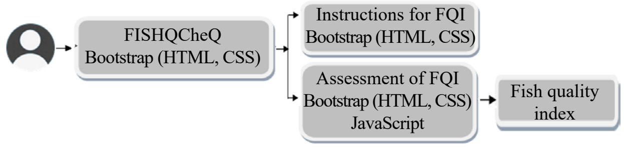

Fig. 1. Software design of FISHQCheQ

web page by HTML codes. The assigned demerit score for each quality attribute was normalised in the system using JavaScript using the Equation (1) to overcome the non-uniformity of range of values for the variables.

$$Z_i = \frac{X_i - X_{min}}{X_{max} - X_{min}},\ X_{min} \leq X_i \leq X_{max},\ \text{with } X_{min} = X_{opt} = 0 \cdots (1)$$

where Z_i and X_i are the variables defined in the JavaScript for the normalised and assigned demerit score of i^{th} quality attribute; X_{min} and X_{max} are the variables defined for minimum and maximum value of each quality attributes in the demerit point sheet and $X_{opt} = 0$ is the optimum value of quality attribute as the quality assessment is being done using demerit score. These normalised values of variables for each sub-quality attributes were defined as another set of normalised variables in the system using JavaScript. The computer codes defined in the system automatically compute weighted sum of normalised variables using Equation (2).

$$S_k = \sum_{i=1} W_i Z_{ik},\ \sum_{i=1} W_i = 1; i = 1,2,....;k = 1,2,...5 \cdots\cdots\cdots (2)$$

where S_k is the variable defined for weighted sum of sub-quality attributes of k^{th} factor; W_k is the variable defined for weightages assigned to the sub-quality attributes defined in Joshy *et al*. (2020) and Z_{ik} is the variable for the normalised value of i^{th} sub quality attribute of k^{th} factor.

The final computational algorithm was integrated in to the system using Equation (3), where W_k is the variable defined in the JavaScript for the weightages assigned to the major quality attributes as per Joshy *et al*. (2018). The screen shot of different variables defined in the JavaScript is given in Fig. 2.

$$FQI = \sum_{k=1}^{5} W_k S_k,\ \sum_{i=1}^{k} W_k = 1; k = 1,2, ...,5 \ \cdots\cdots\cdots (3)$$

The value of FQI ranged from 0 to 1 and if the range of computed value of FQI is 0, 0-0.10, 0.10-0.40, 0.40-0.52, 0.52-0.70 and 0.70-1.0, then the system shows that fish quality is excellent, very good, good, moderate, moderate to bad quality and worse quality, respectively (Joshy *et al*., 2020). This quality description was integrated into the system using HTML codes and automatically appears in the output page along with FQI score.

Architecture of the system

The architecture of the developed system was based on the web application architecture as well as user and server side rendering. The frontend or user side, designed in HTML and CSS, was intended to interact with the user on the local device like mobile or computer, which collects the inputs from the users and communicates from the

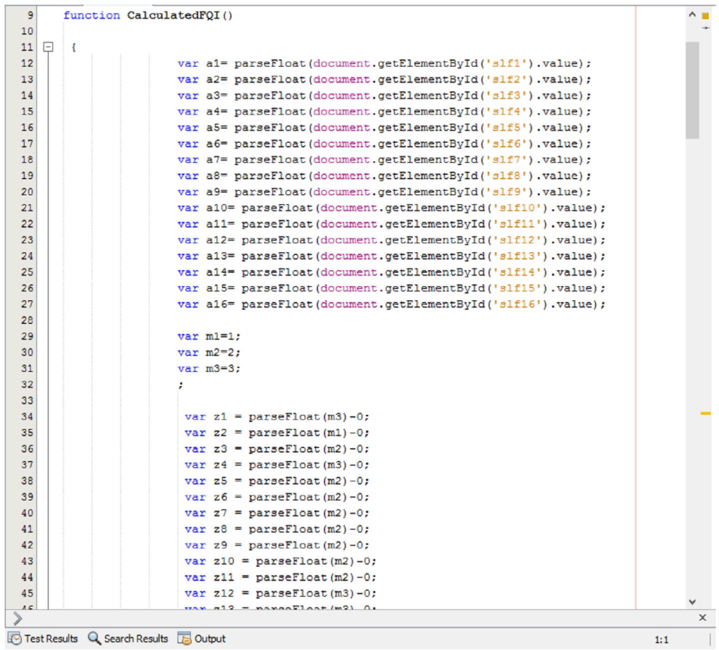

Fig. 2. Screen shot of JavaScipt codes for FQI computation

local device to the server through internet. The backend or the server side process the input data and computes the FQI score using the algorithm written in JavaScript. The backend server processes the HTTP request received from each user, computes the FQI score and renders back the result to the local device of the user in the defined manner through internet (Yehuda and Tomer, 1998). The web-based architecture of the developed system is given in Fig. 3.

Validation of the system

The developed software system was validated with real time storage experiment conducted for Indian oilsardine (*S. longiceps*) and tilapia (*O. mossambicus*) in chill stored condition. The fish were brought to the lab and kept in the chill stored condition at 0±2°C. The samples were drawn at different storage days; quality

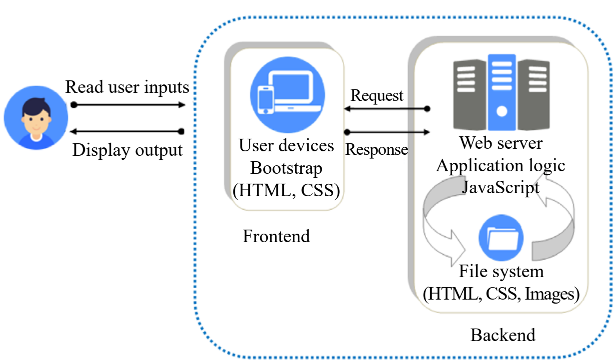

Fig. 3. Architecture of the web based system

evaluation was done and the panelists were asked to select the appropriate demerit score for each quality attribute integrated in the web page "Assessment of FQI". The FQI score on each sampling day was obtained by clicking on 'compute fish quality index' in the system with a quality description using the algorithm defined in the previous section.

Results and discussion

Internet assisted and web-based software (FISHQCheQ) was developed to assess the quality of fish using different computer languages like HTML and JavaScript. The output of home page "Introduction to FQI" of the developed system is given in Fig. 4. The home page provides a brief description about the developed system and a menu bar is placed in the home page with a hyperlink that redirects user from home page to other web pages like "Instructions for FQI" and "Assessment of FQI", respectively.

The output of compiled HTML codes of the webpage "Instructions for FQI" is depicted in Fig. 5. This page helps the user to clearly read and understand the instructions given for examining each quality attribute while assessing the quality of fish. Instructions on how to evaluate and assign the demerit score on appearance of fish and the conditions of its eye, gill, belly and vent is provided in the output of this web page.

The output of webpage "Assessment of FQI" is depicted in Fig. 6, which is the core part of the developed system to assess the quality of fish. The user has to select appropriate demerit score from the drop-down menu of

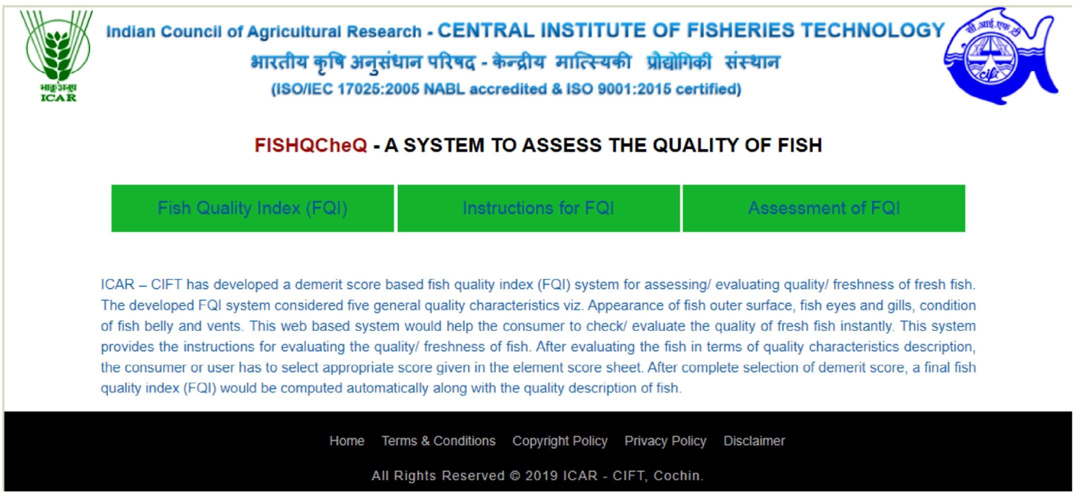

Fig. 4. Home page of FISHQCheQ

Fig. 5. Webpage of instructions for FQI

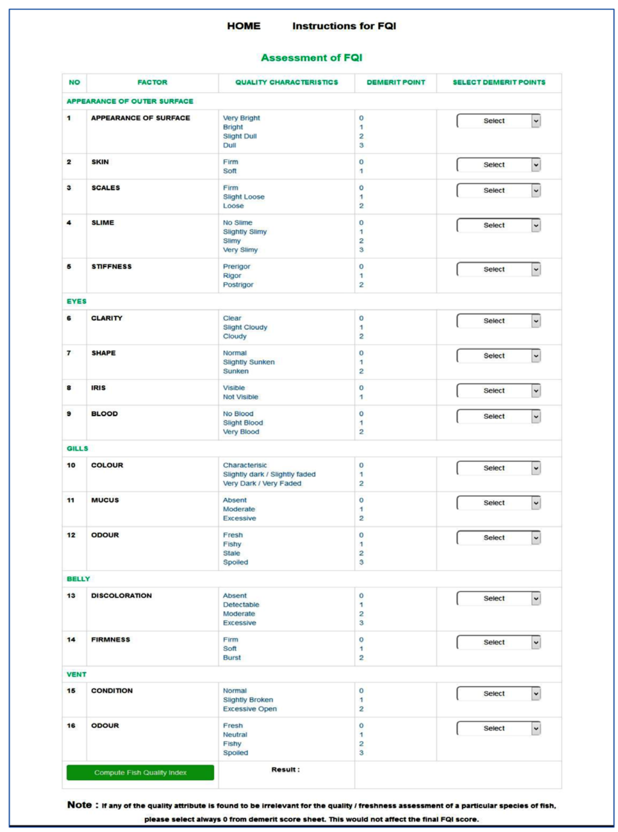

Fig. 6. Assessment of FQI

'SELECT DEMERIT POINTS' after carefully examining each quality attribute of the fish. Finally, user has to click on the radio button 'Compute Fish Quality Index' and final FQI score appears in the 'Result' along with a quality description about the fish based on the computed FQI value. A thematic representation of FQI value and quality description of fish is given in Fig. 7.

If the user misses out demerit score for any of the quality attributes, the system sends a warning message to the user to select the demerit score without computing the final FQI score.

FISHQCheQ is a cost-effective and non-destructive system, which evaluates the integrated sensory characteristics of fish (Hyldig *et al*., 2007; Joshy *et al*. 2020) and works

Fig. 7. Thematic representation of the output of FISHQCheQ

on internet assisted platforms. The user or consumer can access the system online for onsite quality evaluation of fish and take a decision whether to purchase the fish or not after assessing the quality of fish just like in a real time manner. This system is different from other techniques like image processing to assess the quality of fish (Dutta *et al*., 2016; Alaimahal *et al*., 2017). Even though the other two methods are non-destructive, the image processing techniques need to develop libraries of images for each species or category of fish to efficiently assess the quality of fish. This again requires large bandwidth to access the image library and compare the image of the targeted fish while assessing the quality of fish. Furthermore, the image-based technique considers only one of the major quality characteristics like changes in gills or eyes at a time, whereas FISHQCheQ considers multiple sensory quality characteristics and consumers experience in assessing the sensory characteristics of fish. Moreover, FISHQCheQ provides an option to educate the user or consumer themselves on how to evaluate the sensory characteristics of fish. Bernardo *et al*. (2020) mentioned different types of techniques like artificial quality index (AQI) to assess the quality of fish. AQI includes electronic nose, electronic tongue and machine vision system to assess the quality and shelf-life prediction of fish. All these techniques require building of different types of libraries of images, odour and colour, with respect to each quality attribute and are very specific to each species of fish. Compared to all these, FISHQCheQ is more generic and rapid, which can be used to assess quality of different species of fish sourced from different water bodies and requires less bandwidth for the user or consumer to access the system.

The developed FISHQCheQ system was validated with real time experimental data of two species of fish *viz*, Indian oilsardine and tilapia. The computed FQI values along with quality description of Indian oilsardine and tilapia at different sampling days obtained using the developed system FISHQCheQ are given in Table 1.

The FQI values of Indian oilsardine and tilapia were found to be increasing as the storage days increased. Based on the demerit score evaluation, the Indian oilsardine had very good quality up to 2nd day, good quality up to 5th day, moderate quality up to 9th day, moderate to bad quality up to 16th day and bad to worse quality from 17th day of storage. Tilapia had very good quality up to 2nd day, good quality up to 4th day, moderate quality up to 7th day,

Table 1. Fish quality index (FQI) values with quality description of Indian oilsardine and tilapia

Storage days	Indian oilsardine		Tilapia	
	FQI score	Quality description	FQI score	Quality description
1.0	0.06±0.02	Very good	0.05±0.02	Very good
2.0	0.07±0.03	Very good	0.09±0.05	Very good
3.0	0.16±0.05	Good	0.26±0.03	Good
4.0	0.28±0.06	Good	0.40±0.02	Good
5.0	0.38±0.04	Good	0.43±0.04	Moderate
6.0	0.47±0.07	Moderate	0.49±0.01	Moderate
7.0	0.47±0.08	Moderate	0.52±0.07	Moderate
8.0	0.51±0.06	Moderate	0.61±0.06	Moderate to bad
9.0	0.49±0.05	Moderate	0.82±0.04	Bad to worse
10.0	0.51±0.08	Moderate		
11.0	0.53±0.02	Moderate		
12.0	0.59±0.05	Moderate to bad		
13.0	0.65±0.07	Moderate to bad		
14.0	0.65±0.09	Moderate to bad		
15.0	0.69±0.04	Moderate to bad		
16.0	0.71±0.04	Moderate to bad		
17.0	0.80±0.06	Bad to worse		
19.0	0.87±0.05	Bad to worse		

FQI Score±SD

moderate to bad quality up to 8th day and bad to worse quality up to 9th day of storage. Indian oilsardine and tilapia had 18 and 9 days of shelf life, respectively under chill stored condition. Based on the quality description, the user can decide whether to buy the fish or not.

Fish being a highly perishable food, quality is a major concern while choosing fish for consumption or sale. Quality of fish may be defined as the degree of freshness of fish or its desirable appearance and texture. Since ages, sensory evaluation methods are practiced to evaluate the freshness of fish by analysing its appearance, odour, colour and texture. With the wide integration of IoT in our day to day activities, implementing systems and techniques to assist the onsite evaluation of fish quality using available electronic devices like mobile phones and tablets is the need of the hour. Accordingly, a web-based fish quality assessment system, FISHQCheQ has been implemented to evaluate the freshness of fish, which can be accessed over the internet through any web-based platform. The system follows the demerit score methodology for assessing the sub-quality attributes derived from the five general characteristics of fish such as its gross appearance and the conditions of its eye, gill, belly and vent to assess the quality of fish. These general and sub-quality attributes were prioritised by giving different weightages using Delphi method. Here, the user has to choose a demerit score after judging the condition of fish and the system will normalise the score and compute the fish quality index value by weighted average using modified algorithm defined in JavaScript. The FQI values ranges from 0 to 1 and with an automated quality description varying from excellent, very good, good, moderate, moderate to bad and bad to worse quality respectively. Bootstrap, HTML, CSS and JavaScript web development languages were used to design and develop the system. The novelty of the developed system is its non-destructive and cost-effective nature and the same was validated with the real time storage data of Indian oilsardine and tilapia.

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