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Changes of Chemical Properties and Functional Compounds during The Germination of Various Brown Rice in Mekong Delta, Viet Nam

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ABSTRACT

For the selection of the most suitable rice varieties for processing of germinated brown rice products in Mekong Delta, six varieties commonly planted in the Mekong Delta (Jasmine85, OM4900, OM2517, CLN, MBD, IR50404) were selected for study. In order to do that protein, starch, amylose, total polyphenol and GABA content were determined during 24 hours of the germination of the brown rice in aerobic and anaerobic conditions. GABA was biosynthesized with the highest levels in four varieties such as Jasmine85, IR50404, MBD and CLN in anaerobic germination conditions as 37.56 mg/100g, 35.39 mg/100g, 30.32 mg/100g and 24.65 mg/100g respectively. During the germination, both polyphenol and GABA showed a significant increase as 1.15 - 4.58 times and 1.56 - 3.34 times respectively. The high level of initial GABA content in the material may relate to the highest increase of this component during the germination. There were no relationship between initial protein and starch content to the capacity of increase of GABA and polyphenol compounds during the germination. However, high initial amylose content related to fast germination to get maximum GABA content but it is not related directly to GABA biosynthesis capacity. In addition, the rice variety which was high ability of making the increase of high protein content during germination seems to be related to the ability to biosynthesize GABA and polyphenol compounds. The results indicate that 3 varieties as Jasmine85, IR50404 and MBD can be used as materials for germinated brown rice production in Mekong Delta.

KEYWORD: Germinated brown rice, anaerobic, aerobic germination, GABA, polyphenol.

INTRODUCTION

Mekong Delta is the best place in Vietnam which has the largest rice producibility. However, people living in this region still cannot have high income due to just selling paddy and rough rice with low value. Therefore, the application of processing technology to diversify rice products is one direction not only helps to balance food security but also increase the income of farmers in the region. One of solution is the production of germinated brown rice due to various nutritional as well as functional advantages [1, 2, 3]. At the present, some popular rice varieties in this region are OM4900, Jasmine85, IR50404, OM2517, Mot Bui Do (MBD), White sticky rice (CLN), each variety processes specific characteristics and different yield as well as suitable for different provinces in the area. OM4900 varieties commonly planted in the alluvial soils of high quality fresh and for export. Jasmine 85 and IR50404 85 varieties are selected from Institute international rice research (IRRI). They are most commonly grown in the Mekong Delta due to be the highly productive varieties. OM2517 is broad adaptation, easy cultivation, suitable with the quadrangle of Long Xuyen and West Hau River. MBD is widely cultivated in this acidification, salinization lands as Bac Lieu province, Vietnam but it is still put on the top of list of delicious rice of Vietnam. CLN with high yield and can produce for all 3 seasons are growing popular in A Giang province.

The nature of the germination process needs energy, relates to the presence of oxygen, even more enzyme activity and a strong need in the early stages of germination, so a possible initial enzyme is essential which decides to speed of germination of brown rice. Indeed, the process of germination occurs in 3 phases [4]. In the phase 1, water absorption process occurs rapidly resulting structural disturbance occurs particularly at the cell membrane, which makes the process of water absorption and activation of enzyme available in the grain. Then, respiration and protein synthesis starts happening. In the phase 2, the embryo begins to germinate, lengthening. In this phase, protein synthesis uses mRNA available, robust cell divides, the demand is huge oxygen to perform the respiratory process, and batch process energy outbreak takes place in the TCA cycle, cycle glycolysis [5]. In the phase 3, this is no longer aerobic respiration stage, new mRNA and DNA synthesis will be biosynthesized, sprouts will grow faster in order to ensure that the development process in the future. The process cannot receive power through the TCA cycle that can be done on a different cycle. It is clearly that the lack of oxygen cannot germinate in the early stages.

The protein and amylose content may be related to the process of germinating brown rice. In 2009, the relationship between glutamic acid, protein and GABA content of Malaysia germinated brown rice was studied [6]. The results indicated that GABA level ranged between 0.01 and 0.1 mg/g corresponding to glutamic acid

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and protein content varied between 10.1-15.2 mg/g and 6.99-10.17% respectively. The results also showed a significant positive correlation between the concentration of protein and glutamic acid as well as between glutamic acid and GABA level. Thus, protein content, rich in glutamic acid levels in the protein composition of rice, brown rice, rice bran may accompany to GABA biosynthesis. GAD (EC 4.1.1.15) is an enzyme which depends on cofactor component as pyridoxal-phosphate 50 (PLP). In 2010, the optimization of germination process of three different varieties (Niaw Peuak Dam Dam, and Chiang Phatthalung Phatthalung Sangyod) of Thailand to achieve highest bioactive substances during germination was investigated [7]. The results indicated that the highest GABA level was obtained when the rice was soaked in solution of at pH 3 (0.1M citrate buffer pH 3) and then germinated in closed vessel for 36 hours with Sangyod Phatthalung red rice (14.69±0.3% amylose, 8.93±0.04% protein) and Chiang Phatthalung white rice (21.72±0.34% amylose, 7.37±0.03% protein) and for 48 hours with Niaw Dam Peuak Dam black sticky rice (amylose just 2.7%, protein 8.06±0.03%). The amylose content of Niaw Dam Dam Peuak was the lowest but had highest capacity for water absorption (40%). This was opposite with Chiang Phatthalung rice (30%). In the process of soaking, GABA levels tended to rise faster in the 6th hour and accelerated after achieving saturation humidity. The rice with the lowest amylose content was capable had the highest capacity of GABA biosynthesis. However, during the incubation period averages amylose varieties Sangyod Phatthalung (14.69% amylose) was capable of the highest GABA biosynthesis (44mg/100g dry matter). Up to now, there are no studies about a correlation between original amylose and protein content to GABA biosynthesis during the germination stage.

Germination process is related to the formation of polyphenols and antioxidants. The germination of brown rice is closely related to changes in levels of phytic acid, phytase enzyme activity [8]. Phytic acid and its hydrolysis products are sources of antioxidants. In the process of germination, the enzyme phytase activity increased to 7.3 times, phytic acid content is significantly reduced during germination. Phytic acid has mainly in bran, phytic acid itself also has high antioxidant activity, DPPH IC_{50} of approximately 115.69 to 138.58 ppm and IC50 of the BHA is 9.24 ppm. Obviously, phytic acid and phytase can participate in the process of germination. In 2013, the study which compared the anti-oxidative activity of white rice, brown rice and brown rice germ was done [9]. The results indicated that the germinated brown rice showed the highest antioxidant activity. However, the relationship between original antioxidant activity and polyphenol content involves in germinated brown rice is still unknown.

Soaking and incubation conditions greatly affect the germination process. In 2007, the effects of immersion and incubation contained no air exchange to the amount of rice generated GABA sprouts from 5 different varieties of Japan was done [10]. The results showed that after 3 hours soaking brown rice and drain, incubated in sealed box environment temperature of 35°C for 21 hours when incubated in the absence of air exchange (closed box), GABA concentrations may reached 20.1mg/100g dry matter, 2.4 times higher than normal aging process. The results also showed that in the soaking conditions, glutamine and glutamic acid were rising despite increased levels of GABA. This indicates that glutamic acid is synthesized by glutamate synthase, glutamine synthetase. These two enzymes play important role in the accumulation of GABA and alanine in anaerobic conditions [11]. So, to understand more about the relationship between the original ingredients, enzymes formation during soaking and germinating brown rice, this study was done. Particularly, in this study aimed to assess the association between protein, starch and polyphenols of six varieties of brown rice on the ability biosynthesis of functional compounds and find the most suitable varieties to produce best germinated brown rice was taken.

MATERIALS AND METHODS

Six varieties (OM4900, Jasmine 85, OM2517, IR50404, MBD, CLN) which planted in Mekong Delta, Vietnam were used for the experiments. After 3 months planted, they were harvested. The moisture content was from 28 - 30%. They were dried until 13.5 - 14% before put into PE package and stored at 28-30^{o}C for 3 months. They were dehusked by Yanmar – ST50 which adjusted to suitable distance between 2 rulos of the machine depending to which variety to get pre-germinated brown rice. This brown rice was soaked into water until saturation before incubated at 37^{o}C for different time (16, 20, 24 hours) under aerobic or anaerobic condition. For analysis, standard chemicals such as GABA, GAE were imported from Merck, Germany. Other chemicals were from Sigma Aldrich.

Determination of starch and amylose content: starch content was determined following Bertrand method and multiply by 0.9 [12]. Amylose content was determined following the method of Chrastil (1987) [13].

Total protein content was determined by Kjeldal method [12].

γ – aminobutyric acid (GABA) was determined by the method of Banchuen et al (2010) [7].

Total polyphenol determination was determined by Folin – Ciocalteau method [14].

Statistical analysis: All experiments were repeated at least 3 times. The results were analyzed by using ANOVA analysis, LSD analysis using Statgraphic 16.1.18 software.

RESULTS AND DISCUSSION

Analysis of initial chemical ingredients of rice varieties

The result in Table 1 showed that there were differences of total protein, amylose, starch, polyphenol and GABA among various rice varieties. Initial level of GABA of OM4900, Jasmine85, IR50404 and MBD was the highest while the highest value of total polyphenol belonged to OM4900, IR50404 and MBD. Total protein content of white sticky rice (CLN) showed significant differences compared to others. Starch content of OM4900 was the highest while the highest amylose content was for IR50404, MBD and OM2517 varieties. The results also indicated that there were significant differences of various ingredients between rice varieties. These differences were not identical between what kinds of ingredient analysis. For example, the highest level of GABA belonged to IR50404 while in Mot Bui Do variety this GABA content was not so high. In contrast, the highest level of total Polyphenol belonged to the Mot Bui Do variety while in IR50404 it was not so high. So, this rule depends on what kind of ingredient like starch, protein and so on.

Table 1. Initial chemical ingredient of rice varieties in Mekong Delta

Variety	Content (Dry basis)				
	Protein (%)	Amylose (%)	Starch (%)	Total Polyphenol (mg/100g)	GABA (mg/kg)
OM4900	7.77^{c}	9.32^{b}	90.32^{e}	9.84^{d}	11.39^{c}
Jasmine85	7.13^{b}	21.52^{c}	74.33^{a}	5.15^{b}	17.63^{d}
OM2517	6.78^{a}	25.42^{d}	74.49^{a}	3.39^{a}	4.06^{a}
IR50404	8.26^{d}	38.94^{e}	77.57^{b}	9.36^{d}	22.66^{e}
Mot Bui Do	6.52^{a}	24.64^{d}	79.79^{d}	15.98^{e}	10.08^{c}
CLN	9.71^{e}	5.72^{a}	78.94^{c}	8.75^{c}	9.40^{c}

The different letters in the same column indicate significant difference statistically at the 95% confidence level

Change of nutritional ingredients during germination of brown rice

The methods for germination of brown rice in aerobic and anaerobic conditions are conducted with three varieties of Thailand in plastic box lid and capping [7]. The incubation time and temperature affect the germination, the best condition for germination is at 37°C for 24 hours are investigated [15]. During the incubation, respiratory of rice also generates heat to promote germination and after 16 hours sprouts begin to appear, as long incubation period, increasing stem length by activating the satellite operations of starch, protein and fat to transform these into a simple matter provides nutrients to nourish the embryo, cells divide into germ grows and sprouts over time. Therefore, in this study, aerobic and anaerobic incubation in a period of 16-24 hours was done.

Total protein

During soaking germination of brown rice, lipid metabolism makes the protein content increases, besides a number of biologically active substances are synthesized as amino acids [16]. The results in Table 2 showed that the protein content increased following incubation time and had significant difference when incubated in two conditions. In anaerobic conditions, protein content increased higher than in aerobic conditions. IR50404 showed the highest protein levels after 24 hours of incubation in anaerobic conditions (11.64%), increased by 1.4 times compared to the initial material, under the same conditions, OM2517 showed the lowest percentage (7.78%).

Table 2. Change of total protein content after germination of brown rice

Incubation condition	Time (h)	Total protein content (%)						Average
		OM4900	Jasmine85	OM2517	IR50404	MBD	CLN	
Aerobic (37°C)	16	5.42	8.06	7.00	8.62	6.58	7.46	7.90^{a}
	20	6.03	8.64	6.82	9.02	7.87	7.94	
	24	6.83	9.09	7.66	9.38	11.18	8.66	
Average		6.09^{a}	8.6^{b}	7.16^{c}	9.01^{d}	8.54^{b}	8.01^{e}	
Anaerobic (37°C)	16	5.90	9.05	6.70	9.7	6.53	8.42	8.58^{b}
	20	6.87	9.59	6.95	10.95	7.22	9.38	
	24	7.84	10.00	7.78	11.64	9.20	10.63	
Average		6.87^{a}	9.54^{b}	7.14^{ac}	10.76^{d}	7.65^{c}	9.48^{b}	

The different letters in the same column or line indicate significant difference statistically at the 95% confident level

Starch and amylose content

During the incubation, the embryo develops and stimulates amylase which hydrolysis starch resulting to maltose, glucose and dextrin thus reduced starch content after germination. The result in Table 3 showed that even though possessed the highest starch content, starch content of OM4900 decreased just 2% in aerobic and 5% in anaerobic condition after germination. OM2517 and Jasmine85 decreased almost 20% of starch, IR50404 and CLN decreased 23-24% while MBD decreased deeply up to 28% comparing to initial starch content. While, after germination, the low starch content rice variety sometime increased very fast GABA content. These results showed that high or low initial starch content may not relate to functional compounds like GABA. The decrease speed of starch may affect to the increasing of GABA content. In 2010, the optimization of germination process of three different rice varieties of Thailand to achieve the highest bioactive substances during germination was done [7]. The initial amylose content of Niaw Dam Peuak Dam black sticky rice, Sangyod Phatthalung red rice and Chiang Phatthalung white rice was around 2.7%, 14.69% and 21.72% respectively. When compared the time for germination to get the highest GABA content, Niaw Dam Peuak Dam brown rice showed the slowest speed to get the highest GABA (48 hours to get 40mg/100g GABA but still increasing), next for Sangyod Phatthalung red rice (36 hours to get 44mg/100g) and then for Chiang Phatthalung white rice (36 hours to get just 29mg/100g). In contrast with this study, when compared the germination of MBD and OM4900 varieties, initial GABA content was almost similar, but amylose content of MBD was almost three times higher than OM4900. However, after germination, MBD showed better capacity of GABA biosynthesis than OM4900. These indicate that low initial amylose content may lead to slow down the germination process. It may be recognized that high initial amylose content related to fast germination to get maximum GABA content but it is not related directly to GABA biosynthesis capacity.

Table 3. Change of starch content after germination of brown rice

Incubation condition	Time (h)	Starch content (%)						Average
		OM4900	Jasmine85	OM2517	IR50404	MBD	CLN	
Aerobic (37^{o}C)	16	89.09	61.47	63.63	59.82	65.19	61.49	64.33^{a}
	20	87.23	59.34	61.03	60.67	57.71	60.16	
	24	88.61	58.20	59.35	57.60	59.35	49.57	
Average		88.31^{a}	59.67^{b}	61.43^{c}	59.36^{b}	60.16^{bc}	57.07^{d}	
Anaerobic (37^{o}C)	16	87.31	58.85	59.97	60.76	66.05	56.83	61.56^{b}
	20	83.89	55.94	57.6	58.41	55.37	52.91	
	24	84.27	53.58	55.79	54.45	51.73	54.32	
Average		85.16^{a}	56.12^{b}	57.79^{c}	57.87^{c}	57.15^{c}	54.69^{d}	

The different letters in the same column or line indicate significant difference statistically at the 95% confident level.

Change of biological and functional compounds during the germination of brown rice
Total polyphenol

Table 4. Changes of total polyphenol content after germination of brown rice

Incubation condition	Time (h)	Total polyphenol content (mg/100g)						Average
		OM4900	Jasmine85	OM2517	IR50404	MBD	CLN	
Aerobic (37^{o}C)	16	6.73	13.42	6.18	13.23	24.34	7.71	14.00^{a}
	20	10.93	14.28	9.52	13.37	27.46	9.80	
	24	11.46	18.68	11.51	14.02	29.36	9.83	
Average		9.70^{a}	15.46^{b}	9.05^{a}	13.66^{c}	27.05^{d}	9.11^{a}	
Anaerobic (37^{o}C)	16	16.65	19.1	4.36	13.23	28.27	6.78	17.15^{b}
	20	19.77	20.89	11.08	13.73	28.30	9.96	
	24	23.52	21.98	15.54	14.02	31.39	10.06	
Average		19.98^{c}	20.66^{c}	10.32^{a}	13.66^{b}	29.32^{d}	8.93^{a}	

The different letters in the same column or line indicate significant difference statistically at the 95% confident level.

Polyphenol content increases after germination due to the activities of antioxidants increases the free radicals leads to disruption of the cells releasing the phenolic compounds [17]. The result in Table 4 showed that during the germination in anaerobic conditions for 24 hours, total polyphenol was also increased. MBD variety showed the highest total polyphenol (31.39 mg/100g), CLN showed the lowest polyphenol content (10.06 mg/100g), OM4900 (23.52 mg/100g), Jasmine 85 (21.98 mg/100g), OM2517 (15.54 mg/100g), IR50404 (14.02 mg/100g).

γ-aminobutyric acid (GABA)

GABA biosynthesis will be accompanied by the consumption of H^+ ions through the decarboxylation. This will improve the condition of cytoplasmic acidosis [18]. Some studies show that under anaerobic conditions will reduce intracellular pH of about 0.4 to 0.8 due to a stress caused by a deficiency of oxygen [19]. The decrease in intracellular pH due to hypoxic conditions will generate increased levels of GABA produced by stimulation the activity of enzyme GAD - the enzyme that synthesized glutamic acid to establish GABA [20]. GAD enzyme activity related greatly to the process of germination of grain [14]. The result in Table 5 showed that the incubation time for germination affect GABA biosynthesis. GABA content showed the highest after 24 hours incubated. Jasmine85 showed the highest GABA (37.56mg/100g). In the same condition, OM2517 showed the lowest content of GABA. Other varieties showed the GABA content in range of 25.96 –

35.39mg/100g. These results are suitable with previous study which studied on Thai Red Jasmine variety, GABA content increase from 6 mg to 41 mg/100g [21].

Table 5. Changes of GABA content after germination of brown rice

Incubation	Time (h)	GABA content (mg/100g)						Average
		OM4900	Jasmine85	OM2517	IR50404	MBD	CLN	
Aerobic (37°C)	16	16.35	23.63	11.79	21.93	28.86	25.66	21.53[a]
	20	17.33	25.31	12.30	25.48	21.6	26.41	
	24	18.20	25.71	13.17	27.96	20.01	25.77	
Average		17.29[a]	24.88[b]	12.42[c]	25.12[be]	23.49[d]	25.95[e]	
Anaerobic (37°C)	16	17.72	30.81	10.39	33.29	20.35	24.39	25.33[b]
	20	18.65	34.96	12.50	35.13	23.28	24.32	
	24	25.96	37.56	13.58	35.39	30.32	26.31	
Average		20.78[a]	34.44[b]	12.42[c]	34.67[b]	24.65[d]	24.65[d]	

The different letters in the same column or line indicate significant difference statistically at the 95% confident level

CONCLUSIONS

During the germination, there were a significant increase of total polyphenol (1.15 - 4.58 times) and GABA (1.56 - 3.34 times), high level of initial GABA and polyphenols in brown rice may relate to the highest increase of these components, there were no relationship between initial protein and starch content to the increase of GABA or polyphenol. High initial amylose content may relate to fast germination to get maximum GABA content but it is not related directly to GABA biosynthesis capacity and the rice with high ability of increase of high protein content may relate to high ability to biosynthesize GABA and polyphenols compounds.

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REFERENCES

1. Okada, T., T. Sugishita, T. Murakami, H. Murai, T. Saikusa, T. Horino, A. Onoda, O. Kajimoto, R. Takahashi, T. Takahasi, 2000. Effect of the defatted rice germ enriched with GABA for sleeplessness, depression, autonomic disorder by oral administration. Nippon Shokuhin Kagaku Kogaku Kaishi., 47: 596–603.
2. Rasolt, D.H, 2008. Chemical in germinated brown rice could benefit diabetics. Latest News and Information, Defeat Diabetes Foundation, Inc Reggina, R., Nebuloni, M., and Brambilla, I. Anaerobic accumulation of amino acids in rice roots: role of the glutamine synthetase/glutamate synthase cycle. Amino Acids., 18: 207–217.
3. Mustapha, U.I., I. Maznah, I. Hairuszah, T. Zaki, R.O. Abdul, 2013. Effects of Germinated Brown Rice and Its Bioactive Compounds on the Expression of the Peroxisome Proliferator-Activated Receptor Gamma Gene. Nutrients., 5: 468-477.
4. Bewley, J.D, 1997. Seed germination and dormancy. The Plant Cell., 9: 1055-1066.
5. Bewley, J.D and M. Black, 1994. Seeds: Physiology of Development and Germination: Book Review, Second edition, Plenum Press: NewYork, pp:445.
6. Roohinejad, S., H. Mirhosseini, N. Saari, S. Mustafa, I. Alias, A.S.M. Hussin, A. Hamid, M.Y. Manap, 2009. Evaluation of GABA, crude protein and amino acid composition from different varieties of Malaysian's brown rice. Aust J Crop Sci., 3: 184–190.
7. Banchuen, J., T. Paiboon, O. Buncha, W. Phaisan, S. Piyarat, 2010. Increasing the bio-active compounds contents by optimizing the germination conditions of Southern Thai Brown rice. Songklanakarin Journal of Science and Technology., 32(3): 219-230.
8. Moonghharm, A and N. Saetung, 2010. Comparison of chemical compositions and bioactive compounds of germinated rough rice and brown rice. Food Chemistry., 122(3): 782-788.
9. Norhaizan, M.E., A.K. Khairul-Kamilah, A. Zulkhairi, A. Azrina, 2013. Antioxidant activity of white rice, brown rice and germinated brown rice (*in vivo and in vitro*) and the effects on lipid peroxidation and liver enzymes in hyperlipidaemic rabbits. Food Chemistry., 141: 1306-1312.
10. Komatsuzaki, N., K. Tsukahara, H. Toyoshima, T. Suzuki, N. Shimizu, T. Kimura, 2007. Effect of soaking and gaseous treatment on GABA content in germinated brown rice. Journal of Food Engineering., 78(2): 556–560.

11. Reggina, R., M. Nebuloni, I. Brambill, 2000. Anaerobic accumulation of amino acids in rice roots: role of the glutamine synthetase/glutamate synthase cycle. Amino Acids., 18: 207–217.
12. AOAC, 2010. Official methods of analysis (15th ed.). Association of Official Analytical Chemists. Washington DC, USA.
13. Chrastil, J., 1987. Improved colorimetric determination of amylose in starches or flours. Carbohydrate Research., 159(1): 154-158.
14. Singleton, V.L, 1981. Naturally occurring food toxicants: phenolic substances of plant origin common in foods. Adv Food Res., 27: 149-242.
15. Duy, L.N.D and N.C. Ha, 2014. Influence of soaking and germination conditions on the γ-aminobutyric acid (GABA) content of 2 rice varieties (IR 50404 AND JASMINE 85) from Mekong Delta. Journal of Science and Development., 12 (1): 59-64.
16. Chiang, P.Y., A.I. Yel, 2002. Effect of soaking on wet milling of rice. J Creal Sci., 35(1): 85-94.
17. Nakamura, K., S. Tian, H. Kayahara, 2004. Functionality anhancement in germinated brown rice. In 11th international flavor conference/3rd George Charalambous memorial symposium Samos, Greece, pp: 356-371.
18. Shelp, B.J., A.W. Bown, M.D. McLean, 1999. Metabolism and functions of gamma-aminobutyric acid. Trends Plant Sci., 4: 446-452.
19. Crawford, L.A., A.W. Bown, K.E. Breitkreuz, F.C. Guinel, 1994. The synthesis of γ-aminobutyric acid in response to treatments reducing cytosolic pH. Plant Physiol., 104: 865-871.
20. Chung, H.J., S.H. Ang, H.Y. Cho, S.T. Lim, 2009. Effects of steeping and anaerobic treatment on γ-aminobutyric acid content in germinated waxy hull – less barley. Lebensm Wiss Technol., 42: 1712 - 1716.
21. Wichamanee, Y and I. Teerarat, 2012. Production of germinated Red Jasmine brown rice and its physicochemical properties. International Food Research Journal., 19(4): 1649-1654.