
MICROCONTROLLER-BASED FRUIT DRYING SYSTEM

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ABSTRACT

An automated fruit drying system for which a PIC microcontroller is the main processing unit is presented in this paper. A controlled environment suitable for fruit drying is developed within a closed chamber and the drying is a three step process. First, the infrared light is used internally to preheat the fruit to speedily remove the water content inside the fruit for fast drying. Second, hot air of a specified temperature is blown inside the chamber to maintain the humidity below a specified level and exhaust the humid air of the chamber. Third, the microcontroller disconnects the power to the chamber after the moisture content of the fruits is removed to minimal. Experiments were conducted with 1kg of fresh tomatoes at three different temperatures (40, 50 and 60 °C) and constant relative humidity of 30% RH. The results obtained indicate a significant reduction in the drying time relative to conventional methods with better preservation of quality.

INTRODUCTION

Fruits are seasonal crops and perish quickly. For a long time, open-air sun drying has been used to preserve fruits (Aliyu, 2008). This traditional method of open air drying makes use of direct solar and wind energy. Although this traditional method is cheap and simple, considerable loss in quality may occur due to various influences such as contamination by dust and insect infestation, losses in nutritional value due to overheating from ultraviolet radiation of the sun, over drying and losses in quantity of dried product due to theft and vandalism from birds and other animals. In addition, the drying stage, which is the longest and most important, is uncontrolled.

Solar drying (Moyle, 1985) is an age-long method which has been used to dry fish, meat, cloth and has proven to generate high quality cash crops with low spoilage (Castaneda-Miranda et al, 2008). Although this method is cheap, easy and popular, its application is restricted by the long drying time and the need for a favourable weather. For example, 6- 9 weeks were required to dry grapes to a water content of 25- 35%, and further steps were required to dry them completely (Tulasidas, 1994).

Another popular method of fruit drying is the microwave system (Zhang et al, 2006, Li, 2004, Sanga et al , 2000, Tulasidas, 1994) which has several advantages including higher drying rate, shorter drying time, lower

energy consumption and better quality of the dried products. However, one of its main demerits is the inherent non-uniformity of the electromagnetic field within an MW cavity (Zhang et al, 2006). In many cases, successful outcome of microwave heating of fruits with high moisture contents depends on the uniformity of heating. Although this problem can be alleviated by means of waveguides and a rotating tray (Cohen & Yang, 1995), the applicable energy level is limited (Zhang et al, 2006).

Marjan et al (2010) developed a microcontroller-based multifruit dryer system which was used to dry banana, apple and plume. The system used two physical properties, viz. temperature and humidity which may result in inefficiency in different environmental conditions.

Other methods in use include freeze-drying (Mohammadi, 2001), Vacuum drying (Li, 2004) and hot-air convective drying (G & Shah, 2009), among others (Misha et al, 2013).

In this paper, a microcontroller-based fruit drying system is presented. Its main features include a drastically reduced drying time due to penetration of infrared rays and efficient operation of the drying process. The dryer can be used for drying many kinds of fruits and very low moisture content is attained compared to several other drying methods. Microcontroller (PIC) is the main processor for the proposed system. A controlled environment suitable for

fruit drying is developed within a closed chamber and is a three step process. Firstly, the infrared light is used to internally heat the fruit to speedily remove the water content inside the fruit for fast drying. Secondly, hot air of a specified temperature is blown inside the chamber to maintain the humidity below a specified level and exhaust the humid air of the chamber. Thirdly, the microcontroller disconnects the power to the chamber after the weight of the fruits (tomatoes/pepper) is reduced to a fraction of its original weight depending on the time taken. This activates a buzzer for duration of ten seconds to indicate the end of the drying process. Fruit drying system is an equipment that removes liquid, generally water from fruit. The drying section gets its control from the PIC microcontroller which puts on/off the heating elements. This is done dynamically and in synchronous manner.

The system, which is enclosed in a single casing, runs from 220V AC power supply. A block diagram of the system is shown in Fig. 1. The block diagram shows the functional parts of the system, from the input unit to the processing unit, drying unit and the LCD display unit. The sensors will sense temperature of the fruit and the humidity inside the chamber. Power control unit will include control variables of the system, which can control the heater as the time constant of the heater is high. The output unit comprises the heater, hot air blower and liquid crystal display (LCD).

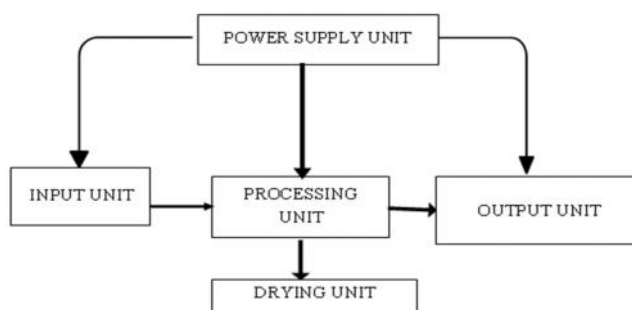


Fig.1: Block Diagram of the System

SYSTEM DESIGN

The circuit diagram of the proposed fruit dryer is shown in Fig. 2. The design was carried out according to the units shown in Fig. 1. The input unit includes the keypad and the pull-up resistors. This unit serves as the user interface.

The processing unit consists of the microprocessor, the sensors and the relay switching section. The microcontroller used is the Microchip[®] PIC16F877A microcontroller and it is the heart of the

board. It is an 8-bit microcontroller with 8k×14-bit flash program memory, 368 bytes of RAM and many other extra peripherals like ADC, universal synchronous/asynchronous receiver/transmitter, master synchronous serial port, timers, compare, capture, pulse-width modulation modules and analogue comparators. It is based on the reduced instruction set computer (RISC) architecture.

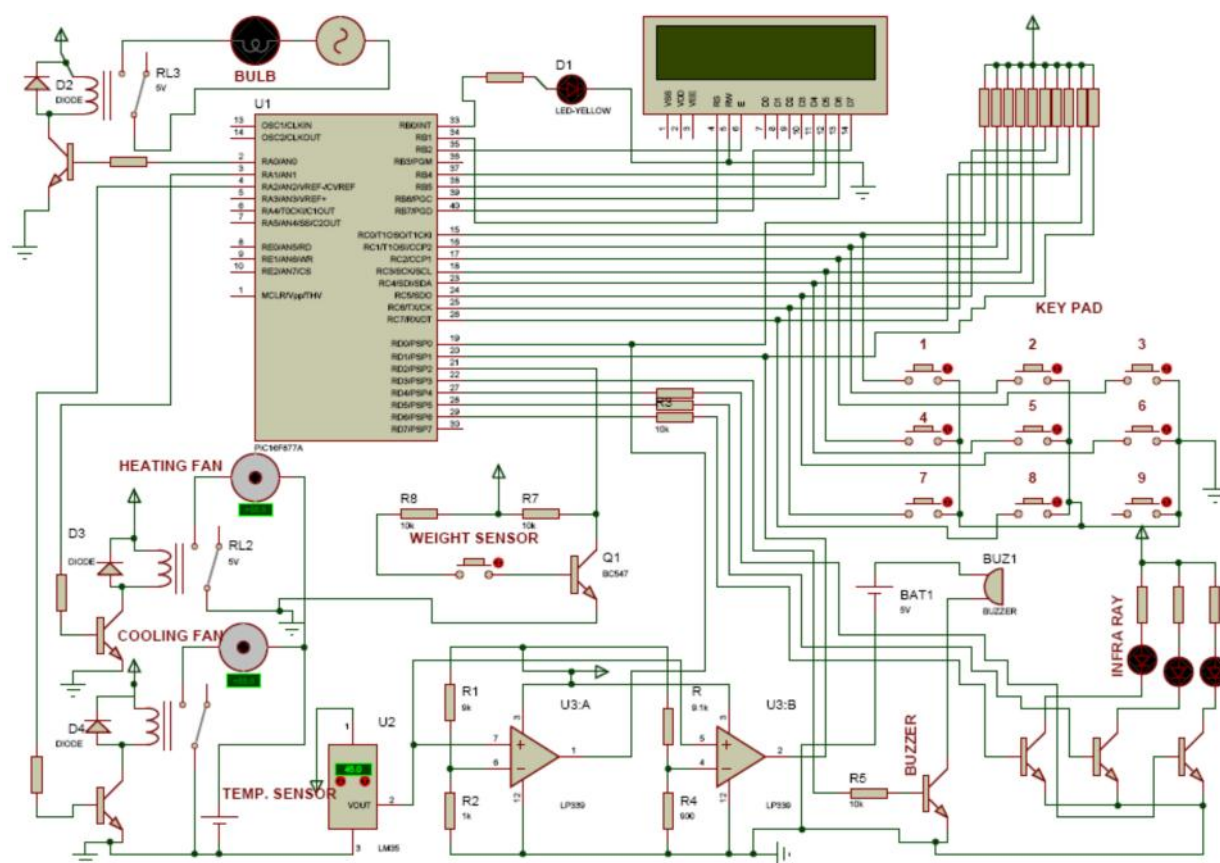


Fig. 2 Circuit diagram of the proposed system

The sensors used are LM35 which is a temperature sensor calibrated in degree centigrade and the weight sensor which consists of a weight balance connected to a transistor switched off when the load weight reaches the desired value. Three different relay

circuits were used with one relay each designed to control heating element, heating fan and cooling fan. A transistor was placed between each relay and the microcontroller to limit the current drawn from the IC.

Components selection was in all cases made using basic electronic design techniques.

The drying unit consists of the heating element and heating chamber section. Both were developed according to the following.

$$\text{Energy} = mC_p(T_f - T_i)$$

$$\text{Energy} = Pt$$

Where

P = Power required in Watts.

t = Time taken in seconds

m = Mass of the tomatoes = 1 kg

C_p = Specific heat of air at constant pressure = 420 J/kg/°K

T_f = Final temperature = 60°C

T_i = Initial Temperature = room temp = 25 °C

Assume that a 1 kg of tomatoes is to be dried for 1 min. Since the maximum temperature which the

$$\begin{aligned} \text{Heat energy} &= 1 \times 420 \times (60 - 25) \\ &= 14700 \text{ Joules} \end{aligned}$$

100 W incandescent bulbs are used as the heating element in the prototype. Therefore the power required is doubled, because some of the energy is converted to light energy (Desa, 1970) and the amount of heating element and infrared needs will be larger because the heating systems will not be 100% efficient. There are some losses in converting electrical power to infrared; there will be losses in transferring the heat energy from the emitter to the product that will be dependent on design of the heating enclosure and materials used in its construction. Consequently the

The specific heat capacity of water is given as 420 J/kg/°K.

The removal of water from a surface requires an amount of heat equal to the latent heat of the evaporation of water during the drying process and is given by

(1)

(2)

fruit can withstand without burning is 60 °C (Aliyu, 2008), the heat input requirement by equation (1)

$$\text{Power, } P = \frac{14700}{60} = 245 \text{ Watt}$$

installed power of infrared will be greater than the calculated heat requirement. Therefore 5 x 100 W bulbs were used.

The heating chamber is designed to accommodate the heater, infrared lamps, temperature sensor and the drying trays. Mild steel is used for the construction of both outer and inner surface of the chamber. The two walls are insulated to avoid heat loss to the surrounding. A cooling fan is mounted on the wall to serve as chimney to blow out the humid air.

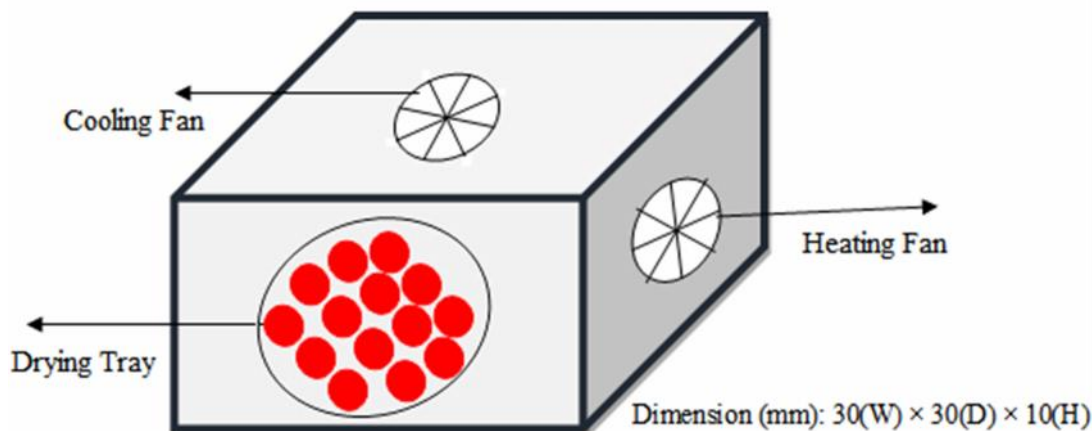


Fig. 3 Drying Chamber

The output unit consists of the LCD, alarm unit and associated circuitry.

The power supply unit consists of 220V from AC mains that power the heating Element (40W bulb) and 5V regulated power supply that power the circuit.

The flowchart is shown in Fig. 4. The program was written in Assembly language and compiled using Hitech C cross compiler in MPLAB IDE.

TEST RESULTS AND DISCUSSION

Fresh tomatoes were obtained. The samples were sorted out and over-ripe or spoilt samples were discarded in order to prevent parasitic contamination. The good samples were then cut into smaller sizes, and their initial weight of 1 Kg and moisture contents were

taken before drying. The drying operation was carried out in three different temperatures (40°C, 50°C & 60°C) at a constant relative humidity of 30%.

The drying was carried out by first of all loading the drying bin (tray) with 1kg of the fresh samples, allowed to dry for some time till the buzzer and LCD were activated. The measurement of the sample mass was carried out after every hour. The samples were dried in batches, one after the other at different time interval. The system is developed to activate the buzzer when the weight of the fruit drops to 0.1kg. The initial weight and subsequent weights taken at intervals of 60 minutes are shown in Table I. The percentage moisture removal at any step can be calculated as follows:

$$PMR = \frac{W_1 - W_2}{W_1} \times 100 \quad (3)$$

where W_1 is the weight at time T_1 and W_2 is the weight at a later time T_2 .



Fig. 5 Flow chart for programming the microcontroller

Table 1: Weight reduction for tomatoes at different Temperatures and constant humidity of 30%

Time (min)	Weight (g)		
	40 °C	50 °C	60 °C
0	1000	1000	1000
60	935	921	900
120	915	880	850
180	875	840	790
240	820	790	730
300	755	730	700
360	670	605	545
420	600	550	480
480	465	430	405
540	405	360	325
600	375	325	280
660	360	280	245
720	310	245	215
780	280	215	140
840	160	130	100

The result of Table 1 is graphically presented in figure 5. It can be observed from the results that the moisture removed increases with an increase in

temperature. Therefore, in view of the presented results, the performance of the dryer can be considered satisfactory.

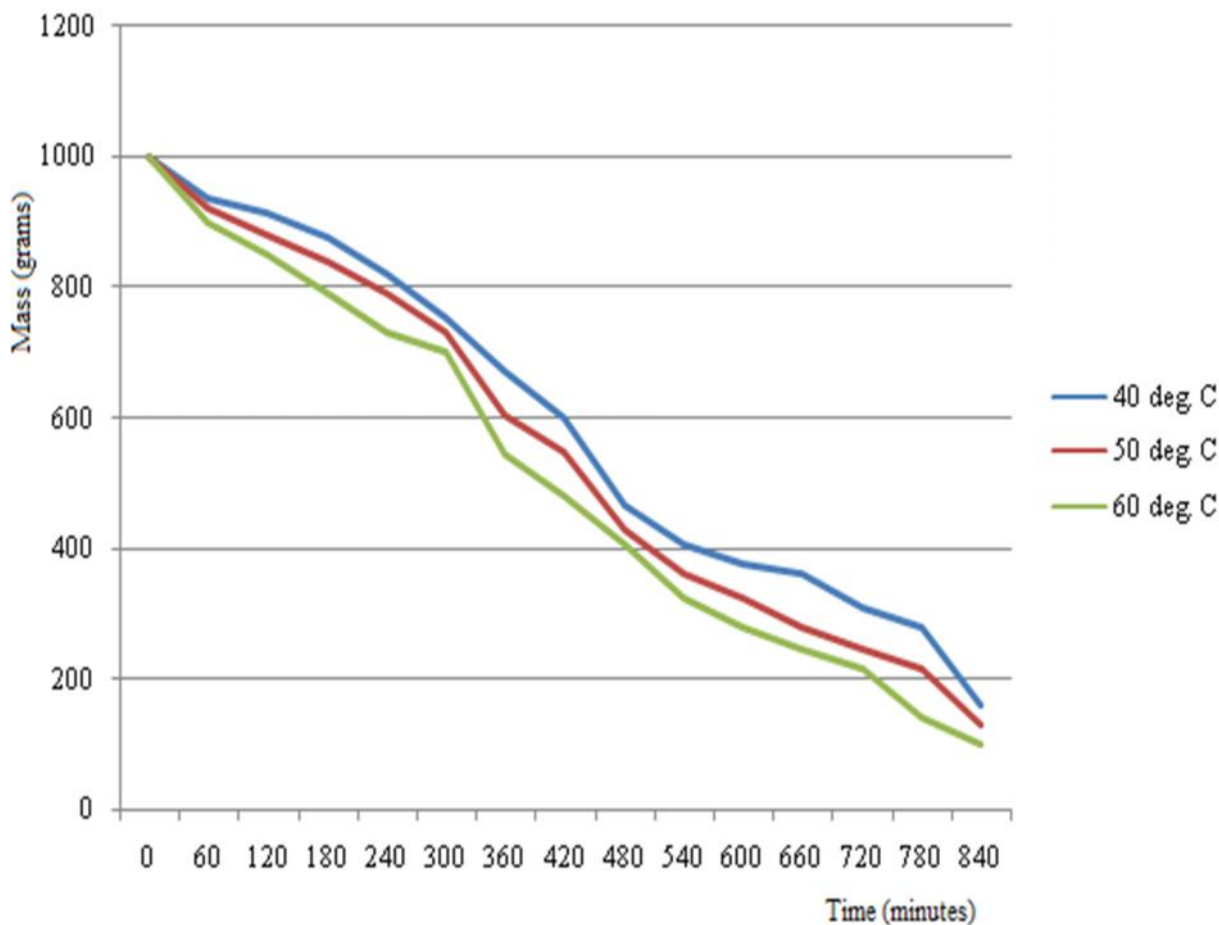


Fig. 5 Variation of time with weight for the Roman type tomatoes at three different temperatures

After the successful completion of the whole drying exercise, quality assessment of the dried fruit was conducted. The dried tomato was given to ten different households, and each household was asked to use it for the preparation of the family meal. A grade from 1-10 was allocated each for flavor, colour, texture, taste and acceptability. The assessment is presented in Table 2. From the numbers presented, it is clear that the flavour of MBD-dried tomatoes is the same as for

tomatoes dried using the conventional open-air dryer. However, the products of open-air dryers are the poorest in taste, colour and are not as acceptable to users as the other two. Although the colour of MBD-dried tomatoes is not as good to most households as of those dried using solar-dryers, the MBD-dried tomatoes are better in all other parameters considered. Overall, therefore, microcontroller-based dryers are the best of the three.

Table 2: Quality assessment of the dried fruits

Fruits	Method of Drying	Flavor	Colour	Texture	Taste	Acceptability	Average Score
Tomatoes	M.B.D	8	8	7.8	8.2	8	8
	Solar Dryer	8	8.5	7	8	7.9	7.88
	Open Air	5.5	5	6	6	5.6	5.62

Note: Quality Score 10 = Extremely Like
 5 = Neither Like nor Dislike
 1 = Extremely Dislike

The results obtained from the system were compared with that of open-air and solar dryers. Table 3 presents the comparison with two other methods of drying. It can be observed the drying rate of fruit is faster in the microcontroller based fruit dryer (MBD) than in the traditional dryers. 1kg of tomatoes with moisture content of 95.1% was used in three different methods of drying. It took 50 hours (more than 2 days) to dry to final moisture of 7.3% in solar dryer. Similarly, the same 1kg took 78 hours (more than 3 days) to dry to final moisture content of 5.6 in open Air dryer. While it

took only 14 hours to dry the same 1 kg tomatoes to 10% final moisture in the micro controller based fruit dryer. The effect of the microcontroller-based fruit dryer on the fruit products is mostly pronounced by their final moisture content and the duration of the drying, which are within the acceptable level of critical moisture content of well dried fruits. Also the final weight shrinkage of the dried fruit has become a good parameter of evaluating the effectiveness analysis of the microcontroller-based fruit dryer.

Table 3: Comparison Of Different Methods Of Drying.

Fruits	Method of Drying	Duration (Hrs)	Gross Weight (kg)		Moisture (%)	
			Initial	Final	Initial	Final
Tomatoes	M.B.D	14	1	0.1	95.1	5.1
	Solar Dryer	50	3	0.49	95.1	7.3
	Open Air	78	3	0.48	95.1	5.6

CONCLUSION

A microcontroller-based fruit drying system has been presented. The system which has a programmed microcontroller with associated circuitry as its main processing unit, has a drying unit consisting of a heating element and heating chamber sections. It is powered from a 220 V ac source. Roman type of tomato

was used to test the efficacy of the proposed system and the results show the supremacy of the proposed system over conventional methods of fruit drying in terms of quality and speed of drying.

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