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Variation in Grain Quality of Upland Rice from Luang Prabang Province, Lao PDR

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Abstract: Luang Prabang Province is located within the area recognized as the center of rice (*Oryza sativa* L.) diversity in Lao PDR. This study reported on grain quality characteristics of 60 upland rice seed samples sharing 49 variety names collected from 6 villages in Luang Prabang in 2015. Most of the samples has non-pigmented pericarp, while red pericarp was found in four samples and purple in five samples. Almost all of the samples were of large grain type, with glutinous endosperm in 70% and non-glutinous endosperm in 30%. The brown (unpolished) rice was found with a wide range of grain nutritional quality, including protein (9.2% ± 0.9%), Fe (15.9 ± 6.9 mg/kg), Zn (19.6 ± 2.1 mg/kg), anthocyanin (0.774 ± 0.880 mg/g), and anti-oxidative capacity (2.071 ± 1.373 mg/g). The varieties sharing similar names had similar morphological characteristics but varied in nutritional concentration, with required confirmation in genetic variation analysis. This study found that some rice varieties with high grain quality may benefit the farmers directly or could be used in varietal improvement programs.

Key words: grain morphology; genetic diversity; nutritional quality; upland rice; rice germplasm

Rice not only supplies the calories, but is also an important source of other essential nutrients such as protein, Fe, Zn and dietary supplement. For example, rice is a rich source of anthocyanin and phenolic compounds which play key roles in human nutrition and health due to their antioxidative properties of reduction of reactive cell-damaging free radicals, preventing the oxidative damage of lipid and low density lipoprotein (Vauzour et al, 2010) and thus reducing the risk of coronary heart disease and cancer (Victor et al, 2009). This benefit of pigmented rice for human health has been well documented (Kim et al, 2006, 2008). However, lower concentration of the nutrients in rice generally grown and consumed, compared with other cultivated *Gramineae* species (Adeyeye et al, 2000), causes malnutrition problems, especially in remote areas where people have limited access to rich sources of nutrients such as animal products (Juliano, 1993). Therefore, rice varieties with high nutrient concentration in the grain are valued for the farmers' benefits.

Breeding the rice variety with high nutrient concentration in the grains has been advocated as an efficient and cost-effective approach to alleviate malnutrition (Gregorio, 2002). Local rice germplasm from the area within the species' center of diversity in Thailand has been found with exceptional grain quality, for example, in grain Fe (Prom-u-thai and

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Rerkasem, 2001), Zn (Saenchai et al, 2012; Jaksomsak et al, 2015), anthocyanin and antioxidant capacity (Yodmanee et al, 2011; Rerkasem et al, 2015).

Lao PDR has been found to possess rich genetic diversity of rice, and is believed to be the center of glutinous rice diversity (Schiller et al, 2006). Almost 98% of the cultivated area in Laos was reported to be under rice cultivation in 1990, with upland rice accounting for one quarter of the rice area. Upland rice in Laos is located mostly in the northern region, including Luang Prabang Province, which accounts for 14.6% of the 3 169 varieties recorded in the country in the early 2000's (Appa Rao et al, 2006a). The uplands in this area are populated by minority groups of Hmong and Khamu who grow rice as a rain-fed upland crop during the rainy season with a slash and burn system of cultivation on steep slopes for 1 to 2 years alternately with a few years of fallow (Schiller et al, 2006). Almost all the rice varieties used are traditional varieties, and 2–5 varieties are maintained by each family. Glutinous rice is the preferred staple rice for the Khamu and majority of Lao population while the Hmong and Yao who live at higher elevations (800–1 200 m) prefer non-glutinous rice (Roder, 1996).

The high genetic diversity of rice in Laos has been investigated; for example, 70 accessions of Khao Kai Noi, a rainfed lowland glutinous rice grown in northern and northeastern Laos, with good grain quality, softness and aroma (Appa Rao et al, 2006b), were investigated by the SSR marker technique (Vilayheung et al, 2016). However, so far, there is no report on variations in other useful traits such as nutritional quality of Lao rice landraces together with physicochemical properties which can be useful in the selection of high nutrient genotypes. This study evaluated variations in the physicochemical properties of the grain and the nutritional qualities of the upland rice varieties maintained by farmers in Luang Prabang Province, Lao PDR.

MATERIALS AND METHODS

Sample collection, processing and measurement, and soil analysis

Rice seed samples (Supplemental Table 1) were collected in 2015 from three districts, Phonxay (PX), Pak Ou (PO) and Xieng Ngeun (XN), with two villages each at Chomchieng (CC) and Houameuang (HM), Hoi-Oth (HO) and Hoi-Loh (HL), and Phasanine (PSN) and Phouthat (PT), respectively, in Luang Prabang Province, Lao PDR, which has altitude ranging from 351 to 1 479 m above the mean sea level. The soil fertility characteristics were determined by replicated analysis of two samples from each village, from up to 30 cm in depth, for pH (1:1, soil:water), organic matter, total nitrogen (Kjeldahl), available phosphorus (Bray II), exchangeable potassium, and diethylenetriaminepentaacetic acid (DTPA)-extracted Fe and Zn. Rice was direct seeded in the slope hill under rain fed condition and grown according to farmer's practice. Seed size (grain length, width and thickness) of unhusked seed was measured by a digital Vernier caliper (50 seeds for each sample), and 100-grain weight was evaluated in three independent replications. The seed was dehusked manually to separate the husk and the brown rice, and recorded visually for the pericarp color.

Chemical analysis of rice samples

The amylose content of white rice (polished brown rice) was determined by iodine-binding protocol (Juliano, 1979), with iodine solution intensity measured at 620 nm using a spectrophotometer (Hitachi, Model 3J0-0100, Japan), and it was determined on a calibrated standard amylose curve of potato starch.

The alkali spreading assay was performed to determine gelatinization temperature (IRRI, 1979). One hundred whole grains of milled rice from each experimental unit were placed individually in a petri dish, 20 grains per each in a total of 5 petri dishes, containing 10 mL of 1.7% KOH, and kept at room temperature for 23 h. Four milled grains of KDML105 (low gelatinization temperature) and RD4 (high gelatinization temperature) were used as checks in each petri dish. The degree of spreading was assessed at the 24th hour using a seven-point scale of 1–7, with lower scores indicating higher gelatinization temperatures. The level classified in the alkali spreading value correlated with the swelling of the kernel: level 6–7, kernel dispersed, merging with collar, and completely dispersed and intermingled [low gelatinization temperature (< 70 ºC)]; level 4–5, split or segregated kernel [intermediate gelatinization temperature (70 ºC to 74 ºC)]; level 1–3, kernel not affected, swollen, and collar complete or narrow [high gelatinization temperature (> 74 ºC)].

Grain nutritional quality analysis

Brown rice samples were oven dried at 75 ºC for 72 h, and 1 g sub-samples were dry-ashed in a muffle