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Cooking Research on Deliciousness and Healthiness: Texture analysis on cooked rice using SEM images and Anti-oxidant capacity of roasted vegetables

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Abstract

We are providing not only gas, but also cooking appliances to residential users and to the commercial customers such as restaurants or hotels. Having scientific information on cooking and assisting the customers in their lives and businesses is crucial to building good relationships with them and/or to increasing customer retention rate. We have started a cooking research project for developing methods aiming at evaluating deliciousness and healthiness and elucidating the mechanisms how they are created.

This paper describes part of the project activities such as "Texture analysis on cooked rice using Scanning Electron Microscope (SEM) images" and "Anti-oxidant capacity of roasted vegetables."

1. Texture Analysis on cooked rice using SEM images

The purpose of the research is to clarify how the microstructure changes depending on the soaking conditions and to investigate the relationships between the microstructure and human senses such as stickiness and stiffness of cooked rice, which eventually lead to understanding deliciousness of rice.

Cooking experiments are conducted under several different soaking temperature and time conditions such as 10 degree C x 60 min or 40 degree C x 20 min. Based on the SEM images, we found that there are at least five stages for the degree of gelatinization shown below.1st stage: Partially gelatinized inside the amyloplast, 2nd stage: Completely gelatinized inside the amyloplast, but the cell membranes are not gelatinized, 3rd stage: Completely gelatinized, but the honeycomb structure is not well developed, 4th stage: Completely gelatinized, and the honeycomb structure is well developed, 5th stage: Completely gelatinized, and the honeycomb structure is fully developed.

The stickiness and the hardness from the texture analyzer, which are well correlated to the human senses, were strongly dependent on the microstructures.

It is suggested that the human senses about stickiness and hardness of cooked rice can be predicted by observing its microstructure.

2. Anti-oxidant capacity of roasted vegetables

The purpose of the research is to clarify the relationships between anti-oxidant capacity which indicates health benefits of some vegetables and roasting time or temperature, which eventually lead to understanding an optimal roasting condition that can maximize the deliciousness and healthiness.

Cooking experiments are conducted under three different roasting time conditions, 180 degree C x 5 min, 10 min and 15 min. Eggplant was used as a food material.

In the case of eggplant, the anti-oxidant capacity increased with the roasting time and the color of it was changed to brown by the Maillard reaction. The promotion of the Maillard reaction was confirmed by the increase in quantity of 3-DG, which is an intermediate substance of the Maillard reaction. Both the anti-oxidant capacity and the quantity of 3-DG increased with the roasting time. Therefore, it is thought that anti-oxidant capacity increased by the Maillard reaction. On the other hand, the deliciousness was good at 10 min and bad at 5min and 15 min.

It is considered that the anti-oxidant capacity increases with the roasting time, but that the the deliciousness peaks at around 10 min and decreases if the roasting time exceeds 10 min.

1. Introduction

We are providing not only gas, but also cooking appliances to residential users and to the commercial customers such as restaurants or hotels. Having scientific information on cooking and assisting the customers in their lives and businesses is crucial to building good relationships with them and/or to increasing customer retention rate. We have established a cooking research laboratory for developing methods aiming at evaluating deliciousness and healthiness and elucidating the mechanisms how they are created.

Fig.1-1 shows our research concept. We have developed many gas appliances based on the evaluation of deliciousness, which includes human sensory test, characterization of the physical properties of foods, and measurement of health-related indices such as antioxidant capacity or lipid content. The aim of this research is not only to measure these values, but also to analyze the reason why deliciousness and healthiness were created, which eventually leads to the development of innovative cooking appliances or the optimal cooking methods. To reveal the mechanism, we have focused on the chemical reactions such as starch gelatinization, Maillard reaction, and enzyme reaction. Furthermore, we tried to clarify the chemical reaction mechanism by observing heat transfer phenomena such as conduction, convection, and radiation.

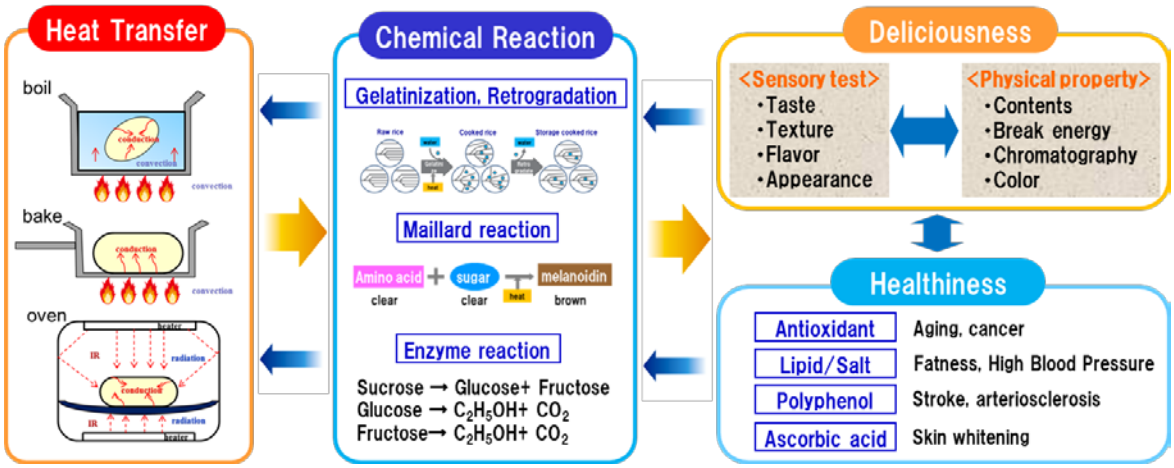


Fig. 1-1 Research concept

2. Rice Research

2-1. Introduction

Understanding micro-structural changes of starch-based foods during and after gelatinization is very important for controlling texture. There are many studies regarding the microstructure of rice for revealing its properties. The purpose of this research is to clarify how the microstructure changes depending on the soaking conditions and to investigate the relationships between the microstructure and human senses such as stickiness and stiffness of cooked rice, which eventually lead to understanding deliciousness of rice.

2-2. Methods

Cooking experiments were conducted under several different soaking temperature and time conditions such as 10 degree C x 60 min or 40 degree C x 20 min. For SEM observation, these samples were rapidly frozen using slush nitrogen and were dried at -50 degree, and then they were coated with gold using a sputter coater (JFC1600, JEOL). The samples were observed by Scanning Electron Microscope (SEM, JSM6510, JEOL) at an accelerating potential of 10 kV.

For texture measurement, cooked rice was pressed by a V-shaped plunger with a texture analyzer (RE2-33005B, YAMADEN) and the force over time was analyzed into elasticity and hardness.

2-3. Results

By observing the cross section of raw rice by SEM, the three hierarchical structures are confirmed. The structures are, from large to small, an endosperm cells (50-100μm), amyloplasts (5-10μm), and starch particles (1-2μm) (Fig. 2-1). These structures were changed by gelatinization after cooking.

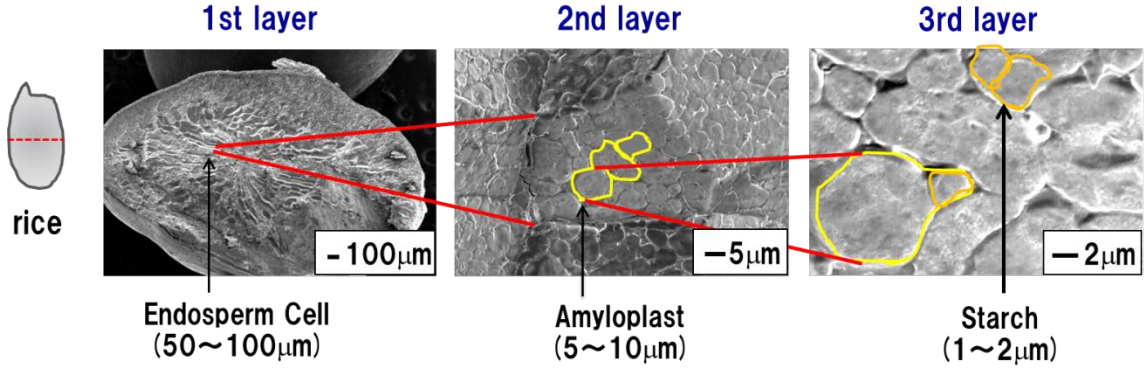


Fig. 2-1 Microstructure of the cross section of raw rice

We found that there are at least five stages for the degree of gelatinization shown below. 1st stage: partially gelatinized inside the amyloplast. 2nd stage: completely gelatinized inside the amyloplast, but the cell membranes are not gelatinized. 3rd stage: completely gelatinized, but the honeycomb structure is not well developed. 4th stage: completely gelatinized, and the honeycomb structure is well developed. 5th stage: completely gelatinized, and the honeycomb structure is fully developed (Fig. 2-2).

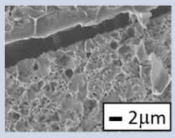
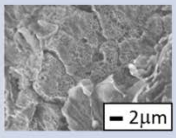
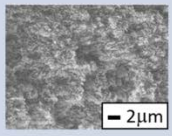
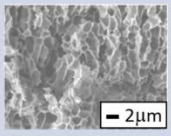
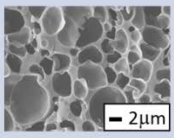
stage	1st stage	2nd stage	3rd stage	4th stage	5th stage
SEM Image					
Amyloplast gelatinization	partially	almost	Completely		
Honeycomb structure	-	-	small	middle	large

Fig. 2-2 Microstructural changes of cooked rice with several soaking conditions

The degree of gelatinization increased from the 1st stage to the 3rd stage, but it did not change from the 3rd stage to the 5th stage. The elasticity and hardness from the texture analyzer decreased as the ordinal number of the stage increased.

2-4. Conclusion

We found that there is a strong relationship between the microstructures of cooked rice and the texture data, which are well correlated to the human senses. Therefore, it is suggested that the human senses about stickiness and hardness of cooked rice can be predicted by observing its microstructure.

References

1) Haruo Tomita, “Development of evaluation method for gelatinization and retrogradation of cooked rice”, Japan City Gas Symposium in 2014 (Tokyo), 2-10
2) Ogawa, K. (1999). Journal of Home Economics of Japan, vol 50, No12, 1281-1289(1999)

3. Roast Vegetable Research

3-1. Introduction

Applying heat to the foods dramatically changes their physical and chemical properties. Optimizing the heating conditions could maximize healthiness or improve deliciousness, which can benefit not only residential or commercial kitchen users, but also food manufactures. This chapter describes how antioxidant activity changes depending on the heating conditions by taking the case as an example in which eggplant is cooked by oven heating. Furthermore, it discusses the mechanism why the antioxidant activity increased/decreased from the point of component changes in the cooked foods.

3-2. Methods

At first, we measured the healthiness change by the antioxidant activity (ORAC method) of roasted and raw eggplants. Then, we measured those components change such as total ascorbic acid (TAA) and total polyphenol (TPC), 3-deoxyglucosone (3-DG). 3-DG is an intermediate substance of the Maillard reaction, browning reaction. Finally, a sensory evaluation was also performed using a scoring system to investigate deliciousness. The baking conditions were at a temperature of 250°C and three different cooking times of 5, 10, or 15 minutes by an oven.

3-3. Result

Antioxidant activity (mmol T.E./100g F.W.) of the specimen heated by oven for 5 minutes was reduced into half (2.0→1.0) as compared with that of unheated specimen. But it increased significantly with extra heating time, the value after 15 minutes of heating being approximately 3.5 times greater (7.3) than that of unheated specimen.

Though TAA decreased at 15 minutes, TPC and 3-DG increased. 3-DG showed simple increase with heating time, this is reasonable for the color change of eggplants, but TPC showed decrease at 5minutes and increase at over 10 minutes. These suggest that the total antioxidant activity is more dependent on the amount of TPC and 3-DG and less dependent on the TAA which are destroyed by heat.

Deliciousness improved with heating times and maximum was 10minutes.

3-4. Conclusion

When eggplant is prepared by oven heating, as well as increasing deliciousness, antioxidant activity also increases, and it showed significant correlation to TPC change and Maillard reaction products (3-DG), demonstrating that preparation by oven heating is a significant method in healthy cooking. As a result, the optimal roasting condition (healthiness and deliciousness) was from 10 minutes to 15 minutes