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The absorption of 2-acetyl-1-pyrroline during cooking of rice (Oryza sativa L.) with Pandan (*Pandanus amaryllifolius Roxb*.) leaves)

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Abstract

Rice (*Oryza sativa* L.) is a staple food for about half of the population in the world. Aroma is one of the most important rice sensory quality characteristics. The chemical compound that contributes mostly to the aroma profile of aromatic rice (e.g. basmati rice) is 2-acetyl-1-pyrroline (2-AP). This highly volatile compound has been found to occur naturally in Pandan leaves. Adding fresh Pandan leaves to enhance the flavour profile of non-aromatic rice is as an old practice in South-East Asia. However, there has been little work done on how 2-AP is extracted from Pandan leaves and the phenomena taking place during cooking. The aim of this study was to investigate the mechanism of absorption of 2-AP from non-aromatic rice mixed with Pandan leaves during cooking. Non-aromatic rice was cooked with fresh Pandan leaves using optimal and excess water conditions. The amount of 2-AP in rice grain was found to decrease at 10 min (optimal water) and 5 min (excess water) of cooking. A possible explanation of this phenomena could be linked to starch gelatinization and the effect it has on interaction with 2-AP from the rice grains.

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Keywords: 2-acetyl-1-pyrroline; non-aromatic rice; Pandan leaves; rice cooking; starch gelatinization

1. Introduction

Rice *(Oryza sativa* L.) is consumed as the staple food for about half of the population in the world. Aroma is the most importance sensory quality of rice. Aroma of rice is caused by a combination of aroma compounds [1] and 2-acetyl-1-pyrroline (2-AP) which is present in a very low concentration has been reported to be the major active aroma compound contributed to the flavour of aromatic rice varieties [2].

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This compound has an odour threshold value as low as 0.1 ppb in water [3]. 2-AP was reported to be present naturally in all part of paddy except for roots and does not form during cooking or post-harvest processing [4, 5]. 2-AP is the main volatile compound in Pandan (*Pandanus amaryllifolius* Roxb.) leaves. In fact, the quantity of 2-AP present in Pandan leaves (of the order of 1 ppm) is more than 10 times of those found in aromatic rice and 100 times of those found in non-aromatic rice [2]. Pandan leaves have been reported as one of the best natural sources of 2-AP [6]; therefore, in South-East Asia, Pandan leaves are commonly used when preparing rice dishes as means of flavour enhancement.

Starch is a primary component of rice flour while starch gelatinization is the most important process in many food modifications including cooking starch based foods such as rice. Cooking of rice is associated with complete gelatinization of the starch which implies significant of changes in physical, chemical, nutritional of starch as well as water and heat diffusity, swelling, rheological behaviour, viscosity, lost of crystalline order and deformation of original starch products by heat treatment in the presence of water [7, 8]. The quality of cooked rice is depends on the rice variety, drying and storage conditions, rice moisture content, amylose and amylopectin content, starch type, water to rice ratio, cooking methods, degree of milling as well as precooking and post-cooking processing [9]. The phenomena during cooking of starch are very complex. Therefore, the aim of this study was to investigate the mechanism of 2-AP absorption from non-aromatic rice mixed with Pandan leaves during cooking. This work is part of a larger study in which extraction of 2-AP [10], its cooking with rice and flavour release in eating are being studied.

2. Materials & Methods

Fresh Pandan leaves and pre-fluffed long grain rice (Sea Isle) were purchased from a local supplier in Birmingham, United Kingdom. In this study, Pandan leaves was used as a main source of 2-AP. Intact Pandan leaves were cut into small pieces (≈5 mm in size), tied in muslin gauze and placed in the middle of an open rice cooker (optimal water) and a covered aluminium cylinder (excess water) immediately before the start of cooking. Optimal water cooking was defined as 240 g rice cooked with 800 ml of tap water, while in the excess water condition, 60 g of rice was boiled in 800 ml of tap water. Cooking was carried out by increasing the temperature with time (optimal water content) or at constant temperature of 100 °C (excess water). Moisture content (w.b.) of raw and rice grains cooked at 5, 10, 15 and 20 min were determined by air oven drying at 105 °C for 24 h. For each cooking time, 10 ml of water, 5 g of rice and 5 g of Pandan leaves from cooking process were taken out for static headspace analysis at 100 °C for 30 min prior to gas chromatography-flame ionization detector (GC-FID) analysis while 1 ml of vapour of cooking was injected directly to GC-FID without headspace analysis process by gas tight syringe. All experiments were performed in triplicate.

3. Results & Discussion

3.1. Moisture content of rice

In this study, wet basis (w.b.) of rice moisture content was determined by oven drying at 105°C for 24 h. This moisture content (w.b.) is defined as the ratio of the water weight to the initial total weight of the rice. Raw rice grain has 11.8 ±0.6 % (w.b.) of moisture content. This result was within the range of moisture content levels (10.2 to 32.5 %) of grain rough rice studied by Chen [11]. During cooking, the moisture content of cooked rice increased with time (Fig.1). This can be explained by increase water diffusion into the rice grains during the cooking process. The amount of water absorbed by starch granules of rice cooked in excess water was higher compared to rice in the optimal water content as a result of the higher temperature (100°C) applied in the excess water cooking. This study indicated that, as expected, the moisture content of cooked rice was significantly affected by water to rice ratio, time and temperature of cooking.

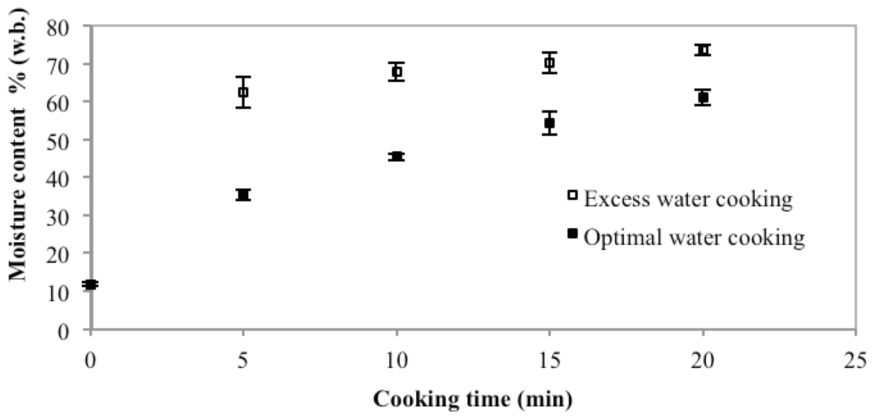

Fig. 1. Effect of cooking time on moisture content of rice grains during cooking of rice with Pandan leaves in optimal and excess water conditions.

3.2. 2-AP absorption by rice cooked with Pandan leaves

Fig. 2 shows the effect of cooking time on the amount of 2-AP absorbed by rice cooked with Pandan leaves in optimal and excess water cooking. The amount of 2-AP in raw long grain rice without any soaking and heating treatment was 1.14 ±0.03 µg. For the optimal water condition, after 5 min of cooking, an *increase* of 2-AP absorption by rice grains was obtained, due to diffusion of 2-AP from Pandan leaves to the rice grains. Pandan leaves was used as a source of 2-AP. However, a *decrease* of the amount of 2-AP was observed to happen twice in optimal water condition; at 10 and 20 min of cooking as shown in Fig. 2. It is interesting to note that amounts of 2-AP at both these cooking time were similar to the amount of 2-AP in raw rice grains.

These results are possibly due to changes in the condition of the starch in the rice, which has been studied using differential scanning calorimetry; bi-phasic endotherms were seen during gelatinization of rice starch at low water level, related to phase transitions of regions within starch granules due to hydration. The first endotherm (at 10 min of cooking) involved melting of partial crystallites. Rice starch structure collapsed due to melting of crystallites and most amylose contents were leached from the granules. This unbranched starch fraction can form helical structures which may entrap 2-AP. In addition, high amylose content in long grain rice used also gave significant absorption of 2-AP. Higher amylose content of rice accompanied higher binding capacity with aroma compound [12]. While the high temperature transition at 20 min of cooking is due to melting crystallites without adequate moisture. At this time, all the crystallites were completely melted. Therefore, amount of 2-AP of cooked rice at 20 min was slightly lower than 10 min of cooking rice. However, for the excess water condition, water absorption by rice starch granules lower the melting points of crystallites and resulted in the disappearance of high temperature transition. This result was in good agreement with Donovan [13].

Acceleration of water absorption of starch by heating at constant boiling point (100°C), promoted the hydration of starch, leading to early starch gelatinization in excess water cooking which happened at 5 min of cooking (Fig. 2). Interestingly, rice cooked in optimal water at 15 min absorbed the highest amount of 2-AP (3.65 ±0.03 µg). This result might be explained by the fact that complex of starch and 2-

AP disrupted after the first transition and there were considerable molecular rearrangements occurring with rice starch granules before they were disrupted again by increasing hydrothermal treatment at 96.7°C.

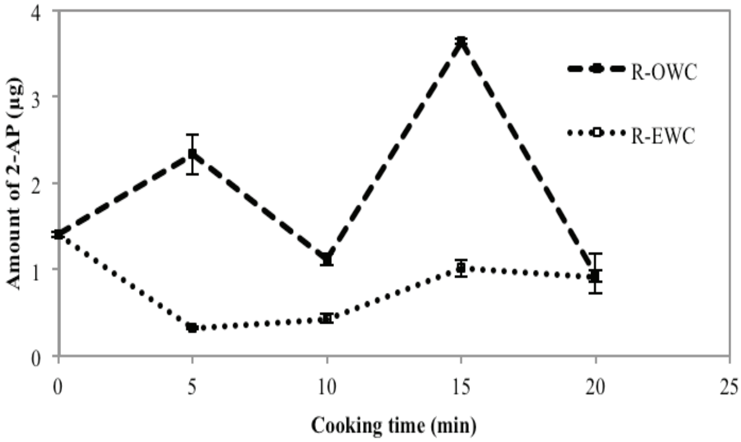

Fig. 2. Effect of cooking time on the amount of 2-AP absorbed by rice grain cooked with Pandan leaves in optimal (R-OWC) and excess water cooking (R-EWC) conditions

In order to investigate the effect of distance between Pandan leaves and rice on the absorption of 2-AP, sample of rice cooked in optimal water content was taken out from cooker at two different collection points, 1 cm (RN) and 7 cm (RF) from the Pandan leaves which were located in the middle of the rice cooker. A similar trend of 2-AP absorption by rice was observed from both collection points (Fig. 3). As expected, rice grains those collected near (RN) to Pandan leaf was absorbed more 2-AP as compared to far (RF) ones. These results can be explained by mass transfer of 2-AP between Pandan leaves and rice grains during cooking process. The distance between rice and Pandan leaves source give significantly impact to the absorption of 2-AP by rice.

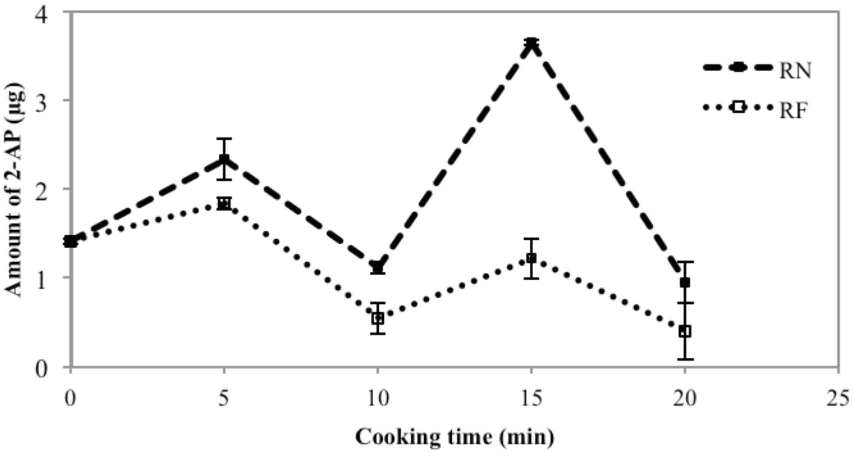

Fig. 3. Effect of cooking time on the amount of 2-AP absorption by rice grain cooked with Pandan leaves in optimal water cooking at different collection points. RN: rice sample is collected 1 cm from Pandan leaf; RF: rice sample is collected 7 cm from Pandan leaf

4. 2-AP amount in cooking water

Fig. 4 illustrates that the amount of 2-AP in cooking water increased with time for both optimal and excess water conditions. However, in optimal water, the amount of 2-AP in cooking water was observed to decrease at 20 min of cooking. When the water in the rice cooker was heated, more 2-AP molecules diffused from the Pandan leaves and were then transferred slowly to the water. From 0 to 15 min of cooking, the amount of water seems enough to carry 2-AP molecules moved out from Pandan leaves. However, as heating proceeds, less water remained in the rice cooker. This result also related to the experiment condition where optimal water cooking was done in an open rice cooker and it resulted in evaporation – excess heating thus leads to the loss of the material from the vessel.

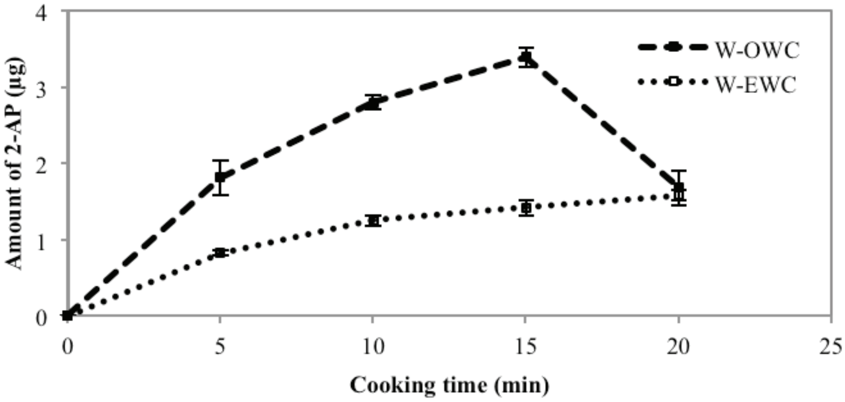

Fig. 4. Effect of cooking time on the amount of 2-AP in water during cooking of rice mixed with Pandan leaves in optimal (W-OWC) and excess water cooking (W-EWC) conditions

Same as to the rice sample, the cooking water samples were collected at two different collection points; 1 cm (WN) and 7 cm (WF) from Pandan leaves source. As indicated in Fig. 5, a similar trend of 2-AP amount in cooking water was obtained from these two collection points. As previously mentioned, Pandan leaf was used as a function of 2-AP source. Therefore, the nearer the water to the Pandan leaf, the greater the 2-AP absorbed to the water.

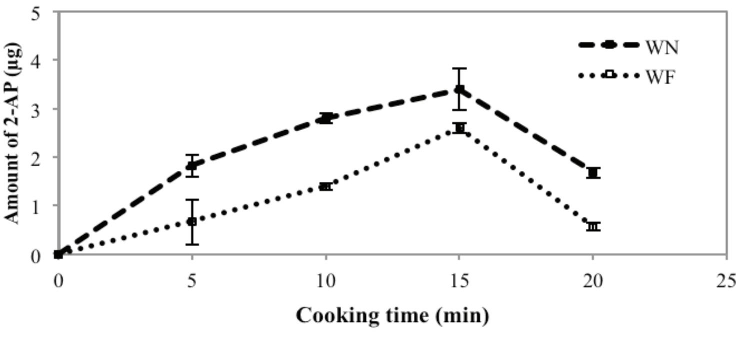

Fig. 5. Effect of cooking time on the amount of 2-AP in water during cooking of rice mixed with Pandan leaves in optimal water cooking at different collection points. WN: cooking water is collected 1 cm from Pandan leaf; WF: cooking water is collected 7 cm from Pandan leaf.

4.1 2-AP release from Pandan leaves

In Fig.6, percentage of 2-AP release from Pandan leaves in optimal and excess water cooking were plotted as a function of cooking time. In both optimal and excess water, the rate of release of 2-AP from Pandan leaves decreased with cooking time. Depending on the presence of enough water and hydrothermal effects, 2-AP molecules from Pandan leaves was transferred to the vapour (air), water and rice during cooking process. At 20 min of cooking, 89% of 2-AP release from Pandan leaves was observed in excess water cooking while only 63% was found released in optimal water. Release of 2-AP from Pandan leaves was significantly affected by temperature and time of cooking of rice.

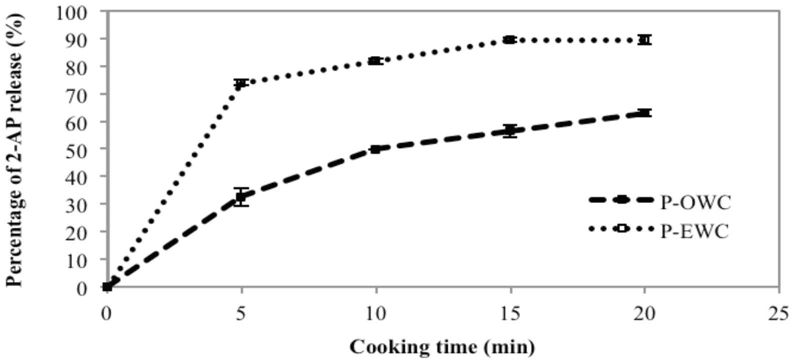

Fig. 6. Effect of cooking time on the 2-AP release from Pandan leaf during cooking of rice mixed with Pandan leaves in optimal (P-OWC) and excess water cooking (P-EWC) conditions

5. Conclusion

This study shown that the mechanism of 2-AP uptake during cooking of rice is quite complex. Absorption of 2-AP by rice in both optimal and excess water cooking was highly dependent on presence of water, moisture content of rice, water to rice ratio, starch gelatinization process as well as temperature and time of cooking. The highest amount of 2-AP absorbed by rice grain was observed at 15 min of cooking time in optimal water condition. Release of 2-AP from Pandan leaves was higher in excess water cooking compared optimal water ones. Static headspace analysis revealed a possible method to quantify the 2-AP absorption by rice grains during cooking of rice with Pandan leaves. However, the usage of Pandan leaves did not enrich the flavour of non-aromatic rice cooked for 20 min. Further work is underway to investigate the mechanism at longer cooking time and during retrogradation of rice starch.

Aknowlegdements

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