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ADVANCES IN SENSORY EVALUATION OF RICE GRAIN: METHODOLOGICAL APPROACHES AND EXPERIMENTAL SIGNIFICANCE

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Abstract
Sensory evaluation is a vital approach for assessing the organoleptic qualities of rice—such as appearance, aroma, taste, and texture—which strongly influence consumer acceptance and market value. This review summarizes current methods for rice sensory assessment, covering traditional human sensory panels as well as advanced instrumental techniques, including gas chromatography (GC), electronic nose analysis, texture profile analysis (TPA), and artificial intelligence (AI)-based systems. The review highlights the importance of panelist training, standardized evaluation protocols, and the application of sensory data in rice breeding, variety approval, and quality assurance programs. By exploring global practices, it emphasizes the critical role of sensory profiling in developing rice cultivars that align with both agronomic performance and evolving consumer preferences.

INTRODUCTION

Rice (*Oryza sativa L.*) is an essential food for more than half the world's population. Beyond produce and nutritive content, organoleptic qualities such as flavor, aroma, and texture significantly impact consumer preference and marketability (Calingacion *et al*., 2014). Sensory assessment delivers a systematic approach to measure subjective traits, enabling researchers and producers to improve varieties and processing methods. While agronomic traits such as yield and disease resistance remain crucial, sensory characteristics significantly influence market preference and adoption. National and international variety release committees increasingly emphasize sensory quality as part of rice variety approval. (Hossen *et al*., 2021)

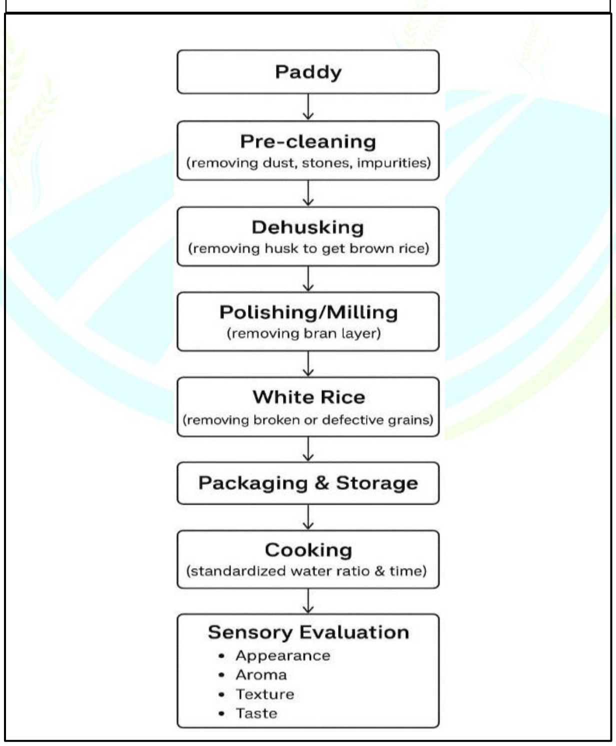
Sensory valuation plays a decisive role in rice breeding as it bridges the gap between agronomic performance and consumer preference. Whereas breeders conventionally focus on yield, pest resistance, and stress tolerance but the ultimate feat ofa rice variety in the market depends on aappearance, aroma, texture, and taste (Bard., 2008; Bett-Garber et al., 2017).

Consumers are cognizant to organoleptic traits, especially in premium varieties such as Basmati and Jasmine rice. Integrating personal perception into the breeding pipeline enables breeders to select lines that not only perform well in the field but also meet or exceed consumer expectations. (Juliano, 2016). Additionally, sensory profiling aids in the diversity of rice varieties for niche markets and confirms consistency as domestic and export standards. As international markets grow more competitive and consumer-driven, sensory evaluation has become a necessary factor of rice breeding programs. (Meullenent et al, 2007; Champagne et al., 2010; Tuano et al., 2022). Sensory evaluation of rice is based on four vital domains, each significantly influencing to consumer acceptance and marketability.

1. Appearance includes grain color, shape, chalkiness and translucency. These visual features influence consumer perception before cooking and can be a decisive reason in selection. (Unnevehr et al., 1992). Recent studies confirm chalkiness and reduced translucency as key drivers of diminished market value and lower consumer preference (Xiao et al., 2025).

2. Aroma is chiefly crucial for aromatic varieties like Basmati and Jasmine which is obsessed by volatile compounds especially 2-acetyl-1-pyrroline (2-AP). It refers to the scent of rice mutually before and after cooking. (Singh and Singh, 2000; Choudhury and Gupta, 2014). Recent research reaffirms that 2-AP is the principal marker of aroma in fragrant cultivars, and that its biosynthesis is genetically regulated (e.g., via BADH2) and environmentally responsive during grain development and processing (Hashemi et al., 2025).

Flow chart of sensory evaluation work flow



Texture comprises of mouthfeel, hardness, softness cohesiveness, stickiness and chewiness. It is typically evaluated after cooking and plays a key role in rice mouth feels and impacts overall satisfaction. (Tairi et al., 1992). A texture analyzer is an instrumental device used to objectively measure the physical properties of food, such as hardness, chewiness, and cohesiveness, providing precise and reproducible texture data. Recent studies have shown that higher adhesiveness (stickiness) correlates with increased amylopectin content, while higher hardness is associated with greater amylose levels (Li et al., 2023).

Taste/Flavor is the collective outcome of taste and aroma, resulting to the overall palatability of the rice. The equilibrium of umami, sweetness and minor bitterness impacts cconsumer's choice. (Bhattacharya and Corke, 1996; Tuano et al., 2022)

Sensory Evaluation Methods

Evaluation techniques are effective for defining the cooking quality and consumer adequacy of rice. It delivers a systematic process to quantity qualities such as texture, aroma, taste and appearance. Following techniques are commonly used in rice sensory appraisal system. (Hossen et al., 2021).

Descriptive Method

Trained panels assess predefined lexicon of rice flavor attributes i.e., nutty, floral or as quantitative and reproducible comprehensive rice's sensory profile to enhance importance of aroma or texture. Feedback of descriptive analysis are numbered on predefined sensory scale for diverse rice varieties. (Stone and Sidel, 2004 Lawless and Heymann, 2010) Discrimination

Methods/ Duo-Trio Test / Triangle Test

The Triangle Test comprise of three samples, two of which are the same and one different, and the trained participants are inquired to identify another sample. A reference sample is given in Duo-Trio Test and participants are allowed to select between two samples, one is the identical as the reference. These trials are suitable for detection of minor alterations in sensory traits i.e., aroma or texture of new varieties or standard. (ISO 2006, Luna 2018).

Texture Profile Analysis (TPA)

It is used to quantify texture qualities of rice i.e., cohesiveness, chewiness, elasticity and firmness. TPA is usually associated with equipment like a Texture Analyzer. It generates unbiased information that is correlated with the judgment of sensory panels. TPA provide valuable data on texture preferences that is tough to capture through human panels alone. Linking TPA and panel data consents an inclusive understanding of rice texture features. Wang et al. (2022) demonstrated significant correlations between instrumental hardness and stickiness with aroma compounds in cooked rice, while Choi and Seo (2023) reported that TPA-derived hardness, stickiness, and chewiness strongly influenced consumer liking across age and gender groups. Similarly, Janani et al. (2022) showed that parameters such as springiness and cohesiveness align with oral processing behaviors, and a post-2020 study on purple rice formulations confirmed that elasticity, hardness, chewiness, and cohesiveness significantly predict sensory evaluation scores.

Aroma Testing Using KOH (Potassium Hydroxide)

Potassium hydroxide (KOH) testing remains a widely used qualitative method for detecting aroma in aromatic rice varieties such as Basmati and Jasmine. The test primarily targets the presence of 2-acetyl-1- pyrroline (2AP), the key compound responsible for the characteristic popcorn-like scent of these rices. In this method, rice grains or leaves are cooked or steamed to release volatile compounds, and a small amount of KOH solution—commonly 1.7%—is added to the sample or its vapor. The alkali enhances the volatility of 2AP, making the aroma more perceptible to trained evaluators. This approach, first described by Haug (1972) and later refined by Gupta et al. (2015), is favored in breeding programs for its simplicity, low cost, and rapid results, despite being subjective in nature. Recent research confirms that KOH testing is effective for rapid screening, though it is increasingly complemented by instrumental methods such as gas chromatography–mass spectrometry (GC–MS) for quantitative accuracy (Hien et al., 2021; Boontakham et al., 2022). Studies have shown that KOH-based aroma detection correlates well with sensory evaluation in distinguishing aromatic from non- aromatic genotypes, making it useful in early- generation selection (Roy et al., 2020). However, as environmental conditions and postharvest handling can influence 2AP concentration, advanced analytical techniques are often employed alongside KOH testing to provide a more robust understanding of aroma profiles. This integration ensures both rapid field-level screening and precise laboratory-based quantification, improving the efficiency of aromatic rice breeding and quality assessment.

Aroma profiling Using Gas Chromatography (GC)

Gas chromatography (GC), particularly when combined with head-space sampling techniques, is a widely used method for analyzing rice aroma because it enables the separation, identification, and quantification of volatile compounds, including trace levels of 2-acetyl-1-pyrroline (2AP) (Liu, 2013). In aromatic rice studies, GC methods such as static head- space GC coupled with flame ionization detection (GC-FID), nitrogen–phosphorus detection (GC- NPD), and mass spectrometry (GC-MS) have been successfully applied to generate detailed volatile profiles (Boontakham et al., 2022). These instrumental techniques provide high sensitivity, reproducibility, and specificity, making them indispensable for precise aroma characterization in quality control and breeding programs.

Despite its advantages, GC is constrained by several practical limitations. The equipment is costly, requires trained personnel for operation, and involves time- consuming procedures for sample preparation, chromatographic separation, and data analysis (Saxena et al., 2000; Jiang, 2008). Consequently, many resource-limited laboratories and small-scale industries face accessibility challenges, often relying on simpler qualitative assays such as the potassium hydroxide (KOH) test for preliminary screening (Roy et al., 2020). Integrating GC with rapid field-level methods offers a balanced approach—enabling both large-scale screening and precise quantification of rice aroma compounds for research and commercial applications.

Advanced Techniques (Smart phone, electronic nose)

Smartphone-based aroma detectors and biosensors hold great potential to revolutionize rice quality testing by providing rapid, portable, and cost-effective tools for on-site aroma and flavor assessment. These devices leverage advances in sensor technology— such as electronic noses, gas sensors, and bio- recognition elements integrated with smartphones—to detect key volatile compounds fir aroma only. Additionally, coupling biosensors with smartphone apps can facilitate data collection, analysis, and sharing, enabling large-scale sensory-instrumental correlations and consumer preference mapping. Although still emerging, these technologies promise to complement traditional sensory panels and instrumental methods, making rice quality evaluation more efficient, objective, and scalable (Banerjee et al., 2021; Li et al., 2023).

An electronic nose (e-nose) is an array of gas sensors designed to detect and differentiate complex volatile compounds, mimicking human olfactory perception, and is increasingly used for rapid aroma profiling in rice (Dutta et al., 2020)

Consumer Testing/untrained testing

Uuntrained panels or wide-ranging consumers are invited to judge the overall suitability of rice. Hedonic scaling or preference tests are employed. This process is mostly used for market research or real-world buyer preferences. (Bourne, 2002). Although it provides straight insights into how well a rice variety is likely to perform in the market but parameters such as taste, aroma, texture, and appearance are misled during overall experience. It is synergistically combined with other methods to refine rice varieties for broad consumer acceptance. (Champagne et al., 2010).

Data Collection, Analysis and Interpretation

Data composed from different panels are tabulated and analysed to quantify the overall strength of the aroma. Consumer preference for most rice varieties based on aroma. Principal component analysis (PCA) is used to quantify aroma preconceptions in different rice varieties. It supports the researchers and breeders to recognize how precise aroma traits are perceived by masses, which is decisive factor for evolving rice varieties that appeal to specific markets. (Lestari et al., 2011)

Composition of the Panel and training

Sensory testing of rice includes diverse panelists, each examining specific quality trait based on their proficiency. A proficient panel typically entails 5-10 persons (knowing hedonic protocols of rice). A semi-trained panel contains 10- 15 members (having some understanding in examining rice taste) frequently guided on scoring to enhance reliability. (Meilgaard et al., 2015)

Whereas a buyer panel / un trained contains 30 - 50 individuals from the general population and is mostly used in acceptability or liking/ disliking of varieties to assess how this specific variety will perceived by common masses. Nominated participants/panel must be unbiased, impartial, non-smokers and healthy to sustain 982586aroma sensitivity. (Delwiche, 2004) Real estimation depends on the skill of a proficient sensory panel. Appropriate training confirms that the participants are able to assess ricecooking parameter's accurately and precisely. Panelists must acquaint with reference standards that demonstrate attributes i.e., nutty, floral or sticky. Furthermore, it is vital for all participants to develop harmony to avoid variations. Strong understanding of parameters i.e., chewy, nutty, flowery, soft, hard, aromatic or firm confirms interpretation. Calibration using identified samples with pre-defined proforma is necessary to perceive attributes accurately. (Lawless 2010; ASTM 2011).

Standardized Sample Preparation Procedure

25g uncooked rice samples are used per sample per replicate. Rice samples are soaked in distilled water for 30 minutes prior cooking. Cooking is carried out using 1:2 rice-to-water ratio in boiling water bath. After cooking, the rice samples are allowed to cool for 5-10 minutes before evaluation. To confirm unbiased assessment, all samples are blind-coded using random numbers for secrecy. Panelists estimate all parameters independently and record scores using a hedonic scale standardized for Basmati/ coarse varieties. For holistic understanding of rice quality traits both human perception and equipments are combined to ensure accuracy and precision, although sensory evaluation merely insights into customer acceptability. (Moskowitz and Gofman 2006).

Lexicon development for sensory descriptors in Basmati rice involves creating a precise, standardized vocabulary to describe its unique quality traits, including grain appearance (slender shape, whiteness, translucency), characteristic popcorn-like aroma from 2-acetyl-1-pyrroline, delicate nutty or floral notes, and cooked grain texture attributes such as softness, fluffiness, and non-stickiness. This process requires selecting representative Basmati samples, engaging trained sensory panels to generate and refine terms, defining each descriptor with clear definitions and reference standards, and establishing intensity scales to ensure consistency across evaluations. Such a lexicon enables breeders, quality controllers, and exporters to communicate quality objectively, link sensory traits with instrumental measurements, and maintain Basmati's premium identity in domestic and global markets (Cruz & Khush, 2000; IRRI, 2024; Matsuda et al., 2024).

Sensory Descriptor	Attribute	Details
Appearance	Slender Grain	Long, thin grain shape / Basmati
	Chalkiness	Opaque white patch in the grain due to loosely packed starch granules.
Aroma	Popcorn-like	Distinct nutty-popcorn aroma due to 2-acetyl-1-pyrroline (2-AP
	Nutty	Aroma reminiscent of roasted nuts.
	Floral	Light, fragrant aroma similar to jasmine
	Sweet Aromatic	Mild sugary scent perceived in freshly cooked Basmati.
Flavor	Nutty Flavor	Roasted nut taste after chewing.
	Sweetness	Natural sweetness in taste after chewing cooked grains.
	Starchy Flavor	Gelatinized starch taste typical of cooked rice.
Texture (Cooked)	Fluffiness	Individual grains remain separate, light, and airy after cooking
	Softness	Low resistance to compression during chewing.
	Non-stickiness	Lack of grain adhesion after cooking.
	Firmness	Resistance to deformation on chewing without hardness.

Future Directions

Sensory evaluation of rice grains plays a critical role in the modern food science sectors. It allows breeders, food scientists and industry stakeholders by scientifically assessing the organoleptic qualities to rise the competitiveness of rice in local and international markets. As global markets become more diverse, the combination of human perception and instrumental methods will expand the accuracy and rice evaluation. Sensory evaluation should be included as mandatory portion of rice breeding program.

Future research should focus on establishing 2-3 training programs for sensory panels and cross-cultural research to ensure international pertinency. In conclusion, sensory evaluation not only assists as a scientific tool for refining rice quality but also as a bridge between field research and consumer satisfaction, ensuring the sustainable achievement of rice in a competitive global market.

Conflict of Interest

The authors declare no conflict of interest.

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