Received: 6 July 2020 | Revised: 19 August 2020 | Accepted: 23 August 2020
DOI: 10.1111/jfs.12857

ORIGINAL ARTICLE

Journal of Food Safety WILEY

Determination of rainbow trout quality parameters with Arduino microcontroller

Emre Yavuzer

Department of Food Engineering, Faculty of Engineering and Architecture, Kırşehir Ahi Evran University, Kırşehir, Turkey

Correspondence
Emre Yavuzer, Department of Food Engineering, Faculty of Engineering and Architecture, University of Ahi Evran, 40100, Kırşehir, Turkey.
Email: emreyavuzer@gmail.com

Abstract

In this study, the rainbow trout was stored under refrigeration conditions (3 ± 1°C) for 18 days. Changes in the resistance levels in head, meat and eyes, changes of color in the head and meat, changes of liquid levels in the skin and meat, and odor values in the head and the meat were measured with Arduino microcontroller card and recorded during the storing period. In order to perform a significant comparison with the data obtained *via* Ardunio, the total viable count, psychrotrophic count and *Enterobacteriaceae* count in the fish meat were identified on a daily basis during storage. The results of the study indicated that the resistance value on the meat decreased significantly as the storage period increased; and that the Arduino-based color, odor and liquid level measurement sensors could be used effectively in identifying the food quality.

1 | INTRODUCTION

Species such as the trout, which are cultured intensively and processed frequently, should be analyzed carefully in microbiological, chemical and sensorial terms before the processing. Rainbow trout (*Oncorhynchus mykiss*), which has a commercial importance as a food, is widely consumed in Europe and bred in various countries. That is mainly because the rainbow trout is delicious and it is rich in fatty acids (Öz, 2018; Özoğul, Yavuzer, Özoğul, & Kuley, 2013; Roy et al., 2019).

The fact that aquatic foods are prone to oxidative spoilage is one of the most significant problems regarding storage within the processing technology of the product. While the undesired changes occurring in the odor and color due to oxidative spoilage could reduce the shelf life (Singh, Marimuthu, Murali, & Bawa, 2005), lipid peroxidation and microbial contamination are indicated as the two significant reasons of food spoilage (Cao et al., 2008; Mahmoudi, Gajarbeygi, Norian, & Farhoodi, 2014). The color, odor, taste, and mucus levels of the fish meat are measured by the experienced panelists in test environments (Yavuzer, Özogul, & Özogul, 2020); however, human senses could be mistaken while switching between the test groups. Therefore, significant results have been obtained from studies where electronic nose is used as the sensorial sensor in recent years (Silvello & Alcarde, 2020; Zhan et al., 2020; Zhu et al., 2020). Considering that the basic requirement in the electronic applications of the industrial field is the applicability in different platforms, easy coding and the ability to connect cheap sensors, the first device that comes into mind is Arduino.

Ardunio, which is an open-source microcontroller platform (Cezar et al., 2020) developed for the use of people from different fields, is a quite popular device that could perform simultaneous tasks with additional equipment (Jahns et al., 2019; Oussalem et al., 2020) enable the desired prototype to be created. Since Arduino has an Integrated Development Environment of its own (Vestenicky, Matuska, & Hudec, 2019), the codes that are generated in any computer could be transferred to the Arduino cards with the help of the USB connection. By using Arduino, signals coming from various sensors could be read, automations, where sensors work in connection with each other, could be developed or different motors could be operated (Vallejo, Diaz-Uribe, & Fajardo, 2020; Vestenicky et al., 2019). In addition to its wide scope of use, one of the most important features of Arduino is that, it has cheap sensors and microcontroller cards.

The microbial load of the fish meat during storage is a significant parameter of fish quality required in industrial processing; and, the increase in the microbial load causes the sensorial and chemical characteristics (Özoğul et al., 2013; Yavuzer et al., 2020) to take an undesired form. Moreover, microbial change affects the quality of the processing and rigor mortis time (Roco et al., 2018). Therefore, the number of microorganisms on fish meat is an important parameter (Haute, Raes, Meeren, & Sampers, 2016) that could be used in estimating the quality of fish during storing and determining the relationship between different storing conditions and chemical quality. Furthermore, previous studies have reported that the microbiological increase is related to chemical changes. For instance, TVB-N ingredient is related to the amino acid decarboxylase activity of the microorganisms during storage (Baltic et al., 2017). In addition, it is an important parameter in determining the TBA and PV lipid oxidation (Sallam, 2007); and, while chemical reactions are generally responsible for the incipient loss of freshness, microbial activity is responsible for marked spoilage (Hassanzadeh, Moradi, Vaezi, Moosavy, & Mahmoudi, 2018, 1996; Sallam, 2007). The other analyses required to test the quality of fish have serious costs. In addition to cost expenses, personnel costs should be included in the consumable costs since the chemical analyses such as TVB-N, FFA, PV and TBARS should be performed by trained staff. In this study, a fish quality control data set was obtained by using the Arduino micro controller and compatible cheap sensors. In the development phase, the fish was stored for 18 days in order to compare the changes in the fish meat with the data detected by Arduino, and the microbiological changes were calculated on a daily basis. Since the odor, liquid level and resistance data that can be measured with Arduino are directly related to the increase in the number of spoilage bacteria, microbiological analyzes were performed instead of chemical quality analyzes during storage. Microbiological data obtained were correlated to the data obtained by Arduino regarding the fish such as resistance, color, odor and liquid level.

2 | MATERIAL AND METHODS

2.1 | Electronics components used in device

In this study, an Arduino Uno R3 microcontroller board using AT mega328 microprocessor was used. Arduino Uno has 14 digital input/output pins. Six of them can be used as PWM (Pulse-width modulation) output. It also has six analog inputs, one 16 MHz crystal oscillator, USB connection, power jack (2.1 mm), ICSP (In-Circuit Serial Programming) header and reset button. Figure 1 shows the Arduino Uno R3 used in this stduy.

Resistance of the meat, head and eyes were measured with only one 10 k ohm resistor, a potentiometer and one breadboard. The resistance measuring circuit used in the study is given in Figure 2.

Liquid Level Sensor is an analog output sensor. To measure the level in fish meat and skin, the output of the sensor is connected to the analog pin of the Arduino and the value here is read. The sensing area of the sensor used in the study (Figure 3) is 40 mm × 16 mm and the operating temperature is between 10°C/−30°C making it ideal for fish quality measurement.

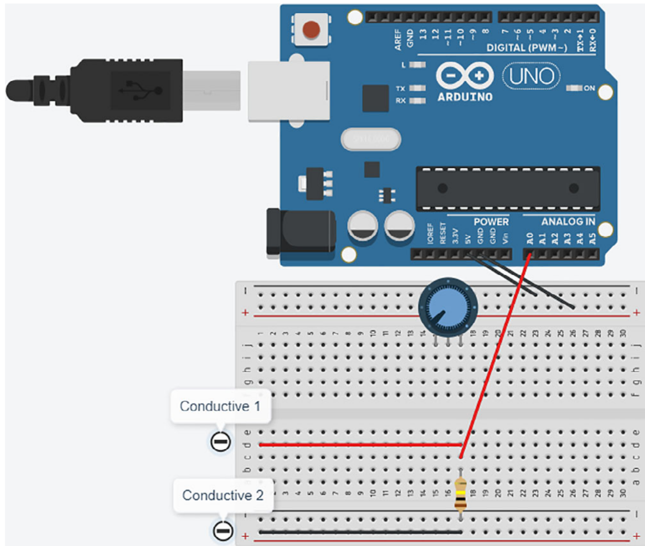

FIGURE 2 The voltage measuring circuit

FIGURE 1 Arduino Uno R3 microcontroller

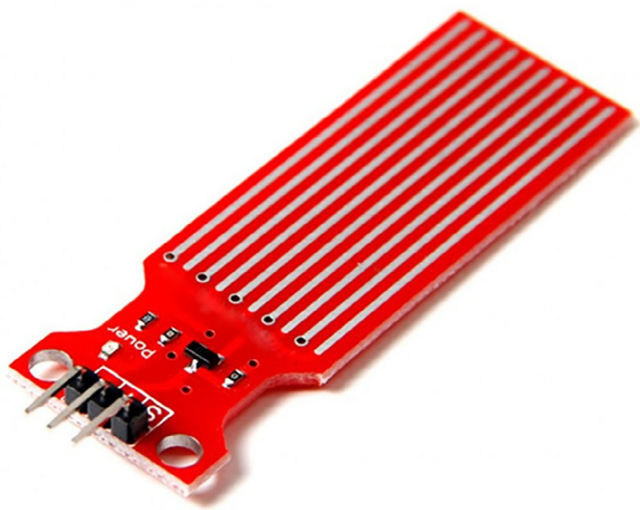

FIGURE 3 Analog liquid level sensor

TCS3200 Color Sensor was used to measure the color changes of the fish (Figure 4). The TCS3200 provides the data it generates with the help of photodiodes and a current-frequency converter and produces a square wave at a frequency proportional to the intensity of the light coming on it. Sixteen of the photodiodes in the 8 × 8 array in the structure of the sensor have red, 16 are blue, 16 are green filters, while the remaining 16 photodiodes do not have filters.

The MQ135 air quality sensor was used to detect odors caused by spoilage in the fish. MQ135 is a gas sensor that calculates the ambient air quality by measuring the amount of ammonia, alcohol vapor, benzene, smoke and carbon dioxide gases. Figure 5 shows the air quality sensor used in the study.

FIGURE 4 TCS3200 color sensor used to determine the rainbow trout's head and meat color

FIGURE 5 MQ135 air quality sensor used to determine the changes of rainbow trout's head and meat odor

2.2 | Fish material

Rainbow trout (*O. mykiss*) was obtained from an aquaculture farm (EZG Limited Company) located in Kırşehir/Turkey. The average weight of the samples were between 330 ± 15 g. Fish were delivered to the laboratory in ice within 45 minutes of harvesting. Before placed polystyrene box containing ice they were left ungutted. Fish-to-ice ratio was 1:1 (w/w) and box was placed in a refrigerator (3 ± 1°C). Fish were selected randomly (just by reaching into the box without looking) and all analyses were performed daily during 18 days of storage.

2.3 | Microbiological analysis

Triplicate samples were taken for total viable count (TVC), psychrotrophic count (PTC) and *Enterobacteriaceae* count. Ninety milliliters of sterile Ringer solution (1/4 strength) to 10 g of fish muscle was mixed with and then Stomached (Masticator Nr S18/420, IUL Instruments, Barcelona, Spain) for 3 min. More decimal dilutions were made, and then 0.1 ml of each dilution was pipetted onto the face of plate count agar (Fluka 70,152, Steinheim, Switzerland) plates in triplicate. After that plates were incubated for 2 days at 30°C for TVC and 10 days at 6°C for PTC. For total *Enterobacteriaceae*, Violet Red Bile Agar (VRBA, Oxoid, CM0107, Hampshire, England) was used. They were incubated for 24 hr at 30°C.

2.4 | Statistical analyses

Analyses were run in triplicate and results were reported as mean values ± standard deviation (SD). Data were subjected to analysis of variance (one-way ANOVA).

3 | RESULTS AND DISCUSSION

Figure 6 presents the changes in the TVC, PTC and total *Enterobacteriaceae* amounts (log cfu/g^{-1}) during the cold storage of rainbow trout fillet. Initial TVC was found to be 2.17 log cfu/g^{-1}. These values were similar with the values found by Pezeshk, Rezaei, and Hosseini (2011) and Öz (2018) for the rainbow trout fillet. *Enterobacteriaceae* are found in the microflora of the rainbow trout (Frangos, Pyrgotou, Giatrakou, Ntzimani, & Savvaidis, 2010) and could be considered as the indicators of hygiene in the foods (Takahashi et al., 2017). In the present study, the *Enterobacteriaceae* counts were initially found to be 1.94 log cfu/g^{-1} and it increased with storage time. The *Enterobacteriaceae* count of rainbow trout was found to be 7.81 log cfu/g^{-1} on the final day of the storage. It is known that psychrotrophic bacteria cause the degradation of aerobically stored fresh fish at cold temperatures (Sallam, 2007). Initial PTC was 2.29 log cfu/g^{-1}. In the study, the TVC and PTC values were close to each other until the seventh day of storing; however, the increase rate of

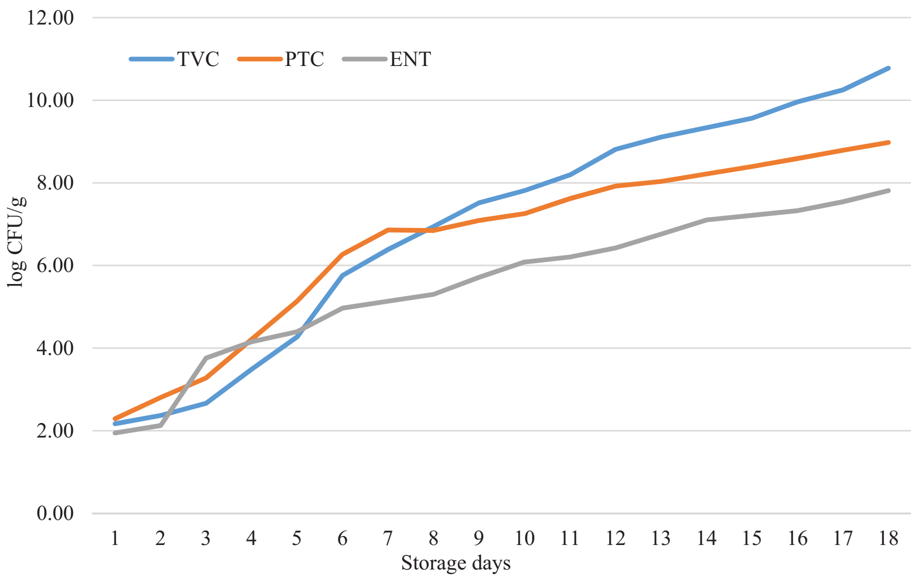

FIGURE 6 Total viable bacterial count, psychrophilic bacterial count, *Enterobacteriaceae* of rainbow trout fillets during storage at 3 ± 1°C for 18 days

TVC counts were higher after the eighth day. On the final day of storage, TVC was found to be 10.78 log cfu/g^{-1}, PTC was 8.98 log cfu/g^{-1} and *Enterobacteriaceae* was 7.81 log cfu/g^{-1}.

In the study, the resistance levels measured for the head, eyes and meat are presented in Table 1. On the first day of storage, resistance levels of head, eyes and meat were 631, 524, and 542, respectively. Head resistance value, which was higher on the first day at a statistically significant level ($p < .05$) compared to the other groups, was recorded at lower levels together with meat on the second day of storage compared to the eye group. From the second day of storage until the fourth day, the resistance level of the eye group was measured at significantly higher values compared to other groups. On the fifth day of storage, the TVC value was identified as 4.27 log cfu/g^{-1} and the head resistance level was over 500 while the other groups remained below this value. As of the sixth day of storage when microbiological levels increased in terms of TVC and PTC values, the resistance levels started to decrease gradually; and, on the eighth day of storage, the head, eye and meat resistance values were 295, 311, and 272, respectively. When a potential difference is applied between the two ends of a conductive substance, an electric field is created in the material and a force effects the electrons. The size of the force is directly proportional to the size of the electric field; however, its direction is the opposite of the direction of the electric field. Electrons are desired to move within the material without encountering any obstacles; however, the atoms in the substance tested usually prevent this. According to the data of the microbiological analysis, TVC, PTC and *Enterobacteriaceae* values increased during storage. Therefore, the bacteria, which are protist living organisms, limited the ability of the electrons to move in the fish meat. The resistance level remained below 300 for all levels as of the ninth day of storage until the end. On the eighteenth day of storage, when TVC value was 10.78 log cfu/g^{-1} and PTC value was 8.98 log cfu/g^{-1} at their highest levels, the resistance levels were at their lowest. Previous studies reported that increased conductivity probably occurred as a result of increased membrane permeability and decreased water retention capacity of muscle fibers (Byrne, Troy, & Buckley, 2000; Lepetit, Sale, Favier, & Dalle, 2002), and also concluded that the ionic substances produced during the growth of bacteria increased the EC value (Ekanem & Achinewhu, 2000). In the present study, the resistance level decreased during storage contrary to the electrical conductivity.

TABLE 1 Changes in the resistance values of trout given by Arduino during chilling storage

Days	Head x̄ ± SD	Eyes x̄ ± SD	Meat x̄ ± SD
1	631 ± 0.81^{aA}	524 ± 1.43^{dc}	542 ± 2.19^{bB}
2	542 ± 2.41^{dB}	625 ± 3.73^{aA}	520 ± 1.42^{cC}
3	572 ± 1.68^{bB}	593 ± 2.22^{bA}	569 ± 2.47^{ac}
4	515 ± 2.22^{eb}	584 ± 2.95^{cA}	450 ± 2.89^{eC}
5	556 ± 3.36^{cA}	392 ± 2.31^{gC}	447 ± 2.26^{fB}
6	415 ± 3.47^{fC}	430 ± 2.46^{eB}	474 ± 2.61^{dA}
7	396 ± 1.89^{gB}	426 ± 1.78^{fA}	296 ± 3.35^{gB}
8	295 ± 1.25^{iB}	311 ± 1.68^{hA}	272 ± 2.17^{iC}
9	292 ± 4.31^{jA}	259 ± 2.50^{iC}	283 ± 2.47^{hB}
10	250 ± 3.60^{lB}	239 ± 2.14^{jC}	262 ± 1.88^{kA}
11	303 ± 1.81^{hA}	224 ± 2.03^{lC}	265 ± 3.49^{jB}
12	254 ± 2.12^{kB}	226 ± 2.58^{kB}	259 ± 1.93^{lA}
13	212 ± 1.84^{mB}	140 ± 1.57^{sC}	256 ± 2.33^{mA}
14	180 ± 3.06^{pC}	182 ± 1.54^{pB}	212 ± 2.07^{oA}
15	201 ± 4.77^{nB}	200 ± 3.75^{mB}	206 ± 3.72^{pA}
16	183 ± 2.43^{oB}	185 ± 4.40^{oB}	205 ± 3.29^{pA}
17	164 ± 3.04^{rC}	188 ± 3.00^{nB}	250 ± 1.77^{nA}
18	152 ± 3.46^{sC}	162 ± 2.50^{rB}	200 ± 2.99^{rA}

Note: Different letters (a–s) in the same column and different letters (A–C) in the same row show significant differences ($p < .05$).

Changes of color occurred in the head and meat of the fish during storage are presented in Table 2. The RGB values increased in both the head and the meat of the fish during storage. The red color, which started at the level of 8 in the meat group, remained at close levels until the eighth day, and this increased gradually after this storage day. The increase in the colors identified by Arduino indicated that those values fin the meat and head of the fish found by the color sensor decreased during storage. Our previous studies (Özoğul et al., 2013; Yavuzer et al., 2020) reported that the color score in the trout decreased during storage in sensorial terms. Similar to the fish meat, the color levels in the head of the fish also increased systematically during storage. There was discoloration in the head and meat due to spoilage; and these values were identified by the Arduino microprocessor in real time.

Changes of odor levels identified by Arduino during storage are presented in Table 3. MQ135 is a sensor that could detect the changes in the air such as ammoniac, carbon dioxide, smoke and malodor (Sai, Mukherjee, & Sultana, 2019); and it produces successful results in identifying the malodor (Farmanesh, Mohtasebi, & Omid, 2019). At the beginning of storage, the odor level identified by MQ135 in the meat group was higher than the odor level of the environment only by 8 units; however, the value in the head group was higher by 6 units. The differences of the measured meat and head values from the environment did not go beyond the level of 50 until the seventh day of storage. As of the eighth day of storage, it started

TABLE 3 Changes in the odor values of trout given by Arduino during chilling storage

Days	Environment $\bar{x} \pm SD$	Meat $\bar{x} \pm SD$	Head $\bar{x} \pm SD$
1	104 ± 0.22^{kC}	112 ± 1.10^{pA}	110 ± 1.20^{pB}
2	114 ± 1.29^{hC}	115 ± 0.76^{oB}	116 ± 1.09^{oA}
3	108 ± 0.80^{jC}	122 ± 1.58^{nA}	120 ± 2.74^{nB}
4	111 ± 0.94^{iC}	137 ± 1.15^{lA}	132 ± 1.41^{lB}
5	104 ± 1.07^{kB}	127 ± 1.99^{mA}	126 ± 1.86^{mA}
6	116 ± 1.15^{gC}	151 ± 1.34^{kB}	157 ± 0.89^{kA}
7	121 ± 0.50^{fB}	161 ± 1.05^{iA}	162 ± 1.70^{jA}
8	111 ± 1.01^{iC}	158 ± 1.33^{jB}	182 ± 0.91^{iA}
9	107 ± 0.51^{jC}	162 ± 1.57^{hiB}	185 ± 2.11^{hA}
10	121 ± 0.51^{fC}	164 ± 1.10^{hB}	203 ± 3.54^{gA}
11	127 ± 2.48^{bcC}	187 ± 2.27^{gB}	212 ± 1.94^{fA}
12	126 ± 1.14^{cdC}	201 ± 3.53^{fB}	218 ± 1.69^{eA}
13	128 ± 1.11^{abC}	201 ± 2.48^{fB}	211 ± 1.45^{fA}
14	117 ± 3.22^{gC}	213 ± 2.02^{eB}	217 ± 1.92^{eA}
15	123 ± 2.24^{eC}	253 ± 2.72^{dB}	263 ± 1.83^{dA}
16	129 ± 1.05^{aC}	262 ± 3.13^{cB}	275 ± 2.72^{cA}
17	126 ± 1.25^{dC}	266 ± 2.33^{bB}	289 ± 3.13^{bA}
18	127 ± 2.90^{bcC}	291 ± 3.74^{aB}	306 ± 2.16^{aA}

Note: Different letters (a–p) in the same column and different letters (A–C) in the same row show significant differences ($p < .05$).

TABLE 2 Changes in the color values of trout given by Arduino during chilling storage

Days	Head color (RGB) $\bar{x} \pm SD$	Meat color (RGB) $\bar{x} \pm SD$
1	$25 \pm 0.32^{m}/27 \pm 0.51^{k}/26 \pm 0.54^{n}$	$8 \pm 0.51^{jk}/13 \pm 0.47^{l}/18 \pm 0.82^{m}$
2	$26 \pm 0.69^{m}/27 \pm 0.51^{k}/26 \pm 0.54^{n}$	$7 \pm 0.60^{l}/14 \pm 0.82^{k}/19 \pm 0.70^{k}$
3	$27 \pm 1.30^{l}/25 \pm 1.43^{l}/27 \pm 0.60^{m}$	$8 \pm 0.67^{k}/16 \pm 0.61^{j}/20 \pm 0.61^{ij}$
4	$29 \pm 0.50^{k}/27 \pm 1.17^{k}/29 \pm 1.72^{l}$	$9 \pm 0.58^{j}/17 \pm 0.77^{gh}/20 \pm 0.61^{ij}$
5	$32 \pm 1.19^{j}/30 \pm 1.65^{j}/31 \pm 1.51^{k}$	$8 \pm 0.42^{k}/15 \pm 0.99^{j}/20 \pm 0.50^{h}$
6	$32 \pm 0.51^{j}/30 \pm 0.51^{j}/33 \pm 1.34^{j}$	$10 \pm 0.50^{h}/16 \pm 0.23^{i}/19 \pm 0.42^{j}$
7	$34 \pm 1.30^{i}/31 \pm 0.93^{i}/32 \pm 1.26^{k}$	$10 \pm 0.37^{h}/17 \pm 0.51^{gh}/20 \pm 0.76^{i}$
8	$35 \pm 0.67^{gh}/31 \pm 1.02^{i}/33 \pm 0.51^{j}$	$9 \pm 0.51^{i}/16 \pm 0.45^{hi}/18 \pm 0.32^{l}$
9	$35 \pm 0.90^{hi}/36 \pm 0.67^{h}/39 \pm 0.51^{i}$	$11 \pm 0.45^{g}/17 \pm 0.37^{g}/21 \pm 0.42^{g}$
10	$36 \pm 0.96^{g}/36 \pm 0.51^{h}/40 \pm 0.62^{i}$	$12 \pm 0.42^{f}/18 \pm 0.51^{f}/20 \pm 0.51^{h}$
11	$36 \pm 0.51^{f}/38 \pm 0.70^{g}/43 \pm 0.69^{h}$	$12 \pm 0.45^{e}/18 \pm 0.37^{f}/23 \pm 0.48^{f}$
12	$37 \pm 0.61^{e}/40 \pm 1.02^{f}/44 \pm 0.95^{g}$	$13 \pm 0.51^{d}/19 \pm 0.48^{e}/25 \pm 0.51^{d}$
13	$39 \pm 0.88^{d}/41 \pm 0.99^{e}/45 \pm 0.75^{f}$	$14 \pm 0.70^{c}/18 \pm 0.48^{e}/23 \pm 0.51^{f}$
14	$40 \pm 1.03^{d}/42 \pm 1.22^{d}/46 \pm 1.01^{e}$	$13 \pm 0.32^{d}/19 \pm 0.51^{d}/24 \pm 0.75^{e}$
15	$42 \pm 1.05^{c}/44 \pm 1.89^{c}/47 \pm 1.03^{d}$	$14 \pm 0.51^{c}/23 \pm 0.67^{c}/26 \pm 0.60^{b}$
16	$44 \pm 0.60^{b}/46 \pm 0.67^{b}/50 \pm 0.85^{c}$	$16 \pm 0.51^{b}/24 \pm 0.51^{b}/26 \pm 0.48^{c}$
17	$47 \pm 2.22^{a}/46 \pm 0.96^{b}/51 \pm 1.30^{b}$	$15 \pm 0.48^{b}/23 \pm 0.70^{c}/24 \pm 0.51^{d}$
18	$48 \pm 2.41^{a}/49 \pm 1.48^{a}/54 \pm 2.55^{a}$	$17 \pm 0.48^{a}/25 \pm 0.51^{a}/27 \pm 0.50^{a}$

Note: Different letters (a–m) in the same column show significant differences ($p < .05$).

TABLE 4 Changes in the liquid level values of trout given by Arduino during chilling storage

Days	Skin x̄ ± SD	Meat x̄ ± SD
1	641 ± 0.93^{B}	681 ± 1.72^{A}
2	625 ± 0.99^{B}	651 ± 0.72^{A}
3	599 ± 1.79^{B}	652 ± 2.40^{A}
4	589 ± 0.85^{B}	651 ± 1.18^{A}
5	527 ± 3.29^{B}	566 ± 2.95^{A}
6	488 ± 1.22^{B}	536 ± 3.34^{A}
7	474 ± 2.35^{B}	524 ± 4.15^{A}
8	427 ± 3.21^{B}	485 ± 2.86^{A}
9	393 ± 2.31^{B}	470 ± 4.17^{A}
10	381 ± 3.01^{B}	401 ± 2.15^{A}
11	381 ± 1.50^{B}	382 ± 1.25^{A}
12	354 ± 2.70^{B}	384 ± 1.67^{A}
13	303 ± 1.52^{B}	362 ± 1.88^{A}
14	271 ± 2.98^{B}	291 ± 3.22^{A}
15	212 ± 2.42^{B}	222 ± 2.05^{A}
16	197 ± 3.13^{A}	194 ± 4.45^{B}
17	185 ± 3.45^{A}	179 ± 3.56^{B}
18	162 ± 1.82^{B}	168 ± 3.40^{B}

Note: Different letters (A–B) in the same row show significant differences ($p < .05$).

to increase rapidly particularly in the head group; and both groups reached differences beyond 150 units by the end of storage. In our previous study (Kuley et al., 2019), it was reported that food-borne pathogenic bacteria caused the production of ammoniac and biogenic amin. Devices that are available in high-level laboratories such as HPLC are required for identifying these values. Considering that the sensor used in the present study was worth around 1 US Dollars and it was able to sense the amount of ammoniac in the environment, its contribution to the identification of quality parameters was quite effective.

Table 4 presents the changes in the liquid levels occurred in the meat and skin of the trout, which were measured by the sensor during storage. The initial level of liquid was 641 for the skin and 681 for the meat. Liquid levels decreased regularly in both groups during storage and the liquid level in the meat was higher compared to the skin until the sixteenth day of storage. Liquid level of the skin was at statistically ($p < .05$) higher levels on the sixteenth and seventeenth days of storage. On the storage days when the liquid level was below 400 units, the TVC value was 7.81 log cfu/g^{-1}, the PTC value was 7.25 log cfu/g^{-1} and the *Enterobacteriaceae* level was found as 6.08 log cfu/g^{-1}. The increase in the microbiological load caused the water holding capacity of the muscles to decrease, and the liquid levels in the muscles to drop. Similarly, previous studies (Olsson, Ofstad, Lødemel, & Olsen, 2003) reported that increased bacterial load causes a decrease in water holding capacity.

When the TVC and PTC values reached 7 log cfu/g^{-1} and the *Enterobacteriaceae* value reached 5 log cfu/g^{-1}, which were the unacceptable levels, the resistance levels in the head, meat and eye fell below 400 units. In addition, the difference of the head and meat odor from the odor of the environment increased over 40 units in these microbiological levels. The liquid level in the skin and the meat fell below 500 units. Moreover, there were significant ($p < .05$) differences between the first day and the eighth day, when the fish exceeded the microbiological threshold in terms of changes in color.

4 | CONCLUSION

In the present study, the levels of color, odor and liquid, and the resistance values were identified by using Arduino microcontroller for the trout that was stored for 18 days. Data obtained demonstrated sharp changes particularly after the days when the fish started to get spoiled microbiologically. According to the data measured by Arduino micro controller regarding the storage of 18 days, the trout fish could be accepted as fresh when the resistance level of the trout meat is above 400 units, the odor difference of the environment is above 40 and the liquid level is above 500 units. Considering that the costs of the sensors and the Arduino microcontroller were quite low, this study, which was performed on fish meat as a food that could get spoiled fast, would inspire future studies on identifying the qualities of different food.

ORCID

Emre Yavuzer https://orcid.org/0000-0002-9192-713X

REFERENCES

Baltic, T., Ciric, J., Velebit, B., Petronijević, R., Lakićević, B., Đorđević, V., & Janković, V. (2017). Changes in total viable count and TVB-N content in marinated chicken breast fillets during storage. IOP Conf. *Series: Earth and Environmental Science*, *85*(2017), 012073. https://doi.org/10.1088/1755-1315/85/1/012073

Byrne, C., Troy, D., & Buckley, D. (2000). Postmortem changes in muscle electrical properties of bovine *M. longissimus* dorsi and their relationship to meat quality attributes and pH fall. *Meat Science*, *54*(1), 23–34. https://doi.org/10.1016/S0309-1740(99)00055-8

Cao, L., Si, J. Y., Liu, Y., Sun, H., Jin, W., Li, Z., … Pan, R. L. (2008). Essential oil composition, antimicrobial and antioxidant properties of Mosla chinensis maxim. *Food Chemistry*, *115*(3), 801–805. https://doi.org/10.1016/j.foodchem.2008.12.064

Cezar, K. L., Caldas, A. G. A., Caldas, A. M. A., Cordeiro, M. C. L., Dos Santas, C. A. C., Cezar, K. L., … Michima, P. S. A. (2020). Development of a novel flow control system with arduino microcontroller embedded in double effect absorption chillers using the LiBr/H_2O pair. *International Journal of Refrigeration*, *111*(2020), 124–135. https://doi.org/10.1016/j.snb.2019.126723

Ekanem, E., & Achinewhu, S. (2000). Effects of shucking method on opening, meat yield and selected quality parameters of west African clam, *Galatea paradoxa* (born). *Journal of Food Processing and Preservation*, *24*(5), 365–377.

Farmanesh, A., Mohtasebi, S. S., & Omid, M. (2019). Optimization of rendering process of poultry by-products with batch cooker model monitored by electronic nose. *Journal of Environmental Management*, *235*(2019), 194–201. https://doi.org/10.1016/j.jenvman.2019.01.049

Frangos, L., Pyrgotou, N., Giatrakou, V., Ntzimani, A., & Savvaidis, I. N. (2010). Combined effects of salting, oregano oil and vacuum-packaging on the shelf-life of refrigerated trout fillets. *Food Microbiology*, *27*(1), 115–121. https://doi.org/10.1016/j.fm.2009.09.002

Hassanzadeh, P., Moradi, M., Vaezi, N., Moosavy, M. H., & Mahmoudi, R. (2018). Effects of chitosan edible coating containing grape seed extract on the shelf-life of refrigerated rainbow trout fillet. *Veterinary Research Forum*, *9*(1), 73–79.

Haute, S., Raes, K., Meeren, P., & Sampers, I. (2016). The effect of cinnamon, oregano and thyme essential oils in marinade on the microbial shelf life of fish and meat products. *Food Control*, *68*(2016), 30–39. https://doi.org/10.1016/j.foodcont.2016.03.025

Jahns, M., Klimke, S., Natke, D., Sindelar, R., Schrewe, U., Patzke, R., & Renz, F. (2019). An Arduino based Mössbauer spectrometer. *Nuclear Instruments and Methods in Physics Research*, *940*(2019), 116–118. https://doi.org/10.1016/j.nima.2019.06.003

Kuley, E., Yavuzer, M. N., Yavuzer, E., Durmuş, M., Yazgan, H., Gezginç, Y., & Özoğul, F. (2019). Inhibitory effects of safflower and bitter melon extracts on biogenic amine formation by fish spoilage bacteria and food borne pathogens. *Food Bioscience*, *32*(2019), 100478. https://doi.org/10.1016/j.fbio.2019.100478

Lepetit, J., Sale, P., Favier, R., & Dalle, R. (2002). Electrical impedance and tenderisation in bovine meat. *Meat Science*, *60*(1), 51–62. https://doi.org/10.1016/S0309-1740(01)00104-8

Mahmoudi, R., Gajarbeygi, P., Norian, R., & Farhoodi, K. (2014). Chloramphenicol, sulfonamide and tetracycline residues in cultured rainbow trout meat (*Oncorhynchus mykiss*). *Bulgarian Journal of Veterinary Medicine*, *17*(2), 147–152.

Olsson, G. B., Ofstad, R., Lødemel, J. B., & Olsen, R. L. (2003). Changes in water-holding capacity of halibut muscle during cold storage. *LWT-Food Science and Technology*, *36*(8), 771–778. https://doi.org/10.1016/S0023-6438(03)00098-7

Oussalem, O., Kourchi, M., Rachdy, A., Ajaamoum, M., Idadoub, H., & Jenkal, S. (2020). A low cost controller of PV system based on Arduino board and INC algorithm. *Materials Today: Proceedings*, *24*(2020), 104–109. https://doi.org/10.1016/j.matpr.2019.07.689

Öz, M. (2018). Effects of garlic (*Allium sativum*) supplemented fish diet on sensory, chemical and microbiological properties of rainbow trout during storage at −18 °C. *LWT-Food Science and Technology*, *92*(1), 155–160. https://doi.org/10.1016/j.lwt.2018.02.030

Özoğul, F., Yavuzer, E., Özoğul, Y., & Kuley, E. (2013). Comparative quality loss in wild and cultured rainbow trout (*Oncorhynchus mykiss*) during chilling storage. *Food Science and Technology Research*, *19*(3), 445–454. https://doi.org/10.3136/fstr.19.445

Pezeshk, S., Rezaei, M., & Hosseini, H. (2011). Effects of turmeric, shallot extracts, and their combination on quality characteristics of vacuum-packaged rainbow trout stored at 4±1°C. *Journal of Food Science*, *76*(6), 387–391. https://doi.org/10.1111/j.1750-3841.2011.02242.x

Roco, T., Torres, M. J., Labarca, V. B., Reyes, J. E., Munizaga, G. T., Stucken, K., … Won, M. P. (2018). Effect of high hydrostatic pressure treatment on physical parameters, ultrastructure and shelf life of pre- and post-rigor mortis palm ruff (*Seriolella violacea*) under chilled storage. *Food Research International*, *108*(2018), 192–202. https://doi.org/10.1016/j.foodres.2018.03.009

Roy, J., Mercier, Y., Tonnet, L., Burel, C., Lanuque, A., Surget, A., … Skiba, S. (2019). Rainbow trout prefer diets rich in omega-3 long chain polyunsaturated fatty acids DHA and EPA. *Physiology & Behavior*, *213*(1), 112692. https://doi.org/10.1016/j.physbeh.2019.112692

Sai, K. B. K., Mukherjee, S., & Sultana, H. P. (2020). Low cost IoT based air quality monitoring setup using Arduino and MQ series sensors with dataset analysis. *Procedia Computer Science*, *165*(2019), 322–327. https://doi.org/10.1016/j.procs.2020.01.043

Sallam, I. K. (2007). Antimicrobial and antioxidant effects of sodium acetate, sodium lactate, and sodium citrate in refrigerated sliced salmon. *Food Control*, *18*(5), 566–575. https://doi.org/10.1016/j.foodcont.2006.02.002

Silvello, G. C., & Alcarde, A. R. (2020). Experimental design and chemometric techniques applied in electronic nose analysis of wood-aged sugar cane spirit (cachaça). *Journal of Agriculture and Food Research*, *2*, 100037. https://doi.org/10.1016/j.jafr.2020.100037

Singh, G., Marimuthu, P., Murali, H. S., & Bawa, A. S. (2005). Antoxidative and antibacterial potentials of essential oils and extracts isolated from various spice materials. *Journal of Food Safety*, *25*(2), 130–145. https://doi.org/10.1111/j.1745-4565.2005.00564.x

Takahashi, H., Saito, R., Miya, S., Tanaka, Y., Miyamura, N., Kuda, T., & Kimura, B. (2017). Development of quantitative real-time PCR for detection and enumeration of *Enterobacteriaceae*. *International Journal of Food Microbiology*, *246*, 92–97. https://doi.org/10.1016/j.ijfoodmicro.2016.12.015

Vallejo, W., Diaz-Uribe, C., & Fajardo, C. (2020). Do-it-yourself methodology for calorimeter construction based in Arduino data acquisition device for introductory chemical laboratories. *Heliyon*, *6*(3), e03591. https://doi.org/10.1016/j.heliyon.2020.e03591

Vestenicky, M., Matuska, S., & Hudec, R. (2019). Simple method of photovoltaic panel power characteristic measurement based on Arduino hardware platform. *Transportation Research Procediai*, *40*(2019), 579–585. https://doi.org/10.1016/j.trpro.2019.07.083

Yavuzer, E., Özogul, F., & Özogul, Y. (2020). Impact of icing with potato, sweet potato, sugar beet, and red beet peel extract on the sensory, chemical, and microbiological changes of rainbow trout (*Oncorhynchus mykiss*) fillets stored at (3 ± 1 °C). *Aquaculture International*, *28*(1), 187–197. https://doi.org/10.1007/s10499-019-00454-7

Zhan, X., Wang, Z., Yang, M., Luo, Z., Wang, Y., & Li, G. (2020). An electronic nose-based assistive diagnostic prototype for lung cancer detection with conformal prediction. *Measurement*, *158*(2020), 107588. https://doi.org/10.1016/j.measurement.2020.107588

Zhu, D., Ren, X., Wei, L., Cao, X., Ge, Y., Liu, H., & Li, J. (2020). Collaborative analysis on difference of apple fruits flavour using electronic nose and electronic tongue. *Scientia Horticulturae*, *260*(2020, 108879. https://doi.org/10.1016/j.scienta.2019.108879

How to cite this article: Yavuzer E. Determination of rainbow trout quality parameters with Arduino microcontroller. *J Food Saf*. 2020;40:e12857. https://doi.org/10.1111/jfs.12857