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Research on the Functional Improvement of Ultra-high Pressure Rice Soaked in Ferulic Acid

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Abstract: In today's society, with the rising number of diabetes patients, the project group studied the effect of different concentrations of ferulic acid solution and ultra-high pressure processing on rice quality. The results showed that ultra-high pressure technology could improve taste, appearance and reduce GI value. With the increase of ferulic acid concentration under the joint action of UHP and ferulic acid solution, the hypoglycemic effect improved. SPSS analysis found that 1.5% ferulic acid and 400MPa, 10min ultra-high pressure treatment had the best comprehensive effects. It is hoped to develop ultra-high pressure rice suitable for diabetics, obese and weight loss people, upgrading ordinary rice to "nutritional rice" and "hypoglycemic rice".

Keywords: Ferulic acid; Rice; Ultra-high pressure technology; Lowering sugar

1. Introduction

1.1 Background Purpose

China has the world's largest number of diabetes patients. In 2021, it reached 141 million, increasing by 24 million compared to 2019 and accounting for 26.2% of the global total. The number is expected to grow to 164 million in 2030 and 174 million in 2045. China values food security and people have higher demands for a healthy diet. Rice is a staple for many but has the drawback of raising blood sugar easily. A patient shared his experience of avoiding rice due to high blood sugar. This project aims to create a rice that doesn't easily raise blood sugar, allowing everyone to enjoy it without concerns of diabetes or weight gain.

1.2 Market survey and preliminary idea

The investigation shows there are few effective hypoglycemic rice on the market now, with high prices and bad taste. Some methods for making it have low practicability and are complex. This project aims to provide a better life for diabetes patients, meet their pleasure of eating rice, and use a simpler and more natural production process to ensure both taste and hypoglycemic effect.

The following are the problems and solutions found during the initial research of this project:

First, the starch content of rice is very high. In order to reduce blood sugar, the starch must be denatured, the content of resistant starch and slow digestible starch must be increased, and the content of fast digestible starch must be reduced. Through a large number of literature review, we learned the special mechanism of phenolic substances on starch [1], among which the research results showed that FA (ferulic acid) had a significant inhibitory effect on the digestion of rice starch, so we selected ferulic acid, a foodborne phenolic acid.

Second, how to make the rice soaked in ferulic acid solution not mildew and rot, so that it can be stored and transported. However, because of the bactericidal effect of ultra-high pressure technology itself, it can prevent rice mildew and eliminate a common and very harmful Aspergillus flavus in rice products.The third is how to make ferulic acid better combined with rice starch, so as to achieve better results in a short soaking time. This problem is better solved by the dipping effect of ultra-high pressure technology. Although our soaking time is only 30min in the laboratory, the hypoglycemic effect is more significant under the action of ultra-high pressure [2].

2. Professional literature and program selection

Through a large number of literature review, summarize.

2.1 Rice

Rice (Rice) contains about 75% carbohydrates, 7%-8% protein, and is rich in B vitamins. The arbohydrates are mainly starch, and the protein is mainly rice gluten, followed by rice gum protein and globulin. The proportion of protein and amino acid is higher than wheat, barley, corn and other cereal crops, and the digestibility is up to 66%. Both nutrition and digestibility are prominent in all kinds of staple foods. Although the nutritional value of rice is high, it has many disadvantages. First of all, rice is easy to mildew in a certain temperature environment, producing Aspergillus flavus, once eaten, it is very harmful to the human body. Secondly, it is also the most unfriendly to diabetic patients. Rice has a high blood sugar index, so it is not conducive to diabetic and hyperglycemia patients.

2.2 Introduction of polyphenols and the role of polyphenols and starch (Selection of feruli c acid)

In recent years, the interaction between polyphenolic compounds and starch has attracted great interest of scholars at home and abroad. We have learned that the functions of polyphenols are mainly antioxidant, affecting food flavor and texture, reducing starch hydrolysis rate, and so on.

Among the phenolic acids, ferulic acid is particularly effective in reducing starch hydrolysis rate(according to Xueqin Li et al.).At the same time, ferulic acid has been proved to have strong inhibitory activity on α-amylase and α- glucosidase[5]. Based on the findings of the above studies, we selected ferulic acid as a phenolic acid.

2.3 Introduction of ultra -high pressure technology

We understand that ultra-high pressure technology as a food non-thermal processing technology, its three functions are: sterilization, blunt enzyme, improve texture. In terms of sterilization, it uses pressure to kill microorganisms in food. On the blunt side, it causes the major enzymes in food to deform. [6-9]

The study by Huang et al. also found that UHP treatment could effectively inhibit the growth of Aspergillus flavus. Therefore, it can be effectively applied to the sterilization and mildew prevention of rice [10]. It destroys non-covalent bonds such as hydrogen bonds and ionic bonds in food, but has no significant effect on covalent bonds. Therefore, it can ensure food safety while reducing the degree of food processing as much as possible. In terms of improving the texture, it can modify or denature macromolecular substances (such as starch and protein). It has been shown to be effective in improving the quality of aged rice, so we took advantage of this to improve the texture of rice.

2.4 Scheme Selection

Lower UHV treatment (200 to 300 MPa) can improve the hardness of rice, while higher UHV treatment (400 to 600 MPa) can significantly reduce the chewiness and resilience of rice, and improve the adhesion of rice. Ultra-high pressure treatment above 400 MPa can significantly reduce the chewiness of rice [2], but has no obvious effect on its resilience. Ultra-high pressure treatment above 400 MPa had a negative effect on the sensory quality of rice, and the greater the pressure, the more significant the effect. The sensory value of rice prepared with high pressure treatment above 400 MPa was significantly improved. Comprehensive indicators, 400 MPa ultra-high pressure treatment can be used as the processing condition of ultra-high pressure rice [2].This project selected the program to design and study the interaction between 0.25%, 0.5%, 1%, 15% concentration offerulic acid and rice at 400Mpa.

3. Experimental process and data analysis

3.1 Plan formulation

3.1.1 Materials and Equipment

Materials: Yongyou 1540 rice (Jiangshan Guiben Farm) (2021. 11), 50 ml conical tip bottom centrifuge tube, ferulic acid, deionized water (Ningbo Academy of Agricultural Sciences), glucose content kit (Granis Biological), iodine, potassium iodide, glacial acetic acid (99.5%), sodium acetate crystal, dilute hydrochloric acid.

Equipment: Mimei rice cooer, Sartorius weighing sensor, HC-3018R high speed refrigerated centrifuge, Spectrumlab UV Visible spectrophotometer, Sunny Constant moisture measuring instrument, mettler toledo FiveEasy plus pH meter, DF-101S heat collection type constant temperature heating magnetic stirrer, H2P-150 type constant temperature oscillation incubator, Jinghong constant temperature and humidity box, X-rite colorimeter, Sohara Zhongtian CQC-600 ultra-high pressure machine.

3.1.2 Sample processing

Uhv pretreatment: 5g of rice in a cup, add 3mL of deionized water and soak at 4℃ for 30min. Place the soaked rice in the UHV equipment. The parameters were set as follows:T0 group (control group) did not receive any treatment, T1-T5 group pressure was 400Mpa, holding time was 10min, ferulic acid solution concentration was 0, 0.25%, 0.5%, 1%, 1.5%.Rice cooking: Put the pretreated rice in a cup and add 4mL deionized water, shake gently to make the surface of the rice grains in the cup smooth without obvious accumulation, and seal with plastic wrap. After the water in the steamer is boiled, the sample is placed in the steamer. After steaming for 30min, the sample is removed and placed at room temperature (25℃) for 30min.

Dry, wrap and dispose.

3.1.3 Sensory evaluation

Cooking: Add water (1:1.5) rice cooker to cook (20min) Fill out the sensory evaluation form.

3.1.4 To explore the effects of different drying methods on the cooking quality of hypoglycemic rice

After ultra-high pressure and treatment, the rice is in a humid state, and it faces problems such as short shelf life and easy to mold in storage. In this experiment, different drying methods were used to treat the rice after ultra-high pressure to make the rice in a dry state and further extend its storage period.

In this experiment, hot air (50 ℃ , 60 ℃) and vacuum freeze-drying were used as drying methods. The color and shape of dried rice grains and the sensory quality of rice after cooking were used as indicators.

3.2 Data and analysis

3.2.1 PH value

The pH values of HPP+ different concentrations of FA.10g of rice was placed in a beaker and 50m L of distilled water was added and allowed to stand for 20min before determination using a p H meter.The PH value of cooked rice in each group was maintained at about 6. 8 under the ultra-high pressure of 40 0 MPa and different concentrations of ferulic acid (0 ~ 1. 5 %), which had little effect on the taste. [11]

3.2.2 Whiteness

Whiteness is the degree to which the surface of a substance is white, expressed as a percentage of the amount of white contained. The whiteness of a substance is usually determined by using magnesium oxide as the standard whiteness of 100%. [12] CR-400 colorimeter was used for determination. The L* value indicates the brightness, the larger the value, the whiter and brighter; The a* value indicates red-green degree, where positive value indicates red, negative value indicates green; b* values indicate yellowish-blue degree, where positive values indicate yellow degree and negative values indicate blue degree. Rice whiteness (W) calculated according to the type: W = 100 - [(100 - L *) 2 + a * b * 2 + 2]$^{1/2}$, parallel determination 3 times, the results averaged.According to the chart, cooked rice under the ultra-high pressure of 400MPa, different concentrations offerulic acid (0~ 1.5%) have almost no effect on the senses.

3.2.3 Light transmittance

Translucency represents the ability of light to pass through a medium and is the percentage of light flux through a transparent or translucent body and its incidentlight flux. [11]5. 0 g of rice sample was accurately weighed and loaded into a 5 0 m L colorimetric tube, and then 25m L of water was added for vibration extraction at 40℃ for 1 h. The volume was fixed to 50m L, and the supernatant was centrifuged and separated (3000r/min, 15 min). The light transmittance was measured at 620 nm. According to the chart, under the ultra-high pressure of 400MPa and different concentrations of ferulic acid (0~ 1%), the light transmittance of cooked rice changes slowly, and the sensory is stable and good. The 1.5% concentration data maybe wrong.

3.2.4 Iodine blue value

Iodine-blue value is an index of the binding ability of starch and iodine, which can reflect the content and chain length of amylose. Amylopectin branches are more, not combined with iodine, iodine staining is purple, amylose branches are less, easy to combine with iodine into dark blue, amylose content is high, rice is slender, toughness taste and elasticity are low, on the contrary, amylose content is low, amylopectin content is high, viscosity after cooking is high, rice toughness taste is high, elasticity is high, taste is good. [13] Weigh 5. 0g of rice sample into 50mL colorimetric tube, add 25m L of water to vibrate and extract 1h mol/L KI-I2 solution and 0. 5mL, 0. 1mol/L HCl at 40 ℃ , add water to constant volume to 50mL, and let it sit for 15min, then determine the absorbance value at 620 nm colorimetry, which is the iodine blue value.

At the ferulic acid concentration of 0 ~ 0. 2 5 %, it increased first, and decreased after the concentration of 0.25%~ 1. 5%, so the taste also increased and then decreased, and the iodine blue value reached the peak at the concentration of 0.25%, so the toughness and elasticity were low and the taste was the worst.

3.2.5 Digestive properties

The model was developed with reference to Englyst's method and slightly modified, using in vitro enzymes to simulate the hydrolysis of starch to glucose in the small intestine. The lg sample was weighed, then 15mL acetate-sodium acetate buffer (0. 2 molL-1, pH5. 2) and a rotor were added, and the mixture was heated and stirred in a boiling water bath for 20min. After the sample was cooled to room temperature (25 ℃), 10 mL of enzyme mixture 11(containinga-amylase2900 U and starch glucosidase 1 5 0 U) was added, and the mixture was shaken in a 3 7 ℃ water bath constant temperature oscillator for 180 min at a speed of 150 r min-1. At 30min, 60min, 90 min, 120 min, 150 min and 180 min, 0. 5 mL of hydrolysate was removed, 4mL of absolute ethanol was immediately added to the hydrolysate, and centrifuged at 3000g for 10min. The supernatant was taken and the glucose content was determined by glucose oxidase method.

Under the synergistic effect of different concentrations of ferulic acid and ultra-high pressure, the content of resistant starch increased with the increase of ferulic acid concentration. The content of slow digestible starch showed an upward trend. The content of fast digestion starch showed a decreasing trend, which was in line with the trend of increasing hypoglycemic effect with the increase of ferulic acid concentration.

At the same time, compared with the pure blank group and the ultra-high pressure treatment, it was found that the ultra-high pressure treatment itself had a certain glucose-lowering effect, reducing the content of fast digestible starch and increasing the content of slow digestible starch.

3.2.6 Sensory evaluation

A rice sensory evaluation scoring rule and record table were designed tosynthesize the obtained sensory evaluation results by collecting rice sensory evaluation scores.

After comprehensive analysis, the sensory evaluation score of blank group 1 (without any treatment) was 71.98, the sensory evaluation score of blank group 2 (only 400MPa ultra- high pressure treatment) was 78.80, the sensory evaluation score of 0. 25% ferulic acid immersion was 75. 34, and the sensory evaluation score of 0. 5% ferulic acid immersion was 74.74. The sensory evaluation score of 1% ferulic acid immersion was 73. 6 8, and that of 1. 5 % ferulic acid immersion was 72. 7 8.

3.2.7 Effects of different drying methods on the quality of boiled rice products

Figs. 7 and 8 show that vacuum-frozen rice is white, similar to glutinous rice in appearance and texture, while hot air-dried rice is like general rice. Ultra-high pressure rice treated by hot air at 50℃ has good quality, while that at 60℃ and without treatment is slightly yellow and hard. The ck group is more elastic than the 60℃ group. Vacuum frozen rice has a more delicate texture and taste. Sensory analysis concludes that the 50℃ group has better morphology and taste, while the vacuum freezing group is softer but less elastic. Different storage methods are suitable for different requirements based on evaluations from many people.

4. Conclusions

The results show that ultra-high pressure technology can improve taste, appearance and feel, and reduce GI value. Under the joint action of UHP and ferulic acid solution, the hypoglycemic effect improves with the increase of ferulic acid concentration. SPSS analysis reveals that with 1.5% ferulic acid and 400MPa, 10min ultra-high pressure treatment, the comprehensive effects are the best for developing hypoglycemic rice.

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