Effect of Grain Morphology on Degree of Milling and Iron Loss in Rice

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ABSTRACT

Grain morphological characteristics were thought to play a significant role in genotypic variation in Fe concentration in white rice. Comparing 17 rice cultivars representing six major grain morphological categories, the present study systematically investigated the relationship between grain morphology, the degree of milling (DOM), and the loss of Fe during the polishing process. The relative importance of key morphological parameters in this relationship was also investigated. The grain morphological characteristics of different rice cultivars significantly affected the degree of Fe loss during polishing to produce white rice. This variation in Fe loss from polishing among the six categories of rice cultivars is mainly due to their difference in DOM ($r = 0.73^{**}$) and this loss in Fe was the primary factor determining the level of Fe concentration in the white rice. Among the morphological parameters investigated, grain length and length-to-width ratios played the most significant role in determining the DOM, which suggests that these two grain attributes may serve as the initial screening parameters when selecting cultivars for high Fe white rice production. Degree of Fe loss was lowest in short-bold grain shape category compared with the other grain shapes.

Breeding rice cultivars with high grain Fe concentration has been suggested as a long-term cost-effective approach to alleviate Fe deficiency-induced anemia, especially in Asia where rice is consumed as the staple food (Bouis 1996; Graham et al 1999, 2000). High Fe rice cultivars have been identified through conventional breeding (Graham et al 1999, 2000; Gregorio 2002) and through transgenic modification by inserting genes for Fe accumulation and storage (Goto et al 1999; Lucca et al 2002; Vasconcelos et al 2003). Unexpectedly, the high levels of Fe in the grain have mostly been limited to brown (unpolished) rice (Graham et al 1999, 2000; Gregorio 2002) rather than white (polished) rice, which is the form of rice preferred by consumers. In the process of milling, up to 85% of the total Fe in brown rice can be lost (Resurreccion et al 1979; Senadhira et al 1998; Prom-u-thai et al, in press), most of which was removed rapidly within the first 20 sec of the milling process (Sun and Siebenmorgen 1993). This is due to the fact that a high proportion of Fe in brown rice is distributed in the outer layers of cells of the kernel (Senadhira et al 1998; Prom-u-thai and Rerkasem 2003; Prom-u-thai et al, in press). This significantly discounts the improved Fe status in the whole kernel (brown rice) through breeding. To maximize the benefit of improved high Fe rice cultivars, one approach is to optimize the milling process for achieving maximal Fe retention without significantly deteriorating the visual quality attributes of white rice.

Varying degrees of Fe loss have been reported in different rice cultivars that cannot be completely accounted for by the genotypic variation in grain Fe content and distribution (Senadhira et al 1998; Prom-u-thai and Rerkasem 2003; Sison et al 2006; Prom-u-thai et al, in press). One main factor causing the varying Fe loss among different rice genotypes is the degree of milling (DOM) that is defined as the extent to which the germ and bran layers of brown rice kernels have been removed during the milling process. Grain morphological characters such as kernel size and shape strongly affect the DOM and milling quality (Goodman and Rao 1985; Sun and Siebenmorgen 1993; Jongkaewwattana and Geng 2002; Siebenmorgen et al 2006; Sison et al 2006). These grain morphological characteristics have varied greatly among rice cultivars (Goodman and Rao 1985; Jongkaewwattana and Geng 2002; Sison et al 2006).

To date, there has been no systematic evaluation of the relationship between Fe loss and grain morphological characteristics in rice cultivars representing the typical morphological categories of rice grain. Research findings will provide the justification for selecting and breeding high Fe rice cultivars from a gene pool with certain morphological characteristics that may ensure maximal Fe retention in white rice after milling. In addition, the findings are expected also to provide key information for optimizing the milling time for a rice cultivar in a given morphological category.

The objectives of the present study were to establish the relationship between grain morphology and the loss of Fe during the polishing process and to investigate the relative importance of key morphological parameters in this relationship. Seventeen rice cultivars were used in this study, representing a range of grain morphology groups.

MATERIALS AND METHODS

Sample Preparation

A total of 17 rice cultivars were selected from the Thai Rice Department and Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University, Thailand (Table I). Seeds were collected and stored in a cold room at 4°C for about one month before being processed and analyzed. The grain moisture content was 14–16%. Paddy grains (1 kg) of each cultivar were dehusked with a labora-

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