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A SINGLE SCREW EXTRUDER FOR POWDER BLOOD

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ABSTRACT Blood of livestock is rich in crude protein. Extrusion processing may increase the protein digestibility (PD). Blood is much more difficult than starch ingredient to extrude, which determines the special design of the extruder. Based on the theoritical analysis and experimental results, the special design for structure and size of the extrusion system, which helps technicians to solve the technique and technological problems, is reviewed in this paper.

KEYWORDS blood, protein, extruder

1 INTRODUCTION

Animal blood is rich in protein, containing up to 80%. There are such common methods to process blood as drum drying, spray drying and fermentation [Pearse Lyons, 1992], which may have the disadvantages of low digestibility, high cost for processing and environmental pollution. Many efforts are made to have good use of blood into protein ingredients for feed in the world. The extrusion cooking (E-C), treating the powder blood with high temperature and short time (HTST), increases the digestibility of the blood. The chicken and fish feeding tests showed its high efficiency.

Blood, an animal protein source, has different characteristics from that of starch and vegetable protein. Single screw extruder parameters for starch and vegetable protein have been well studied in the literature. Karin [1989] have studied the effects of E-C on starch, Shen has made the experimental investigation of the effects of the extruder parameters on the properties of extruded soybean [Kokini *et al.*, 1992]. But there are no studies on the extruder for blood.

A specific extruder was designed, constructed in Shanghai Chuanbang Machinery Works, and has commercial service in Mianzu Extrusion Institute of Sichuan. The design and construction of the single screw extruder with special features is reviewed.

2 DESCRIPTION OF THE SINGLE SCREW EXTRUDER

This extruder consisted of following main parts: extrusion system, electrical heating elements, gear reduction box and motor, as showed in Fig. 1. The machine was driven by a 17.5KW AC motor via a 4.3 gear reduction. When it worked, powder blood was fed by a screw conveyor into hopper at a controlled and steady feeding rate at all times. Moving through the channel from hopper to die, the powder with a moisture content of about 20% was pushed forward, compressed, sheared and heated. And the pressure and temperature developed rapidly to make the powder blood plasticize. With the significant pressure reduction at die, the hot blood fluid expanded greatly to be porous while being pushed through the die opening. Puffing occured because of the expansion of moisture as steam.

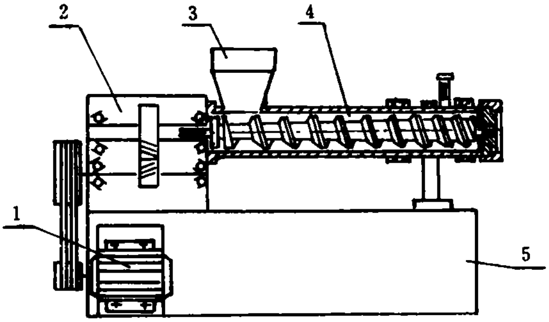

Fig. 1 Schematic diagram of the extruder
1. motor, 2. reduction gear box, 3. hopper, 4. extrusion system, 5. support

3 DESIGN OF MAIN PARTS OF EXTRUSION SYSTEM

The extrusion parameters such as temperature T(℃), operating die pressure p (MPa) and residence time t (s) have a significant effect on the quality of blood extrudate, while the extrusion parameters are mainly affected by the structure, geometry and size of the main parts of the extrusion system besides the screw speed, feeding rate and moisture content. Thus the design of extrusion system is the key to the technique and technological problems.

In this single screw extruder, the extrusion system consisted of screw, resistance plate, die, anti-blockage rod, cooling water jackets and electric heater, as showed in Fig. 2. The special design of the extrusion system is illustrated in the following.

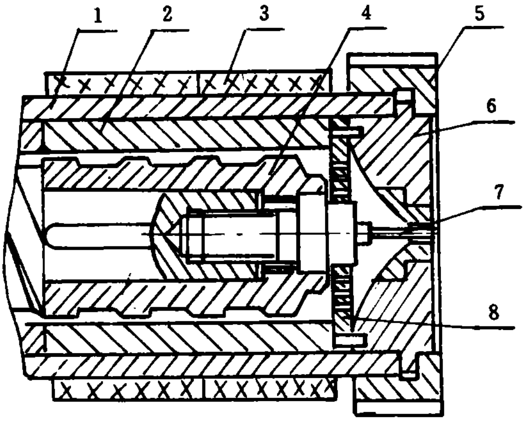

Fig. 2 Schematic diagram of extrusion system
1. barrel, 2. liner, 3. heater, 4. screw tip, 5. locknut, 6. die, 7. anti-blockage rod, 8. resistance plate

3.1 Screw

The screw is the most important part. The extruder uses a 75mm diameter of constant pitch (64mm), gradual decreasing channel depth and double start screw on account of compression ratio, operating stability and it's production convenience, the screw speed is 450r/min. From practical use, we found that the portion of the screw, 120mm long from the tip wore more than other portion. High viscosity of plastcized blood, the leakage flow within the flight and barrel and high temperature was thought to be the main reasons. Because of this, we designed a two-section screw, spray coated with F201(a Ni alloy), which reduces the cost of replacing worn parts.

3.1.1 *Compression ratio Cr*

The high operating die pressure demands a greater Cr than 1.5—1.8, the normal value for starch-rich ingredient. In this extruder, the Cr was 2.8.

3.1.2 *The ratio of length(L) to pitch(S) L/S*

For a out-heated extruder for blood which is somewhat difficult' to extrude, the residence time (t) and shear have a greater effect on the extrusion quality. t is related to L/S when the screw speed, die pressure and specific flow rate and other parameters get their constant values, with the greater L/S, the greater t. In this extruder a greater L/S of 12.0 was chosen.

3.1.3 *The axial flight width (e) at diameter of the screw*

Leakage flow, which is in an axial directon from die to feed port, occurs when the extruder has to pump against a resistance such as die. The little e will increase the leakage flows, influencing the extruder performance. But the great e will make the power consumption higher and the extrusion ingredient locally too hot. The manufaturing way of the screw, makes the e to get a gradual increase from feed port to die naturally, which is expected for the gradual increase of the pressure.

And because of the great Cr and L, the difference between that at feed port and that at die may be up to 12mm, it is necessary to predict the e value at every position. Fig. 3 shows the cross-sectional view of the flight. Once the actual flight height on the leading edge is determined, the actual flight width at diameter of the screw can be calculated.

$$e_\theta = \frac{s - b - h \times \cos\beta \times tg\alpha_1 + h_\theta \times \sin\beta}{\cos\beta + \sin\beta \times tg\alpha_1}$$

$$= \frac{s - b}{\cos\beta + \sin\beta \times tg\alpha_1} + h_\theta \frac{\sin\beta - \cos\beta \times tg\alpha_1}{\cos\beta + \sin\beta \times tg\alpha_1}$$

where s is screw lead

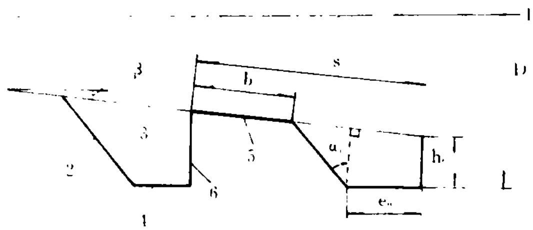

Fig. 3 Calculation of axial flight width e_θ

1. screw axis, 2. trailing edge, 3. flight, 4. land, 5. root, 6. leading edge

b is the channel width at root of the screw

β is the taper angle of conical root

α_1 is shown in Fig. 3

h_θ is the actual flight height on the leading edge

let $A=\dfrac{s-b}{\cos\beta+\sin\beta\times tg\alpha_1}$ and $B=\dfrac{\sin\beta-\cos\beta\times tg\alpha_1}{\cos\beta+\sin\beta\times tg\alpha_1}$

then e_θ becomes

$$e_\theta=A+B\times h_\theta$$

3.2 Barrel

The barrel configuration with liners was used. There were three segments of liner, which makes it possible to replace the worn part easily and decrease the replacing cost.

The large barrle-screw clearance increases the possibility of leakage flows at high operating pressure, while the small clearance leaves a difficulty in assembly. The liner's internal diameter was 75.2, leaving a screw-barrel clearance 0.1mm. When the clearance increases to about 2mm(especially near die), it is necessary to replace the liner and/or screw tip. It is suggested that the extruder not be operated long without ingredient in the channel.

3.3 Anti-blockage rod and cooling water jackets

Fig. 4 illustrates the temperature distribution on the barrel along the screw axis.

The temperature at feed port might be high if the cooling water jackets were not installed. The high temperature at feed port may make viscosity change to influence the feed rate. The cooling water jackets were connected to a mini pump to make the barrel temperature near hopper constant under 40℃

A temperature drop on the die makes the blood viscosity smaller to block the die opening. An anti-blockage rod was mounted on the top of the screw through the die opening. The rod transmits heat and shears the blockage material in the opening, solving the blockage problem.

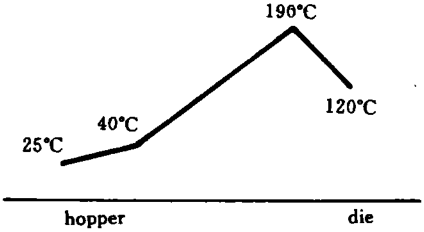

Fig. 4 Distrubition curve of temperature on barrel along screw axis

3.4 Dies

As known to all, the die diameter and shape are important factors influencing the extruder performance characterstics. The fluid chute was designed as streamlined to let the fluid flow fluently. Dies with different internal diameters were used to adjust the pressure.

4 DISCUSSION AND FUTURE DESIGN

A resonably higher moisture content will strengthen the reaction of blood in the channel, reduce the power consumption, decrease the screw and barrel wear[Harper, 1981].

But in the experiments, we found that the steam flowed backward to hopper greatly when moisture content was higher than 20%, and the feeding might be difficult. To design a steam valve between feed and compression section may be a good access.

As discussed before the working pressure is a very important factor influencing the extruder. The adjustment of pressure was by replacing dies with different opening sizes. The fine adjustment of pressure is now gaining our increasing consideration. Fig. 5 shows a prototype of the consideration. The system makes possible the adjustment by compressing the spring to a certain extent, changing the die opening accordingly.

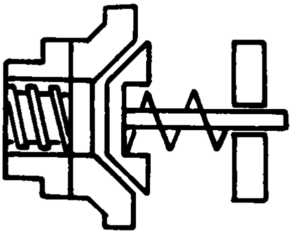

Fig. 5 Pressure adjustment apparatus

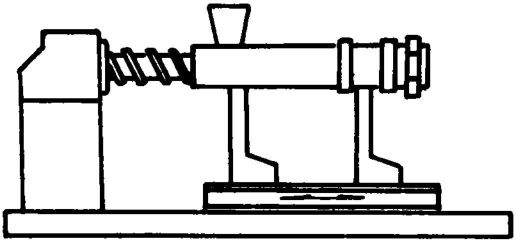

Fig. 6 Simple barrel opening system

Cleaning is one of the problem faced in the extruder operation. Convenient and fast cleaning is needed. An attached screw was mounted through the hollow shaft of the gear reducer to push the main screw out of the barrel to clean the remaining ingredient, which proved sometimes impractical because of the great viscosity of the plasticised blood. A frame, connected with the barrel, is to be driven along the screw axis by hydraulic power (Fig. 6). The simple barrel opening system may make a rapid cleaning and simpler mounting and dismounting.

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血粉膨化机的设计

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提　要　禽畜血液富含粗蛋白，目前常用的加工方法如喷雾干燥法，发酵法等存在产品消化率低，投资较大等问题，膨化处理能提高蛋白消化率。但血粉比淀粉类原料难膨化，存在着设计上的特殊性。本文在理论分析及试验结果的基础上，对膨化机的特殊结构及尺寸设计进行了分析。实际应用表明该设计基本解决了技术及工艺问题。

关键词　血粉，蛋白，膨化机