Comparison of the sensory properties of fragrant and non-fragrant rice: The role of the popcorn-like aroma compound 2-acetyl-1-pyrroline

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Abstract

2-Acetyl-1-pyrroline (2-AP) has been widely reported as being a key contributor to the popcorn-like aroma of fragrant rice. To understand more about the contribution of 2-AP to the aroma of fragrant rice and to highlight the sensory differences between fragrant and non-fragrant rice, quantitative descriptive analysis was conducted, to examine the sensory properties of six boiled rice samples (three fragrant rice and three non-fragrant rice) by 11 panellists, with emphasis on popcorn-like odour and flavour. The results showed perceived intensity of popcorn odour and flavour in fragrant rice were higher than in non-fragrant rice ($p = 0.016$, $p = 0.026$, respectively). However, the panellists could not differentiate between fragrant boiled rice varieties based on popcorn odour or flavour. 2-AP was extracted from the six boiled rice samples by headspace solid-phase microextraction and quantified by gas chromatography-mass spectrometry. 2-AP was found in fragrant rice samples (146 µg/kg in Jasmine, 113 µg/kg in Basmati and 80 µg/kg in Sintanur) but could not be quantified in non-fragrant varieties (below 5 µg/kg). These results suggested that although 2-AP is a key contributor to popcorn-like notes in fragrant rice, the differences in level of 2-AP content between different boiled fragrant rice samples may be too small to cause perceptual discrimination. In addition, popcorn-like notes were perceived in non-fragrant rice samples, despite levels of 2-AP being below detection limits.

Introduction

2-Acetyl-1-pyrroline (2-AP) is a volatile compound with a popcorn-like odour and a low detection threshold (0.1 µg/kg in water). It was firstly identified in boiled fragrant rice [1]. When popcorn odour intensities in several fragrant rice varieties were ranked, 2-AP was considered as the most important contributor to this odour [2]. However, Yang et al. [3] reported that popcorn-like note may not be the only important characteristic in boiled fragrant rice odour. In addition, Limpawattana et al. [4] reported no correlation between popcorn flavour and 2-AP. Moreover, 2-AP has been reported to be generated only during fragrant rice growth and not during other postharvest procedures or cooking [5].

Lexicons of rice descriptors have been established in several studies, especially for fragrant rice [6-8]. The selection of descriptors depends on the panellists' culture and familiarity with the samples [9]. However, no rice lexicon has previously been reported using a UK sensory panel. In this study, different boiled rice varieties were evaluated using quantitative descriptive analysis (QDA). A lexicon was developed for both boiled fragrant and non-fragrant rice varieties using a UK-based panel. Differences in flavour and odour between fragrant and non-fragrant rice were evaluated. In addition, the relationship between popcorn flavour/odour and 2-AP content in boiled fragrant and non-fragrant rice was examined.

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Experimental

Materials

Six varieties of white rice were obtained in summer 2016, including three fragrant rice varieties (Basmati and Thai Jasmine from ASDA supermarket; Sintanur from Indonesia Centre of Rice Research) and three non-fragrant rice varieties (American long grain from ASDA supermarket; Arirang from Korea Foods Company Limited; and Ciherang from Indonesia Centre of Rice Research). 2-AP and deuterated 2-AP (2-AP-d2) standards were used for 2-AP quantification (both 30,000 ppm in dichloromethane (DCM), Aroma Lab, Germany).

Quantitative Descriptive Analysis (QDA) in boiled rice

Milled rice (200 ± 1 g) was weighed and then boiled using 300 mL mineral water in a rice cooker (0.8 L, Lloytron, UK). Cooking proceeded for 20 min before the rice cooker automatically turned to warm mode. The samples were kept warm (65 °C) for 20 min before serving to panellists for evaluation.

Quantitative descriptive analysis (QDA) was conducted for six rice samples, using 11 trained UK panellists. A vocabulary was developed for appearance, odour, taste, flavour, mouthfeel and after-effect. A pre-heated ceramic cup (50 mL) filled with boiled rice (20 g) covered by foil was served to panellists for developing odour attributes and another 20-g sample was then served in the same manner for developing all the other attributes. The scoring for each attribute of sample was conducted in individual booths in duplicate on separate days, and samples labelled with three-digit codes were presented randomly in a balanced order. Data were collected using Compusense at-hand (Canada).

2-Acetyl-1-pyrroline quantification in boiled rice

Rice samples (1 g ± 0.001 g) and 1.5 mL HPLC-grade water were added to 20-mL SPME glass vials with metal screw-caps and PTFE-faced silicone septa. Vials were then heated in a GC oven at 100 °C for 20 min. A 1.5-mL aliquot of 2-AP-d_2 aqueous solution (approximately 100 µg/kg, prepared by replacing DCM with HPLC-grade water) was added into the vials after they were cooled to room temperature. 2-AP in boiled rice was extracted from these samples by automated SPME (GC Sampler 120, Agilent). Samples were incubated with magnetic shaking for 10 min at 40 °C, and then extracted with a Supelco DVB/CAR/PDMS SPME fibre for 1 hour at 40 °C. After extraction, the extracts were analysed by gas chromatography-mass spectrometry (GC-MS) using a 7890 GC with 5975C MS (both Agilent). The SPME fibre was desorbed in the GC injector at 250 °C for 20 min, in splitless mode, onto the front of a Zebron ZB-Wax column (30 m × 0.25 mm; 1 µm film thickness; Phenomenex). The carrier gas was helium at a constant column flow rate of 0.9 mL/min. The initial GC oven temperature was 40 °C and held for 2 min, then increased to 60 °C at the rate of 2 °C/min; then the rate increased to 6 °C/min until the temperature reached 250 °C. Electron ionisation (EI) mode was used at 70 eV. Full scan mode was used for analysis from m/z 30 to 280. Simultaneous selective ion monitoring was also applied: ions *m/z* 68, *m/z* 83 and *m/z* 111 were monitored for 2-AP; *m/z* 86 and *m/z* 114 were monitored for 2-AP-d_2. The dwell time of monitored ions was set at 100 ms/ion.

Results and discussion

Quantitative Descriptive Analysis (QDA) in boiled rice

Thirty-seven attributes (covering appearance, odour, taste, flavour, mouthfeel and after-effect) were found in six boiled rice samples by 11 trained UK panellists. Significant differences between samples were found in all appearance attributes ($p < 0.0001$), popcorn odour ($p = 0.028$) and cohesive mouthfeel ($p < 0.0001$). Popcorn-like attributes were not only found in fragrant rice, but also in non-fragrant rice. When the six samples were grouped into fragrant (Jasmine, Basmati and Sintanur) and non-fragrant rice (long grain, Arirang and Ciherang), the perceived intensities of popcorn odour and flavour in fragrant rice were found significantly higher than in non-fragrant rice ($p = 0.016$, $p = 0.026$, respectively; Figure 1a). Although a significant difference in perceived popcorn odour was observed by ANOVA between different rice varieties (Figure 1b, $p = 0.028$), this difference was caused by a difference between Jasmine and Ciherang ($p < 0.05$); differences between other rice varieties were not observed. Jasmine and Sintanur tended to show higher perceived popcorn flavour than other samples, but no significant differences in popcorn flavour were found between rice varieties (Figure 1b, $p = 0.134$). These results indicated that although the panellists could not detect a difference in popcorn odour and flavour between individual boiled rice varieties, fragrant and non-fragrant rice could be categorised based on popcorn odour or flavour.

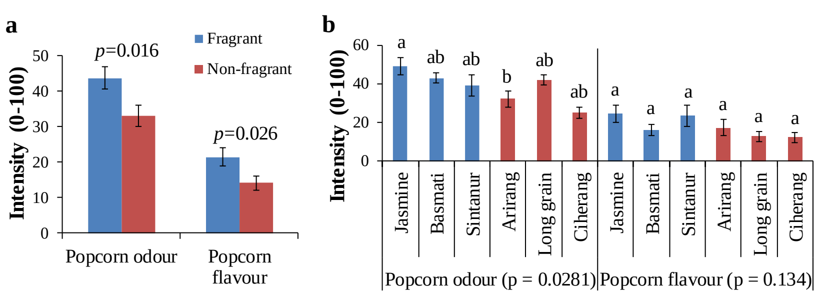

Figure 1: popcorn odour and flavour in fragrant and non-fragrant rice (a); perceived popcorn odour and flavour among six rice samples (b). Bars not sharing a common letter are significant different ($p<0.05$). Error bar represents standard error. Blue bars represent fragrant rice; red bars represent non-fragrant rice.

Quantification of 2-acetyl-1-pyrroline in boiled rice

Concentrations of 2-AP in six boiled rice samples are shown in Figure 2. Significant difference in 2-AP concentrations was observed between the three boiled fragrant rice samples ($p = 0.028$). The concentrations of references (four levels of 2-AP standards) used for popcorn odour in QDA training were 5 or 10-fold in difference, and the trained panellists could rank these samples in order of intensity with no difficulty. However, the two-fold difference in 2-AP (Jasmine *vs* Sintanur) was not great enough to be noticed by panellists, which might explain why there was no significant difference in popcorn odour or flavour between fragrant rice samples. Limpawattana et al. [4] reported that although 2-AP was the only contributor to popcorn-like note in boiled rice, this compound did not correlate with popcorn flavour. Therefore, as rice contains numerous volatile compounds, the interaction of other compounds with 2-AP might affect the perception of popcorn odour and flavour. In three non-fragrant rice varieties, although traces of 2-AP were detected in the GC-MS chromatograms, the concentration in these samples was too low to be quantified (Figure 2). The lowest concentration of 2-AP that could be quantified in this study was 5 µg/kg. However, these concentrations may be still about 50-fold higher than the 2-AP detection threshold (0.1 µg/kg in water), which could be the reason that popcorn-like attributes in non-fragrant rice were also detected by panellists.

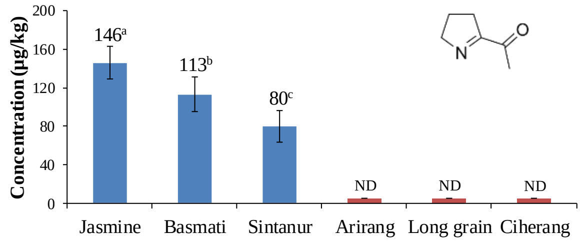

Figure 2: 2-acetyl-1-pyrroline concentrations in six boiled rice samples. Bars not sharing a common letter are significantly different ($p < 0.05$). Error bar represents standard deviation. ND: not detected, concentration lower than 5 µg/kg. Blue bars represent fragrant rice; red bars represent non-fragrant rice.

Yang et al. [3] analysed odour-active compounds in five boiled fragrant rice and one boiled non-fragrant rice samples. They found that 2-AP was detected in all six rice varieties, and popcorn-like odour was also detected in the non-fragrant rice variety. However, no other compounds that contributed popcorn-like odour were detected in their study. As no other compounds known to possess popcorn aroma were found in the current study, this suggests that trace levels of 2-AP in the non-fragrant varieties may be responsible for their popcorn-like aroma.

Conclusion

A lexicon was developed by a trained UK panel to describe six boiled rice varieties (three fragrant and three non-fragrant rice types). Popcorn odour and flavour were found in both fragrant and non-fragrant rice, but it was difficult to differentiate all six boiled rice varieties based on these attributes. However, significant differences were observed in both popcorn odour and popcorn flavour when fragrant and non-fragrant rice were compared by t-test. Significant differences in 2-AP concentration were found between the three fragrant rice varieties, although such differences were too small to cause a significant perceptual difference. Much higher levels of 2-AP were found in fragrant rice than non-fragrant rice. However, trace levels of 2-AP may contribute to popcorn attributes in non-fragrant rice varieties.

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