Electronic Tongue: Study on the Freshness of Milk

By

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Electrical & Electronic Engineering Programme

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In partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

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Approved by,

____

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UNIVERSITI TEKNOLOGI PETRONAS

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December 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMAD NAZRIN BIN JAAFAR

ABSTRACT

Electronic tongue is an artificial sensory system that uses sensor arrays to collect a number of data for classification purposes. The main objective of our study is to define freshness of milk and identify factors that affect them. Recently, there are some issues concerning the reliability of expiry date labeled by the food industries. There are complaints about lots of product that are already spoilt even though the expiry date is still far from due. We are interested to identify factors such as temperature variation and amount of additive used that makes them to spoil slower. As from our stance, an experiment was performed to describe the effect of temperature variations on the freshness of milk. In the experiment, we used two types of milk; pasteurized and unpasteurized, which were placed at two different temperature; cold (in refrigerator) and room. From the experiment, we observed the changes in pH value of the milk due to the temperature as well as taking into accounts the physical changes of the milk; taste, color, smell and texture. After the experiment has been done, the data obtained was used in Matlab for classification purpose. By using the Neural Network algorithm, we are actually able to find the threshold line which actually separates the fresh and spoilt milk into two different regions. Meanwhile, based on the experiment that we have conducted, we could say that the use of the pH sensor itself which represents the e-tongue is not enough to determine whether the milk has become spoilt or not. As discussed with our supervisor, we have come to a conclusion that, the changes and drop in pH value cannot determine if milk is already spoilt since the one that remains fresh also have noticeable drop in its pH value. Even though we managed to estimate a threshold line that separates good and bad milk, still, the used of extra sensors (e-nose) will be a major boost to obtain a better classification.

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SECTION A: INTRODUCTION

A.1 Background of study

Human sensory system is very unique and powerful. Over the years, technologies and devices have been developed to imitate the five human sensors. Even though these technologies and devices are incomparable to our biological senses, still the interest to develop a better sensory system that can mimic the humans' are still being pursued. A device named Electronic Tongue (e-tongue) is one of the examples of the artificial sensory system which is widely being used in the food processing industries.

An e-tongue uses sensor arrays that can collect multiple data at once. These data collected will then be processed by using proper techniques. Commonly used techniques to obtain data for e-tongue are potentiometry and voltammetry. Due to the simplicity of the voltammetric e-tongue, this technique has established very well in the industrial applications Studies about voltammetric e-tongue have shown that this device can be used to observe the quality changes in the beverages [1][3] including to discriminate samples between beverages [1-7]

In the context of our study, the e-tongue will be used to classify and determine the freshness in milk by evaluating them using artificial Neural Network. The data acquired will then be further analysed on Matlab by using the artificial Neural Network namely Multilayer Perceptrons (MLP) to classify the freshness of milk whether good or bad. Perhaps, the e-tongue can later be integrated with the e-nose to obtain various data for better classification results.

A.2 Problem Statement

A.2.1 Determining Freshness of Milk

The most common way for ones to determine the freshness of milk or any other beverages is depending solely on the expiry date labeled on the box or can. However, quite sometimes, these labels are not completely correct. Some might turn bad in just a few days after it was opened regardless their expiry date.

Maybe, the labeling is done correctly, but the incorrect handling of the milk during transportation or after drinking might trigger other factors that may affect the freshness of the milk. Temperature might be one of the main factors that can affect the freshness of milk. Increase in a temperature could stimulate the activities of bacteria known as *Lactococci* [12][13] that will grow in number causing the milk to spoil [12][13].

As from our position, we will run several experiments on two types of milk; pasteurized and unpasteurized, by using the e-tongue made by pH sensor with respect to the temperature effect. Not to forget, the physical changes of the milk will also be taken into account. At the end of our studies we can classify between good and bad milk based on their chemical properties.

A.3 Objectives and Scope of Study

Objectives	Scope of Study
➢ To make a literature review on the e-tongue	✓ Make a research on e-tongue that focuses on the freshness of milk and factors affect
➢ To use suitable hardware and software tools	✓ Focusing more on the software development by using Matlab
➢ To classify and analyze data obtain from the e-tongue	✓ Study and understand how to use the 'Neural Network" functions on Matlab
➢ To integrate e-tongue with e-nose	✓ Perform some experiments with the used of e-tongue and e-nose

Table B.1 Objectives and Scope of Study

A.4 Relevancy

Over the years, e-tongue has shown it significant in many fields especially towards the food industry. Recently, the shelf life and quality of the food produced nowadays have become a major concern since the food may rot faster than expected which leads to food poisoning. There are a lot of measures taken to improve their food produced which includes sensor intervention. Thus, the development of e-tongue is relevant in a way that no one needs to risk their health on tasting the spoilt food where in our case, milk so that the food quality can be controlled and maintained to be good.

A.5 Feasibility

- ❖ Available tools and software
- ❖ A lot of guidance and references
- ❖ Tasks are distributed to each members
- ❖ Proper planning and schedule

SECTION B: LITERATURE REVIEW

B.1 Applications of e-tongue

Many scholars have agreed that the development of e-tongue has contributed a lot to the world whether towards the economy, health or the environment. This can be seen in the writing done by P. D Chaudhari under the topic 'Electronic Tongue: A Review', where he mentioned the application and contribution of e-tongue in many sorts of fields [8]. This idea was also supported by K. Anderson [9] in his writing 'Functionality Test with the Electronic Tongue'. Some of the fields where the e-tongue has been applied are:

i. **Foodstuff industry**
ii. **Pharmaceutical**
iii. **Safety**
iv. **Environmental pollution monitoring**
v. **Chemical industry**

As for our project, we are mainly focusing on developing an e-tongue to monitor the quality changes in milk which may applicable for food quality control in the food industry.

B.2 Quality changes in milk due to temperature

Variation in temperature will somehow affect the freshness of milk. For a milk to stay fresh, it must be keep at temperature below 9.5 degree Celsius [12][13]. Even it is kept at room temperature, it is enough to start the growth of a bacteria known as *Lactococci* [12][13].

Eventually, these bacteria will continue to grow in number and subsequently changes the lactose present in milk into lactic acid that causes drop in pH value. When this happened, the milk will become spoilt. Some of the indications that show the milk becomes spoilt include a sour odor, sour taste, yellowish in color and texture becomes lumpy [12][13].

B.3 Integrating e-tongue with e-nose

Normally, we can feel that our taste becomes less sensitive when we are having flu or nose blockage. According to Peggy and David, most of what we taste is actually come from our sense of smell [14]. A receptor known as *Olfactory* is responsible for this job where it will detect the odor molecules from the food we consumed and send it to the brain [14]. Thus, during flu, lining of mucus will block this receptor make it unable to perform its job. Therefore, the food will seem to be tasteless.

Taking this into consideration, we are thinking that, by integrating both e-tongue and e-nose, a better result can be obtained where some researchers also agreed on that [10][11]. Based on the experiment that we have done, we also believes that there is also gas emitted that gives the sour odor when the milk become rotten. Rather than solely depending on the effect of temperature on the pH value, we would also try to investigate the type and amount of gas produced during this process where we can use the data for better classification results.

B.4 Data analysis by using Neural Network in Matlab

A Multi-Layer Perceptron (MLP) is one of the functions in the Neural Network toolbox. It is created to perceive how the neurones in human brain work. This artificial Neural Network is generally used to solve problems involving classifications and approximation. The MLP consists of a series of neurones that map input vector to the output vector by introducing a weight at the input side. This weight will be constantly updated by using a method name ‘back propagation’ where the error is put into consideration so at the end the input will be equal to the output.

Generally, the MLP can solve the XOR problem where patterns are not linearly separable. A single perceptron could only solve the AND/OR gate problem where the outputs are linearly separable. Figure bellows illustrates the AND gate and X-OR problems.

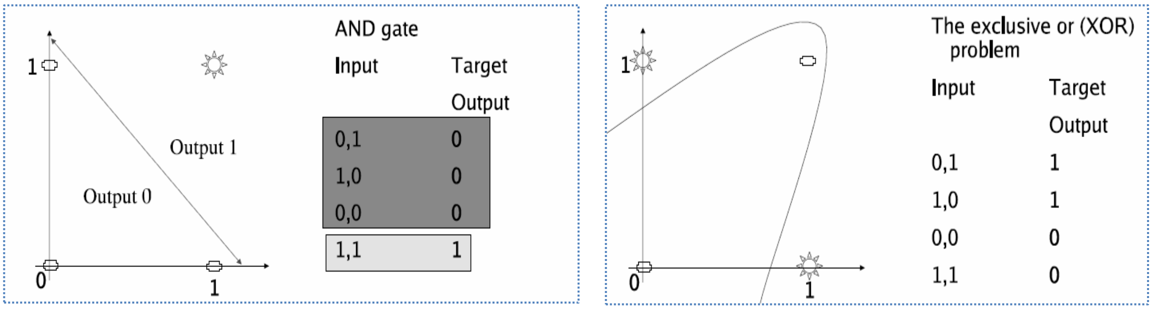


Figure B.1 AND and XOR Gate Problems

Example below shows how MLP help to solve this XOR problem.

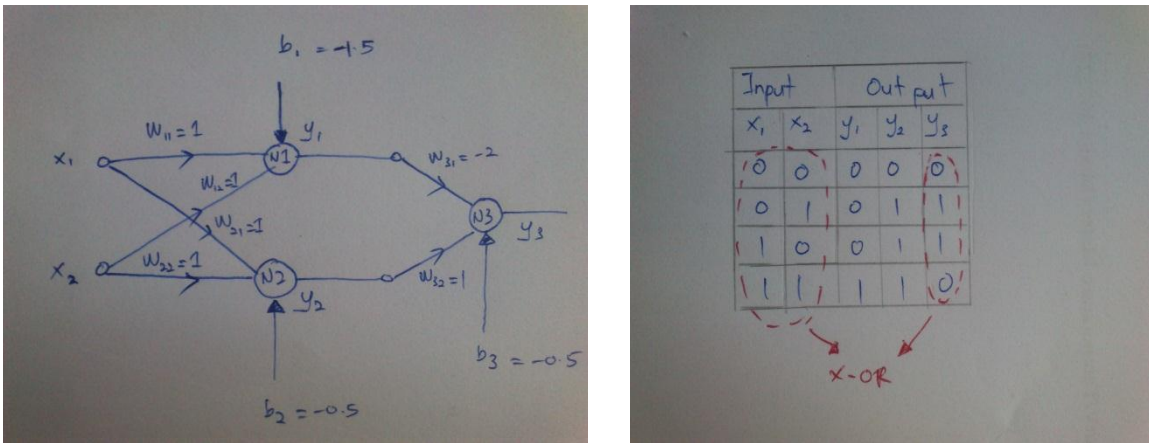


Figure B.2 MLP Solving XOR Problem

Xn = Input	*Wnn = Weight*
Nn = Perceptron/Neuron	*bn = Bias*
Yn = Output	

The input Xn (either ‘1’ or ‘0’) will be multiplied with the weight. If the multiplication value is larger than the bias, bn, then output, Yn will be ‘1’, else ‘0’.

SECTION C: METHODOLOGY

<u>C.1 Work done</u>

C.1.1 Literature Review

Some reviews on e-tongue were made by referring to articles generally related to the e-tongue. The purpose is to get familiar with the concept and mechanism behind the e-tongue. After several readings, discussions have been made with the project members where a decision was made to develop an e-tongue for observing the quality changes of milk. Later on, more readings were made that focus on defining the freshness of milk, the factor that could make the milk become spoilt, and the previous experimental done. In addition, some reviews are also done on the integration of e-tongue with e-nose as well as the techniques used for data acquisition and classifications.

C.1.2 Getting familiar with Neural Network in Matlab

As we are going to make the data classifications from the measurements we obtained, a series of study is also made to understand the idea on how to use the Neural Network functions in the Matlab software. The Neural Network is used as it is able to perform self-learning from the data given as well as its ability to extract patterns from complex data. Below shown some of the demos that are being used to explain and understand the Neural Network functions.

<u>C.1.2.1 Determining the boundaries</u>

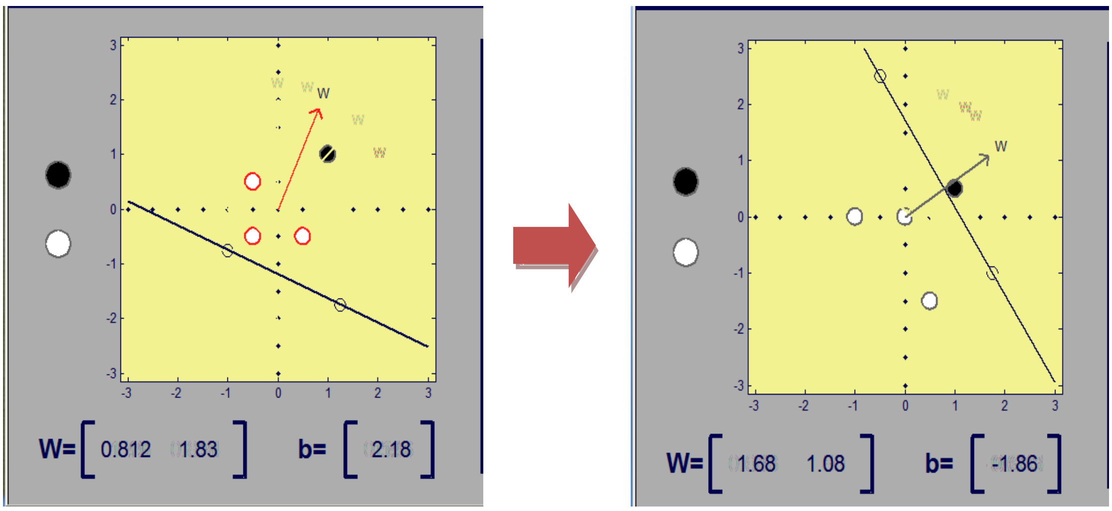


Figure C.1 Determining the boundaries

White dots = Good Milk *W = Weight*

Black dots = Bad Milk *b = Bias*

For this section, the boundary line is manually being adjusted so that the black and white dots are classified into their own region. Noticed the change of color of the white dots before and after the boundary line is applied. The change in color indicates that the classification is accomplished manually.

C.1.2.2 Perceptron Learning Rule

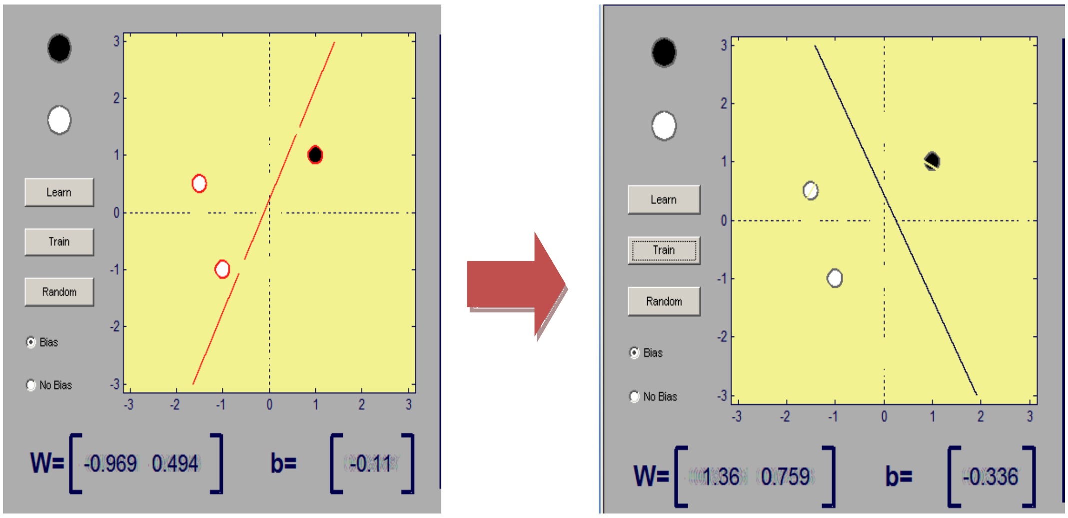


Figure C.2 Perceptron Learning Rule

In the previous section, the boundary line is to be estimated manually. Meanwhile, for this section, the perceptron are trained up to several times before the boundary line can be estimated automatically. In the second picture, we notice that the white and black dots can be classified according to their region after the boundary line is estimated.

C.1.3 First Experimentation

An experiment has been conducted during FYP1 for us to obtain some data that can be used to play around with the Matlab. The experiment was done such that two types of milk are used; pasteurized and unpasteurized, where the experiment is done under cold (fridge) and room temperature. The purpose for conducting this experiment was to see the effect of temperature variation on the freshness of milk. In our case here we are going to measure the pH value of the milk while also taking into account the physical changes of the milk to determine the freshness of milk with respect to the temperature.

C.1.3.1 Tools and Materials

- 0.5 Liter of unpasteurized milk (Fresh from cow)
- 0.5 Liter of pasteurized milk (Dutch Lady Fresh Milk)
- 150mL beaker × 4
- pH meter and temperature kit
- Plastics

C.1.3.2 Procedure

1) Two beakers were filled with the pasteurized milk while the others were filled with the unpasteurized milk.
2) These beakers were then labeled as A,B, C and D. (A=Pasteurized/Cold, B= Pasteurized/Room, C=Unpasteurized/Cold, D= Unpasteurized/Room)
3) After that, an initial reading of temperature and pH value were taken and recorded.
4) Once data measurement had been done, the beaker were covered with plastics as to prevent any other substances entering the beaker
5) Next, all the beakers were placed at their respective places as labeled.
6) Every five to seven hours, the readings of the pH and the temperature were taken for each of the beakers and are recorded. In addition, the physical changes of the milk were also observed and recorded.
7) Make sure that the pH and temperature rods were cleaned before dipping them into other beakers to avoid any mixing of milk.
8) For each beaker, once measurements have been taken, the beaker must be covered immediately to prevent any substances from entering.
9) For the beakers that are put in the refrigerator, the readings were taken at a fixed temperature (13.8 for pasteurized and 16.3 for unpasteurized) as the temperature will tend to increase to be equal to the room temperature once we put it outside.
10) The experiment was conducted for five days to obtain more data for classifications.

C.1.4 Second Experimentation

A second experiment has been conducted recently to improvise what had been done during the first experiment. In this second experiment, a new pH sensor was used that gives much more stable and accurate results. To further improve the results, the sensor was dipped around 5 to 8 minutes inside the milk so that more accurate data can be measured. One more improvement done in this second experiment was to introduce the milk kept inside the fridge to a room temperature after 3 to 4 days of experiment. The purpose is to make the milk become bad after almost 1 day left outside before putting it back into the fridge. Then, the data measurements are done as the same.

Generally, the experiment was done such that two types of milk is used; pasteurized and unpasteurized, where the experiment was done under cold (fridge) and room (locker) temperature. The purpose for conducting this experiment was to see the effect of temperature variation on the freshness of milk. Same as in the first experiment, we are going to measure the pH value of the milk while also taking into account the physical changes of the milk to determine the freshness of milk with respect to the temperature.

C.1.4.1 Tools and Materials

- 0.5 Liter of unpasteurized milk (Fresh from cow)
- 0.5 Liter of pasteurized milk (Dutch Lady Fresh Milk)
- 150mL beaker × 4
- pH meter and temperature kit
- Plastics

C.1.4.2 Procedure

1) Two beakers were filled with the pasteurized milk while the others were filled with the unpasteurized milk.
2) These beakers were then labeled as A,B, C and D. (A=Pasteurized/Cold, B= Pasteurized/Room, C=Unpasteurized/Cold, D= Unpasteurized/Room)
3) After that, an initial reading of temperature and pH value were taken and recorded.
4) Once data measurement had been done, the beaker were covered with plastics as to prevent any other substances entering the beaker
5) Next, all the beakers were placed at their respective places as labeled.

6) The readings of the pH and the temperature were taken normally between 2 to 7 hours (whenever available) for each of the beakers and were recorded. In addition, the physical changes of the milk were also observed and recorded.
7) The pH and temperature rods must be cleaned before dipping them into other beakers to avoid any mixing of milk.
8) The beaker must be covered immediately once measurements have been taken to prevent any substances from entering.
9) The experiment was conducted for 3 to 4 days to obtain more data for classifications.
10) The milk kept in the fridge were then brought out to room temperature for almost 1 day to make it bad
11) The pH and temperature of the milk are measured along with it physical characteristics until the milk turn bad
12) The milk was then put back into the fridge once it has spoilt. Steps 6 to 9 were repeated for the milk.

C.2 Project Activities

i. Literature review on e-tongue applications in determining freshness of milk
ii. Get to know Neural Network in Matlab
iii. Make some experiments to obtain reasonable data
iv. Analyse the data obtained with Matlab Neural Network toolbox for data classifications

C.3 Project Flow Chart

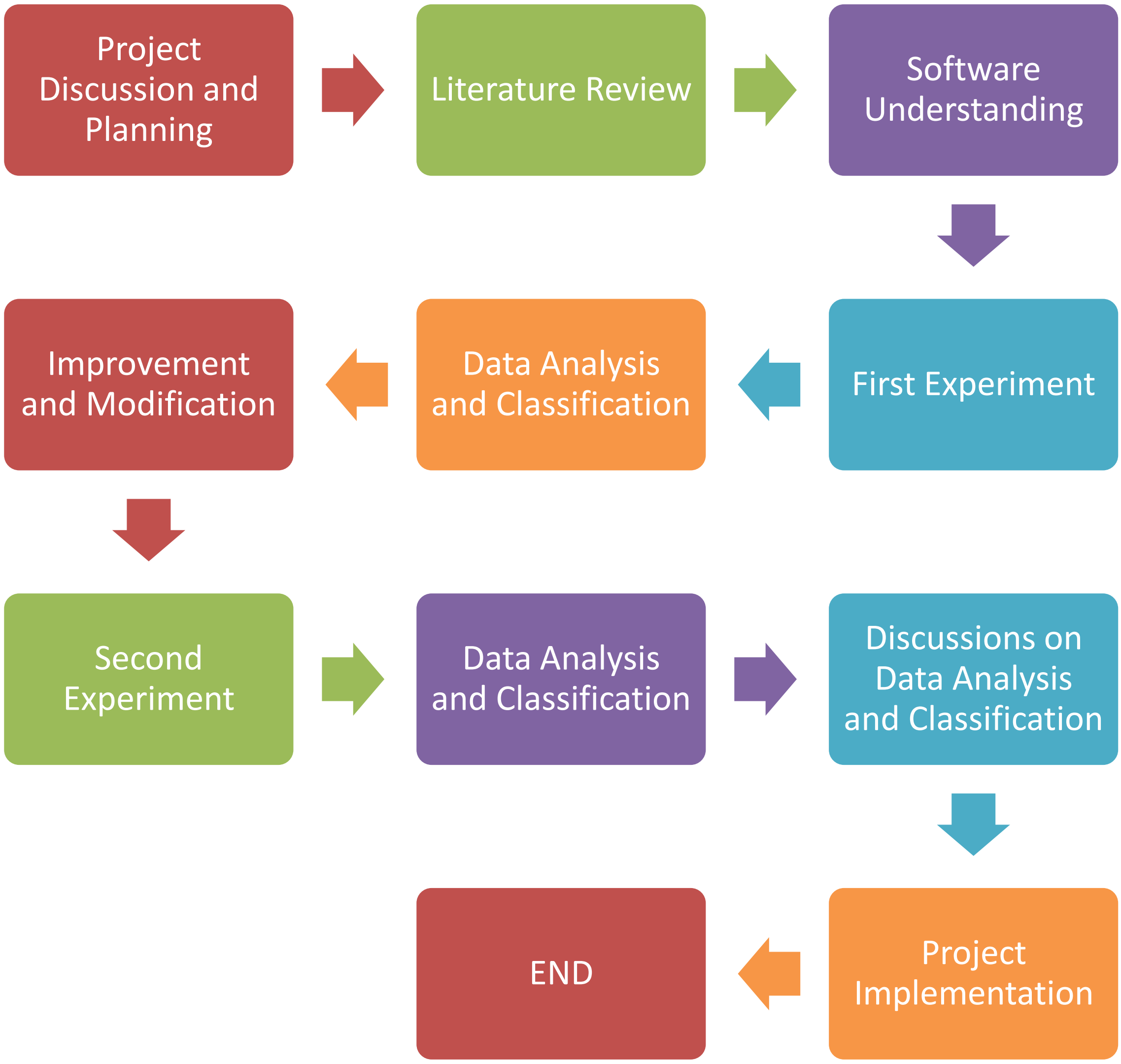


Figure C.3 Project Flow Chart

C.4 Gantt Chart and Key Milestone

FYP1

No	Detail / Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14
1	Topic Selection	■	■													
2	Review on e-tongue		■	■	■	■		■		■						
3	Submission of Extended Proposal						★									
4	Proposal Defence										★					
5	Study on the Neural Network in Matlab software						■	■		■	■					
6	Software development and understanding									■	■	■	■	■	■	
7	Submission of Interim Report														★	

Table C.1 Gantt Chart and Key Milestones

FYP2

No	Detail / Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14
1	Experiment				■	■	■	■								
2	Data Review	■	■			■	■	■		■	■					
3	Developing Matlab codes for multilayer perceptrons						■	■		■						
4	Submission of Progress Report									★						
5	Improvement on Matlab codes											■	■	■	■	■
6	Electrex												★			
7	Viva															★
8	Submission of Final Report														★	

Table C.1 Gantt Chart and Key Milestones

■	Processes
★	Milestones

C.5 Tools and Materials Needed

i. pH sensor

ii. Thermometer

iii. Extech Instruments Heavy Duty pH/mV/Temperature Meter (Model 407227)

iv. Pasteurized and Unpasteurized milk

v. Beakers

vi. Matlab Software

SECTION D: RESULTS & DISCUSSIONS

D.1 First Experiment

D.1.1 Results

		A (Pasteurized/Cold)		B (Pasteurized/Room)	
Day	Time	pH value	Temp (deg C)	pH value	Temp (deg C)
24/7/2012	1100pm	7.05	22	7.05	23
25/7/2012	830am	6.92	13.8	6.88	29.5
25/7/2012	230pm	6.9	13.8	6.53	32.4
25/7/2012	10pm	6.9	13.8	6.11	31.1
26/7/2012	100am	6.85	13.8	5.56	30.5
26/7/2012	300pm	6.67	13.8	5.33	31.9
26/7/2012	540pm	6.46	13.8	5.21	31.8
26/7/2012	1100pm	6.25	13.8	4.72	30.8
27/7/2012	830am	6.06	13.8	4.68	30
27/7/2012	1200pm	5.95	13.8	4.23	32.9
28/7/2012	1000am	6.08	13.8	4.17	31.6
28/7/2012	300pm	6.15	13.8	4.17	32.4
28/7/2012	930pm	6.17	13.8	4.05	31.1
29/7/2012	10am	6.55	13.8	3.87	31.5
29/7/2013	300pm	6.76	13.8	3.77	32.5
29/7/2014	930pm	7.6	13.8	3.63	32

Table D.1 pH and temperature for pasteurized milk

		C (Unpasteurized/Cold)		D (Unpasteurized/Room)	
Day	Time	pH value	Temp (deg C)	pH value	Temp (deg C)
24/7/2012	1100pm	9	21	9	23
25/7/2012	830am	8.66	16.3	8.33	29.5
25/7/2012	230pm	7.81	16.3	8.43	32.4
25/7/2012	10pm	7.79	16.3	7.05	31.1
26/7/2012	100am	7.56	16.3	6.54	30.5
26/7/2012	300pm	7.44	16.3	5.94	31.9
26/7/2012	540pm	6.79	16.3	5.24	31.8
26/7/2012	1100pm	6.77	16.3	4.45	30.8
27/7/2012	830am	6.64	16.3	4.33	30
27/7/2012	1200pm	6.54	16.3	4.34	32.9
28/7/2012	1000am	6.77	16.3	4.2	31.6
28/7/2012	300pm	6.93	16.3	4.22	32.4
28/7/2012	930pm	7.05	16.3	4.2	31.1
29/7/2012	10am	7.11	16.3	4.12	31.5
29/7/2013	300pm	7.58	16.3	4.05	32.5
29/7/2014	930pm	8	16.3	3.97	32

Table D.2 pH and temperature for unpasteurized milk

D.1.2 Observations

Based on the experiments and observations that we have made, we also have compiled a table discussing on the physical changes of the milk for each day where we come to a conclusion on deciding which milk is good and spoilt after few days.

	A (pasteurized)	B (pasteurized)	C (unpasteurized)	D (unpasteurized)
Temperature	cold	room	cold	room
1st day	Freshest	Freshest	Freshest	Freshest
2nd day	Freshest	• Little sour smell like yoghurt, • a bit thick • a little yellowish	• Smells ok, • No coagulation	Sour smell like yoghurt, thicker than C, a little yellowish
3rd day	Freshest	• More sour smell • thicker at bottom, • yellowish in color	• Smells ok, • starts too coagulate	More sour, thicker on top, yellowish in color
4th day	Freshest	• Thicker layer on top, • strong sour smell, • yellowish in color	Very little sour smell, two layers of textures	Strong sour smell, lumpy, yellowish in color
5th day	Freshest	• Thicker layer on top, • very strong sour smell, yellowish in color	Very little sour smell, two layers but more thick on top	Very strong sour smell, very lumpy, yellowish in color
Conclusion	Best	Bad	Ok but not advisable	Bad

Table D.3 Properties of milk in different beakers

D.1.3 Discussions on Results and Observations

From the results and findings that we have obtained, we can say that after one day, the milk that was placed at room temperature already spoilt. We come to this conclusion as we already discussed the physical changes that would determine the freshness of milk by observing their taste, smell, color and texture. Apart from that, we could also see there were drastic changes in pH value after two days being put in room temperature. Thus, we can say that the milk that have been put in room temperature become spoilt very fast due to the higher bacteria growth rate and activity which in turns dropped the pH value as well as changed in its physical properties.

As for the milk that was stored in the refrigerator, we can say that for the pasteurized milk, it remained fresh after few days. Even though they are slight dropped in the pH value due to bacteria activity, but the properties of the pasteurized milk remained the same which can be said the milk still remain fresh. The dropped in pH might due to the exposure to the room temperature when taking the measurements which causes the bacteria to be active. However, since the temperature in the refrigerator is very cold; around 2 degrees Celsius, this will limit the bacteria activities.

Whereas for the, unpasteurized milk under cold temperature, it was also able to retain its freshness as the pasteurized milk. However, after few days we can see that it was nearly become spoilt as there was a drop of pH value as well as very little sour smell and two layers of textures are formed. Perhaps, the cold temperature of the refrigerator has limited the bacteria activity which makes it able to remain fresh for a few more days.

D.1.4 Conclusion and Recommendation

From the experiment that we have conducted, we believed that the pH meter which relatively represents the e-tongue alone cannot tell us whether the milk has become spoilt or not. This is because, the pH value that we obtained does not have a concrete reason to be assumed that at this certain value or drop in pH, the milk become spoilt. This is to be said since the milk that we stored in the refrigerator also has dropped in pH but remained fresh.

Meanwhile, we are also still depending on the physical changes in the milk such as the smell and color to decide on the freshness of the milk. This basically shows the limitation of using e-tongue with only pH as the sensor as there is only pH value to be evaluated. Thus, there comes the e-nose which basically will be used to detect the gas released by the milk. This is perhaps can increase the performance of the e-tongue to obtain a better result.

D.2 Data Classification in Neural Network (First Experiment)

In this section, we are going to use the Neural Network functions to classify the data obtained by finding the boundary line to separate the fresh and the spoilt milk. Since we were only using the pH meter and temperature sensor, the data obtained are limited. However, we are still able to use the values to classify them accordingly.

D.2.1 Labeling the Data/Results

The results need to be labeled as we are actually going to predetermine the output so that when the training of the network is applied, the network can actually learn by itself to determine the boundary line.

1 = Fresh

0 = Spoilt

		A(Pasteurized/Cold)			B(Pasterurized/Room)		
Day	Time	pH value	Temp (deg C)	Label	pH value	Temp (deg C)	Label
24/7/2012	1100pm	7.05	22	1	7.05	23	1
25/7/2012	830am	6.92	13.8	1	6.88	29.5	1
25/7/2012	230pm	6.9	13.8	1	6.53	32.4	1
25/7/2012	10pm	6.9	13.8	1	6.11	31.1	1
26/7/2012	100am	6.85	13.8	1	5.56	30.5	0
26/7/2012	300pm	6.67	13.8	1	5.33	31.9	0
26/7/2012	540pm	6.46	13.8	1	5.21	31.8	0
26/7/2012	1100pm	6.25	13.8	1	4.72	30.8	0
27/7/2012	830am	6.06	13.8	1	4.68	30	0
27/7/2012	1200pm	5.95	13.8	1	4.23	32.9	0
28/7/2012	1000am	6.08	13.8	1	4.17	31.6	0
28/7/2012	300pm	6.15	13.8	1	4.17	32.4	0
28/7/2012	930pm	6.17	13.8	1	4.05	31.1	0
29/7/2012	10am	6.55	13.8	1	3.87	31.5	0
29/7/2013	300pm	6.76	13.8	1	3.77	32.5	0
29/7/2014	930pm	7.6	13.8	1	3.63	32	0

Table D.4 Labeling of Data for Pasteurized Milk

		C(Unpasteurized/Cold)			D(Unpasterurized/Room)		
Day	Time	pH value	Label	Temp (deg C)	pH value	Temp (deg C)	Label
24/7/2012	1100pm	9	1	21	9	23	1
25/7/2012	830am	8.66	1	16.3	8.33	29.5	1
25/7/2012	230pm	7.81	1	16.3	8.43	32.4	1
25/7/2012	10pm	7.79	1	16.3	7.05	31.1	0
26/7/2012	100am	7.56	1	16.3	6.54	30.5	0
26/7/2012	300pm	7.44	1	16.3	5.94	31.9	0
26/7/2012	540pm	6.79	1	16.3	5.24	31.8	0
26/7/2012	1100pm	6.77	1	16.3	4.45	30.8	0
27/7/2012	830am	6.64	1	16.3	4.33	30	0
27/7/2012	1200pm	6.54	1	16.3	4.34	32.9	0
28/7/2012	1000am	6.77	1	16.3	4.2	31.6	0
28/7/2012	300pm	6.93	1	16.3	4.22	32.4	0
28/7/2012	930pm	7.05	1	16.3	4.2	31.1	0
29/7/2012	10am	7.11	1	16.3	4.12	31.5	0
29/7/2013	300pm	7.58	1	16.3	4.05	32.5	0
29/7/2014	930pm	8	1	16.3	3.97	32	0

Table D.5 Labeling of Data for Unpasteurized Milk

D.2.2 Matlab coding

Once the labeling is done, we need to transfer these data into Matlab coding before we can actually classify them. The Neural Network function is also introduced in this Matlab coding.

```
% ------------------Coding Starts---------------------%

clear all;
clc;

%--------------- Pasteurized Milk -------------%
M = [22 13.8 13.8 13.8 13.8 13.8 13.8 13.8 13.8 13.8 13.8 13.8 13.8
13.8 13.8 13.8 23 29.5 32.4 31.1 30.5 31.9 31.8 30.8 30.0 32.9 31.6
32.4 31.1 31.5 32.5 32.0;
7.05 6.92 6.9 6.9 6.85 6.67 6.46 6.25 6.06 5.95 6.08 6.15 6.17 6.55
6.76  7.6 7.05 6.88 6.53 6.11 5.56 5.33 5.21 4.72 4.68 4.23 4.17
4.17 4.05 3.87 3.77 3.63];
```

```
N = [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0];
L = [12 35 3 8];

figure (1)
plotpv (M,N,L)

net = newp([-1 1;-1 1],1);
net.adaptParam.passes = 100;
[net,y,e] = adapt(net,M,N);
display('Mean Square Error for Pasteurized')
mse(e)


plotpc(net.IW{1},net.b{1})
title ('Pasteurized Milk')
xlabel('Temperature (deg C)')
ylabel('pH value')

%--------- Unpasteurized Milk ------------%

A= [21 16.3 16.3 16.3 16.3 16.3 16.3 16.3 16.3 16.3 16.3 16.3 16.3
16.3 16.3 16.3 23 29.5 32.4 31.1 30.5 31.9 31.8 30.8 30.0 32.9 31.6
32.4 31.1 31.5 32.5 32.0;
9 8.66 7.81 7.79 7.56 7.44 6.79 6.77 6.64 6.54 6.77 6.93 7.05 7.11
7.58 8 9 8.33 8.43 7.05 6.54 5.94 5.24 4.45 4.33 4.34 4.2 4.22 4.2
4.12 4.05 3.97];
B = [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
0];
L = [15 35 3 10];

figure(2)
plotpv (A,B,L)

net = newp([-1 1;-1 1],1);
net.adaptParam.passes = 100;
[net,y,e] = adapt(net,A,B);
display('Mean Square Error for Unpasteurized')
mse(e)


plotpc(net.IW{1},net.b{1})
title ('Unpasteurized Milk')
xlabel('Temperature (deg C)')
ylabel('pH value')


% ------------------Coding Ends---------------------%
```

D.2.3 Plotting Results

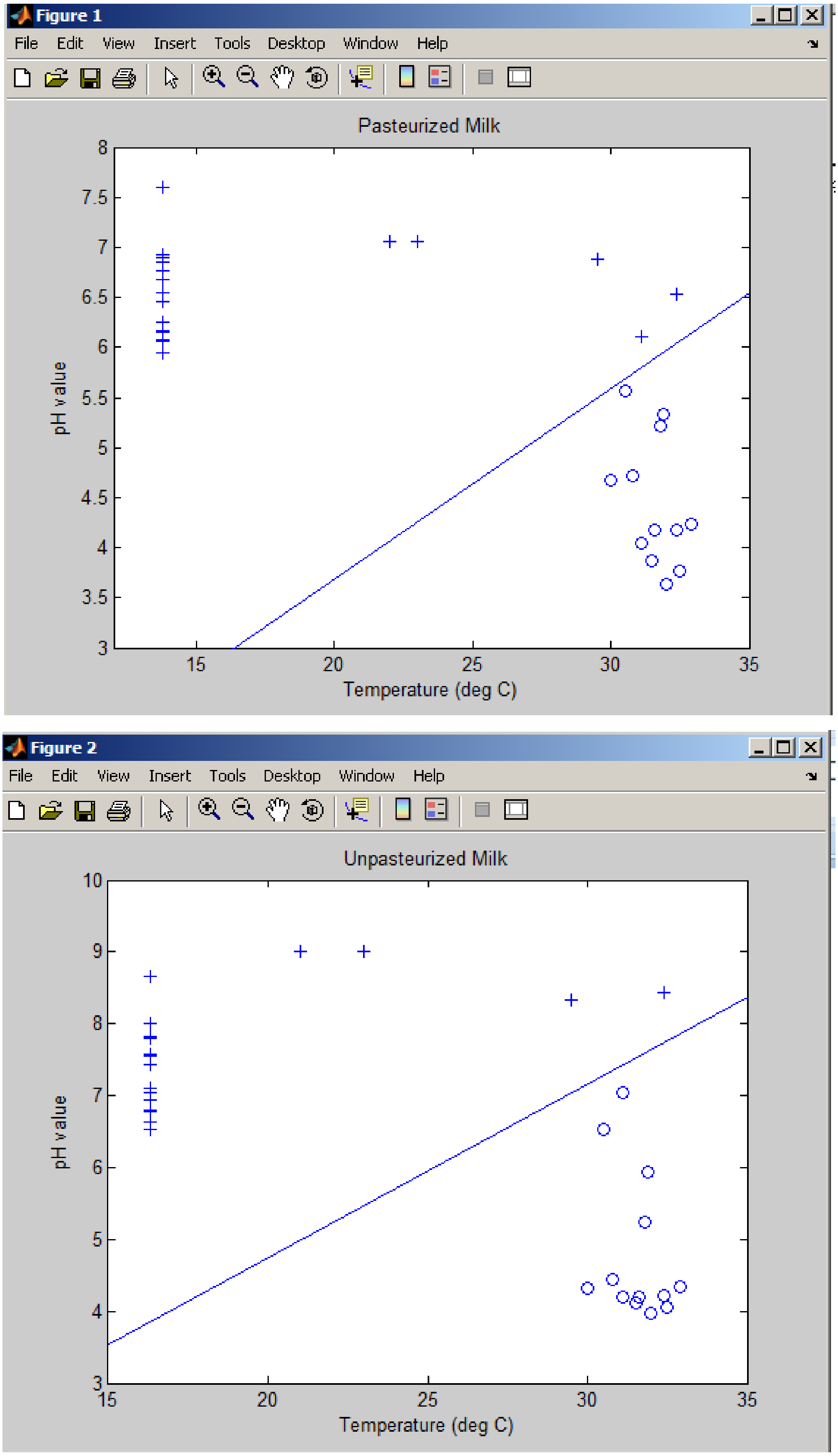


Figure D.1 Results plot for Pasteurized and Unpasteurized Milk

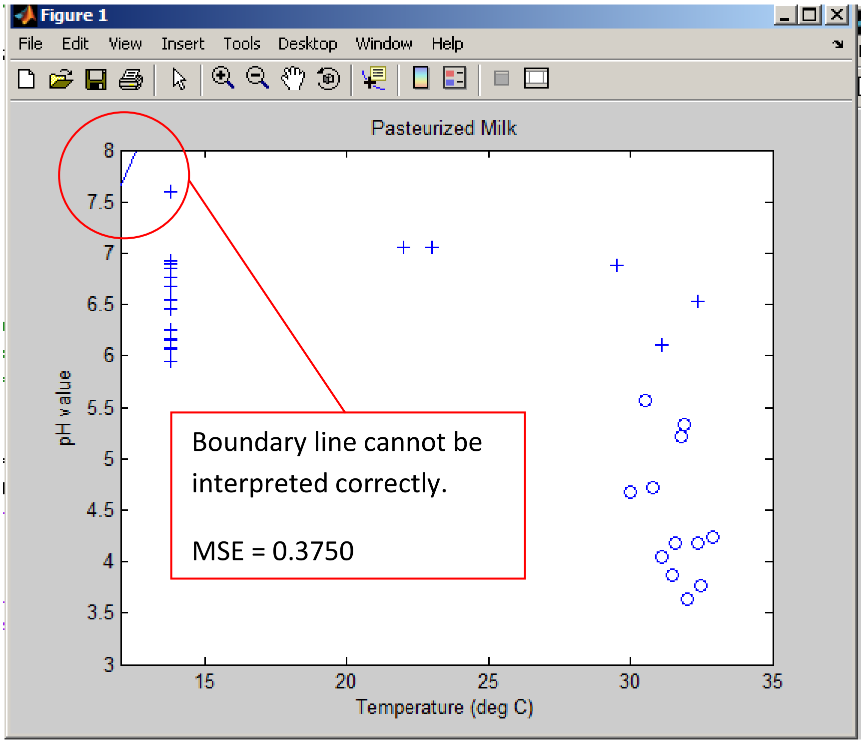
D.2.4 Explaining the Codes

```
M = [22 13.8 13.8 13.8 _ _ _ _;7.05 6.92 6.9 6.9 _ _ _ _];
N = [1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0];
L = [12 35 3 8];
figure (1)
plotpv (M,N,L)

net = newp([-1 1;-1 1],1);
net.adaptParam.passes = 100;
[net,y,e] = adapt(net,M,N);
display('Mean Square Error for Pasteurized')
mse(e)

plotpc(net.IW{1},net.b{1})
title ('Pasteurized Milk')
xlabel('Temperature (deg C)')
ylabel('pH value')
```

- `M`
  → defines the input vector containing two elements
- `N`
  → the target vector (the one we do labeling before)
- `L`
  → define the graph limits [Xmin Xmax Ymin Ymax]
- `plotpv (M,N,L)`
  → this command will basically plot the inputs and targets vector within the limit sets
- `[net,y,e] = newp([-1 1;-1 1],1);`
  → this command will create a single perceptron with two inputs element ranging from [-1 1] and [-1 1] containing one neuron
- `net.adaptParam.passes = N`
  → the network will adapt to N numbers of passes to identify the relationship between the inputs and target signals. Larger N will cause error to be very small
- `[net,y,e] = adapt(net,M,N)`
  → allow the network to adapt with the inputs and target vectors
- `mse(e)`
  → Calculate the mean square error for the network
- `plotpc(net.IW{1},net.b{1})`
  → this command will plot the boundary line by creating a single perceptron with inputs received from M.

D.2.5 Example if net.adaptParam.passes is very small

```
net.adaptParam.passes = 20 → Pasteurized
net.adaptParam.passes = 15 → Unpasteurized
```



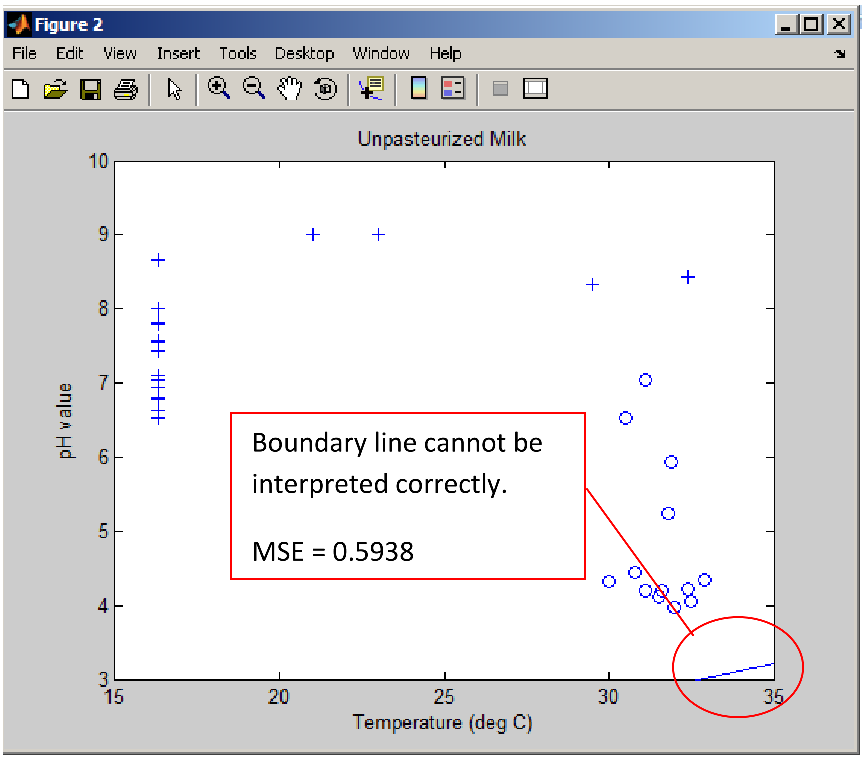


Figure D.2 Small net.adapt.Param.passes

D.3 Second Experiment

D.3.1 Results

		A (Room/Pasteurized)		
Date	Time	pH value	Temp (deg C)	Label
26/10/2012	1030am	7.02	30.4	1
27/10/2012	520pm	6.98	31.9	1
27/10/2012	1135am	6	31.6	0
27/10/2012	523pm	5.98	33	0
27/10/2012	11pm	5.46	32.4	0
28/10/2012	820am	5.18	30.7	0
28/10/2012	930am	5.2	31.1	0
28/10/2012	350pm	5.17	34.7	0
28/10/2012	7pm	5.16	32	0
28/10/2012	920pm	5.12	31.3	0
29/10/2012	230am	5.11	30.4	0
29/10/2012	915am	5.09	29.9	0
29/10/2012	1210pm	5.11	30.1	0

- 1 : Good
- 0 : Bad

Table D.6 pH and Temperature for Pasteurized Milk (Room)

		B (Cold/Pasteurized)		
Day	Time	pH value	Temp (deg C)	Label
26/10/2012	1030am	7.02	30.4	1
27/10/2012	1140am	7.18	6.6	1
27/10/2012	610pm	7.17	8.8	1
27/10/2012	9pm	7.22	8	1
27/10/2012	1055pm	7.24	8.1	1
28/10/2012	934am	7.22	7.7	1
28/10/2012	1030am	7.17	7.7	1
28/10/2012	357pm	7.06	31.4	1
28/10/2012	7pm	7.07	30.8	1
28/10/2012	915pm	7.07	30.7	1
29/10/2012	225am	6.29	30.2	0
29/10/2012	915am	5.89	9.8	0
29/10/2012	1215pm	5.88	10.5	0
29/10/2012	5pm	5.94	11.3	0
29/10/2012	950pm	5.93	9.6	0
29/10/2012	1115pm	5.94	10	0
30/10/2012	815am	5.92	9.4	0
30/10/2012	945am	5.91	9.6	0
30/10/2012	1050am	5.91	9.6	0
30/10/2012	320pm	5.92	10.7	0
30/10/2012	930pm	5.89	10.5	0
31/10/2012	1am	5.86	10.4	0
31/10/2012	730am	5.83	9.1	0
31/10/2012	130pm	5.82	9.7	0
31/10/2012	750pm	5.81	10.5	0
01/11/2012	1am	5.83	8.6	0
01/11/2012	640am	5.82	9.4	0

- 1 : Good
- 0 : Bad

Table D.7 pH and Temperature for Pasteurized Milk (Cold)

		C (Room/Unpasteurized)		
Day	Time	pH value	Temp (deg C)	Label
5/10/2012	11pm	7.69	16	1
6/10/2012	2am	6.87	30	1
6/10/2012	5pm	6.82	31.9	0
6/10/2012	840pm	6.76	31.2	0
6/10/2012	945pm	6.59	31.2	0
7/10/2012	1003am	6.12	30.2	0
7/10/2012	1116am	6.1	30.8	0
7/10/2012	1pm	6	31.3	0
7/10/2012	430pm	5.8	31.2	0
7/10/2012	850pm	5.65	31	0
8/10/2012	118am	5.62	30.3	0
8/10/2012	1pm	5.5	32.2	0
8/10/2012	10pm	5.45	31	0
8/10/2012	1115pm	5.37	31	0
9/10/2012	540pm	5.17	31.8	0
9/10/2012	1045pm	5.06	31	0
10/10/2012	220am	5.02	30.8	0

- 1 : Good
- 0 : Bad

Table D.8 pH and Temperature for Unpasteurized Milk (Room)

		D (Cold/Unpasteurized)		
Day	Time	pH value	Temp (deg C)	Label
5/10/2012	11pm	7.69	16	1
6/10/2012	2am	6.9	6.7	1
6/10/2012	5pm	6.86	2	1
6/10/2012	840pm	6.84	2.3	1
6/10/2012	945pm	6.82	2.3	1
7/10/2012	1003am	6.8	1.7	1
7/10/2012	1116am	6.8	1.8	1
7/10/2012	1pm	6.79	1.5	1
7/10/2012	430pm	6.83	0.6	1
7/10/2012	850pm	6.83	0.8	1
8/10/2012	118am	6.82	0.2	1
8/10/2012	1pm	6.8	0.5	1
8/10/2012	10pm	6.8	0.7	1
8/10/2012	1115pm	6.83	0.2	1
9/10/2012	540pm	6.82	0.1	1
9/10/2012	1045pm	6.8	1	1
10/10/2012	220am	6.83	0.8	1
12/10/2012	630am	5.95	30.5	0
12/10/2012	910am	5.87	5.2	0
12/10/2012	12pm	5.83	1.3	0
12/10/2012	3pm	5.82	1.3	0
12/10/2012	8pm	5.8	0.9	0
12/10/2012	11pm	5.81	1.2	0
13/10/2012	1am	5.8	1	0
13/10/2012	9am	5.76	0.5	0
13/10/2012	12pm	5.75	0.6	0
13/10/2012	5pm	5.75	0.6	0
13/10/2012	10pm	5.74	0.8	0
14/10/2012	1230am	5.75	0.7	0
14/10/2012	920am	5.74	0.7	0
14/10/2012	1220pm	5.73	0.9	0
14/10/2012	3pm	5.73	1.1	0
14/10/2012	730pm	5.73	1	0
14/10/2012	11pm	5.72	1.1	0

- 1 : Good
- 0 : Bad

Table D.9 pH and Temperature for Unpasteurized Milk (Cold)

D.3.2 Observations

From the experiments, we also have created a table discussing on the physical changes of the milk where we can come up with a conclusion on deciding whether the milk remains good or spoilt after few days of experiment.

Environment	Observation/Characteristics
Room Temperature	• Both pasteurized and unpasteurized become spoilt after half a day ➢ Give out a sour smell ➢ Curdles and yellowish in colour • pH drops are obvious for pasteurized milk whereas it is not very major for unpasteurized milk
Cold Temperature (Good Milk)	• Both pasteurized and unpasteurized milk are able to maintain their pH and freshness • Unpasteurized milk shows some physical changes: ➢ Thicker at the top ➢ Smell like cheese • Both types of milk still drinkable even though the unpasteurized milk had some physical changes
Cold Temperature (Spoilt Milk)	• Both pasteurized and unpasteurized become spoilt after half a day ➢ Give out a sour smell ➢ Curdles and yellowish in colour • pH drops are obvious for pasteurized milk whereas it is not very major for unpasteurized milk • pH value can be maintained after milk are put back into fridge

Table D.10 Observations and Characteristics of Milk

D.3.3 Discussions on Results and Observations

From the results and observations that we have obtained, we can say that after half a day, the milk that was being placed at room temperature whether pasteurized or unpasteurized already spoilt. We come to this conclusion as we already discussed the physical changes that would determine the freshness of milk by observing their taste, smell, color and texture. Apart from that, we could also see there were drastic changes in pH value of the milk after few days exposed to room temperature. Thus, we can say that the milk that have been put in room temperature become spoilt very fast due to the higher bacteria growth rate and activity which in turns dropped the pH value as well as changed in its physical properties.

As for the milk that was stored in the refrigerator, we can say that for the pasteurized milk, it remains fresh until the end of experiment. We can say that based on the properties of the pasteurized milk that does not change throughout the experiment. This maybe the effect of the temperature in the refrigerator that is very cold; around 0 to 10 degrees Celsius, that limits the bacteria activities.

Whereas for the, unpasteurized milk under cold temperature, it was also able to retain its freshness as the pasteurized milk. However, after few days we can see that it was nearly become spoilt as there are some obvious changes in its physical characteristics that give out a cheesy smell and forming two layers. Perhaps, the cold temperature of the refrigerator has limited the bacteria activity which makes it able to remain fresh for a few more days.

Meanwhile, for the cold milk that was exposed to the room temperature, they became spoilt after half a day as expected. The milk became sour and also started to curdle as well as changing color. On the other hand, we can also see drastic dropped in pH value when the milk become bad. Once the milk spoilt, they are put back into the refrigerator where we can see the pH value continue to drop a little before it settles down. Again, the cold temperature of the refrigerator might has limited the bacteria activity that prevents the milk to become much spoiler.

The threshold pH value for the transition between good to spoil has also become another discussion in this project. From the results obtained, we can easily say that for the pasteurized milk, the threshold pH value for it to become spoilt can be approximately around pH 6.5. However, for the unpasteurized milk, it is very hard to determine the threshold value since the pH value between good and spoilt overlaps each other at around pH 6.84. This might due to the cold temperature effect that inhibits the bacteria activity which is supposed to make the milk bad at around pH 6.84 if placed in room temperature. With regards to this situation, we can take pH 6.84 as the threshold value for the unpasteurized milk if the bacteria were active.

In addition, the difference between the threshold pH value of pasteurized and unpasteurized is maybe due to the treatment received by the pasteurized milk that helps to lower the threshold value and increase the lifespan of the milk.

D.3.4 Conclusion and Recommendation

From the experiment that we have conducted, we believed that the pH sensor which represents the e-tongue alone cannot tell us whether the milk had become spoilt or not. We can only assume the threshold value for the milk to become bad but it might vary depending on situation especially for the unpasteurized milk where in this experiment we found it hard to be determined. Perhaps, a more focused study can be conducted on the transition of the milk from good to bad so we can have better threshold value especially for unpasteurized milk.

Meanwhile, we are also still depending on the physical changes in the milk such as the smell and color to decide on the freshness of the milk. This basically shows the limitation of using e-tongue with only pH as the sensor as there is only pH value to be evaluated. Thus, there comes the e-nose which basically will be used to detect the gas released by the milk. This is perhaps can increase the performance of the e-tongue to obtain a better result for classifications.

D.4 Data Classification in Neural Network (Second Experiment)

D.4.1 Matlab coding

```
% ------------------ Coding Starts -------------------- %

clear all;
clc;

%--------------- Pasteurized Milk -------------%

M = [31.9 31.6 33 32.4 30.7 31.1 34.7 32 31.3 30.4 29.9 30.1 6.6 8.8
8 8.1 7.7 7.7 31.4 30.8 30.7 30.2 9.8 10.5 11.3 9.6 10 9.4 9.6 9.6
10.7 10.5 10.4 9.1 9.7 10.5 8.6 9.4;
6.98 6 5.98 5.46 5.18 5.2 5.17 5.16 5.12 5.11 5.09 5.11 7.18 7.17
7.22 7.24 7.22 7.17 7.06 7.07 7.07 6.29 5.89 5.88 5.94 5.93 5.94
5.92 5.91 5.91 5.92 5.89 5.86 5.83 5.82 5.81 5.83 5.82];

N = [1 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0];

L = [5 36 4.5 8];

figure (1)
plotpv (M,N,L)
title ('Pasteurized Milk')
xlabel('Temperature (deg C)')
ylabel('pH value')

net=newff(M,N,3,{'logsig' 'purelin'});
net.trainParam.lr = 0.5;
net.trainParam.mc = 0.9;
net.trainParam.epochs = 70;
net.trainParam.goal = 1e-4;
net=train(net,M,N);

display('Pasteurized Milk')
new = [30.5 6;6.2 6]
output = sim (net,new)

[net,y,e] = adapt(net,M,N);
display('Mean Square Error for Pasteurized')
mse(e)
```

```
%--------- Unpasteurized Milk ------------%

P = [30 31.9 31.2 31.2 30.2 30.8 31.3 31.2 31 30.3 32.2 31 31 31.8
31 30.8 6.7 2 2.3 2.3 1.7 1.8 1.5 0.6 0.8 0.2 0.5 0.4 0.2 0.1 1 0.8
30.5 5.2 1.3 1.3 0.9 1.2 1 0.5 0.6 0.6 0.8 0.7 0.7 0.9 1.1 1 1.1;
6.87 6.82 6.76 6.59 6.12 6.1 6 5.8 5.65 5.62 5.5 5.45 5.37 5.17 5.06
5.02 6.9 6.86 6.84 6.82 6.8 6.8 6.79 6.83 6.83 6.82 6.8 6.8 6.83
6.82 6.8 6.83 5.95 5.87 5.83 5.82 5.8 5.81 5.8 5.76 5.75 5.75 5.74
5.75 5.74 5.73 5.73 5.73 5.72];

Q = [1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];

R = [-1 33 4.5 7.5];

figure (2)
plotpv (P,Q,R)
title ('Unpasteurized Milk')
xlabel('Temperature (deg C)')
ylabel('pH value')


net=newff(P,Q,3,{'logsig' 'purelin'});
net.trainParam.lr = 0.5;
net.trainParam.mc = 0.9;
net.trainParam.epochs = 100;
net.trainParam.goal = 1e-4;
net=train(net,P,Q);

display('Unpasteurized Milk')
new = [7;6.95]
output = sim (net,new)

[net,y,e] = adapt(net,P,Q);
display('Mean Square Error for Unpasteurized')
mse(e)



% -----------------Coding Ends--------------------%
```

D.4.2 Results Plotting and Discussion

D.4.2.1 Pasteurized Milk

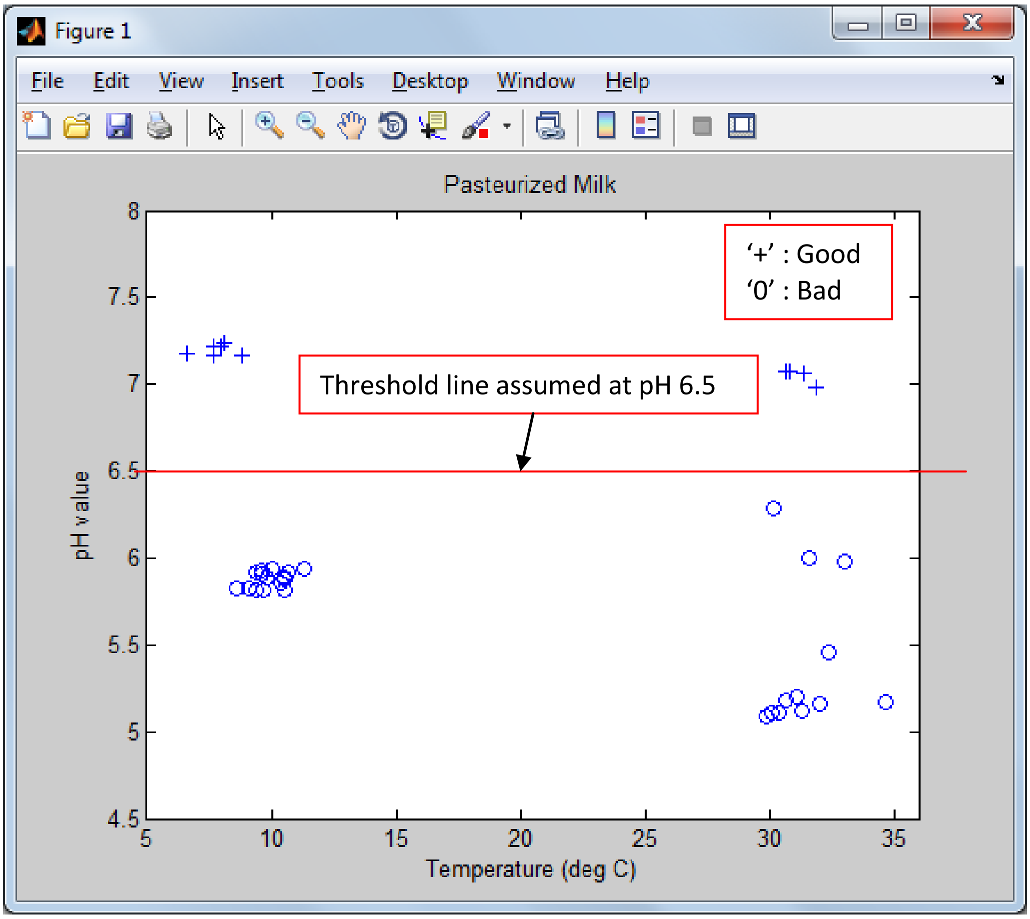


Figure D.3 Results plotting for Pasteurized Milk

From the diagram, we can see that both of the good and spoilt milk can be separated into two different sectors visually. However, by making an assumption that the threshold value is pH 6.5, it is safe to say that below this value the milk already spoilt and may not be consumed.

D.4.2.2 Unpasteurized Milk

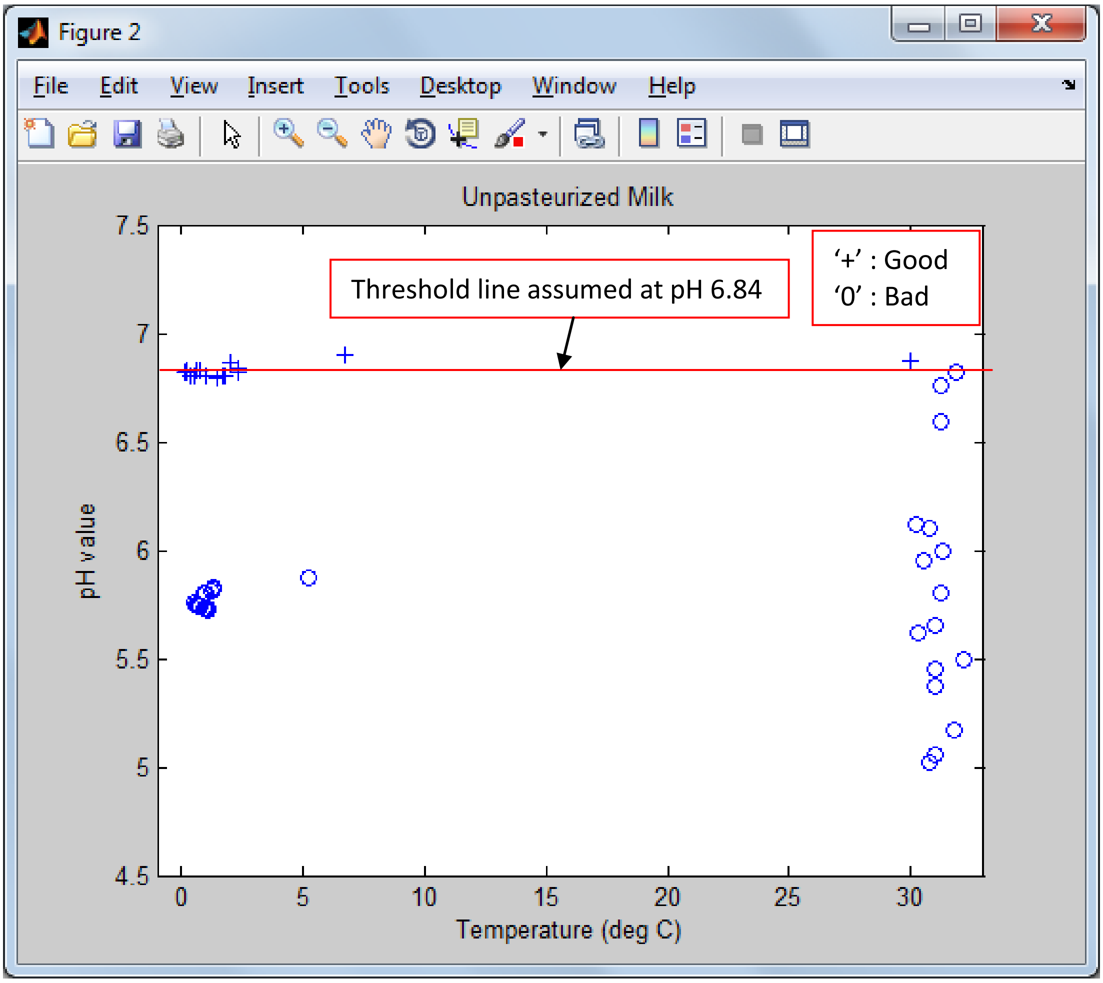


Figure D.4 **Results plotting for Unpasteurized Milk**

From the diagram, we can observe that it is very hard to determine whether the milk placed in the cold temperature still good or bad since some of the readings are below the assumed threshold line. However, when we took into account the properties; taste and color ,of the milk stored at cold temperature, we can say that it is still drinkable even though there are slight yoghurt smell and two layers are formed. Perhaps, the milk was supposed to become bad but the cold temperature inhibits the bacteria activity which makes the milk to be drinkable for few more days.

D.4.3 New Input Entry

The matlab codes written earlier also includes the part where a new measurement data can be tested by our trianed network. If a new set of data is keyed in, the Neural Network will automatically classify where the milk belong. By taking the pasteurized milk as an example, we could see how a new set of data is classified

Codes:

```
display('Pasteurized Milk')
new = [30.5 6 31.2 3;6.2 5.8 7 6.9]
output = sim (net,new)

[net,y,e] = adapt(net,M,N);
display('Mean Square Error for Pasteurized')
mse(e)
```

Results:

```
Pasteurized Milk

new =

   30.5000    6.0000   31.2000    3.0000  → Temperature
    6.2000    5.8000    7.0000    6.9000  → pH value


output =

    0.0021    0.0288    0.9800    0.9996  → 0 = Bad, 1 = Good

Mean Square Error for Pasteurized

ans =

  3.6100e-005        → Small value is good
```

From the results, we can see that the Neural Network are able to classify the new data into bad or good milk. The output layer shows that a nearly ‘0’ value is bad whereas a nearly ‘1’ value is good milk. By using the Neural Network, more data can be included later on to obtain a better classifications.

D.5 Overall Discussions

For the first experiment we can say that even though the data obtained was not very reliable at first place, we were still be able to classify the milk into good and bad through the Neural Network by using just a single perceptron. As to overcome the problems appeared during the first experiment, a follow up experiment have been made.

In the second experiment, we were using a new pH sensor which are more reliable for measurements. As an improvement, we were also using a MLP for the data classifications based on the measurements obtained from the second experment. The introduction of MLP have made the classifications much better where we were able to include new sets of measurements into our trained network. Apart from that, we were also managed to determine the threshold line for the milk to turn from good to bad. The threshold line obtained shows that the pasteurized milk has far lower threshold value compared to the unpasteurized milk. This in turn lengthen the shelf life of the pasteurized milk.

Overall, we could say that milk exposed to the room temperature will be spoilt after half a day due to high bacteria activities.Whereas, milk that is kept at a cold temperature is able to maintain their pH value which keeps the milk stay fresh. Moreover, we can observe that, a milk that are kept at cold temperature is able to maintain its freshness even though the pH already drops below the threshold value. Thus, we can say that a cold temperature will inhibit bacteria activity that helps milk to stay fresh for a longer time.

In addition, the use of Neural Network in Matlab has greatly helps in term of classifying the data. The Neural Network does not only able to classify the data based on the experiment we did, but also could be used to classify any future data if any new experiments are conducted.

SECTION E: CONCLUSIONS & RECOMMENDATIONS

The purpose of FYP II is basically to continue and improvise what we had left during the FYP1. Recently, a follow up experiment have been done to tackle the problem found during FYP 1. In the second experiment, a new pH sensor was introduced. Readings taken from this new sensor are far more accurate and stable. The sensor was also let to dip for about 5 to 8 minutes before being measured. A new thing that is being applied was to make the milk placed inside the refrigerator become spoilt by putting them at room temperature for one day and place back in refrigerator.

Same as in FYP 1, the data obtained will then be used with Neural Network in Matlab to classify this milk as good or bad. Previously, we were only using one perceptron to classify these data. As an improvement, in FYP 2, we were using multi-layer perceptrons which can classify the data much better. In addition, we also added a new feature in the codes where a new set of data can be included into the network for classifications.

Meanwhile, we managed to determine the threshold pH value when the milk turned bad. This was achieved based on the results of the experiment via the Neural Network where we found out that the threshold value for the pasteurized milk is lower compared to the unpasteurized milk. The lower threshold value might be due to the treatment that the pasteurized milk received that helps it to stay fresh for a longer time.

As the conclusion, I can say that the classification of milk by using e-tongue is promising. Some recommendations are provided below that can be very useful to enhance our FYP for future development.

Recommendations

i. Apply more types of sensors into our project. CO sensor which represents e-nose could give a major boost to the results obtained.
ii. Study that focus on the transition period when milk turn from good to bad can be done to get a better threshold value especially for the unpasteurized milk

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