Composition and Development Prospects of Scented Rice

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Abstract Containing higher aromatic composition, scented rice is better than ordinary rice varieties in taste and nutrition. Major composition of scented rice is 2-acetyl-1-pyrroline (2-AP). Different scented rice varieties have different content of 2-AP. The content of 2-AP is not only influenced by genetic factors, but also closely connected with types and content of nutrition elements in soil, soil moisture management, environmental temperature, and storage. 2-AP synthesis and regulation are possibly connected with Proline and enzyme.

Key words Scented rice, 2-acetyl-1-pyrroline (2-AP), Scented substance, Proline

1 Introduction

Scented rice is the rice with natural chemical compounds which give it a distinctive scent. It can be used just like conventional rice for cooking, but adds a new dimension of flavor and aroma to meals[1]. Apart from special natural fragrance, scented rice also has high nutritional value, and contains many kinds of amino acids, proteins, alkaloids, vitamin B1, and vitamin B2, and other essential nutrients for human[2]. Sekhar *et al*[3] measured composition of amino acids in 12 varieties of scented rice (including Basmati 370) and ordinary rice, and found that average total amino acids in 12 varieties of scented rice is 77.13 mg/g, the protein is 14.03% higher than ordinary rice, and the average content of granular protein in 12 varieties of scented rice is 11.22-11.36%, higher than the control group. Scented rice contains high protein and amino acids. According to reports, Henan Yangguang scented rice is rich in trace elements such as Se, Zn and Ca, and many kinds of vitamins, and many essential amino acids beneficial to human health. Scented rice features excellent taste, is nutritious and healthy, and has high economic value, so it is highly favored by consumers and becomes a hot spot of current rice researches[5]. In recent years, China has undertaken extensive researches about scented rice, explored a good many local scented rice varieties, and selected a lot of new scented rice varieties. Content of scented substances in scented rice is not only regulated by genetic substance, but also influenced by cultivation environment and methods[5]. Strengthening research on breeding and cultivation of new varieties of scented rice can promote production and development of scented rice in China and diversified development of scented rice in China, and enhance international competitiveness of China's scented rice.

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2 Varieties of scented rice

Thailand has cultivated many varieties of scented rice, such as Jasmine; Pakistan has Basmati rice; Australia has Goolarah and YRF varieties; the United States has developed Jasmine rice[6]. With more than 100 rice production countries, China is the kingdom of rice, and the rice yield accounts for 35% of world rice yield ranking the first place in the world[7]. Planting of scented rice has a long history in China and it can be dated back to more than 1800 years ago[8]. China is vast in territory, great difference in geographical environment, climatic conditions, forming rich germplasm resources and precious local varieties of accented rice, such as Jiangyong scented rice of Hunan Province, Qubu scented rice of Shandong Province, and Jingxi scented rice of Beijing[9]. Through seed introduction and using local scented rice varieties, China has cultivated Zhongjian 2, Yixiang 1577, and a good many new scented rice varieties[10-13].

China has taken fragrance of rice as an essential quality indicator[14]. Generally, scented rice can be divided into Pandanus tectorius scented rice, violet scented rice, Jasmine scented rice, lettuce scented rice, hickory nut scented rice, Basmati scented rice, toasted bread scented rice, crispy rice scented rice, popcorn scented rice; major volatile substances include hydrocarbons, aromatic hydrocarbons, aldehydes, ketones, esters, acids, alcohols, and alcohol-based alkylene, heterocyclic compounds, *etc*[15].

3 Composition and approach of fragrance of scented rice

Yajima *et al*[16-17] measured composition of Japanese scented rice Oshihikari and Kaorimai using Gas Chromatograph Mass Spectrometer and found 114 substances in those scented rice varieties, compared with ordinary rice varieties, pyrrolidinone and indole are significantly higher. Buttery *et al*[18] found that the content of 2-acetyl-1-pyrroline (2-AP) in Basmati 370, Khao Dawk Mali, Malagkit Sungsong, and Hieri is several to several dozens of times of ordinary rice. Daniels *et al*[19] also found that 2-AP is the major composition of scented rice, 2-AP concentration in brown rice is

1500 μg/kg, higher than findings of Buttery *et al.*[20]; the closer to seed coat, the higher the content. Mahattanatawee *et al*[21] found 26, 23, 22 kinds of scented substances in Jasmine, Basmati, and Jasmati scented rice respectively; 2-AP exists in those three types of scented rice varieties; 2-acetyl-2-thiazoline (2-AT) only exists in Jasmine scented rice; they found dimethyl sulfide, 3-Methyl-2-butene-1-thiol, 2-Methyl-3-Furanethiol, dimethyl trisulfide, and 3-Methylthio propionaldehyde also are scent active substances. Bryant *et al*[22] believed that volatile substances of rice are diversified. 93 types of volatile substances were found in rice. Except 2-AP, there are differences in volatile substances of scented rice and ordinary rice; 16 types of volatile substances exist in scented rice, and some are unique to scented rice[23]. Gu Jianming *et al*[24] analyzed composition of fragrant japonica rice 8618 using, found that No. 6 peak is consistent with mass fragmentography of artificially synthetic 2-AP GC-MS, and its fragrance has popcorn taste like artificially synthetic 2-AP. Besides, they also analyzed possible lytic pathways of 2-AP under mass spectral lytic theory[25]. Pinson[26] studied scented substances of scented rice Della-xa, A-301, Jasmine 85, and Amber, and concluded that the difference between scented rice and ordinary rice lies not in existence of 2-AP, but in the content of 2-AP. Yu Biyu *et al*[27] also found 2-AP in Baixiangnuo (a common vegetable corn variety). Mathure *et al*[28] found that 2-AP content of non Basmati scented rice is higher than Basmati; 2-AP content is positively correlated with 1-tetradecene and indole, negatively correlated with benzyl alcohol; content of nonanal, caprylic aldehyde base, aldehyde, and 1-Octen-3-ol is different between Basmati and ordinary rice varieties. These indicate that fragrant substances of scented rice are diversified, deep or light scent of scented rice may be related with combined action of many scented substances; major element of scent is 2-AP; indole, phenylethanol, a-pyridine is higher in scented rice than ordinary rice varieties[29]. With constant progress in technologies, new fragrant substances in scented rice are gradually recognized.

According to mass researches, 2-AP nitrogen source precursor is proline[18, 30-31], through a series of enzymatic action of proline oxidase, proline is finally converted to 2-AP[32]. Gu Jianming *et al*[24] found that low soluble molecular weight extract of corn contains much free L-proline, glucose, and fructose, and heating L-proline and glucose and fructose can generate 2-AP, proved L-proline and glucose and fructose are precursors of 2-AP, and derived the approach of generation of 2-AP through heating, but did not explain all intermediates in the whole reaction process. Chen *et al*[33] held that betaine aldehyde dehydrogenase (BADH2) catalyzes betaine aldehyde in cytoplasm, and γ-Aminobutyraldehyde oxidation reaction with 3-amino-propionaldehyde, while GABald may be probably precursor of 2-AP biosynthesis. Tadashi *et al*[34] proved that the most important precursor for generation of 2-AP in rice seedlings is proline, proline forms pyrroline-5-carboxylate through catalysis of proline oxidase, forms pyrroline through catalysis of pyrroline-5-carboxylate decarboxylase, and finally forms 2-AP through transferase action of pyrroline and acetyl-CoA. Free proline, proline oxidase, and total free amino acid are major factors for synthesis of aroma of scented rice, while there is no significant correlation between ornithine transaminase and aroma of scented rice[35]. The synthesis of scented substances is related to proline and prolinase, but it is still not clear about dynamic matters in 2-AP and the key enzyme influencing generation of 2-AP in grains.

4 Factors influencing quality of fragrance of scented rice

4.1 Nutrition elements Aroma of scented rice is not only influenced by genetic matters of scented rice, but also influenced by growth environment and nutritional ecology. Huang Shuzhen[36-37] found that quality of scented rice in scented rice production area is better than other areas; organic matters, total nitrogen, available nitrogen, total phosphorus, available phosphorus, Fe, Mn, Cu, and Zn of soil in scented rice production area is higher than non-production areas; lanthanum (la), titanium (ti), and cobalt (Co) in soil and rice stems and leaves and vanadium and nickel in soil are higher than non-production areas, and lanthanum and titanium may be essential elements influencing the generation of aroma of scented rice. Sun Shuxia *et al*[38] also proved that planting scented rice in soil containing higher total nitrogen, available nitrogen, and Zn, the aroma of scented rice will be denser. Yang *et al*[39] studied factors influencing generation of aroma of scented rice varieties in China, and found that the higher the total nitrogen in soil, the denser the aroma of scented rice, so the total nitrogen increase is the major factor influencing increase of aroma. Increasing nitrogen fertilizer can increase content of free proline, so as to increase 2-AP content in scented rice, but there are differences between different scented rice varieties[40]. Lanthanum fertilizer (lanthanum chloride) application can increase yield and aroma of scented rice, the highest application of lanthanum fertilizer ($LaCl_3$) for the highest content of aroma in brown rice is 3180 mg/kg, the content of $LaCl_3$ for increasing yield and aroma of scented rice is 100 mg/kg[41], lanthanum fertilizer can improve activity of proline oxidase, so as to reduce proline content of rice grain[42]. Zn fertilizer can significantly increase 2-AP content in rice grain of different scented rice varieties, but the amount of increase is different for different varieties[43], and the optimum $ZnCl_2$ base fertilizer application for increasing aroma concentration of scented rice is 80 – 120 mg/kg[44]. Potash fertilizer can increase yield of scented rice and aroma of brown rice, and plays a certain role in improving quality of scented rice[45]. Application of potash fertilizer can significantly increase free proline and improve proline dehydrogenase activity, increase 2-AP content of scented rice about 10.70 – 67.65%, there is certain difference between aroma increase and application of potash fertilizer, and through quadratic curve fitting, the highest potash fertilizer application for aroma of scented rice is K_2O123.46 – 187.50kg/hm^2[46]. Therefore, appropriate application of plant nutrients can result in chan-

ges in precursor proline and related enzyme activities for generation of 2-AP, so as to bring about changes in aroma of scented rice[47-48]. This is the most simple and effective method for adjusting aroma of scented rice in cultivation of scented rice varieties.

4.2 Moisture Researches indicate that proper irrigation can effectively increase aromatic composition of scented rice without influencing physiological features of rice growth, and also can increase aroma of scented rice[49]. When moisture is kept in 0-(-25 ±5) kPa at the tillering stage, it can significantly increase aromatic components of scented rice and free proline in rice grain, and also can improve proline oxidase in leaves, stem and sheath and rice grain in mature period; when the moisture is kept in 0-(-50 ± 5) kPa at the tillering stage, the aromatic components of scented rice drops[50]; if the moisture is kept 0-(-25 ± 5) kPa at booting stage, it can increase aromatic components of scented rice, improve proline oxidase activity in leaves and rice grain, while it will reduce aromatic components of scented rice when soil moisture is in 0-50 (±5) kPa[51]. Certain water and nitrogen interaction can increase 2-AP content of scented rice, moisture stress and suitable tillering cultivation condition can realize higher level of aromatic components[52]. These indicate that proper management of soil moisture is an essential measure for adjusting aroma of scented rice.

4.3 Temperature Environmental temperature not only influences rice quality, but also affects its aroma. Generally speaking, aroma of scented rice mature in high temperature condition will be weak, while aroma of scented rice mature in lower temperature will be denser[53]. Average daily temperature of 30℃ will reduce seed setting, filled grains, head rice rate, amylose content, alkali spreading value, flavor score and aroma. In grain-filling period, average daily temperature of 23℃ can realize higher yield, quality and aromatic components[54]. Yang Shuying *et al*[55] found that during early and middle grain filling period, the scented rice varieties have denser aroma with low average-daily-temperature, low highest-daily temperature, low lowest-daily-temperature. Aromatic components are varied. Low average daily temperature and great daily temperature difference can increase free amino acids and unsaturated aliphatic acids of rice, thus it may be one of reasons for dense aroma of Chinese local scented rice varieties. Average daily temperature and relative humidity in grain filling period are major factors influencing content of soluble proteins of rice grain, and there are differences in soluble proteins of rice grain between different scented rice varieties[56]. Through experiment, Yang Xiaojuan *et al*[57] found that early season rice sowed in March 10 in south China contains high 2-AP, and 2-AP is negatively correlated with illumination hours. For the sown period with high 2-AP content, the free proline and proline dehydrogenase activity keep higher level. Late rice (sowed in July 20) contains higher 2-AP; for the sown period with high 2-AP content, the free proline and proline dehydrogenase activity keep higher level[58]. Thus, temperature is an essential factor influencing rice quality, and its major approach may be activity of proline and proline enzyme. Selecting suitable sowing time is an important measure for improving quality of scented rice.

4.4 Illumination Yang Xiaojuan *et al*[57] found that scented rice with higher content of 2-AP contains high free proline and activity of proline dehydrogenase, and 2-AP is negatively correlated with illumination time. Mo Zhaowen *et al*[59] found shading 15 days after flowering, the content of 2-AP in rice grain also significantly increases, and it also can increase content of GABA (γ-aminobutyricacid). In other words, weak light can increase aromatic content of scented rice.

4.5 Other factors Apart from the above factors, changes in aromatic components of scented rice are also influenced by other factors. Extracting natural aroma to store rice can increase content of 2-AP[61]. Gay *et al*[62] held that salt of soil plays a positive role in 2-AP of scented rice, but salt stress will influence yield of scented rice. Besides, grain weight and soil electric conductivity are negatively correlated with 2-AP content. They believed that increase of 2-AP in scented rice is resulted from shrinkage of grain size due to salt. However, Fitzgerald *et al*[63] studied the relation between leaves of scented rice and 2-AP content and salt stress in Jasmine and Basmati, and found that there is no significant stress relation between them. Study of Sugunya *et al*[53] indicated that lower temperature for desiccation grain can promote increase of 2-AP; during 10 months storage period, with increase of storage time, the content of 2-AP drops.

5 Application prospects

Unique aroma and nutrition of scented rice make it ranking in an important position in international rice trade. According to statistics of Food and Agriculture Organization of the United Nations, rice consumption has reached 407.8 million tons in 2000, and the trade reached 17.116 million tons[6]. The price of scented rice in international market is 2-3 times or even 10 times higher than conventional rice, showing huge commercial value and market potential, and increasingly favored in recent years. Besides, developing scented rice has higher economic benefits compared with conventi onal rice varieties. Scented rice has higher economic benefits, so it may be an effective approach for increasing income of farmers in mountainous areas. At present, domestic scented rice has price up to 3 – 4 times of the ordinary rice, and 2 times higher than conventi onal high quality rice[64]. Apart from food, scented rice can also be used as special purpose for industrial development, such as making rice beer, rice wine, rice vinegar, and rice cake. Therefore, application of scented rice is large and development prospect of scented rice industry is promising. In recent years, demand of scented rice gradually rises in all over the world. China is the largest rice production country, and scented rice varieties are varied, but the export is nearly zero. Further speeding up research and development of scented rice varieties and cultivation technologies are of great significance for development of China's scented rice industry and effective supplement of demands of scented rice market.

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able harvesting period, and harvest time is usually the 22nd d after pollination.

5 Conclusions and discussions

Ditian 6 has high sweetness, good flavor, few residues and full kernel, and its quality is at the upper level. It is an ideal healthy food favored by urban and rural people. This variety has large ear, long husk, moderate stalk, good density tolerance, and high-level ear-bearing rate. Ditian 6 is an early-maturing variety with short growth period, and growers can adjust sowing date according to actual needs. Based on excellent and appropriate cultivation measures, the suitable regions can carry out double cropping or interplanting to increase multiple cropping index and greatly improve economic efficiency. Ditian 6 is super sweet corn, and the top soil strength of Ditian 6 is weaker than that of ordinary corn, so it is necessary to ensure enough fertilizer and moisture during planting and increase the seeding rate, to lay a good foundation for harvest[10].

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