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Original Research Article

Effect of drying and storage times on aroma quality of Khao Dawk Mali-105 brown rice

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ABSTRACT

Khao Dawk Mali-105 (KDML) is fragrant Thai rice variety which is well-known and popular in the United States and many countries in Asia and Europe. Drying and storage times are factors affecting aroma of an aroma of fragrant rice. Therefore, the aim of this study was to investigate the effect of drying and storage times on aroma quality of KDML fragrant brown rice (KBR). KBR was dried in tray dryer at 35°C for 2 and 6 hours. Then, KBR was kept in linear low density polyethylene (LLDPE) bag at the dark at room temperature for 8 months. Aroma descriptive analysis, 2-acetyl-1-pyrroline (2-AP) and hexanal content, thiobarbituric acid (TBA) value and moisture content of KBR at 0, 2, 4, 6 and 8 months were evaluated. Drying time did not significantly affect aroma characteristics of KBR. The intensity of desirable aroma such as pandan-like aroma of uncooked KBR and cooked corn-like aroma of cooked KBR decreased significantly with longer storage time. On the contrary, the intensity of undesirable odors such as rancid and musty odors significantly increased upon storage. Cooked KBR that dried at 35°C for 2 and 6 hours had higher intensity of cooked corn-like aroma and lower intensity of undesirable odors than those of non-drying treatment. The 2-AP content of KBR was decreased after drying treatment and during longer storage. The hexanal content and TBA value of KBR were significantly increased along with storage. The moisture content of KBR (12.58%) significantly decreased after drying treatment for 2 and 6 hours (10.83% and 10.25%, respectively); however, the storage time did not influence on moisture content of KBR. These results indicate that drying and storage times affect on the aroma quality of KBR. Therefore, these factors should be considered in order to maintain rice aroma quality during storage.

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INTRODUCTION

Khao Dawk Mali-105 (KDML) or "Jasmine rice" is fragrant Thai rice variety which is well-known and popular in the United States and many countries in Asia and Europe. The unique aroma of KDML is interested by many researchers. Therefore, there are many research focus on various aspects of aroma of fragrant rice such as the key aroma profiles of KDML (Buttery et al., 1986; Tanchotikul et al., 1991; Yoshihashi, 2002; Bryant and McClung, 2010), pathway for presence of fragrance in rice (Daygon et al., 2017) and factors influenced to the change of KDML aroma (Wongpornchai et al., 2004; Yoshihashi et al., 2006; Tulyathan and Leeharatanaluk, 2007; Luangmalawat et. al., 2008).

Brown rice is an unpolished rice grain. It is covered by rice bran which is composed of embryo and endosperm layers. These layers are sources of nutritional and biofunctional components such as dietary fibers, γ-oryzanol, vitamins and minerals (Cho and Lim, 2016). Therefore, brown rice has been promoted as one of the potent functional foods (Gao et al., 2018). However, the compositions that contain in brown rice could generate aroma compound from chemical reactions that change the aroma quality of rice. For example, lipid oxidation is a major cause of rancid which produced off-flavor from hexanal formation (Elmore and Mottram, 1998). Recently, there is only little report on aroma quality of KDML fragrant brown rice (KBR).

There are many factors influencing the stability and aroma quality of fragrant rice such as maturity at harvesting time, drying method, moisture content, temperature, time and light during storage. Generally, drying is the treatment used to reduce moisture content and microbial growth of paddy rice. However, drying treatment might reduce 2-acetyl-1-pyrrolin (2-AP) which is an important key aroma compound of fragrant rice. Meanwhile, drying treatment might accelerate the lipid oxidation that produce undesirable compounds such as hexanal. Moreover, storage conditions; such as light, oxygen, temperature and time have been reported as factors that influenced on the aroma quality of fragrant rice (Yoshihashi et al., 2005; Tulyathan and Leeharatanaluk, 2007). Therefore, the effect of drying and storage times on aroma quality of KBR were investigated.

MATERIALS AND METHODS

The Khao Dawk Mali-105 brown rice (KBR) (*Oryza sativa* L.) was obtained from Patum Rice Mill and Granary Co., Ltd (Bangkok, Thailand). Hexanal and 2, 4, 6-trimethylpyridine were purchased from Sigma-Aldrich Co. (Missouri, USA). Other chemicals in this study were analytical grade.

Drying and storage times

KBR was dried in tray dryer at 35°C for 2 and 6 hours. After drying, 5 kg of KBR was kept in linear low density polyethylene (LLDPE) bag at the dark at room temperature (25±2°C) for 8 months. Sensory evaluation, 2-AP, hexanal and moisture content of KBR samples at different drying times after storage for 0, 2, 4, 6 and 8 months were analyzed. KBR sample was milled by centrifugal mill ZM 1000 (Retsch GmbH, Haan, Germany) and smaller particles passed through the 100 mesh screen was kept at -20°C after milling.

Sensory evaluation

Aroma characteristics of uncooked and cooked KBR were evaluated by 10 trained panels. Sensory assessment was performed using a modified from Theerakulkait et al. (1995) which composed of panel selection, term generation, development of definitions and references for the attributes, scale design and training and sample testing. The uncooked KBR was prepared by weighing 5 g of KBR powder into glass bottle (80 mL) and added 10 mL of deionized water. Then, the glass bottle was covered with aluminium foil and kept in room temperature for 15 min before sniffing. Cooked KBR was prepared by weighing 5 g of KBR powder and added 10 mL of deionized water into glass bottle. Then, the glass bottle was cover with aluminium foil before cooking in steamer for 40 min. Then, cooked KBR was cooled down to room temperature before sniffing. The reference standards were prepared at different concentration levels; the standards were used as references for training before rating the aroma intensities of the samples. Then, aroma intensities (score 0-15) of KBR were rated by trained panel "none (0)" and "very strong (15)". Term and definition used in sensory descriptive analysis were presented in Table 1. Pandan leaves; which was used as the standard reference of pandan-like, was blended with distilled water at the ratio of 1: 2.5 (w/w). Then, the concentration was prepared at different 4 levels during training period (8×10^{-4}, 8×10^{-3}, 4×10^{-2} and 8×10^{-2} g/mL).

Table 1. Term and definition used in sensory descriptive analysis.

Term	Definition
Pandan-like	The characteristic note of "pandan-like" associated with popcorn, white bread and jasmine rice
Pounded unripe rice (khao-mao)-like	The characteristic note of "khao-mao-like" associated with baked bread and sweet
Cooked corn-like	The characteristic note of "cooked corn -like" associated with cooked rice and boiled corn
Rancid odor	The characteristic note of "rancid odor" associated with oil and stale
Musty odor	The characteristic note of "musty odor" associated with moldy, stale and long closed-room smell

Determination of 2-AP and hexanal content

2-AP and hexanal content of KBR powder at different drying times at 0, 2, 4, 6 and 8 months were determined according to procedure of Widjaja et al. (1996). KBR powder (5 g) was weighted in 20 mL vial and 2 μL of internal standard (2, 4, 6-trimethylpyridine) was spiked into the sample. The vial was sealed with aluminium seal and methyl silicone septum. The volatile compounds in headspace of the vial were collected and operated in Headspace Sampler (Hewlett-Packard, USA) before transfer to Gas Chromatograph-Mass Spectrometer (GC-MS) system. The GC-MS system consisted of a 6890 GC/5973 mass selective detector (Hewlette Pakgard, USA). Separation of volatile compounds was achieved with a Innowax capillary column (30 m × 0.25 mm i.d. × 0.25 μm film thickness, Agilent Technologies, Inc., USA) in splitless mode (inlet temperature was 200°C). The initial oven temperature was 50°C for 3 min. After that, the oven temperature was increased at a rate of 1 °C/min to 53 °C and hold for 5 min. Then the temperature was increased at a rate of 10 °C/min to 110 °C and at a rate of 1 °C/min to 120 °C. The final temperature was 200°C and hold for 10 min. The flow rate of helium carrier gas was 1 mL/min. The mass spectra were monitored using selected ion monitoring (SIM) mode. Mass spectrum 29, 43, 57 and 86 were recorded at the beginning (0-6 min). After that at 6-12.8 min, mass spectrum 27, 39, 55, 58, 67, 71, 72, 82, 89 and 100 were recorded. Then, at 12.8-21.5 min, mass spectrum 41, 42, 43, 52, 54, 55, 67, 68, 83 and 111 were recorded. Finally, at 21.5-26.7 min, mass spectrum 27, 39, 51, 77, 79, 106, 120 and 121 were recorded. The 2-AP content was calculated by the area under peak ratio of 2-AP and internal standard. The amount of hexanal was calculated by using standard curve which was plotted between the amount of the standard of hexanal and area under peak.

Determination of thiobarbituric acid (TBA) value

The powder of KBR at different drying times at 0, 2, 4, 6 and 8 months was weighted 10 g into test tube before adding 30 mL of water. Two mL of the solution was taken and mixed with 1 mL of EDTA, 3 mL of the mixture of butylated hydroxyanisole (BHA) and propyleneglycol in Tween-20, 3 mL of TBA solution and 17 mL of TCA-HCl, respectively. The tube was purged with nitrogen gas and boiled for 30 min. The 15 mL of the solution was added with 5 mL of chloroform and centrifuged. The absorbance of the solution was read at 535 nm (modified from Shibata and Kinumaki, 1979).

Determination of moisture content

The moisture content of KBR at different drying times at 0, 2, 4, 6 and 8 months were determined according to AOAC procedures (AOAC, 1990).

Statistical analysis

Data on sensory aroma profiles, three replicates were designed for chemical analysis such as 2-AP and hexanal content, TBA value and moisture content of KBR were analyzed using analysis of variance (ANOVA) and significant difference ($p \leq 0.05$) among treatments was detected using Duncan's multiple range test.

RESULTS AND DISCUSSION

Moisture content and aroma characteristics of KBR

The moisture content of KBR at different drying and storage times are presented in **Figure 1.** The moisture content of KBR with non-drying treatment (12.58%) significantly decreased after drying at 35 ºC for 2 and 6 hours (10.83% and 10.25%, respectively). The storage time did not influence on moisture content of KBR, because of the good water vapor barrier properties LLDPE bag (Goswami and Mangaraj, 2011).

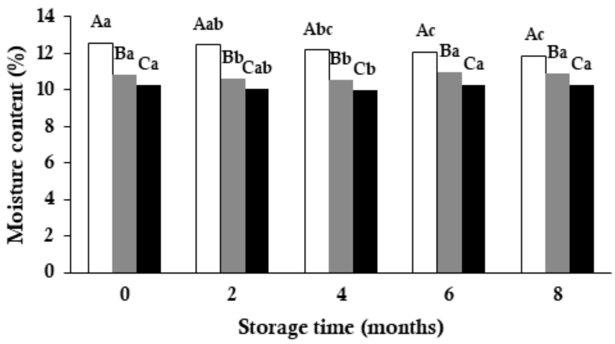

Figure 1. Moisture content of KBR at different drying and storage times. ☐ KBR with non-drying treatment, KBR dried at 35°C for 2 hours and ■ KBR dried at 35°C for 6 hours.

[A-C] Different letters in the same storage time indicate significant difference at $p \leq 0.05$.

[a-c] Different letters in the same drying treatment indicate significant difference at $p \leq 0.05$.

Although the drying time significantly affected on the reduction of moisture content of KBR, it did not affect on the aroma characteristic of KBR. The aroma characteristics of uncooked and cooked KBR are presented in **Figure 2** and **3**, respectively. The aroma characteristics of pandan-like, pounded unripe rice (khao-mao)-like, rancid and musty aromas were reported as the aroma attributes of uncooked KBR (**Figure 2**).

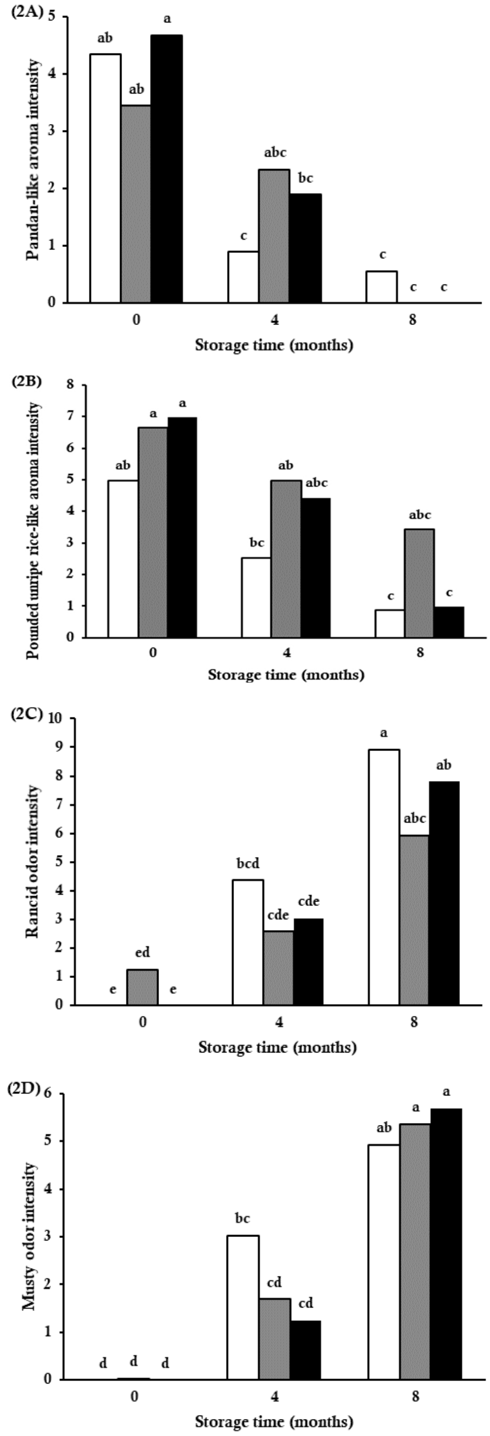

Figure 2. The aroma characteristics of uncooked KBR at different drying and storage times. (A) pandan-like aroma, (B) pounded unripe rice-like aroma, (C) rancid odor and (D) musty odor. ☐ KBR with non-drying treatment, ■ KBR dried at 35°C for 2 hours and ■ KBR dried at 35°C for 6 hours.

[a-e] Different letters in the same aroma characteristic indicate significant difference at $p \leq 0.05$

Drying time did not significantly influence on pandan-like, pounded unripe rice-like, rancid and musty aromas of uncooked KBR (Figure 2A, 2B, 2C and 2D, respectively). However, the intensity of desirable aroma such as pandan-like aroma of uncooked KBR decreased significantly with longer storage time. On the contrary, the intensity of undesirable odors such as rancid and musty odors significantly increased upon storage.

Cooked corn-like, rancid and musty aromas were reported as the aroma attributes of cooked KBR (**Figure 3**). Drying time did not significantly influence on cooked corn-like, rancid and musty aromas of cooked KBR (Figure 3A, 3B and 3C, respectively). Wongpornchai et al. (2004) reported that the modified treatment with low temperature (30–40°C) could promote better aroma quality of KDML than using high temperature. Drying KBR at 35°C of could significantly preserved pandan-like or cooked corn-like aroma of uncooked and cooked KBR at the initial storage time (**Figure 2A** and **3A**, respectively).

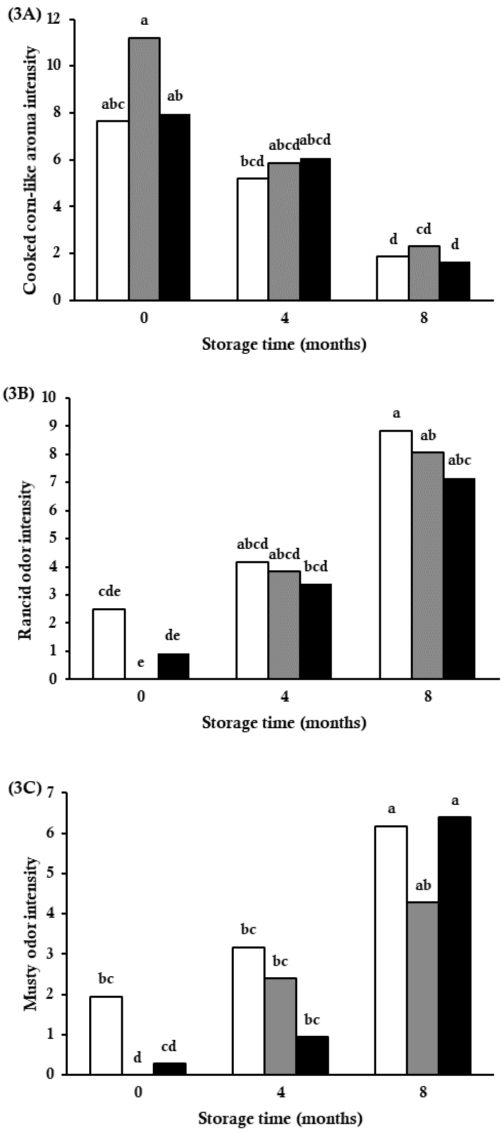

Figure 3. The aroma characteristics of cooked KBR at different drying and storage time. (A) cooked corn-like aroma, (B) rancid odor and (C) musty odor. □ KBR with non-drying treatment, ■ KBR dried at 35°C for 2 hours and ■ KBR dried at 35°C for 6 hours.

[a-e] Different letters in the same aroma characteristic indicate significant difference at $p \leq 0.05$.

The desirable aroma such as cooked corn-like aroma of cooked KBR decreased significantly with longer storage time (Figure 3A). In contrast, the intensity of rancid and musty odors significantly increased with longer storage time (Figure 3B and 3C). The rancid and musty odors of uncooked and cooked KBR might be originated from lipid oxidation during storage because oxygen could pass into the LLDPE bag during storage (Goswami and Mangaraj, 2011).

The content of 2-AP and hexanal

The amount of 2-AP of KBR at different drying and storage times are shown in **Figure 4**. The 2-AP content of KBR was decreased after drying treatment and during longer storage.

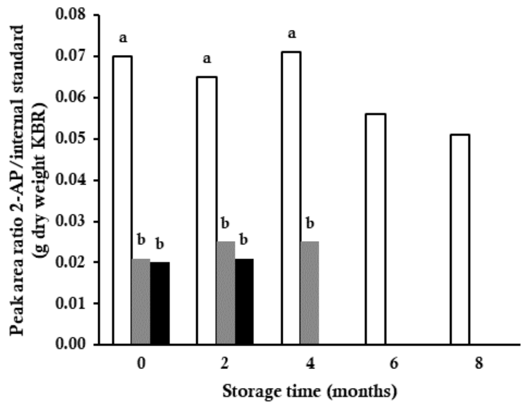

Figure 4. The amount of 2-AP of KBR at different drying and storage times. □ KBR with non-drying treatment, ■ KBR dried at 35°C for 2 hours and ■ KBR dried at 35°C for 6 hours.

[a-b] Different letters in the same drying treatment indicate significant difference at $p \leq 0.05$.

These were related to the aroma characteristics of KBR. The significant reduction of pandan-like of uncooked KBR was detected with longer storage time. 2-AP is an important compound contributing to a popcorn-like aroma which has been found to occur naturally in pandan leaves (Laksanalamai and Ilangantileke, 1993; Yahya et al., 2011). Generally, 2-AP has been reported as a highly unstable compound. The half of 2-AP concentration reduced from its originate after 3 months of storage fragrant rice (Widjaja et al., 1996), 2-AP in popcorn decreased 80% during storage at room temperature for 1 week (Schieberle, 1995). Yoshihashi et al. (2005) also reported that 2-AP content was decreased at higher storage time and temperature. In addition, the reduction of 2-AP content of rice was inversely correlated with fat acidity. As a result of unstable property of 2-AP; therefore, 2-AP content and pandan-like aroma decreased after drying and longer storage time.

The amount of hexanal of KBR at different drying and storage times are reported in Figure 5. Hexanal is an aldehyde which originate from breakdown products of oxidation. Hexanal is a good indicator for flavor deterioration and a reliable indicator for assessing the degree lipid oxidation (Shahidi, 1998). The KBR that dried at 35°C for 2 and 6 hours had lower hexanal content than those of non-drying sample.

The hexanal content of KBR with longer drying time were lower than that of non-drying KBR during storage for 4 months. In addition, hexanal content of non-drying KBR and KBR dried at 35°C for 2 and 6 hours did not significantly different after 4 months of storage. This is might be due to the autoxidation of unsaturated fatty acid and the substrate limitation in KBR of lipoxygenase.

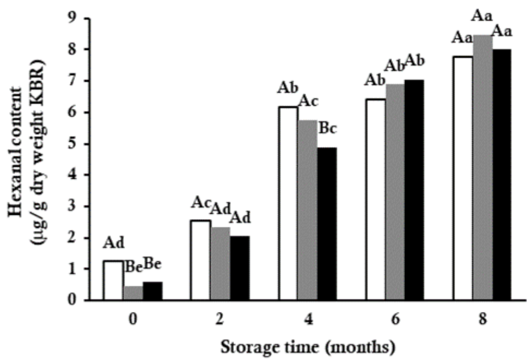

Figure 5. The amount of hexanal of KBR at different drying and storage times. ☐ KBR with non-drying treatment, ■ KBR dried at 35°C for 2 hours and ■ KBR dried at 35°C for 6 hours.

A-BDifferent letters in the same storage time indicate significant difference at $p \leq 0.05$.

a-eDifferent letters in the same drying treatment indicate significant difference at $p \leq 0.05$.

However, Sowbhaya and Bhathacharya (1976) reported that peroxide and carbonyl content; which are product of fat oxidation, increased during storage of polished rice at lower moisture content. Because the lower moisture content could increase the concentration of fat and possibility of oxidation reaction. Moreover, drying at 35°C could not delay the oxidative rancidity that might occur during storage. Therefore, hexanal contents of all non-drying and dried KBR samples, were significantly increased along with storage. Moreover, drying could increase hexanal and 2-pentyl furan; which are off-flavor, throughout the experimental period of 10 months (Wongpornchai et al., 2004). The hexanal content was related to undesirable odors; rancid and musty odors, of uncooked and cooked KBR. Therefore, these undesirable odors development of uncooked and cooked KBR were detected as increasing hexanal content during storage. This might be due to the lipid oxidation development of KBR during storage.

The determination of TBA value

TBA value of KBR at different drying and storage times are shown in Figure 6. The TBA value were significantly increased as longer storage time. This might be due to the lipid oxidation development of KBR during storage because TBA test measures malonaldehyde produced from oxidation of fatty acids with three or more double bonds (Yang and Boyle, 2016). TBA value is critically evaluated as a standard chemical index of oxidative rancidity (Downey, 1969). The significantly higher TBA value went along with the increasing of undesirable odors and hexanal content with longer storage time. The undesirable odors of KBR might originate from both enzymatic rancidity during milling paddy rice and oxidative rancidity during storage. The rancid odor in KBR had the high correlation coefficient with hexanal content and TBA value (0.984 and 0.956, respectively; data not shown). Moreover, musty odor in KBR had the high correlation coefficient with hexanal content and TBA value (0.948 and 0.988, respectively; data not shown).

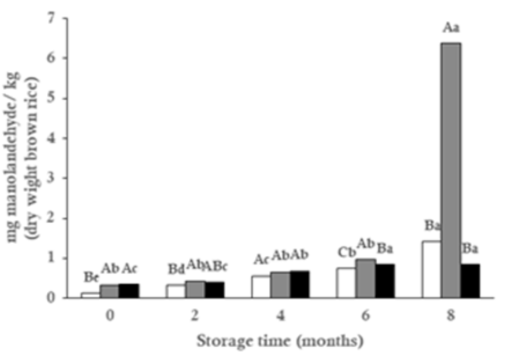

Figure 6. TBA value of KBR at different drying and storage times. ☐ KBR with non-drying treatment, ■ KBR dried at 35°C for 2 hours and ■ KBR dried at 35°C for 6 hours.

A-CDifferent letters in the same storage time indicate significant difference at $p \leq 0.05$.

a-eDifferent letters in the same drying treatment indicate significant difference at $p \leq 0.05$.

CONCLUSIONS

These results indicate that drying and storage times affect on the aroma quality of KBR. The desirable aromas; pandan-like aroma of uncooked KBR and cooked corn-like aroma of cooked KBR, decreased significantly with longer storage time. In contrast, rancid and musty odors significantly increased upon storage. Moreover, 2-AP content significantly decreased as treated by drying treatment and kept for longer storage time. The hexanal content and TBA value increased along with storage. The enzymatic and oxidative rancidity should be the crucial reactions that changed the aroma quality of KBR. Therefore, the factors the influence on these reactions should be considered in order to maintain rice aroma quality during storage.

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