Molecular Breeding (2024) 44:31
https://doi.org/10.1007/s11032-024-01469-6

Molecular Breeding

SHORT COMMUNICATION

Huamoxiang 3, a variety bred for steaming and cooking type of whole grain black rice

Qinglu Zhang[1] · Qifa Zhang[1] · Jinghua Xiao[1] · Hao Chen[1] · Yanhua Li[1] · Sibin Yu[1] · Yuqing He[1]

Received: 4 February 2024 / Accepted: 21 March 2024 / Published online: 15 April 2024

Dear Editor:

Polished (or milled) rice has been the principal consumption form of rice, which is approximately equivalent to the endosperm of rice grain, composed mainly of starch (70–80%) with proteins and other nutrients in small proportions. In contrast, whole grain (WG) rice is less processed, consisting of pericarp, seed coat, aleurone, embryo, and endosperm (Zhang 2021a). Although the processing into polished rice improves palatability and may also prolong the shelf-life of rice, it removes all the sections except endosperm, losing the great majority of the nutrients including proteins, dietary fiber, oil, minerals, vitamins and a rich diversity of bioactive compounds, which are beneficial for human health.

According to the grain color, WG rice can be classified as white, brown, red and black. Compared to other WG rice, WG black rice (WGBR) is rich in anthocyanins, a water-soluble natural pigment produced in the pericarp and seed coat, which has strong antioxidant and antiinflammation activities, thus can provide protective effects in a wide range of health conditions, such as eye health, cardiovascular disease, obesity, diabetes, microbial infection, cancer, neurodegeneration etc. (Tena et al. 2020, Kusumawati et al. 2023). Therefore, consumption of WGBR can both increases the edible part of rice by at least 20%, and also greatly enhances the nutrition intake for improving consumers' health (Zhang 2021a, Zhang 2021b).

Although consumption of WG has been advocated by nutrition experts worldwide, the actual consumption rate has remained low in most parts of the world (Willett et al. 2019, GBD 2017 Diet Collaborators, Aune et al. 2016). In particular, very small amounts of WGBR have been produced and consumed globally, although the estimate for the actual quantity is not available. One of the main reasons is that the majority of black rice varieties has poor taste. Moreover, to the best of our knowledge, very few rice products have been branded as WG in

✉ Qinglu Zhang
qingluzhang@mail.hzau.edu.cn

[1] National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, and Hubei Hongshan Laboratory, Wuhan 430070, China

the market; there has been no breeding program devoted to WG rice. Thus, development of WGBR varieties with superior eating quality and, at the same time, increasing public awareness of the nutritional and health benefits may promote the consumption so that eventually WGBR may become a staple food as proposed (Zhang 2021a, Zhang 2021b).

We have been carrying on a breeding program for WGBR, with Huamoxiang 3 (HMX3) as the first variety certified by the Hubei Provincial Crop Variety Certification Committee. HMX3 was bred by continuous selection from the offspring of the cross Huamoxiang 5 (HMX5)× Yangdao 6 (YD6). HMX5 is a natural mutant of Y236, a landrace variety of black rice from Yunnan Province, China, showing earlier heading than Y236, with glutinous endosperm. The WG of both Y236 and HMX5 is highly palatable. YD6 is a leading restorer line of *indica* hybrid rice in China.

In the summer of 2015, the cross was made using HMX5 as the female parent and YD6 as the male parent in the Experimental Farm of Huazhong Agricultural University (HZAU), and F_1 hybrid was planted in HZAU rice winter nursery in Lingshui County, Hainan Province. Evaluation and selection for performance and palatability were carried out subsequently from F_2 to F_8 in Wuhan (summer) and Lingshui (winter) each season. In the summer of 2019, 5 selected lines of F_9 generation were planted in Ezhou, Wuhan and Jianli, all in Hubei Province, for yield comparison and quality evaluation. The line showing the highest taste score was selected and named HMX3.

During the summer growing seasons of 2021 and 2022, HMX3 participated in the regional test organized by the Green and Nutritious High-Quality Rice Variety Test Union of Hubei Province, a new action of rice variety evaluation. HMX3 passed the test with satisfying performance (Table S1, S2), and was certified as a new variety in 2023 (Fig. 1).

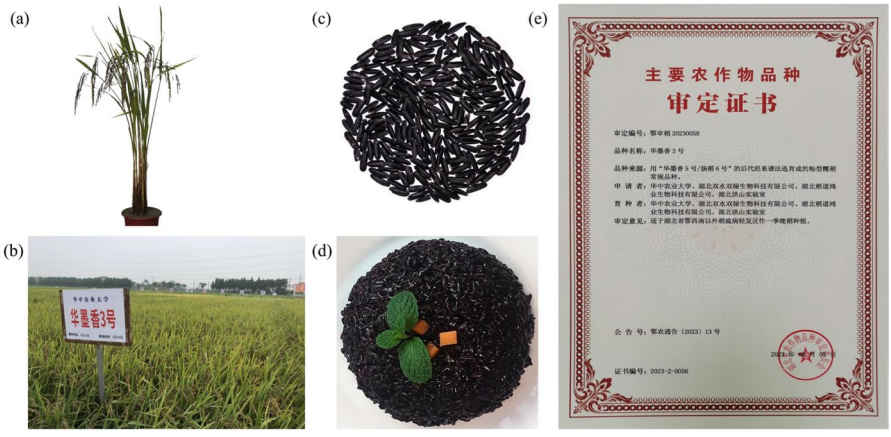

Fig. 1 Approval of HMX3 as a new rice variety. **a** Whole plant of HMX3. **b** Field performance in Jingzhou, 2022. **c** Whole grains of HMX3. **d** Cooked whole grain rice of HMX3. **e** Approval certificate by Hubei Provincial Crop Variety Certification Committee

HMX3 yielded 448.60–506.88 kg/667m^2 in the 10 test sites and two years. The whole growth duration was 122.5–123.9 days, with plant height 114.9–122.1 cm. It was moderately susceptible to rice blast (resistance index of 3.8–4.5), susceptible to bacterial blight (resistance index of 5–7) and highly susceptible to sheath blight. Based on these characteristics, HMX3 is recommended for one-season late rice cropping outside rice blast-prone areas in Hubei Province.

The WG rate of HMX3 was 76.3–77.1% and head milled rice rate ranged 61.1–64.1%, with length–width ratio 3.0–3.1. The endosperm was glutinous with amylose content 1.4–1.5%, gel consistency 90–100 mm, and alkali spreading value 5.8–6.2.

We measured nutritional composition of WG in comparison to milled grain (MG) of HMX3 (Table S3). WG contained more crude protein and dietary fiber than MG, but less starch. The contents of all the sixteen amino acids tested were 1.32–1.97 times higher in WG than in MG, except for cystine. Oil content of WG was 6 times higher than MG. Oleic acid and linolic acid, the two major unsaturated fatty acids in rice, account for 73.87% of the oil in WG compared to 65.33% in MG, whereas the proportions of the three saturated fatty acids especially palmitic acid were higher in MG than in WG. All mineral elements including macro and micro minerals, except Na and Cr, were magnitudes of higher in WG. The contents of B vitamins were 1.49–2.39 times higher in WG than in MG. Choline content in WG was 4 times higher than that in MG. WG contained five times higher GABA than did MG. The contents for three of the four oryzanols were 30.31–47.00 times higher in WG than in MG; while the fourth oryzanol, β-sitosterol ferulate found in WG at 0.22 μg/g, was not detected in MG. In addition, WG was rich in vitamin E, lutein and β-carotene, all of which were not detected in MG. Anthocyanins are the characteristic pigment of black rice (mostly C3G and P3G), the total content of anthocyanins was 1.77 mg/g in WG but not detected in MG.

We evaluated the palatability of HMX3 using a sensory panel. In doing so, cooked rice of HMX3 and 15 black rice varieties that were obtained from the market were independently tasted three times (Table S4). The taste scores of HMX3 averaged 90.72, which is comparable with the best milled rice varieties, while taste scores of other varieties ranged from 53.46 to 76.14. HMX3 has been under demonstration and commercial production in many rice producing areas in the last three years, its taste and flavor have received highly favorable response from a wide spectrum of consumers.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11032-024-01469-6.

Acknowledgements We thank Professors Xingming Lian for measuring mineral elements of rice and Lin Li for the picture of cooked HMX3 rice. We acknowledge participation of Hubei Shuangshuishuanglü Bio-Science and Technology Co., Ltd and Hubei Daodao Hongye Bio-Science and Technology Co., Ltd in the breeding. The authors declare no competing interests.

Author Contributions Qinglu Zhang completed the field work of the breeding. Qifa Zhang put forward the concept of whole grain black rice and designed the breeding experiments. Jinghua Xiao and Yanhua Li conducted the palatability evaluation of whole grain rice. Hao Chen performed nutritional composition evaluation. Sibin Yu and Yuqing He participated in varietal evaluation.

Funding This work was supported by grants from the Wuhan Science and Technology Major Project (No. 2022021302024850), the Hubei Fund for Seed Industry High-Quality Development Project (HBZY2023B001-08), the National Natural Science Foundation of China (32261143466 and 31821005) and the Earmarked Fund for China Agriculture Research System (CARS-01).

References

Aune D, Keum N, Giovannucci E, Fadnes LT, Boffetta P, Greenwood DC, Tonstad S, Vatten LJ, Riboli E, Norat T (2016) Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. BMJ 353:i2716. https://doi.org/10.1136/bmj.i2716

GBD (2017) Diet Collaborators (2019) Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 393:1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8

Kusumawati AH, Garmana AN, Elfahmi E, Mauludin R (2023) Pharmacological studies of the genus rice (Oryza L.): a literature review. Braz J Biol 83:e272205. https://doi.org/10.1590/1519-6984.272205

Tena N, Martín J, Asuero AG (2020) State of the art of anthocyanins: antioxidant activity, sources, bioavailability, and therapeutic effect in human health. Antioxidants 9(5):451. https://doi.org/10.3390/antiox9050451

Willett W, Rockstrom J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D, Declerck F, Wood A, Jonell M, Clark M, Gordon LJ, Fanzo J, Hawkes C, Zurayk R, Rivera JA, De Vries W, Sibanda LM, Afshin A et al (2019) Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet 393:447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Zhang Q (2021a) Ensuring food security and promoting nutrition and health: making black rice staple food for the future. J Huazhong Agric Univ 40 (3) 1–2. In Chinese with English Abstract. https://doi.org/10.13300/j.cnki.hnlkxb.2021.03.001

Zhang Q (2021b) Purple tomatoes, black rice and food security. Nat Rev Genet 22:414. https://doi.org/10.1038/s41576-021-00359-3