ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 9, Issue 1, January 2022

Fish Spoilage Detector

[1]Anju Asok, [2]Fathima Risvana P R, [3],*Neemavas A, [4]Punnya Appukuttan, [5]Sruthi R Menon

[1]Food Technology, Kerala University of Fisheries and Ocean Studies, Kochi

*Corresponding author. Email: simplymevass@gmail.com

Abstract*— This project work involves using Arduino Uno software integrated with MQ 137- Ammonia Gas Sensor, MQ 135- Gas Sensor Module and Humidity Sensor Module DHT11 to set up a Fish Spoilage Detector model for the determination of spoilage in fish. The study takes into consideration spoilage seen in fishes and how to detect it. To study the threshold values of Ammonia, and other gases like Carbon Monoxide, model trial runs are carried out to arrive at appropriate hard measures of the threshold values, to improve the stability of a conceptual fish spoilage detector. The ammonia sensor is initially tested with a pure ammonia sample before being used to quantify total volatile basic nitrogen in various fish samples of various freshness levels. When compared to standard procedures like microbe count and chromatography, which take hours to get a result, the sensor can determine the freshness of a sample in a matter of seconds. The sensor response was shown to be highly linked with fish deterioration, demonstrating that using sensors is an effective technique to swiftly test for spoiling in a sample. After calibrating the sensor(which involved watching the fish degrade for almost two days), it was put to the test using random samples, demonstrating that it can accurately distinguish the degree of freshness of the preserved fish at varied temperatures(for measuring which a temperature sensor is also fixed). The model is run until visible indications of fish spoilage are seen. The sensors detect critical levels of ammonia, carbon monoxide and also measure humidity and temperature thereby, emitting warning signals in the form of flashes of light and a sound warning. The model setup also consists of a 1602 (16x2) LCD Display with a 12C/11C Interface that will display the temperature, humidity levels as well as that of ammonia and other gases like carbon monoxide and thus, helps in spoilage detection when the levels of these reach a particular threshold value. Calibration could be improved with detailed studies containing data regarding the rate of spoilage in fishes, temperature and humidity parameters.

***Index Terms*— Fish Spoilage Detector, Arduino Uno, Ammonia Gas Sensor, Gas Sensor Module, Humidity Sensor Module**

INTRODUCTION

Less perishable, moderately perishable, and extremely perishable foods are divided into 3 categories. food is historically thought of as perishable food. thanks to the high wetness content and also the accessibility of nutrients for microorganism growth, they're less stable. The temperature of the surrounding atmosphere encompasses a vital impact on the soundness of the product. The word "fresh product" refers to a product that retains its original features. As a result, spoiling may be a sign of changes that occur when harvest. Differences in physical traits are often used to detect spoilage. Some of the traits found in rotten fish include changes in colour, odour, texture, eye colour, gill colour, and muscle suppleness.In most cases, the action of enzymes, bacteria, and chemicals found in fish causes spotting. Furthermore, fat content, increased moisture and protein content, weak muscular tissue, ambient temperature, and unsanitary handling are all variables that contribute to fish rotting. Spoilage of fish is a complex process involving enzymes, microorganisms, and chemical elements. The fish dies before the spoiling process begins. Rigor mortis, autolysis, bacterial invasion, and putrefaction are the three steps of this process. Temperature, physical damage, and intrinsic variables are the key elements that influence the rate of deterioration in chilled fish [1].

The bacterial multiplication and therefore the buildup of biogenic paraffins are each caused by fish putrefaction. Microorganism load in fish like anchovies might not sometimes correspond well with biogenic amine synthesis. The impact of biogenic amine buildup varies supported the particular bacterial strains involved, similarly as biogenic amine bacterium produce amine buildup throughout the decaying of fish. amine buildup encompasses a injurious impact on human health. Fish spoilage bacteria equivalent to Ponte spp., S. maltophilia, and Ent. cloacae are found to provide histamine. Foodborne infections such as K. pneumoniae and Staph. aureus produce a lot of histamine. Most seafood spoilage microorganisms are also known to produce tyramine buildup. Histamine and tyramine are produced by fish spoilage bacteria, which are detrimental to human health and damage food safety. Additionally, because amines are created in such little amounts in unspoiled fish and are consequently linked to bacterial deterioration, they are particularly effective in evaluating the freshness or degree of decomposition in fish[2].

Fish deterioration is caused by chemical and physical changes. Off- flavours that are unpleasant and uncomfortably strong are hypothesised to be influenced by microbial development and metabolism. Microorganisms are the principal cause of degradation in most seafood products.

Non-destructive detection of fish degradation can be done with wireless basic sensors. The sensor's response is linked to the rotting pattern seen in fish. When ammonia and other chemicals reach threshold levels in fish, the sensor can clearly detect them. In the instance of protein catabolism, the final result is ammonia. It is kept in large amounts in the bodies of fish when compared to their baseline excretion rates. Ammonia is harmful if it is allowed to build up. Transmembrane pH gradients carry ammonia, as well as other weak acids and bases, between tissue compartments. The distribution of NH3 between compartments is generally

ISSN (Online) 2456 -1304
International Journal of Science, Engineering and Management (IJSEM)
Vol 9, Issue 1, January 2022

equilibrated, whereas the distribution of NH4+ is determined by the pH. Upon passage through the gills, ammonia is eliminated from the blood.

MATERIALS AND METHODS

The inputs needed for the fish spoilage detection apparatus includes sensors that detect ammonia, air quality, temperature and humidity, LCD, acrylic display case (with hinged lid), Arduino nano communication and programming. To set up the device, sensors are the dominating materials for checking whether the fish is spoiled or not. The study area taken into consideration is the spoilage seen in fish and the several gases it produces are being investigated with a purpose to expand a detection device that may perceive adjustments in air excellent in addition to the presence of ammonia fuel line in spoilt fishes. The version became constructed the usage of a sensor-primarily based meals tracking device. The fundamental cause of this fish spoilage detector is to discover fish rotting via way of means of figuring out particular ammonia, air excellent, temperature, and humidity thresholds and detecting them with sensors. The version became calibrated, and assessments have been performed in real-international situations. This technique will help enhance the delivery of sparkling fish whilst additionally making sure patron safety.

A. Sensors

Non-destructive detection of fish spoilage can be made using wireless basic sensors. The sensor's response is linked to the pattern of rotting in fish. They will tell once ammonia and alternative gases, appreciate CO2 (CO2), reach critical levels in fish. they're wont to quickly and simply verify the freshness and quality condition of fish. Its ability to assess the freshness of a sample during a matter of seconds, as opposition hours for ancient approaches like bug count and chromatography, has been demonstrated. The device was tested with random samples whereas it absolutely was being calibrated, indicating that it can distinguish between the degrees of freshness of fish hold on at different temperatures.

B. MQ 137 Ammonia gas sensor module

MQ 137 Gas Sensor can be used for monitoring the concentration of Ammonia gas (NH3). The gas sensitive material that is used in MQ 137 gas sensor is tin dioxide (SnO2), which normally has low conductivity in clean air. The sensor's conductivity appears to rise as the amount of ammonia in the air increases. Pure ammonia is measured using an ammonia sensor to determine total volatile standard nitrogen, and different samples of fish at various freshness degrees are taken. The conversion of the change in conductivity into an output signal matching to the gas concentration can be done with a simple circuit.MQ 137 gas sensor is highly sensitive to ammonia, and is also ideal for monitoring other organic amines (such as trimethylamine, ethanolamine, etc.). This sensor can also be used to detect a variety of ammonia-containing gases [10]-[12].

C. MQ 135 Air Quality Gas Sensor Module

The MQ-135 Gas sensors (fig 2.2) are primarily used in air quality control equipment and are suitable for detecting or measuring NH3, NOx, alcohol, organic chemical compounds like benzene, smoke like air pollutants and CO2. It has SnO2 in it, which has a lower conductivity than clean air. When the target explosive gas is present, the sensor's conductivity rises in tandem with the rising levels of gas concentration. It transforms charge conductivity to a corresponding output signal of gas concentration utilising basic electrical circuitry. The air quality sensor has a small potentiometer that allows the load resistance of the sensor circuit to be adjusted. 5V energy deliver to the air exceptional sensor.[3]-[9]
It detects the presence of alcohol fueloline withinside the environment and outputs an analog voltage as a measurement. With a electricity deliver of much less than one hundred fifty Ma to 5V, the sensor may be operated at temperatures ranging from -10 to 50° C. The sensing variety is 0.04 mg/L to four mg/L, making it suitable for breath analyzers. The MQ- a hundred thirty five fueloline sensor senses gases like ammonia, nitrogen, oxygen, alcohols, fragrant compounds, sulfide, and smoke. As the awareness of dangerous fueloline rises, so does the conductivity of the fueloline sensor.

Fig. 1. MQ-135 Gas sensor/air quality sensor/alcohol sensor (adapted from[b])

D. DHT11 Temperature and Humidity Sensor

The DHT11 is a low-cost virtual temperature and humidity sensor with a simple design. Its factors encompass a capacitive humidity sensor and a thermistor for the scale of the ambient air which detect temperature and output a virtual sign at the data pin (no analog enter pin required). The moisture-protecting substrate acts as a dielectric between the electrodes of the humidity sensor capacitor. This alteration resistance values are strategized and virtualized by the IC degree.The price of capacitance changes as humidity levels change. This sensor makes use of a terrible temperature coefficient thermistor for measuring temperature and reasons a lower in its resistance price with an with an growth in temperature.
This sensor is often built of semiconductor ceramics or polymers to induce a higher resistance value even for the smallest temperature difference. The DHT11 has a 2 percent accuracy range of 0-50°C and a 5 percent accuracy range of 20 to 80 percent humidity. Digital pin or analog pin accustomed to accomplish this as shown within. Power the module with 5V and will notice an LED glow. Also, the

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 9, Issue 1, January 2022

output LED will remain off when there is no gas, indicating that the digital output pin is at 0V. These sensors must be maintained during warm-up before they could be operated together. Then introduce the sensor to the gas you wish to detect and you will see the output LED travel high together with the digital pin, if not use the potentiometer until the output gets high. So, the digital pin will go high (5V) whenever the sensor gets introduced to the current gas at this particular concentration. Otherwise, it will remain low (0V).

- **16 X 2 LCD display with 12C/11C Interface**

16 x 2 LCD (12C/11C Interface) is the most used in embedded projects. The operating voltage is 4.7V to 5.3V. Its current consumption is 1Ma without backlight. It is an alphanumeric LCD module that can display alphabets and numbers consisting of two rows with each row able to print 16 characters. It can deal with both 8-bit and 4-bit models, also with custom-generated characters. It comes with a green or blue backlight (fig 2).

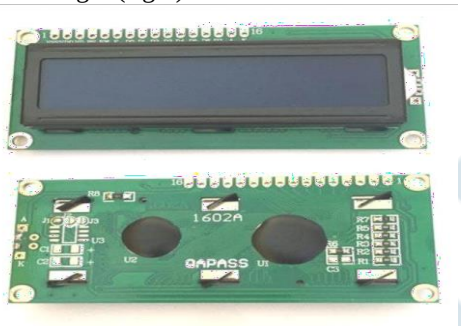

Fig. 2 16 X 2 LCD Module(adapted from[e])

- **Arduino nano communication and programming**

As demonstrated in fig 3, an Arduino Nano board, a second Arduino board, a computer, and microcontrollers from various vendors be utilised as a communication channel. Serial connectivity is advantageous in the Nano board's microcontroller (Atmega328). Through Future Technology Devices International data (FTDI) is transmitted and the USB link in the direction of the computer, the TX (Transmitting) and RX (Receiving) LEDs on the Nano board will light up. Using the board`s digital pins, serial communication is enabled by a library-like software serial. Arduino software is utilized for the Arduino nano programming.

Fig. 3. Arduino nano board (adapted from[f])

- Acrylic display case with hinged lid

Acrylic is the only glass that is custom made and has a high markup due to its superior optical clarity above most other types of glass. Because acrylic panels are 50% lighter than glass, acrylic display cases (fig 2) are extremely lightweight. This implies that even if your acrylic display case is pushed over or forcibly thrown, it will not break - indicating that it can withstand normal wear and tear. Acrylic's strength also makes it a better material for use on ships, as it prevents breakage during transit. This cover is more handy in this case since it allows the other components, such as sensors and LCDs, to be placed safely and properly.

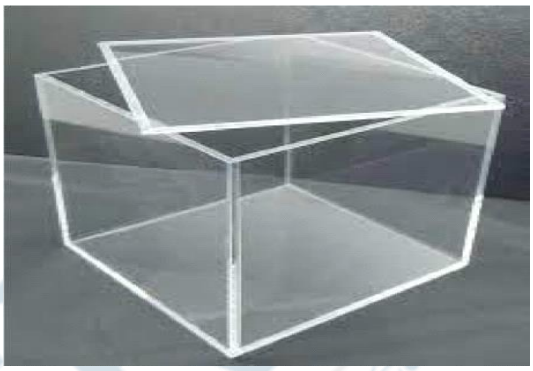

Fig. 4. Acrylic display case with hinged lid(adapted from[g])

III. RESULTS AND DISCUSSIONS

The task of modelling was completed with by utilizing Arduino Uno Coupled Model which is depicted in Figure 5. The effects are acquired after acting numerous versions of simulations in accordance with the steps of the technique defined in earlier. The principal parameters like ammonia, humidity and temperature ranges was analyzed to reach on the favored effects and conclusions. The observations along with the evaluation of effects was achieved through cautious examination of the parameters along with the impact of fish spoilage was also studied.

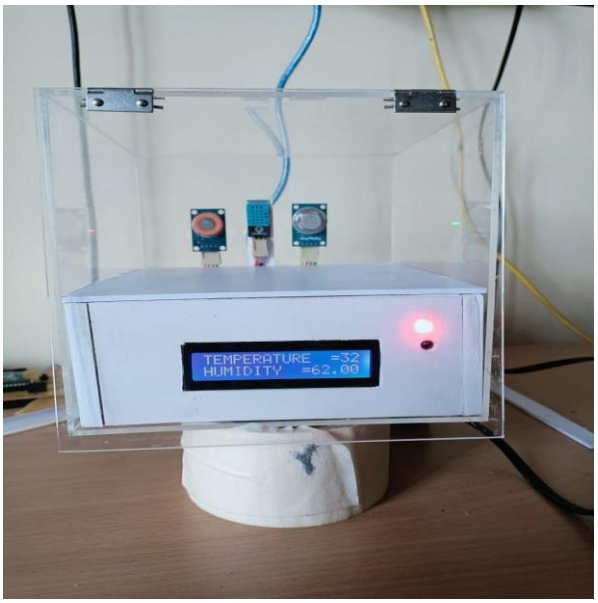

Fig. 5. A modelling setup of fish spoilage detector

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 9, Issue 1, January 2022

A. **Detector model setup**

The model is run until visible indications of fish spoilage are seen. A nested approach was used in creating a spoilage monitoring system to minimize the spoilage seen in fish. As given in Figure 6(a & b), three sensors are affixed into the Acrylic Display Casing (with Hinged Lid) namely, MQ 137 Ammonia Gas Sensor, MQ 135 Gas Sensor Module and Humidity Sensor Module DHT11, and a 1602 (16x2) LCD Display with 12C/11C Interface. These sensors detect harmful levels of Ammonia, Carbon Monoxide and also measure humidity and temperature thereby, emitting warning signals in the form of flashes of light and a sound warning. A 1602 (16x2) LCD Display with 12C/11C Interface that will display the temperature, humidity levels as well as that of ammonia and other gases like carbon monoxide and thus, helps in spoilage detection when the levels of these reach a particular threshold value. Arduino Uno was used to building the program used for the calibration run. The calibration model result was validated using multiple trials to get the threshold values of ammonia and carbon monoxide. If the value displayed is other than the threshold value, a warning sound will be generated, it indicates the fish is spoiled. (Figure 6 (b))

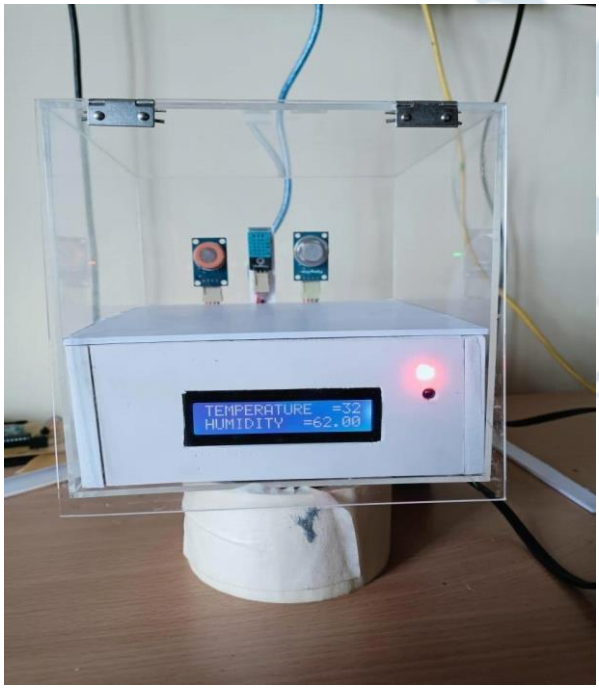

Fig. 6. (a) Measurement of Temperature and Humidity using Fish Spoilage Detector

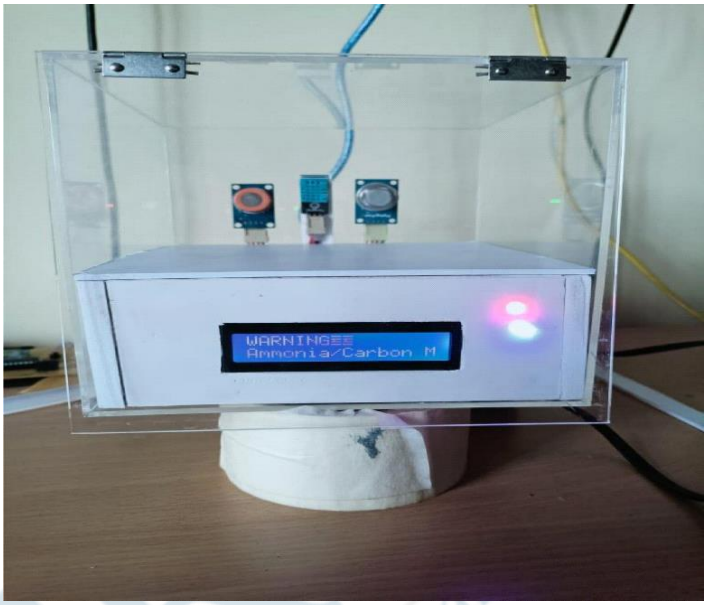

Fig. 6 (b) Warning Sign when Ammonia or Carbon Monoxide levels reach the threshold value

B. Expected outcome

The spoilage detection of various varieties of fish become decided with respect to the content of ammonia, carbon monoxide, air quality, humidity and temperature. As the values have been displayed at the LCD deflects from the threshold value that of fresh clean fish, the given fish taken into consideration is considered as spoiled. The conclusion of values of diverse parameters acquired with the aid of comparing the fishes inside the spoilage detector are as below (Table 3.1).

Table 3.1. Result of values of parameters of fresh fish and spoiled fish

Standard parameter values of fresh fish				
Temperature	Ph	Relative humidity	Ammonia	Carbon monoxide
Below 4-degree Celsius	6.1-6.9 (~7)	65-90%	100-300mg/Kg	97-152 ng/g
Expected values of parameters of spoiled fish				
Above 20-degree Celsius	Above 7	Above 90%	above 300mg/Kg	Above 200ng/g

As results of individual experiments of various fishes on determining ammonia, TMA and TVBN were fairly similar, average values were calculated and they are graphically depicted in figures 3.3(a) and (b).

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 9, Issue 1, January 2022

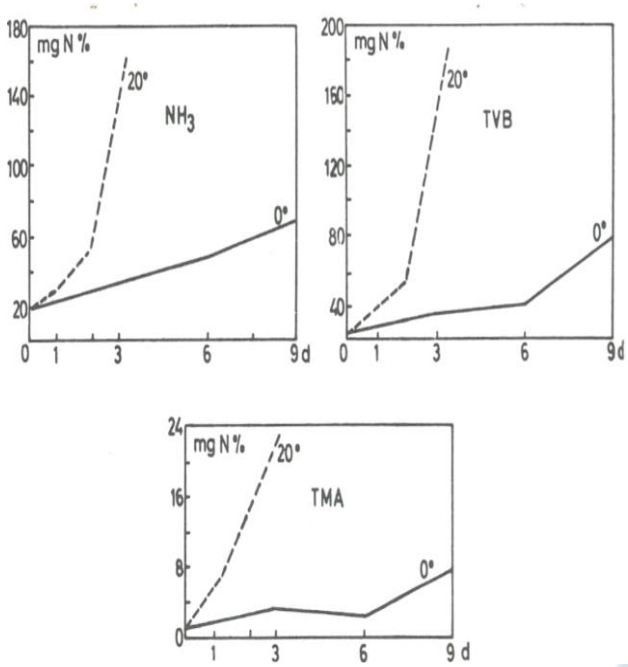

Fig. 7(a) Evolution of NH_3, TMA and TVBN in shrimp (Crangon vulgaris Fabr.)

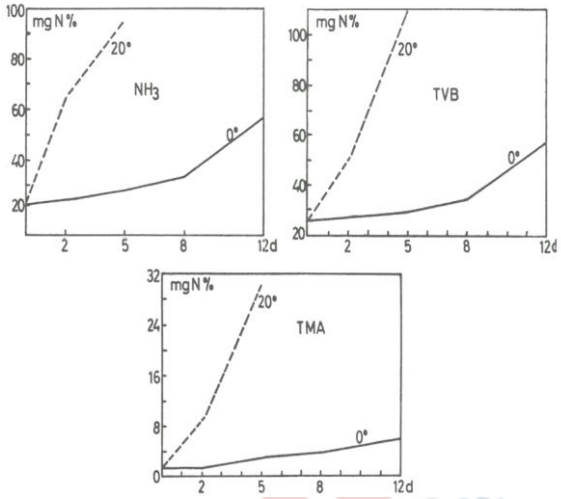

Fig. 7(b) Evolution of NH_3, TMA and TVBN in Lobster (*Nephrops norvegicus L*)

C. PUBLIC HEALTH HAZARDS AND RISKS ASSOCIATED WITH SPOILED FISH CONSUMPTION

There are some public health risks and dangers related to the consumption of spoiled fish. Therefore, powerful techniques that assist in preventing the dangers of pathogens are to be arrived at. Fish has become an essential supply of protein and different factors vital for the upkeep of and a healthful body. The standard and quality of fish is of fundamental importance to companies, clients, and public health authorities alike. Along with this, supplying safe, wholesome, and proper fish and its meals from merchandise to clients is of extreme importance. So, the manipulation of microorganisms is important to satisfy those objectives. Deterioration spotted in fish may be of physical, microbiological and chemical sorts and the standard of fishes degrade, because of a complicated procedure which is to be crucially analysed. Although only a few number of agents of infection in fish can be observed to be infecting humans, some exceptions do exist that would lead to high fatalities. However, in view of the fact that humans consume raw, insufficiently processed or spoiled fish and fish products from time to time, human health can be at exceptional risk. Contamination in fishes with pathogens may be considered as a serious health concern. Presence of *Salmonella* in seafood ends in pathogenic contamination seen in fish that can be considered as an intensive health concern nowadays. The countries such as Vietnam, Sri Lanka, India, Thailand, Taiwan, Japan, and Nigeria have been counseled to have traces of *Salmonella* in seafood. Pathogenic and zoonotic *Vibrios* species are seen to have additionally been remoted from the stool of diarrhoea infected sufferers consistent with latest studies. *Vibrio vulnificus* and *V. parahaemolyticus* amongst different pathogens pose a substantial danger to health human beings who would be afflicted by immune disorders, hemochromatosis or liver diseases. It is very important to make the general public privy to the damaging conditions which can accompany with managing fish, intake of fish that is improperly cooked, and spoiled fish [13],[14].

Fish which have proven to produce symptoms and symptoms of spoilage must now no longer be offered to the general public a good way to raise the fitness widespread of the general public. The Fish Spoilage Detector is designed to prevent fish that are not safe from reaching the customer.

D. SIGNIFICANCE OF PRODUCT IN THE MARKET

'Fresh fish' is generally assumed to be in a good state and is safe for consumption. In a market, finding whether a particular fish is fresh and safe for consumption or not is a tough task for consumers. The freshness of the fish is generally determined by a sensory assessment that relies enormously on the assessors who is in charge. This type of analysis is a subjective one and the conclusion derived for the same fish may vary significantly according to the evaluation. Hence, it is high time to find an alternative, instrumental method to provide an objective measurement system for the assessment the fish freshness. The method should also be affordable, reliable, rapid, non-destructive, and easy to use. Multiple spoilage indicating parameters of fish should be considered in the development of an instrumental technique with the least error produced[15]-[17].

In this context, this model helps to check if the fish is spoiled or not. The sensors mainly ammonia sensor helps in the detection if the fish contain ammonia levels in high amounts or not. Also, the temperature sensor and air quality sensor measure the temperature value and air freshness around the fish surroundings respectively.

This model is very useful for laboratory purposes. It can be further developed for large-scale usage also. Its availability in

the market helps the customers to keep the fish safe and healthy. Every seller has to ensure that customers are given healthy products without spoilage. Thus, all customers have greater acceptance for fresh fishes that are fit for consumption [18].

IV. CONCLUDING REMARKS

A Fish Spoilage Detector model with a 1602 (16x2) LCD Display with 12C/11C Interface was created using MQ 137 Ammonia Gas Sensor, MQ 135 Gas Sensor Module, and Humidity Sensor Module DHT11 which was calibrated by placing fish samples to detect spoilage. The model simulation runs which include the ammonia, carbon monoxide, temperature, and humidity detections were completed successfully and outputs were analyzed to arrive at suitable results and conclusions. Major observations can be summarized as follows:

• The only safe level of ammonia is 100-300mg/kg. Only lower ammonia levels are safe, beyond which the fish spoilage detector identifies it as spoilage and communicates it with the consumer.

• Samples tested that contain a carbon monoxide higher than the level that is expected to be there in fresh fish are found to be spoiled. Samples that have levels above 200 ng/g of CO (which is the current regulatory limit in the European Union and Japan) are not fit for human consumption. This is detected by the Fish Spoilage Detector, thereby warning the consumer of the same.

• The Fish Spoilage Detector prototype can be developed further by in-depth research and can be used in laboratories, marketplaces, etc. to find out the spoilage in fishes, thereby aiding in human health.

ACKNOWLEDGEMENT

Our inner most appreciation is going out to all that gave us the essential aid to complete this project. We thank the Almighty for blessing us with the bodily and intellectual stamina to finish it. We would like to deliver our honest gratitude to the institution that made this project work possible, the Kerala University of Fisheries and Ocean Studies, Kochi for arranging the executive methods needed.

It is our privilege to specify our heartfelt gratitude to the Project Guide, Prof. (Dr.) D. D. Nambudiri Adjunct Faculty, Dept. of Food Science & Technology, Kerala University of Fisheries and Ocean Studies, for his treasured mentorship, encouragement, whole-hearted aid, together with the determination to assist us deal with all our worries in the course of the project work.

We owe our heartfelt gratitude to **Dr. Suriyakala C.D**., Dean, Faculty of Fisheries Engineering, **Er. Rashida Rajuva**, Class In-charge (Btech-17 Batch), Faculty of Fisheries Engineering, Kerala University of Fisheries and Ocean Studies (KUFOS) for permitting us to pursue the project at KUFOS. We would also like to thank our classmates for supporting us throughout the project period.

REFERENCES

[1] Abinaya, T., Ishwarya, J., Maheswari, M. (2019) – "A Novel Methodology for Monitoring and Controlling of Water Quality in Aquaculture using Internet of Things"-IEEE, DOI: 10.1109/ICCCI.2019.8821988

[2] Adedeji Ob et al. (2012) - "Benefits, Public Health Hazards and Risks Associated with Fish Consumption"- Research Gate (New York Science Journal 2012;5(9))

[3] Bate Smite, E.C and Bendall, J.R. (1956) - "Changes in fish muscle after death"- British Medical Bulletin 12, pp.2305

[4] B. G. Kermani, S. S. Schiffman, and H. T. Nagle (2005) – "Performance of the Levenberg Marquardt neural network training method in electronic nose applications"-Sensors and Actuators B, 110(1), pp. 13–22

[5] Burt, J.R. (1976) - "Hypoxanthine a biochemical index of fish quality"- Process Biochemistry. 11(10)

[6] Conte, F., Passantino, A., Longo, S., & Voslářová, E. (2014) -"Consumers' attitude towards fish meat"- Italian Journal of Food Safety, 3(3)

[7] Dharmendra Kumar, Shivesh Kumar, Dr. N. S. Rajputan (2020) – "Intelligent system for fish freshness quality assessment using artificial neural network"- International Journal of Creative Research Thoughts 8(2)

[8] Esmeray Kuley et al. (2017) - "Fish Spoilage Bacterial Growth and Their Biogenic Amine Accumulation"- International Journal of Food Properties (Volume 20, 2017)

[9] Fayyaz A. Nauman., Conrado M. Gempesaw., J. Richard Bacon., Alberto Manalo Eg: Ackerley, N., Sertkaya, A., & Lange, R. (2010) - "Food transportation safety: Characterizing risks and controls by use of expert"- MaHnf Resource Economics. 1995 Food Protection Trends, 30(4), 212– 222

[10] Fayyaz A. Nauman., Conrado M. Gempesaw., J. Richard Bacon., Alberto Manalo (1995) - "Consumer Choice for Fresh Fish: Factors Affecting Purchase Decisions"-Marine Resources Foundation. Volume 10. pp. 117-142

[11] Gopakumar,K.(2000)- "Enzymes and Enzyme products as Quality Indices"- Seafood Enzymes, pp 337-363. Harrd N.F and Simpspn, B.K., (Eds). Marcel Dekker, Inc.New York, Basel, U.S.A.

[12] Ikape S.I., Cheikyula, J.O (2017) - "Fish Spoilage in The Tropics: A Review"- Octa ournal of Biosciences, Vol. 5(2):34-37

[13] Karube, I., Marouka, H., Suzuki, S., Watanabe, E and Toyana, K. (1984) –"Determination of fish freshness with an enzyme sensor system"- J.Agric and Food Chemistry. 32: 314-319

[14] Kinnera Bharath Kumar Sai, Somula Ramasubbareddy and Ashish K.R. Luhach. (2019) - "IOT Based Air Quality Monitoring System Using MQ135 and MQ7 With Machine Learning Analysis"- Scalable Computing: Practice and Experience (Volume 20, Number 4, pp. 599–606)

[15] Lima Dos Santos, C.A.M, James, D and Teutscher, F. (1984) - "Guidelines for chilled fish storage experiments"- FAO Fisheries Technical paper, No 210 (FAO, Rome)

[16] Marko Petric, Filip Dodigović, Ivana Grčić, Petar Markužić, Lucija Radetić, Mateo Topić. (2019) - "Ammonia Concentration Monitoring Using Arduino Platform"-Research Gate - Environmental Engineering Vol.6, No.1, 22-27

[17] Matteo Tonezzer (2021) - "Detection of Mackerel Fish Spoilage with a Gas Sensor Based on One Single SnO2 Nanowire"- MDPI Journal Chemosensors 2021, 9, 2

[18] Muhammad Rivai, Budiman, F. Purwanto, D. Simamora J (2018) – "Meat freshness identification system using gas sensor array and color sensor in conjunction with neural

network pattern recognition"- Journal of Theoretical and Applied Information Technology 96(12):3861-3872

[19] Nicholas G. Eror et al. (1995) - "Expanding the Vision of Sensor Materials"- National Research Council Washington, Committee on New Sensor Technologies: Materials and Applications National Materials Advisory Board Commission on Engineering and Technical Systems, National Research Council, National Academy Press, Washington, D.C. 1995

[20] Olumide Adedokun Odeyemi, Oluwadara Oluwaseun Alegbeleye, Mariyana Strateva and Deyan Stratev (2020) - "Understanding spoilage microbial community and spoilage mechanisms in foods of animal origin"- Comprehensive reviews in Food Science and Food Safety, 19(2), 311-331

[21] Putro, S. (1986) - "Better on-board handling of oil sardines in the Bali Strait using chilled sea water"- Infofish Marketing Digest. 86(1): 33-35.