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DESIGN CONCEPTION OF A FOOD DEHYDRATOR

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Abstract: Nowadays, the household is unimaginable without the three main pillars of the technical field, which are mechanical engineering, electrical engineering and IT. The paper deals with the design conception of a food dehydrator unit. These types of devices are capable of drying fruits and mushrooms. The article covers the design conception of a specific version, and then by building a test system, it becomes possible to check the correctness of the control program code belonging to the system.

Keywords: *Food dehydrator, Arduino development platform, fritzing*

1. INTRODUCTION

Before the invention of machines, mankind dried fruits, vegetables, mushrooms and herbs directly with the help of the sun, and indirectly, e.g., in the attic, because this is one of the ways which can preserve the taste of fruits. The other method, preservation with salt, is also quite an old and proven method. Salt, as well as the warm flowing air during drying, extracts moisture from the fruit in order to terminate the survival conditions of bacteria and mould. During drying, the fruits were laid on a net or pulled over a wire and dried in the sun, which has the disadvantage of a long drying time and weather dependence (Haq & Khan, 2019).

Through the development of IT over the past 50 years, even this process can be made simpler and more efficient, thanks to the availability of programmable drying equipment with which the drying time and temperature can be adjusted.

An energy efficient food dehydrator using electrical heat generation has been designed with PID controller. In this configuration an Arduino Uno, temperature control module and an intel fan were installed, and the temperature range was from 45°C to 55°C. There were published the design calculations and three-dimensional model of the dehydrator (Madhankumar, Muthukkhumaran, Navaneeth, Padmanabhan, & Shriram, 2021). Another research dealt with development of a uniform dehydrator which can dry up to 50 kg vegetable on uniform temperature (Perera, 2022). The improvement of efficiency and environmental impact of a low-cost food dehydrator was analysed by Timothy J. Bowser and his colleges (J. Bowser, 2011). It was declared that coefficient of performance (COP) of the dehydrator increased 39 % when a ventilation waste heat recovery (VHR) system was implemented, carbon emissions equivalent was reduced by 35 % and product drying time was also reduced increasing the amount of production time available (J. Bowser, 2011).

The main goal of the article is the design of a drying device, which contains the 3D model of the unit and programming a test system to check the correctness of the control program (Czigler, 2023).

Section 2 describes the types of drying devices which are common in households. Then it deals with the requirements of a food dehydrator. Section 3 shows the 3D model of the system and its size. The self-devised program code of a test system is detailed in Section 4.

2. FOOD DEHYDRATOR STRUCTURES

In most households, two types of drying solutions have spread, as shown in Figure 1. The main parts of the units are the following: 1 – base; 2 – fan; 3 – heater unit; 4 – trays; 5 – ventilation cover; 6 – door; 7 – protective grid. In the cylindrical version, the heater and the fan are located on the base. Fan ensures adequate air movement in the equipment. The heating element is a resistance wire with a high melting point, through which an electric current flows, thereby producing heat. Sliced fruits, vegetables, mushrooms or herbs must be placed on the trays. The ventilation cover is located on the top of the device in the cylindrical version, and in the grooves behind the door in the cuboid version, plays a role in removing moist air. The door is visible in the case of the cuboid version, where the drying process can be easily followed through the glass, and by opening the door, the products can be rotated for even drying. The grid protects the operator of the equipment from the hot heater and the rotating fan blades.

In the following, the requirements for the unit to be designed will be determined (Czigler, 2023), which are formulated during the study of several commercially available units. The design conception of the unit will be detailed in Section 3.

The advantage of plastic cylindrical drying equipment is that the number of trays can be expanded. In this way, even more elements can be stacked on top of each other than the number given by the manufacturer upon delivery. This advantage is more likely to apply only to higher-performance equipment, since, in addition to the low heating power, the drying is less efficient in the parts further away from the heating element. Compared to stackable plastic trays, the stainless-steel housing is a fixed size. A big advantage of dryers with metal housing is the position of the heater, which is located on the side in the middle of the dryer, therefore all trays heat up evenly, it is not necessary to change their order from time to time.

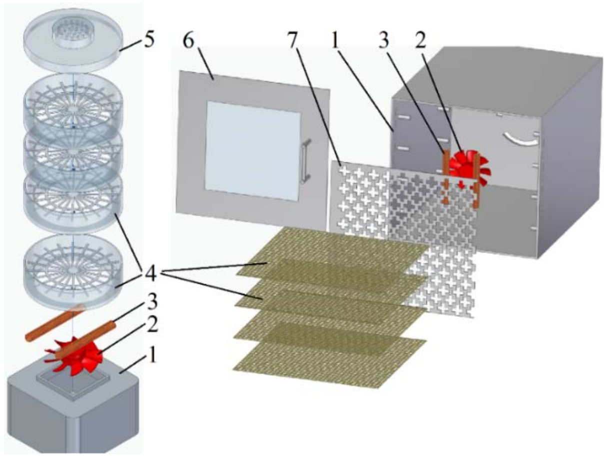

Figure 1. *The main parts of different dryer designs*

Assuming the floorspace, the cuboid type dryer structure can hold more fruit, therefore it proves to be better in terms of space utilization compared to the cylindrical version.

The material quality of the drying unit is an important parameter. The decomposition time of plastics can be hundreds of years, depending on the type used, which means a large environmental burden, for this reason they are increasingly trying to favour environmentally friendly plastics. The advantage of using metal lies in the fact that customers associate it with better quality and a longer service life. Therefore, sheet metals will be used to construct the casing of the unit.

The important requirements for the design of the drying equipment are included in the following list:

- Size of each drying tray: 450x540,
- Number of the trays: 5,
- Material of the cover and trays: stainless steel,
- The self-devised controller unit should be performing temperature control, timer function,
- HMI function will be provided by a touchscreen.

3. DESIGN CONCEPTION OF THE SYSTEM

The designed trays provide a drying surface of 0.24 m^2 each, five trays 1.2 m^2, which can be used to dry 8-12 kg of fruit or mushrooms, depending on the size characteristics of the product. There is 25-40 mm between the trays of commercially available fruit and mushroom drying equipment, depending on the type. The model contains a 100 mm gap between the trays, which can be seen in Figure 2.

Axial fan is used to ventilate the air. With its help, the heat generated from the resistance wire is evenly distributed in the dryer, and the steam generated from fruits and mushrooms flows more easily from near the surface of the product, thus increasing the drying speed.

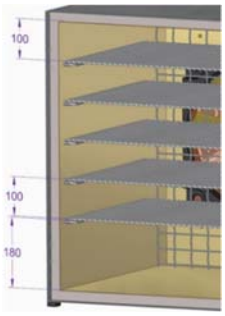

Figure 2. *3D model of drying equipment*

The model of the food dehydrator is shown in Figure 3. On the right side of the unit there is a compartment designed for the control unit. The height of the equipment: 752 mm, width: 727 mm, depth: 660.5 mm.

Figure 3. *3D model of drying equipment*

4. DESIGN OF THE CONTROL, PERFORMING TESTS

The following elements are used to build a test system: a desktop computer case, a computer fan, the heating element of a sandwich oven and the corresponding heat transfer plate, a temperature sensor and a temperature and humidity sensor, a cover for touch protection, under which the cables, buttons, relays, microcontroller, test panel, display are located. The microcontroller and various inputs are connected to a test panel. The connection of these elements is illustrated in Figure 6.
The breadboard wiring diagram of the control system for testing is shown in Figure 4. The Arduino Nano development platform is responsible for controlling the system. The program code was developed in the Arduino IDE software.

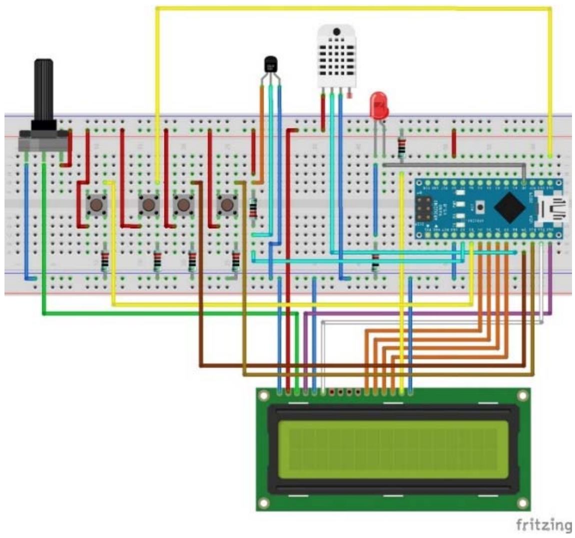

Figure 4. *The breadboard scheme of the control circuit*

The first step is to define the necessary variables, outputs and inputs. In the main program, if the value of the set temperature is not zero and is below the value of the upper hysteresis during the heating phase, the heating element is switched on by the system. If the temperature exceeds the set value, the heating stops.
There are 3 operating modes on the test display, which can be used to set the desired values in a user-friendly way. In addition, the values required for the user are also displayed.
The first mode provides information about the current state of the unit. The display shows the current temperature, humidity and remaining time. The temperature can

be adjusted in the second mode. This can be achieved by pressing the mode button, the temperature can be adjusted from 25°C to 75°C. By pressing the plus (+) button the temperature can be increased by five, while by pressing the minus (-) button, it can be decreased by five. The desired temperature can be set by pressing the set button.

The third mode is responsible for setting the timer. The counter can be set from 0 to 24 hours, the program allows adjustment every half hour. The flowchart of the program is shown in Figure 5.

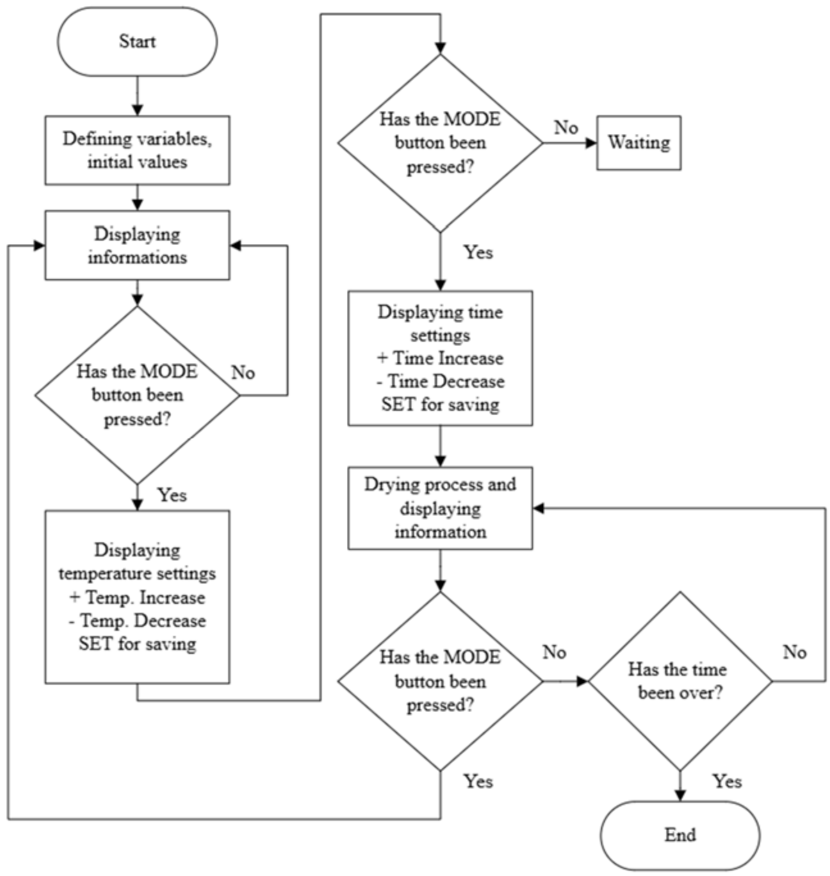

Figure 5. *The flowchart of the control program*

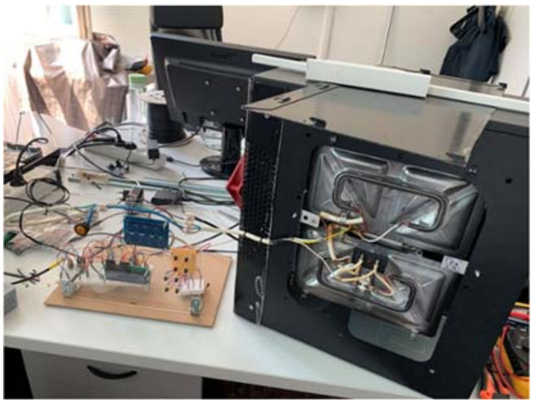

Figure 6. *The picture of the test unit*

5. SUMMARY

The article dealt with the design conception of a food dryer system and its programming. The correctness of the control program was checked by a test system. The system was built from a desktop computer case and a sandwich heater. In the future the case of the system will be manufactured, and then the control unit will be attached to it.

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