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A new method for preparing the instant quinoa by piecewise gelatinization

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Abstract

In recent years, the market has great demand for the instant quinoa. However, the high content of protein and fat in quinoa grain inhibited the gelatinization and extension of starch molecules. The instant quinoa prepared by conventional gelatinization method has poor rehydration. In order to solve this problem, the sectioned heating method was used according to the properties of quinoa starch and protein. The purpose of the first heating stage was to gelatinize the starch with sufficient water, and the technological conditions were: the mass ratio of water to quinoa 4:1, the temperature of water bath 70 °C, the time of water bath 60 min. The purpose of the second heating stage was to denature the protein with less water, and the technological condition was that the quinoa was heated by atmospheric steam for 5 min. The instant quinoa prepared by above method had excellent rehydration. Compared to the raw quinoa, the content of protein, fat and reducing sugar in instant quinoa increased slightly, while the content of starch and polyphenols decreased slightly. The mass loss percentage of instant quinoa was 11.5% and the score of sensory evaluation for the sample prepared under the optimum conditions was 87.

Keywords: instant quinoa; piecewise gelatinization; rehydration.

Practical Application: The piecewise gelatinization method can solve the contradiction between excessive dissolution and sufficient gelatinization of quinoa starch, which provides useful reference for the preparation of instant rice.

1 Introduction

Quinoa is a new type of pseudocereal introduced into China in recent years, and it is an annual dicotyledonous plant of the genus *Chenopodium*. Quinoa can be regarded as a "functional food" which contains a variety of beneficial substances such as minerals, vitamins, fatty acids, phytohormone and antioxidants (Wu et al., 2022; Acosta et al., 2022; Hu et al., 2018; Ding et al., 2015). Besides, quinoa is suitable to be used as an auxiliary diet for people with diabetes (Wang et al., 2014), so it is favored by consumers in the world. Since quinoa was successfully introduced into Shanxi Province of China in 2011, the large-scale planting of quinoa has been expanded to more than 10 provinces. Up to now, the sown area in China has reached more than 20,000 hm^2, and the total output of quinoa grain is 45000 tons (Chen, 2021; Zhou et al., 2021). However, although quinoa grain has high nutritional value, it takes a long time to cook, so it is difficult to meet the needs of modern fast-paced life (Valenzuela-González et al., 2022).

At present, there are two main ways to prepare the instant quinoa, the first method to prepare the instant quinoa by prilling process using the quinoa flour (Meng et al., 2015, 2021; Wang et al., 2022), the second method is to prepare the instant quinoa by cooking process using the quinoa grain (Tan, 2016). The instant quinoa prepared by the first method can be quickly transformed into paste after being mixed with boiling water. However, this process destroys the original shape of quinoa grain and reduces its market competitiveness. The instant quinoa prepared by the second method has poor rehydration, therefore, it is difficult to become softening after being mixed with boiling water. Previous studies have shown that the rehydration property of instant quinoa prepared by the conventional method was poor (Tan, 2016). The main reason is due to the excessive dissolution of starch during the gelatinization process under high temperature and large amount of water conditions. Our previous experiment showed that the starch dissolution increased significantly when the temperature exceeded 75 °C with sufficient water. The excessive dissolution of starch above 75 °C causes adhesion of quinoa grains and decreases its rehydration. On the other hand, the quinoa protein can interact with the starch to form a complex which inhibits the gelatinization and extension of starch molecules (Shi et al., 2020; Niu et al., 2011), therefore, the effects of protein on the gelatinization of starch must be taken into account. Since the denaturation temperature of quinoa protein is 98 °C (Yan et al., 2018; Janssen et al., 2017), the heating temperature should be greater than 98 °C in order to eliminate the effect of protein on starch gelatinization. However, in this way, the dissolution of starch and the denaturation of protein will appear in contradiction.

In order to solve the above technical problem, the piecewise gelatinization method was used for preparing the instant quinoa in the present study. For the first stage of heating, the temperature is controlled at 70 °C by water bath (with sufficient water) to gelatinize the starch, and for the second stage of heating, the temperature is controlled at 100 °C by atmospheric steam (with a little water) to denature the protein. The above innovative methods can improve the rehydration of instant quinoa with less sticky.

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2 Materials and methods

2.1 Materials

Quinoa grain was provided by Shanxi Yilong Quinoa Development Limited Company, Jingle County, Shanxi Province, China.

2.2 Technology process

Quinoa grain → mixing with water → water bath heating → water rinsing → steam heating → oven drying → instant quinoa.

2.3 Effect of water-quinoa mass ratio on the rehydration of instant quinoa

Twenty grams of quinoa grain was put into a 300 mL beaker and mixed with a certain amount of water. The mass ratio of water to quinoa ranged from 2:1 to 5:1, and the beakers were put into a water bath in turn and heated at 70 °C for 60 min. The quinoa grain was taken out and rinsed with water for 1 min, then the quinoa grain was put into a stainless steel steamer and heated with steam at atmospheric pressure for 5 min. When the heat is done, the quinoa grain was transferred into an oven and dried at 70 °C to constant weight. The rehydration property of the instant quinoa will be measured according to the following description.

2.4 Effect of temperature of water bath on the rehydration of instant quinoa

The mass ratio of water to quinoa was controlled at 4:1, the temperature of water bath was controlled at 60 °C, 65 °C, 70 °C, 75 °C and 80 °C, respectively. The other operations are the same as above.

2.5 Effect of heating time of water bath on the rehydration of instant quinoa

The mass ratio of water to quinoa was controlled at 4:1, and temperature of water bath was controlled at 70 °C. The heating time of water bath was 30, 40, 50, 60, 70, 80 and 90 min, respectively. The other operations are the same as above.

2.6 Effect of heating time of atmospheric steam on the rehydration of instant quinoa

The mass ratio of water to quinoa was controlled at 4:1, and then heated by water bath at 70 °C for 60 min. The heating time of atmospheric steam was 0, 1, 3, 5 and 10 min, respectively. The other operations are the same as above.

2.7 The measurement of rehydration of the instant quinoa

Five grams of quinoa grain had been treated as above methods was put into a 100 mL beaker, then 50 mL boiling water was put into the beaker. After fully mixing, a lid was put on the beaker, and then the beaker was placed in a 100 °C water bath. Taking out a few grains from the beaker at regular intervals to determine the softening time of instant quinoa.

2.8 Determination of nutritional components of instant quinoa

The protein and fat content of instant quinoa was determined by Kjeldahl method and Soxhlet extraction method, respectively. The content of reducing sugar and starch was determined according to GB 5009.7-2016 and GB 5009.9-2016 (The National Health and Family Planning Commission of the People's Republic of China, 2016a, 2016b), respectively. The polyphenols were determined by spectrophotometric method (Liu et al., 2021).

2.9 Determination of moisture, density and mass loss rate of instant quinoa

According to the results of single factor test, the optimized process parameters were selected to prepare the instant quinoa. The water content (W_C) of instant quinoa was determined by drying method at 105 °C; the apparent density (ρ) of instant quinoa was measured by the ratio of weight (g) to volume (cm^3); the mass loss percentage (M_{LP}) of instant quinoa was calculated by the mass changes before and after processing. The calculating formulas are expressed as follows (Equations 1, 2 and 3):

$$W_C(\%) = \frac{M_1 - M_2}{M_1} \times 100 \quad (1)$$

$$\rho = \frac{M_1(M_2)}{V} \quad (2)$$

$$M_{LP}(\%) = \frac{M_B - M_A}{M_B} \times 100 \quad (3)$$

where: W_C is water content of the tested sample, %; M_1 and M_2 are the mass of instant quinoa before and after drying at 105 °C respectively, g; M_B is the mass of raw quinoa before processing, g; M_A is the mass of instant quinoa after processing, g; V is the volume of instant quinoa, cm^3.

2.10 Sensory evaluation of instant quinoa

The sensory evaluation method was established referring to the China National Standard GB/T15682-2008 (General Administration of Quality Supervision Inspection and Quarantine of the People's Republic of China, 2008) combined with the characteristics of quinoa grain. A panel of tasters were made up of 10 volunteers. The scoring criteria were shown in Table 1.

2.11 Statistical analysis

All experiments were performed in quadruplicate. The data are represented as mean ± standard error.

3 Results and discussion

3.1 Effect of water-quinoa mass ratio on the rehydration of instant quinoa

The rehydration of instant quinoa was expresses as the softening time of quinoa grain. As shown in Figure 1, the softening time of quinoa grain decreased gradually with the increase of the mass ratio of water to quinoa from 2:1 to 4:1. However, the

Table 1. Sensory evaluation criteria of the instant quinoa.

Items	Total score	Features description	Score
Appearance description	20	The quinoa grains are intact and less adhered to each other.	16-20
		The quinoa grains are basically intact and partially adhered to each other.	10-15
		The quinoa grains are incomplete and clumped together.	0-9
Color and luster	20	The color of quinoa grain is green white, which is basically consistent with the raw grain.	16-20
		The color of quinoa grain is grayish brown, which is different from the raw grain.	10-15
		The color of quinoa grain is brown, which is significantly different from the raw grain.	0-9
Smell	20	It has the unique aroma of quinoa and the flavor is strong.	16-20
		It has the unique aroma of quinoa but the flavor is light.	10-15
		It lacks the unique aroma of quinoa.	0-9
Rehydration property	20	The rehydration property is excellent.	16-20
		The rehydration property is good.	10-15
		The rehydration property is poor.	0-9
Taste	20	The taste is delicate and the soup is thick.	16-20
		The taste is ordinary and the soup is not thick.	10-15
		The taste is rough and the soup is light.	0-9

softening time of quinoa grain increased when the mass ratio of water to quinoa reached 5:1. The above results indicated that the appropriate mass ratio of water to quinoa was 4:1. If the mass ratio of water to quinoa continues to increase, the viscosity of instant quinoa increased, resulting in prolonged softening time.

3.2 Effect of temperature of water bath on the rehydration of instant quinoa

As shown in Figure 2, the softening time of instant quinoa decreased sharply with the increase of water bath temperature from 60 °C to 65 °C, then the decrease of softening time gradually became slow. Although the softening time of instant quinoa decreased with the increased temperature of water bath, the viscosity of instant quinoa became larger when the temperature of water bath was more than 75 °C, therefore, the appropriate temperature of water bath was 70 °C.

3.3 Effect of heating time of water bath on the rehydration of instant quinoa

When the water bath time increased from 30 to 90 min, the softening time of instant quinoa decreased firstly and then increased slowly. The minimum softening time was observed when the water bath time was 60 min (Figure 3).

3.4 Effect of heating time of steam on the rehydration of instant quinoa

The effect of steam heating time on the rehydration of instant quinoa was shown in Figure 4. It can be seen from Figure 4 that the softening time of instant quinoa decreased from 11.0 to 5.5 min with the increase of steam heating time from 0 to 5 min, indicating that the steam heating can reduce the softening time of instant quinoa. Compared to the water bath without steam heating, the softening time of instant quinoa reduced by 40.9% (from 11.0 to 5.5 min). The result showed that the sectioned heating method can enhance the rehydration of instant quinoa, and the appropriate time for steam heating was 5 min.

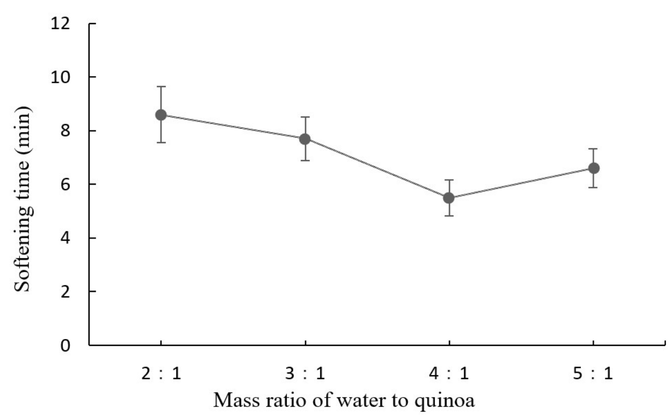

Figure 1. Effect of mass ratio of water to quinoa on the rehydration of instant quinoa.

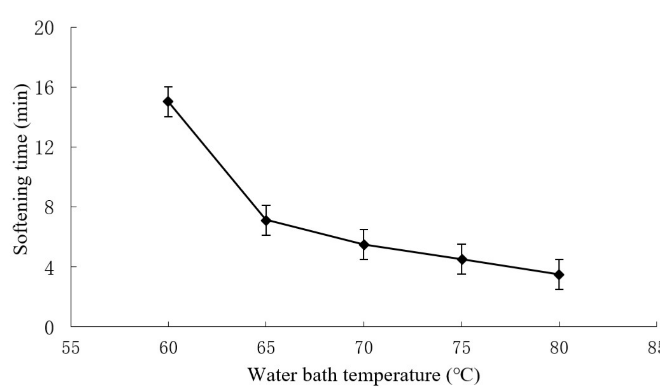

Figure 2. Effect of temperature of water bath on the rehydration of instant quinoa.

It was reported that the starch-protein complexes can inhibit the starch gelatinization and its rehydration (Zheng, 2018; Shi et al., 2020). Since the protein content of quinoa is much higher than that of common cereals, its effect on the rehydration of instant quinoa should not be ignored. The above results showed that

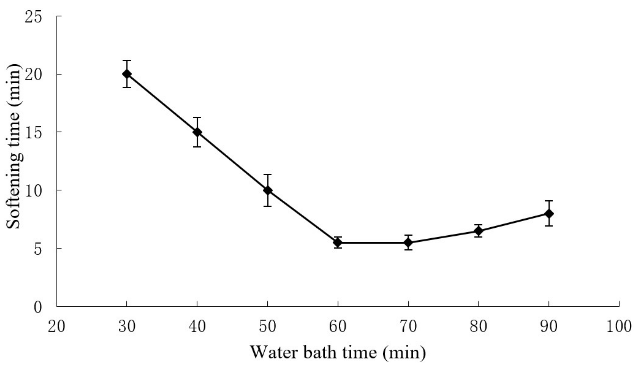

Figure 3. Effect of water bath time on the rehydration of the instant rice of quinoa.

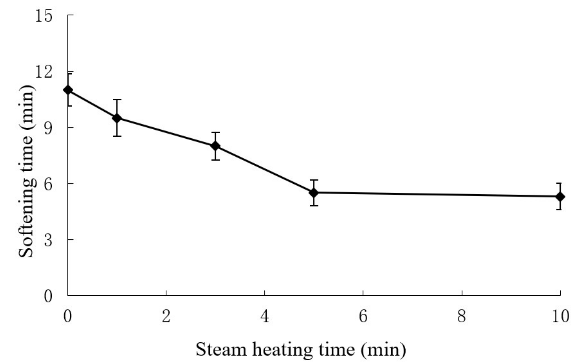

Figure 4. Effect of steam heating time on the rehydration of instant quinoa.

it is necessary to denature the protein of quinoa by the steam heating after the water bath.

3.5 The physicochemical parameters and sensory evaluation of instant quinoa

The moisture, apparent density, mass loss percentage and sensory evaluation of instant quinoa were shown in Table 2.

As can be seen from Table 2, the moisture content of quinoa decreased from 10.67% to 8.64%, and the apparent density of quinoa decreased from 0.746 g/cm^3 to 0.664 g/cm^3 after the raw quinoa was processed into the instant quinoa. The decrease of moisture is due to the good drying of instant quinoa while the raw quinoa is not pre-dried; the decrease of apparent density is due to the volume expansion of quinoa when it was processed into the instant quinoa. The sensory score of instant quinoa prepared by the optimized process parameters was 87, which had good taste and rehydration property. However, it is worth noting that the mass loss percentage of the instant quinoa was 11.5%, which was higher than the moisture of the raw quinoa (10.67%). The results showed that the mass loss percentage of quinoa is related not only to the decrease of moisture content (from 10.67% to 8.64%) but also to the loss of sticky wall and rinsing process.

3.6 The nutritional composition of instant quinoa

The changes of nutritional composition of the instant quinoa before and after cooking were shown in Table 2. After the raw quinoa was processed into the instant quinoa, the content of protein, fat and reducing sugar increased slightly, while the content of starch and polyphenols decreased slightly. The decrease of starch content is due to the hydrolysis of starch during the gelatinization process, leading to an increase of the content of reducing sugar. Because the protein and fat cannot be destroyed by the gelatinization temperature, therefore, their content increased slightly due to the starch loss. Starch and polyphenols in cereals can interact with each other through non-covalent bonds such as hydrogen bond, hydrophobic bond and ionic bond to form starch-polyphenol complex (Ren et al., 2021). After the gelatinization of starch, the starch-polyphenol complex was destroyed, resulting in the release of polyphenol. Due to the good water solubility of polyphenols (Qu et al., 2021), the content of polyphenols in instant quinoa decreased.

Table 2. Changes of physicochemical parameters and nutritional components of the instant quinoa before and after cooking.

Test items	Raw quinoa	Instant quinoa
Moisture content (%)	10.67	8.64
Density (g/cm^3)	0.746	0.664
Mass loss (%)	-	11.5
Protein (%)	15.62	17.66
Starch (%)	60.63	52.79
Reducing sugar (%)	5.60	7.30
Fat (%)	7.54	11.39
Polyphenol (%)	1.324	0.9210
Sensory score	-	87

Since the starch content in grains is generally more than 60% (Wang et al., 2017a), the gelatinization of starch becomes the key technology for making the instant grains (Wang et al., 2017b; Li et al., 2022a). However, quinoa is a kind of new pseudocereal introduced into China, and its nutritional composition and processing characteristics are very different from the ordinary cereals, therefore, the preparation of instant quinoa cannot copy the same processing method with other cereals. It was reported that the gelatinization temperature of quinoa starch is between 61.9 and 64.4 °C (Li et al., 2022b), theoretically speaking, the heating temperature exceeding the temperature of starch gelatinization can complete the gelatinization of quinoa grains. In fact, a heating temperature slightly higher than the gelatinization temperature of quinoa starch cannot meet the requirements of the gelatinization of quinoa grain due to the effects of fat and protein. Quinoa has two to three times as much fat as regular cereals (Wang et al., 2019), therefore, the fat can form a complex with starch by hydrogen bonding (Ding et al., 2021; Li, 2022c), which inhibits the gelatinization of quinoa starch. On the other hand, the protein content of quinoa (12.5%-16.7%) is much higher than common cereals, and the protein interacts with the starch to form a complex network structure which protects starch particles (Shi et al., 2020). Therefore, the gelatinization temperature of quinoa grains is much higher than that of pure starch. In addition, the denaturation temperature of quinoa protein is about 98 °C (Yan et al., 2018; Janssen et al., 2017). In order to fully destroy the protein-starch network complex, the heating temperature should be more than the protein denaturation temperature (98 °C). However, the direct cooking of quinoa is not appropriate due to the dissolution of starch when the temperature is more than 75 °C. That is to say, the ratio of water to quinoa should be adjusted with the increase of temperature. When the temperature is below 75 °C, the water content should be sufficient to facilitate the water uptake of quinoa; when the temperature is above 75 °C, however, the water content should be minimized to reduce starch leaching. The above analysis is the basis for the piecewise gelatinization.

The importance of instant rice has been highly recognized by consumers. However, many instant rice products are still facing problems with poor rehydration ability and eating quality. The main factors affecting the rehydration of instant rice include the adaptability of raw materials, gelatinization process, and the retrogradation of gelatinized starch during drying and storage (Wang et al., 2021; Jiao, 2013). Among these factors, more attention has been paid to the control of retrogradation of gelatinized starch during the drying process, while the gelatinization of starch seems to have received relatively little attention. So far, the effects of various drying method such as hot air drying, microwave drying and vacuum freeze-drying on the rehydration of instant rice have been investigated (Long et al., 2018; Wang et al., 2017b, 2021). In addition to drying methods, the effects of various additives on the rehydration of instant rice have also been explored. These additives mainly include trehalose, sucrose esters, sucrose, sorbitol, pullulan, polyglutamic acid and α-amylase (Yu, 2018; Xia et al., 2018; Tan, 2016). It has been reported that these additives could inhibit the retrogradation of starch to a certain extent. In fact, the gelatinization method of grain is equally important. In our studies, we found that the gelatinization of quinoa starch became complicated due to the influence of high content protein and fat. In view of this situation, the piecewise gelatinization of quinoa was put forward to prepare the instant quinoa, which could solve the contradiction between excessive dissolution and sufficient gelatinization of starch.

4 Conclusions

According to the starch, fat and protein properties of quinoa, the piecewise gelatinization was used to prepare the instant quinoa. Through the piecewise gelatinization process, the starch and protein in quinoa can be gelatinized and denatured respectively, and the instant quinoa has good rehydration. Compared to the raw quinoa, the content of protein, fat and reducing sugar in instant quinoa increased slightly, while the content of starch and polyphenols decreased slightly. The mass loss percentage of instant quinoa was 11.5% and the score of sensory evaluation for the sample prepared under the optimum conditions was 87.

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