Research on the digestibility of glutinous rice starch based on high hydrostatic pressure technology

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Abstract. Glutinous rice was a traditional Chinese crop, made from glutinous rice dumplings, rice cakes and so on by the national favorite. However, glutinous rice itself contains up to 98% amylopectin, so it is difficult to be digested and absorbed in the human stomach. Moreover, traditional food processing technology cannot improve the digestibility of glutinous rice starch. As a new type of food processing technology, high hydrostatic pressure technology had prominent advantages in food sterilization, modification, extension of shelf life, etc. Therefore, it was undoubtedly a new innovation to use high hydrostatic pressure technology to improve the digestion and absorption rate of glutinous rice.

1. Introduction
Since 1899, Hite B.H. [1] has been concerned about the effects of high hydrostatic pressure technology on fresh milk sterilization and prolonged shelf life. The new technology of high hydrostatic pressure to improve the processing technology of glutinous rice starch could not only killed the pathogenic bacteria, changed the original gelatinization characteristics of glutinous rice starch, destroyed cell wall and cell membrane on the surface of glutinous rice, but also adjusted its internal material structure and improve the digestibility. The high hydrostatic pressure technology has the ability to change the physical characteristics of food. Therefore, the structure of amylose and amylopectin of glutinous rice treated with high hydrostatic pressure technology will change accordingly. Starch was mainly absorbed in the small intestine, which secreted large amounts of intestinal fluids contained enzymes capable of digesting sugars, fats and proteins [2]. This experiment used different pressure and pressure maintaining time to study the effect of high hydrostatic pressure technology on the digestibility of glutinous rice, referred to the study on germinated brown rice starch and sweet potato slow digestibility starch by Lehmann U. [3], Wang X. [4], Chen C.L. [5], etc., and adopted a relatively scientific and reasonable in vitro digestibility research method because of professional restrictions. The experimental principle was to simulate the characteristics of the digestive system in the human body, so as to achieve the quantification of the results of the digestion and absorption of glutinous rice in the human body.

2. Material and Methods
The fresh glutinous rice: Anhui Yan Zhifang Food Co.
Anhydrous glucose: Tianjin Zhiyuan Chemical Reagent Co.
Alpha amylase: Xingtai Wanda Biological Engineering Co.
3.5- dinitrosalicylic acid: Tianjin Guangfu Fine Chemical Research Institute Co.
F-C 200/1000-600 Vertical food cold isostatic press, Sichuan Bairuilong Machinery Equipment Co.
TU-1901 Double beam UV spectrophotometer, Beijing General Instrument Co.

2.1 Use high hydrostatic pressure equipment to process glutinous rice.

Weighed 600 g glutinous rice, rinsed and placed in glass dish with distilled water for 24 h. A total of 17 g glutinous rice samples were weighed and placed in a food cooking bag. The sample was placed in the ultra-high pressure treatment reactor, and the effect of different pressure (200, 300, 400 and 500MPa) and reaction time (2.5, 5, 10 and 15 min) on digestibility of glutinous rice were investigated. Then the rice were cooked by use the high temperature cooking pot (120°C, 15 min). Respectively accored to take 2.5 g steamed glutinous rice in the grinding bowl, added 10 mL pH6.81 phosphate buffer, carefully grinding glutinous rice into paste, then added in phosphate buffer solution constant volume to 50 mL after placed in the conical flask, added five small glass beads, covered the cork in the constant temperature water bath cradle of preheating (37°C, 12 min). After preheated, 4 mL 0.5% alpha amylase and 0.3% saccharifying enzyme were added to each sample, and then the sample was put into a constant temperature water bath shaking table for reaction. The samples were taken out at 0 min, 20 min and 120 min, then 0.2 mL sample solution was absorbed in the test tube with a pipette, and 4mL distilled water was added. The solution was shaken continuously until the internal solution was homogeneous, and then the enzyme was sterilized by boiling water. After removing the enzyme, 1000 μL sample was added to the DNS reagent of 2000 μL. The sample reagent was prepared by boiling water again for 6 min and immediately cooled by running water. Some reagents were taken in the colorimetric dish, and the absorbance value of the sample was measured under the wave length of 540 nm by using a double UV spectrophotometer.

3. Results and Discussion

3.1. Effects of different pressure and pressure maintaining time on the digestibility of glutinous rice starch.

Glutinous rice starch generally consists of three types of starch: RDS, SDS and RS.

RDS could be decomposed by the enzyme system of trypsin and saccharifying enzyme within 20min. The concentration of RDS was calculated according to equations (1).

$$RDS = \frac{G_{20} - G_0}{TS \times 0.9 \times 100\%}$$  \hspace{1cm} (1)

SDS could be decomposed by the enzyme system of trypsin and saccharifying enzyme within 20min to 120min. The concentration of SDS was calculated according to equations (2).

$$SDS = \frac{G_{120} - G_{20}}{TS \times 0.9 \times 100\%}$$  \hspace{1cm} (2)

RS couldn’t be decomposed by the enzyme system of trypsin and saccharifying enzyme after 120min. The concentration of RS was calculated according to equations (3).

$$RS = 100\% - SDS - RDS$$  \hspace{1cm} (3)

RDS was a fast-digested starch. SDS was slow digestion starch; RS was resistant starch. TS was the total starch content in the sample. G₀, G₂₀ and G₁₂₀ were the glucose content after 0, 20 and 120 min of in vitro digestive reaction. By calculation, the in vitro digestibility curves of RDS, SDS and RS of each sample were plotted.

3.2. Influence of different pressure and maintaining time on RDS

RDS referred to starch that could be rapidly digested and absorbed within 20 min in the human digestive system. The figure 1 shows that under the action of different pressure and the holding time, the highest content of RDS under the pressure (200 MPa, 2.5 min), on the contrary, the content of RDS under 500 MPa was low. This possible that the internal molecular structure of glutinous rice starch begun to be destroyed under 200 MPa pressure, starch pasted phenomenon appeared, so the original digestion and absorption rate of rice was improved. And when the pressure increased to 500 MPa, glutinous rice starch accumulation crystal structure was completely destroyed, the surface concave and convex not neat, lost its complete form originally, after pressure treatment of gelatinized starch adhesive, in the digestion and absorption reaction due to its internal structure was more compact, so
the in vitro digestion absorption rate of sticky rice under 500 MPa pressure less than 200 MPa pressure.

![Graph][1]

Figure 1 curve diagram of digestion absorption rate of RDS

3.3. Influence of different pressure and maintaining time on SDS
SDS referred to starch that could be fully digested within 20-120 min. As it slowly released glucose during digestion, it had a unique role in reducing the glycemic index and improved insulin secretion. As could be seen from the figure 2, under the pressure (200 MPa 2.5 min), the SDS of sticky rice starch reached the maximum value, with the increased of pressure and reaction time, the SDS of glutinous rice starch decreased. This possible that the glutinous rice starch granule structure suffered minor damage under low pressure, more internal hydrogen bond was exposed, the probability of the reaction point contact between enzyme and substrate was increased, at the same time, the in vitro digestibility was increased. With the further increase of pressure and retention time, the grain structure of glutinous rice starch had been completely destroyed. The high pressure made the small molecules inside the starch rearrange, the hydrogen bond was greatly reduced, and the binding ability with water molecules was reduced. The enzymatic hydrolysis reaction was inhibited, the content of SDS declined.

![Graph][2]

Figure 2 curve diagram of digestion absorption rate of SDS

3.4. Influence of different pressure and maintaining time on RS
RS referred to starch that was difficult or even impossible to be digested and absorbed by human body after 120 min. At present, foods rich in RS have been listed as functional dietary fiber foods, because it was difficult to be digested and absorbed in small intestine and has a strong sense of satiety, so it was generally favored by consumers who lost weight and go on a diet. As could be seen from the figure 3, the content of RS of glutinous rice starch at 200 MPa was the lowest. As the pressure increased, the content of resistant starch also increases. Tu Zongcai found that 200 Mpa processed glutinous rice

![Graph][3]
starch granule surface sag, the water swelling role has changed, has good holding water, and with the processing pressure, and the extension of time, the coagulation retrogradation of rice starch paste was more clear, the combination of water molecules and glutinous rice molecular hydrogen bonding effect was abate, enzymolysis reaction degree was reduced, and the RS rose [6].

![Figure 3 curve diagram of digestion absorption rate of RS](image)

4. Summary
As a new food processing technology, high hydrostatic pressure technology was effective in improving the extracorporeal digestibility of glutinous rice. The in vitro digestibility of the glutinous rice was highest under the pressure (300 MPa, 2.5 min). As a kind of energy substance required by the human body-sugar, starch could provided 70-80% calories to the human body. The glutinous rice starch treated by high hydrostatic pressure has changed its enzyme activity point, crystallization structure and gelatinization characteristics [7]. As the pace of modern life was speeded up, people's eating habits tended to be fast and convenient. After high hydrostatic pressure processed, the digestion and absorption rate of glutinous rice starch could be improved, and the continuous feeling of satiety brought by traditional practices of glutinous rice could be alleviated, which adapted to the current dietary trend and has broad development and application prospects.

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