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The Eating and Cooking Qualities of Rice : A Review

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ABSTRACT

As a major cereal crop, rice (Oryza sativaL.) is crucial to food security for at least half the world population. After yield, quality is one of the most important aspects of rice breeding. Preference for rice quality varies among cultures and regions; therefore, rice breeders have to tailor the quality according to the preferences of local consumers. Rice quality assessment requires routine chemical analysis procedures. Eating and cooking qualities (ECQs) are important determinants of cooked rice grain quality. ECQs comprise three physical and chemical characteristics of starch in the endosperm: amylose content (AC), gel consistency (GC) and gelatinization temperature (GT). Grain quality is a general concept which covers many characteristics ranging from physical to biochemical and physiological properties. The advancement of molecular marker technology has revolutionized the strategy in breeding programs. The availability of rice genome sequences and the use of forward and reverse genetics approaches facilitate gene discovery and the deciphering of gene functions. A well-characterized gene is the basis for the development of functional markers, which play an important role in plant genotyping and, in particular, marker-assisted breeding. In addition, functional markers offer advantages that counteract the limitations of random DNA markers.

Keywords: Rice (Oryza sativaL.), Eating and Cooking Quality, Quantitative Trait Loci (QTL), Marker-Assisted Breeding

I. INTRODUCTION

Oryza Sativa L (Rice) is a vital worldwide agriculture product. It is one of the leading food crops of the world as more than half of the world's population relies on rice as the major daily source of calories and protein (Rohit, 2011). Botanically, cultivated rice belongs to the Poaceae family and includes two species: Oryza sativa L. (commonly known as Asian rice) and Oryza glaberrima Steud. (Commonly known as African rice) (Linares, 2002). Rice is mainly consumed as cooked rice, but during the last decade the consumption of rice flour has increased due to its application in breadmaking. Rice has unique sensorial and nutritional advantages for developing gluten-free foods. Specifically, rice flour has a neutral flavor, low levels of sodium, easy digestibility, hypoallergenic proteins, and does not contain gluten. These characteristics make rice flour a suitable ingredient for gluten-free bakery products (Marco & Rosell, 2008). The eating and cooking qualities (ECQs) of rice are important in determining its economic value in the export market and for consumer acceptance (Pingali, 1997).The preferences for rice eating and cooking qualities within a certain region and culture may not be accepted by other cultures. In general, the Japanese prefer short grain, sticky rice that is usually used in making sushi. Conversely, in India, Pakistan and the Middle East, Basmati rice is well-liked due to its fragrance and its elongated, dry grains when cooked (Suwannaporn & Linnemann, 2007). As the largest proportion of milled rice, the starch component in the endosperm is a key factor in determining the eating qualities of table rice and the processing qualities of rice flours. The cooking and eating qualities (ECQs) of rice are largely determined by some physicochemical characteristics of the starch in the endosperm: apparent amylose content (AAC), gel consistency and gelatinization temperature (GT) and pasting properties (Bao, 2012). Grain quality can be considered as physical,chemical, cooking and nutritional quality groups. Grain quality traits are controlled by major and minor quantitative trait loci (QTLs), implying that the genetic mechanisms underlying quality traits are complex. QTL analyses have identified several markers linked to grain quality (Shao et al., 2010; Fan et al., 2005; Lestari et al., 2009 & Tabkhar et al., 2012). But validation of those markers is essential to add value to those markers in a diverse set of germplasm before using them in marker aided breeding programme. Such information is very limited in rice particularly for quality traits. Therefore, the present investigation was carried out to find association of markers for quality traits.

II. METHODS AND MATERIAL

A. The Genus Oryza

Rice belongs to the genus Oryza and family Poacae tribe Oryzeae. It originated in Asia (O. sativa L.) and West Africa (Oryza glaberrima Steud) (Vaughan et al., 2003). According to Vaughan (2004) the genus Oryza is made up of 23 species, with two species being cultivated (O. sativa and O. glaberrima), while the other 21 are not domesticated. The O. sativa has further three subspecies; indica Kato, japonica Kato and javanica (Roschevicz, 1931). The subspecies japonica has two strains, namely tropical and temperate which is commonly sticky rice due to high amylopectin content. Indica are found in tropica land sub -tropical regions, while javanica are mainly grown in Indonesia and japonica are found in temperate regions. In terms of grain characteristics; the indica varieties have long grains. While, japonica have short grains and javanica have broad grains (Jones , 1997; Khush, 2005).

B. Grain Quality In Rice

Rice grain quality is determined by its physical and physicochemical properties. Physical properties include kernel size, shape, milling recovery, degree of milling and grain appearance (Cruz and Khush, 2000). Physicochemical properties of rice are determined based on amylose content, gel consistency and gelatinization temperature (Rohilla, 2000). In rice, eating and cooking qualities are mainly controlled by the physicochemical properties which greatly influence the consumer's affinity (Rohilla, 2000). Therefore, eating and cooking quality can be considered as a vital intrinsic quality component of rice grains that have to be focused in future rice breeding programmes to meet market demands at both local and international level. Volume expansion over cooking is another quality parameter which influences the edible volume which is the final output after cooking (Rebeira, 2014).

C. Amylose Content

Waxy rice has near zero amylose, and is used for special foods such as desserts and snacks. High amylose cultivars (>25%) are common inindica rice, and are dry and fluffy on cooking, often becoming hard after cooling. Low amylose cultivars (15–20%) are soft and sticky, and include nearly all-temperate japonica cultivars. Intermediate amylose (20–25%) rice is soft but not sticky, and is widely preferred by most consumers. AAC is largely genetically controlled by the Wx locus on chromosome 6, or specifically by the amount of Wx protein present (Wang, 1995).Therefore, high AC will lead to the deterioration of viscosity, softness, luster, and palatability, but AC does not absolutely determine the texture of cooked rice because the palatability of cooked rice with similar AC may vary greatly. However, the rapid viscosity analyzer (RVA) profile characteristics of rice endosperm starch can make up for the deficiency in using AC to appraise the palatability of cooked rice. Namely, RVA, breakdown viscosity (BDV) and setback viscosity (SBV) can be used to evaluate the palatability differences of cooked rice with similar ACs (Shu, 1998; Wu , 2001).

D. Gelatinization Temperature (GT) In Rice

The gelatinization temperature determines the time and energy input required for cooking. Gelatinization temperature (GT) is another important quality predictor in determining the cooking quality of rice. Low GT rice needs less energy input during cooking than high GT rice. GT in rice is mainly controlled by the starch synthase IIa (SSIIa) gene which is located on chromosome 6 (Umemoto, 2002, 2004; Waters, 2006). In terms of the impact of climate change on rice starch, a high temperature during the grain-filling stage decreases the levels of amylose and long-chain-enriched amylopectin (Yamakawa et al., 2007) . The subsequent reduced expression of granule-bound starch synthase I, as well as the activity of the starch-branching enzyme

IIb at a high ripening temperature, was considered to be primarily responsible for the changes in amylose content (Yamakawa et al., 2007) and amylopectin structure,(Jiang et al., 2003) respectively. However, little is known about the effects of ripening temperature on the fine structure and molecular characteristics of amylopectin and on starch crystallinity. Chun et al. (2015) suggested that an increase in cooking temperature and time would be required for rice grown at higher temperatures. A high ripening temperature increased the peak, trough, and final viscosities and decreased the setback due to the reduction in amylose and the increase in long amylopectin chains. With regard to starch crystallinity and amylopectin molecular structure, the highest branches and compactness were observed at 28/20°C. Rice that was grown at temperatures above 28/20°C showed a deterioration of cooking quality and a tendency toward decreased palatability in sensory tests.

E. Gel Consistency

Gel consistency is a measure of firmness of cooked rice. It is used to classify rice varieties by measuring the length of a cooled gel made from flour previously cooked in 0.2M KOH (Cagampange et al.,1973). Gel consistency used in rice improvement programs focusing on rice varieties with intermediate and lower AC classes. Rate of hardnening and hardness differences in cooked rice correlate with GC (Rohilla et al., 2000). If the GC is hard, then the cooked rice tends to be less sticky and if the GC is soft, then the cooked rice is more tender (Juliano, 1985).

F. Aroma In Rice

More than 100 volatiles contribute to rice aroma. Among these, 2-acetyl-1-pyrroline (2AP) possesses low odor threshold value; hence, it is regarded as principle aroma compound contributing to the aroma character of rice (Buttery et al. 1982, 1983). Nadaf et al. (2006) have developed a histochemical test to detect 2AP in scented rice. A marker system for validation of basmati types is developed at the Center for DNA Fingerprinting and Diagnostics (CDFD), Hydrabad, by Nagaraju et al. (2002).The quality of rice grains has great economic interest, characteristics such as yield, shape and defects being important in marketing,while the aroma of the cooked product, in particular when prepared in the Asiatic mode, has a big impact on consumers. The aroma of both aromatic and non-aromatic rice cultivars consists of a complex mixture of odor-active compounds. Several authors have studied the composition of the cooked rice volatile fraction,identifying a large number of components and defining several key-aroma compounds (Champagne, 2008; Jezussek et al., 2002; Widjaja et al., 1996a; Yang et al., 2008; Yang et al., 2008; Zeng et al., 2009). These include saturated and unsaturated aldehydes, alcohols, and cyclic compounds; in particular, hexanal, 1-octen-3-ol and 2-pentylfuran are markers of both quality and ageing, while 2-acetyl pyrroline (2-AP) is one of the aroma quality markers for aromatic rice (Buttery et al., 1988; Champagne, 2008; Grimm et al., 2001; Laguerre et al., 2007; Mahatheeranont et al., 2001; Widjaja et al., 1996a).

G. Roles Of GBSSI And Ssiia In Determining Amylose

Multiple isoforms exist for each type of enzyme. For instance, four classes of SS have been identified: SSI, SSII (including SSIIa, SSIIb and SSIIc), SSIII and SSIV, while two GBSS isoforms, GBSSI and GBSSII, have been reported (Ball & Morell, 2003). GBSSI and SSIIa genes are believed to have major single nucleotide polymorphisms (SNPs) that influence the properties of rice starch (Kharabian-Masouleh et al., 2009). Although several past studies have reported the functions of GBSSI and SSIIa in influencing key starch physiochemical properties (such as pasting, gelatinization, retrogradation and texture properties) (Lu et al., 2010; Yang et al., 2014), amylose content (Chen et al., 2008b) and the CLD of short amylopectin chains (Umemoto et al., 2002), current knowledge on the roles of GBSSI and SSIIa in controlling the CLDs of amylose and long amylopectin chains (which could not be precisely characterized in the past) is still limited.

III. RESULT AND DISCUSSION

Molecular Markers for the Analysis of Genetic Diversity of Amylase Content and Gel Consistency

ADP glucose pyrophosphylase catalyzes the first reaction in starch synthesis, producing the activated glucosyl donor ADP-glucose (ADPG). AGPiso (AGPlarge subunit isoform) codes for the protien glucose-1-phosphate adenylyl transferase which is composed of 518 amino acids. Previous research revealed that AGPiso gene is responsible for GC of japonica rice (Sun et al., 2011) and acts as a minor gene affecting GC in all rice cultivars (Tian et al., 2009). AGPiso is a PCR based SSR marker linked to the AGPiso gene and the expected product size is approximately 98 bp (Hsu et al., 2014). A major quantitative trait loci (QTL) contributing largely to the ECQ has been mapped to chromosome 6 corresponding to the Waxy locus. It encodes GBSS1, a key gene determining the percentage of amylose and ratio between amylose to amylopectin, the two critical factors affecting the ECQ. Six alleles of Wx have been found in natural germplasm (Hsu et al., 2014). GBSS1 marker is a SSR type PCR based marker derived from OSR19 to RM587of QTL region (Kwon et al., 2008). The expected PCR product is 170 bp in size. The WX marker is a STS type PCR based marker with an expected band size of 100 bp (Han et al., 2004). There are two classes of brancing enzymes (BE); BEI and BEII; that differ in terms of the length of the chains they transfer (Guan & Preiss, 1993). The amylopecten structures (Umemoto et al., 2002) and the percentage amylose content (Takeda et al., 1986) vary between japonica and indica rice.

Functional Marker

FMs, also known as perfect markers are an alternative to random DNA markers. FMs are developed from polymorphic sites within genes that cause phenotypic trait variation (Andersen and Lübberstedt, 2003). In contrast with random DNA markers, FMs are directly linked to the allele of the trait of interest (Vars hney et al., 2005). Therefore, FMs are outcompeting random DNA markers, especially in marker-assisted breeding (MAB). Thus far, numerous FMs have been developed for the breeding of quality rice.

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