ABSTRACT: With the development of 3D printing technology, 3D printing products are appeared in our daily life gradually. Especially the food 3D printing, it will bring us a more healthier and creative life. According to the characters of chocolate food processing, the key technologies of chocolate 3D printer are analyzed. The frame type mechanical structure, the modular control system and the separately temperature controlled nozzle are introduced in detail. Through the product testing, the feasibility and validity are verified. The chocolate 3D printer provides a new way of 3D food printing.

KEYWORDS: 3D printing; Chocolate 3D printer; Mechanical structure; Control system; Nozzle design

1. INTRODUCTION

3D printing is a new kind of rapid prototyping technology combining computer science and numerical control technology. Based on the NC file, objects can be printed layer by layer with metal powder or plastic. 3D printing technology may replace traditional machining ways with so many advantages, like fast, convenient, flexible, high-accuracy, high-quality and low-cost. Scholars and companies in the whole world have paid attention to it now[1,2]. Taken as one of the most significant push factors of the Third Industrial Revolution, 3D printing has been used widely in medical area, aeronautics industry, food processing industry and building materials industry [3].

3D food printer is a kind of fast food manufacturing machines based on 3D printing technology. It has a high degree of processing flexibility that the traditional food processing industry never had before, and can save a lot of time, money and energy [4,5]. On the other hand, as a popular food in the world, chocolate has a big market in the world. But in the Asia Pacific region, the per capita consumption is still low with the impact of economic factors, high investment and complex process and other issues [6,7]. Many well-known chocolate domestic enterprises purchase foreign equipment to produce high quality chocolate products, but the prices of the equipment are usually so expensive that few enterprises can accept. What’s more, the traditional chocolate making machine is hard to achieve the goal when the domestic chocolate manufacturers have new product ideas [8, 9]. So, it is urgent to develop a new technology of chocolate with low cost and high capacity.

Under this circumstance, the 3D printing technology is introduced into the processing and production of chocolate in this paper. Personalized customization and rapid prototyping of 3D printing technology are combined with chocolate processing to realize the manufacture of chocolate processing at a low cost and a high productivity.

2. PRINCIPLE AND DESIGN OF CHOCOLATE 3D PRINTER

2.1 The principle of chocolate 3D printer

The working principle of 3D chocolate printer is similar to common FDM (Fused Deposition Modeling) desktop 3D printer, as is shown in Fig.1. The model is built by computer and layered by slicing software, and then the forming path of each layer is generated. The printer control software communicates with the firmware in electronic devices and prints the model according to the instruction of the software. Printer is mainly composed of software system, hardware control system, mechanical system and temperature control structure.
Software system: the software system can process and optimize the model, and generate the G-code file which can be executed by the machine. We can obtain a model through the three-dimensional scanning, CAD modeling, model library, graphic or simple drawings, then use the slicing software to calculate, optimize, process, and ultimately generate machine instructions which can be performed by motion control system.

Hardware control system: control components mainly plan and execute path trajectory which is generated by slicing software, at the same time, collect the position coordinates and various state signals, and determine the next step. Also, it gives feedback to web pages, touch screen control terminals, mobile phone APP (application) based on real-time monitoring information.

Mechanical system: create an X,Y,Z Cartesian coordinate system through mechanical components and drive three axis movement by half open loop feedback stepper motor. By the synthesis processing of the three axis motion, the movement track of the implementation can be completed. The nozzle and squeeze feeder are mainly used to control material printing conditions and feeding speed, which is the sticking point to design the chocolate 3D printing machine.

Temperature control structure: temperature control is the main factor that determines the success of the chocolate model printing and the high forming quality. When the chocolate just comes out of the nozzle, the temperature needs to be stable at around 35 degrees Celsius, and then, it need to be quickly reduced to ensure that the model can be solidified. So, the two parts need to be in good interaction.

2.2 The design of chocolate 3D printer

The 3D printer model is shown in Fig.2, which includes the key technologies, as control system, structure design, and human-computer interaction software.

Control execution unit includes a control board Arduino, 12V DC power supply, stepper motor, print extruder, temperature control devices and other components in Fig.3. The unit use ATSAM3X8E chip as the core, through Ethernet, serial communication or mobile phone APP sending G-code commands and associated control signal, which is added to the buffer area to realize real-time control and get the feedback of the movement structure, extruders and temperature control devices. The hardware frame diagram is shown as below:

As the characteristics of chocolate material, if it is under the condition of normal temperature, it appears as solid. Its melting temperature is 35 degrees. The melting state has strong liquidity. And the design of the extruder based on chocolate material is the focus of this article.

The Ruhr locking structure of glass syringes is designed as hoppers of extruder. The chocolate raw material will be heated to liquid and inhaled in syringes. Through the gear drive screw nut pair movement in printing, the step motor extrudes the syringes and makes its internal volume contraction. The chocolate extrusion speed and flow rate are changed to match the motor system.

In the chocolate 3D printer, the chocolate is extruded by syringe and cooled by the cooling device of the temperature control system to speed the solidification molding. The extrusion machine model is shown in Fig.4.
The material storage area and the extrusion nozzle area are heated respectively by the way of segmented temperature control system. In order to make sure the mobility of chocolate, the temperature should be maintained at about 35 °C in these areas.

Some key problems should be resolved about the nozzle. First, because of the large contact area between the nozzle spout and outside, it is hard to ensure the heating efficiency. So, the chocolate will be solidified easily leading to the nozzle block during the printing process. Second, due to the poor thermal conductivity of glass syringes, when it is heated, it will not be uniform conduction heating to maintain the stability of temperature. For these problems, the nozzle is designed as following: for the heating structure of chocolate, the segmented heating and segmented control system are used. The flexible heating plate is wound on the Aluminum cylinder which is the outer parts of the material storage. At the same time, the thermistor is affixed to the same place to collect the real-time temperature data. The temperature control program uses the PID regulator to adjust the heating resistor voltage to change the heating power and ensure the stable and rapid adjustment of temperature for the glass syringe. At the outlet of the nozzle, the heating rod is used and the other temperature sensor is embedded therewith a Luer lock. By this way, the syringe structure can transmit temperature to the nozzle very well. Also, the temperature detection and adjustment methods are the same as above in this area.

3. IMPLEMENTATION OF THE CHOCOLATE 3D PRINTER

In order to verify the feasibility of the chocolate 3D printer, it is assembled and debugged. The nozzle structure is shown in Fig.5. The printer is shown in Fig.6. In Fig.7, it is shown the 3D printing chocolate products.

4. SUMMARY

In this paper, the chocolate 3D printer is implemented which can realize the automatic 3D chocolate processing. The key technologies, such as the hardware system, the nozzle structure, the
segmented temperature control system are discussed. Also, the personalized chocolate 3D printing products are shown. Food 3D printing will be an interesting and healthy digital chicken revolution and will come into our daily lives in the short future.

5. ACKNOWLEDGEMENT

This research is supported by Science and Technology Program of Hubei Province of China (Grant No. 2014BAA018).

REFERENCES