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Abstract- The largest population of livestock in Africa is found in Ethiopia. The country produces about 3.2 billion liters of milk annually from 10 million milking cows. Yogurt processing is one of the ways to prolong the shelf life of milk. Thus a low-cost yogurt incubator suitable for small scale production which was equipped with a microcontroller was developed. The main components of the incubator include the microcontroller and temperature sensor, alarm circuit, power supply circuit, and the embedded program. The incubation chamber was made of a locally available ½ inch ordinary plywood. The components were assembled and installed after the incubation chamber was constructed. The operating temperature of the incubator was set at 42°C ($\pm 1^\circ\text{C}$). The incubator was tested using one liter of pasteurized cow's milk inoculated with *Lactobacillus* bacteria. The inoculated milk was placed in bottles and incubated for 24 hours. Results of the sensory test showed that the incubator produced a good quality yogurt comparable to that being sold in the area.

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DEVELOPMENT OF YOGHURT INCUBATOR FOR SMALL SCALE PRODUCTION USING PIC16F877A MICROCONTROLLER

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Development of Yoghurt Incubator for Small-Scale Production using PIC16F877A Microcontroller

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Abstract- The largest population of livestock in Africa is found in Ethiopia. The country produces about 3.2 billion liters of milk annually from 10 million milking cows. Yoghurt processing is one of the ways to prolong the shelf life of milk. Thus a low-cost yoghurt incubator suitable for small scale production which was equipped with a microcontroller was developed. The main components of the incubator include the microcontroller and temperature sensor, alarm circuit, power supply circuit, and the embedded program. The incubation chamber was made of a locally available ½ inch ordinary plywood. The components were assembled and installed after the incubation chamber was constructed. The operating temperature of the incubator was set at 42°C (±1°C). The incubator was tested using one liter of pasteurized cow's milk inoculated with *Lactobacillus* bacteria. The inoculated milk was placed in bottles and incubated for 24 hours. Results of the sensory test showed that the incubator produced a good quality yoghurt comparable to that being sold in the area.

Keywords: microcontroller, incubator, yoghurt, temperature sensor, relay driver, relay, heater and buzzer.

I. INTRODUCTION

In 2010, it was reported that Ethiopia had the largest population of livestock in Africa consisting of 49.2 million cattle, 46.8 million sheep and goats, and 9 million pack animals. It also produces approximately 3.2 billion liters of milk per year from 10 million milking cows [1]. Eighty-three percent of all milk produced in Ethiopia comes from cattle and the remainder comes from goats and camels [2]. The shortage of crossbreed dairy cows, lack of capital by dairy producers, inadequate animal feed resources, unimproved animal husbandry systems, inefficient and inadequate milk processing materials and methods, low milk production and supply to milk processing centres and poor marketing and market information systems are some of the main reasons for the low productivity of livestock production system in Ethiopia [3].

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Yoghurt processing is one of the ways to prolong the shelf life milk. At present, rural farmers in Ethiopia process yoghurt using the traditional method which takes about 2 to 3 days in places where temperature is favourable. In highland areas of Ethiopia, production of yoghurt is very limited owing to cold temperature. This problem can be addressed with the availability of low-cost yoghurt incubator that can be made using locally available materials and technology. The incubator shortens the incubation time of yoghurt from 2-3 days to about 12 to 24 hours and thus help milk producers in increasing the yoghurt production in the area.

This research was aimed to develop an incubator, equipped with a temperature microcontroller for small-scale yoghurt production in Ethiopia. The output of the research is expected to benefit small food entrepreneurs and local dairy farmers engaged in yoghurt processing.

II. HARDWARE AND SOFTWARE COMPONENTS OF THE YOGHURT INCUBATOR

The yoghurt incubator consist of five main component namely, temperature sensor, microcontroller, relay and relay driver, heater and buzzer. Figure 1 shows the simplified block diagram of the yoghurt incubator. The microcontroller is the heart of the system. It controls the buzzer and heater based on the embedded program stored in it. The temperature sensor detects the temperature inside the incubator and convert the temperature into analog voltage and send it to the microcontroller.

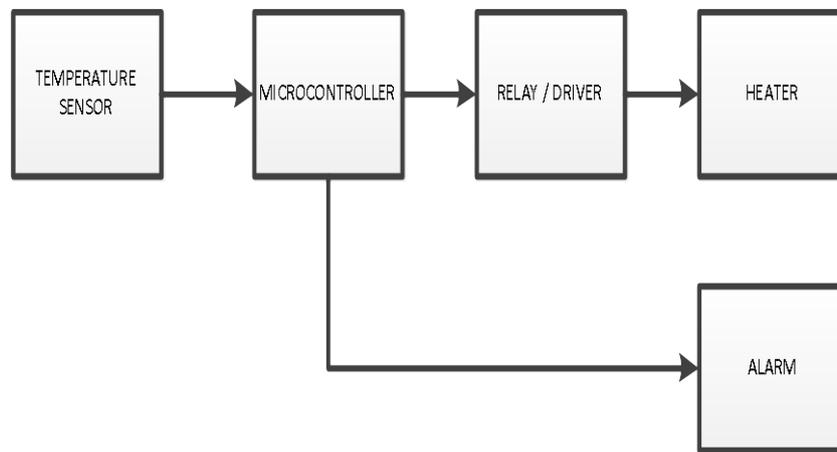


Figure 1 : The Hardware Block Diagram of Yogurth Incubator

a) The Microcontroller and Temperature Sensor

Figure 2 shows the schematic circuit diagram of the configuration of the PIC16F877A microcontroller. It uses a 4 MHz crystal oscillator with 22 pF ceramic capacitor as filter connected to the crystal oscillator. The connection of the oscillator and the filter capacitor is based on the microcontroller manufacturer configuration standard. From the PIC16F877A datasheet oscillator pin is directly connected with pin 13 and 14 as shown in Figure 2. The

LM35 temperature sensor was used to measure the temperature inside the yogurt incubator. It was used to maintain the average temperature of 42 (±1) degrees centigrade. The output terminal of the LM35 was connected to pin 2 of the microcontroller. This pin is the analog input of the said microcontroller. The LM35 sensor converts the temperature to analog voltage. The converted analog voltage is sent to the analog input of the microcontroller for checking the desired cut-off voltage to turn on or off the heater circuit.

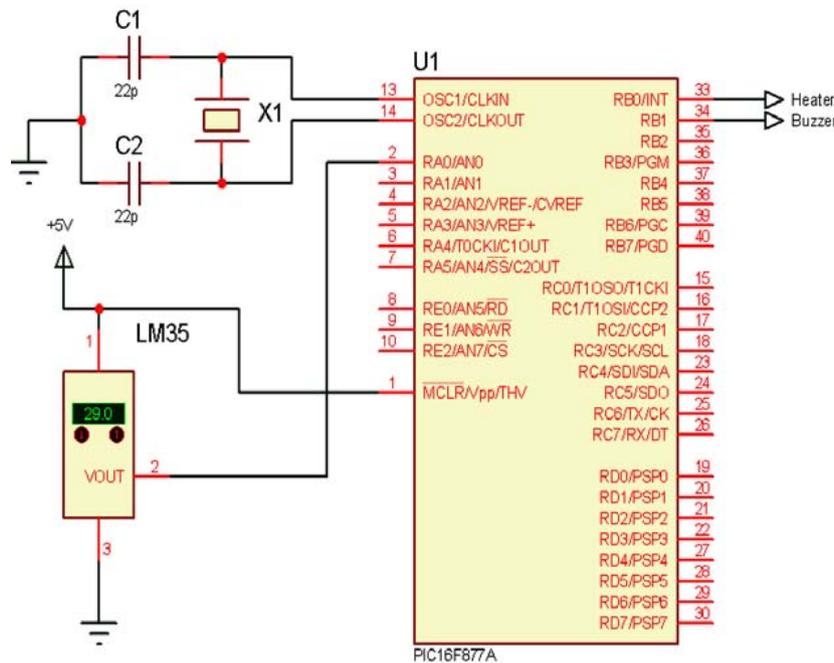


Figure 2 : The Microcontroller and Temperature Sensor Circuit

b) The Relay driver, Relay and Heater

Figure 3 shows the relay driver circuit connected to the relay to control the heater. A 100 watt 220 Vac incandescent bulb was used as the heater of the incubator. The 9013 general purpose NPN transistor was used in the circuit. From the datasheet it has a

collector current of 1000 mA. The relay coil operates at 12 VDC supply.

$$I_b = \frac{I_c}{\beta}$$

Where:

Ic = Relay coil current

$$\text{Relay Coil Current} = \frac{\text{Coil Voltage}}{\text{Coil Resistance}}$$

Based on the resistance test, the coil resistance was found out to be 100 ohms.

Thus; Relay coil current is equal to 120 m. and Ib = 1.2 mA

$$R1 = \frac{5 - 0.7}{1.2 \text{ mA}}$$

R1 = 3.6 KΩ

$$\text{Current of the bulb} = \frac{\text{Watt}}{\text{Volt}}$$

Thus;

Current of the bulb is approximately 455 mA

Since the relay coil current is 120 mA, a 9013 general purpose NPN transistor can be used. The D1 as flywheel diode that protects the transistor uses 1N4007 rectifier diode. From the datasheet, it has a maximum current of 1000 mA and the peak inverse voltage of 600 volts. A 5 ampere relay contactor was used in the circuit.

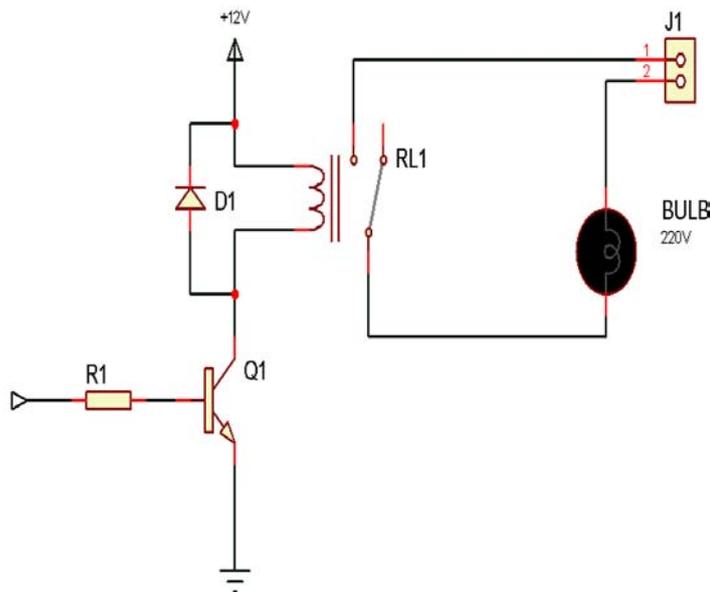


Figure 3 : The Relay Driver and Relay connected to Heater

c) The Alarm Circuit

A small buzzer with a 5 volts DC supply was used in the project as shown in Figure 4. The buzzer was used to produce a sound to alarm the user that the yogurt is ready to be removed from the incubator. This this was done to prevent excessive fermentation of

yogurt. The 9013 general purpose transistor was also used in the circuit to drive the buzzer. The buzzer operates at a maximum current of 100 mA. The component used in the circuit is the same as the relay driver since less amount of current is required by the buzzer.

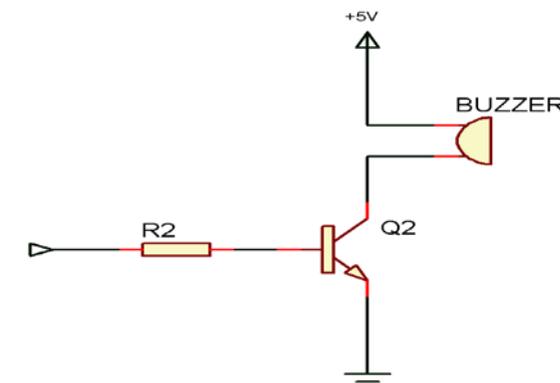


Figure 4 : The Alarm Circuit

d) The Power Supply Circuit

The power supply circuit is shown in Figure 5. The 220 Vac supply coming from the convenience outlet was converted into 12 and 5 volts DC. These voltages were required for the different circuits to operate

properly. The 12 volts DC was used by the relay while the 5 volts was used by the microcontroller and the alarm circuit. The stepdown transformer was connected directly to the 220Vac power supply. The transformer used in this project was 750 mA 12 volt center tap.

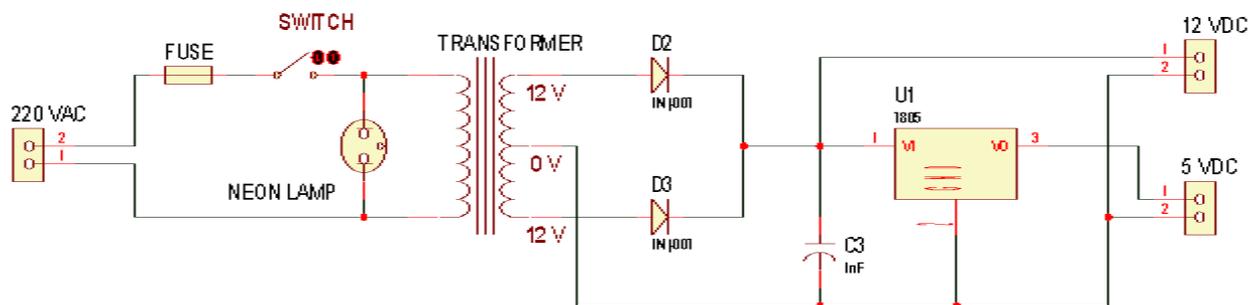


Figure 5 : The Power Supply Circuit

The power supply uses a full wave rectifier circuit. The LM7805 voltage regulator was used to maintain a 5 volt DC supply to the microcontroller and alarm circuit. Based from the datasheet the LM7805 regulator has a maximum current of 1000 mA. Since the total load current required for 5 volts DC supply was approximately 150 mA, LM7805 was used. The total current required for the whole hardware was approximately 300 mA. A 0.5A fuse was connected to the primary input of the transformer. The neon lamp 220Vac was used as power indicator for the power supply circuit.

e) The Embedded Program

Figure 6 shows the flowchart diagram of the embedded program used in the microcontroller. The program was written using MikroC v.8.0. The first step in writing the program was to configure the different ports of the microcontroller. Port RA0 on the microcontroller was configured as analog input that will read the output of the LM35 temperature sensor. Ports RB0 and RB1 were configured as outputs of the microcontroller that will be used to turn on and off the heater and alarm circuit, respectively. After the configuration on all the ports the heater will be turned on automatically. And the temperature inside the incubator will be measured using the LM35. The analog output of this sensor will be read and converted into digital signal using the ADC module of the microcontroller. If the temperature is less than 42 degrees Celsius the heater will still be on. And if the temperature is equal or greater than 42 degrees Celsius the heater will be off. The timer in the program will continue for eight hours. If the timer reaches 8 hours the alarm will be turned on to signify that the yogurt is ready to be remove from the incubator.

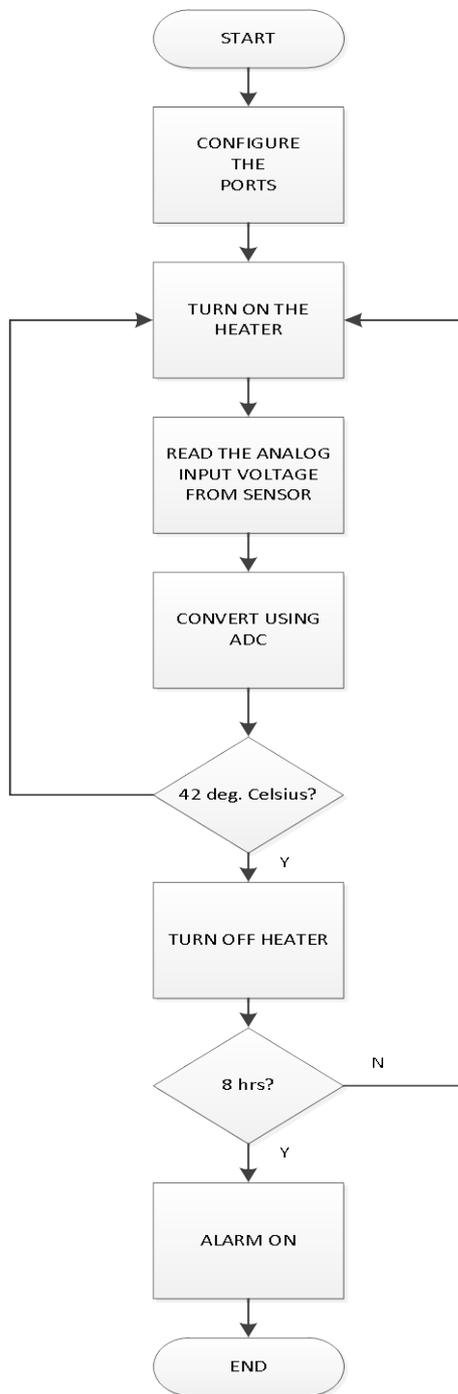


Figure 6 : The Flowchart Diagram of the Embedded Program

III. IMPLEMENTATION RESULTS

The final implemented output is discussed in this section. The yogurt incubator has two main components, the hardware and the embedded program. Figure 7 shows the hardware controller component with the power supply. The entire components were installed using the PCB.



Figure 7 : The Hardware Controller Component

The different hardware circuits receive power supply directly from the convenience outlet via the transformer and regulator circuit.

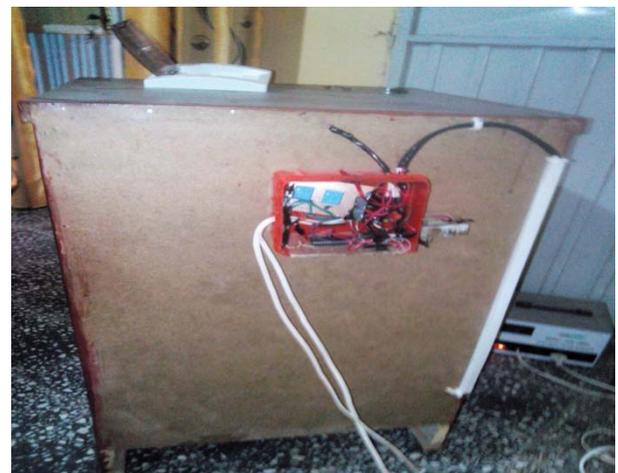


Figure 8 : The Hardware Controller Installation

The hardware controller was installed at the back of the yogurt incubator as shown in Figure 8. This was done to facilitate maintenance of the controller.

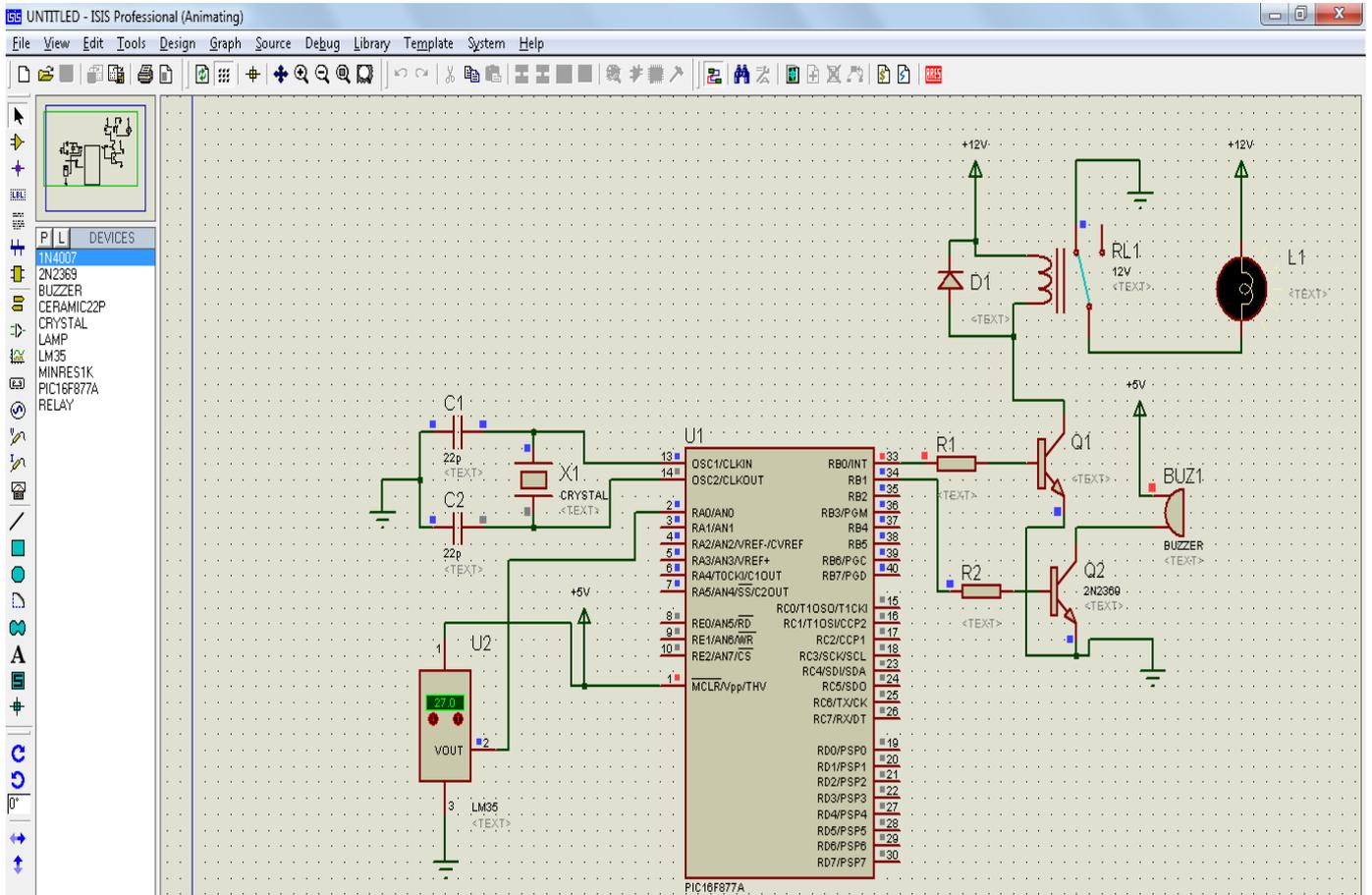


Figure 9 : The Hardware Controller Simulation in Proteus

The result of the hardware controller simulation done in Proteus is shown in Figure 9. The simulation of the embedded program and the simulation run was based on the operating temperature requirement of the yogurt incubator. When the temperature is under 42 degrees celsius the relay is turned on and when it is equal or more than 42 degrees celsius the relay is turned off. When the timer reaches 28800 seconds which is equal to 8 hours, the alarm is turned on.

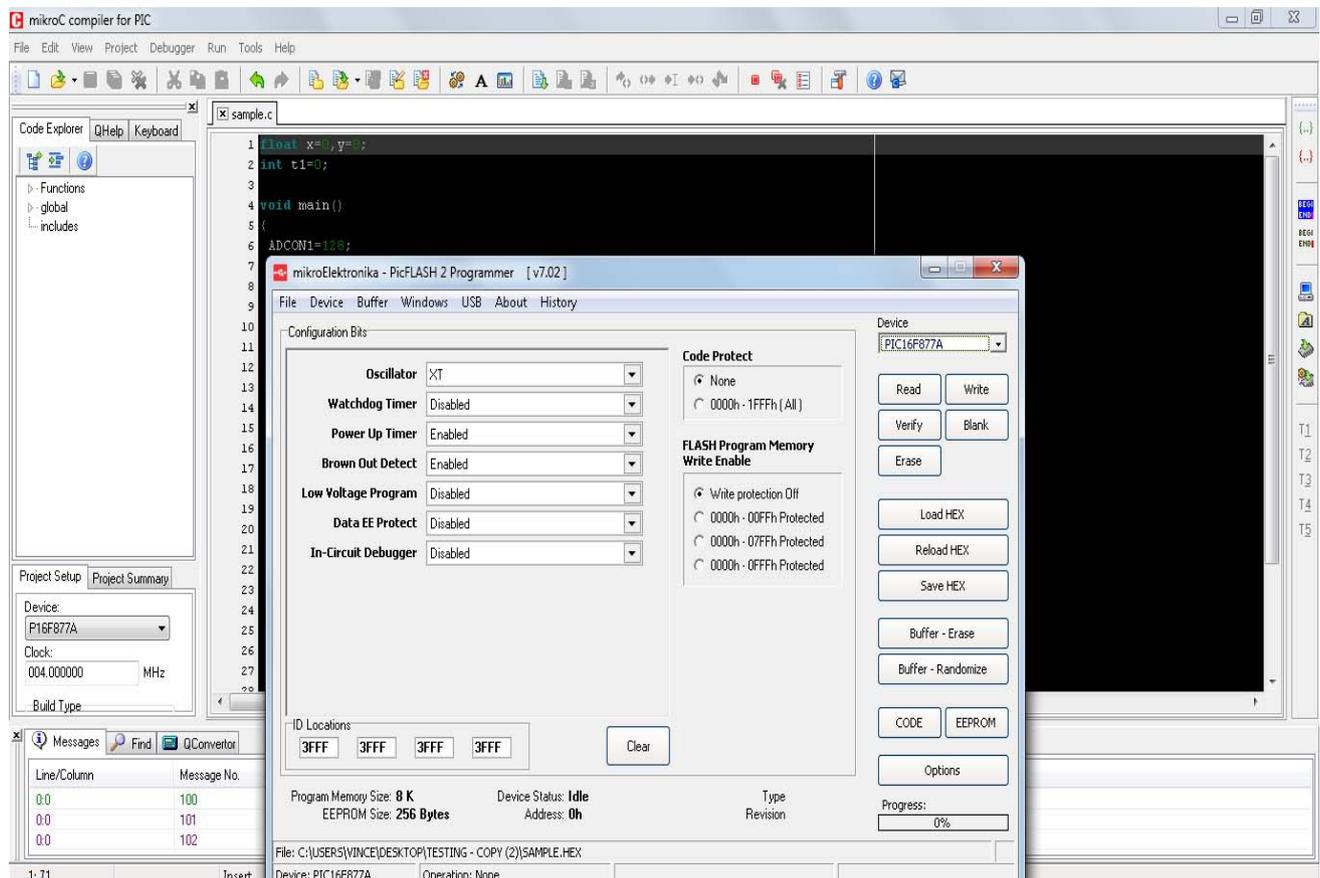


Figure 10 : The Compilation of the Embedded Program using MikroC

The embedded program was written and compiled using MikroC as shown in Figure 10. The hardware needs a hex file that will be loaded to the microcontroller. By using MikroC, the hex file is generated and made ready for loading into the microcontroller.

Figure 11 shows the prototype yogurt incubator. All the hardware controllers were connected to the incubation box. The front side consists of a small rectangular glass mounted on the door of the incubator. The incubator can hold about 100 bottles per batch containing 150ml each.



Figure 11 : The Yogurth Incubator

The samples of yogurt produced using the incubator are shown in Figure 12. Results of the preliminary sensory test showed that the taste of yogurt produced was comparable to that of the commercial yogurt being sold in the area.



Figure 12 : Samples of yogurt produced using the incubator

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