International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 13 Issue 4, April-2024, Impact Factor: 8.375

The properties of GABA (Gamma-probioticin nutritional drinks

Wong Jest Phia, Nutthaya Srisuvor, Karunee Kwanbun Jan, Chanchira Phosat, Migasena Changbumrun[5], Pornpimol Panprathip, Charunee Thiabpho

Rajamangala University of Technology Krungthep, Dusit, Bangkok
Westwood Clinic, Malaysia
Tropical Nutrition & food science Mahidol University, Thailand
Vegetarianism and Nutrition Association Thailand
Public health, Mahidol University, Thailand

ABSTRACT

The quantities of -aminobutyric acids (GABA) and total sugar of the germinated brown rice (GBR) and germinated brown rice drinks supplemented with probiotic and oligofructose (GBRD-PO) were measured by high-performance liquid chromatography. The physicochemical properties (i.e., total soluble solids, total solids, moisture, pH, total acidity, and apparent viscosity) and sensory properties of the GBRD-PO were investigated during 21-days storage. The survival of probiotics was counted. The results showed that the quantities of GABA, total sugar, glucose, and maltose depended on the types and cultivars of the germinated rice. The quantities of GABA and total solids increased but the sucrose and pH decreased in the GBRD-PO during chilled storage. The survival of probiotics averaged 8.26 log CFU/ml throughout the storage. The sensory properties of GBRD-PO were in an acceptable range. This research is a prototype for the development of GABA quantities in the fermented rice drinks supplemented with synbiotics for health.

Keywords: -aminobutyric acid, germinated brown rice, rice drink, probiotic, oligofructose

INTRODUCTION

Germinated brown rice (GBR) is an innovative food. Its major bioactive compounds increase during the germination process. GBR contains levels of high vitamins, minerals, fiber, antioxidants, polyphenols, inositols, ferulic acids, phytic acids, γ-oryzanol, prolylendopeptidase inhibitors, and □-aminobutyric acids (GABA) (Cho & Lim, 2016; Kayahara, Tsukahara, & Tatal, 2001; Wu, Yang, Toure, Jin, & Xu, 2013). GABA is a four-carbon non-protein amino acid. It is a significant component in most microorganisms, plants, and vertebrates. The biosynthesis pathway of GABA is accomplished by GABA shunt. In GABA synthesis, L- glutamate is catalyzed to form GABA by glutamate decarboxylase (GAD). The quantities of GABA were dependent on L-glutamate concentration and GAD activities (Rashmi, Zanan, John, Khandagale, & Nadaf, 2018; Shelp, Bown & McLean, 1999). It has been shown that environmental stresses promoted the accumulation of GABA

in plant tissues (Bown & Shelp, 2016). In mammals, GABA is a major neurotransmitter in the central nervous system (Bouche, Lacombe, & Fromm, 2003; Olsen, 2002). It has multiple biological functions which help to prevent Huntington's chorea, Parkinson's disease, Alzheimer's disease, anxiety, depression, panic, and insomnia (Gajcy, Lochyński, & Librowski, 2010). Therefore, the germinated rice can be used as a bio-active composition in functional foods, such as fresh germinated colored rice noodle, germinated red rice yoghurt, and GBR bread (Anawachkul & Jiamyangyuen, 2009; Cornejo, Caceres, Martínez-Villaluenga, Rosell, & Frias, 2015; Ohtsubo, Suzuki, Yasui & Kasumi, 2005; Thao, 2018). Several researchers have studied the enhancing GABA, ferulic acid, γ-oryzanol, tocopherols, phenolic compounds, anthocyanins, and antioxidant capacities of germinated rice and GBR. (Banchuen, Thammarutwasik, Ooraikul, Wuttijumnong & Sirivongpaisal, 2010; Chaiyasut et al., 2017; Lin, Pao, Wu & Chang, 2015; Ng, Huag, Chen & Su, 2013; Singh, Simapisan, Decharatanangkoon & Utama-ang, 2017).

Few researchers studied GBR beverages mixed with chlorophylls and GBR beverages mixed with cereals (Assumption University, 2015; Division of Rice Research and Development, 2016). Recently, GBR products such as rice balls, rice-burger, soup, baked goods, wines, meat, vegetables, legumes, beverages, and dairy products are widely enjoyed by consumers (Diana, Quílez, & Rafecas, 2014; Patil & Khan, 2011). However, there has been no research on

the development of the germinated brown rice drinks supplemented with probiotic and oligofructose (GBRD-PO) and its properties. This product does not contain the cow's milk which is suitable for the lactose intolerant. This plant drink can be easily absorbed by the body.

A “probiotic” is a food supplemented with viable bacteria. It has several benefits for the body, adjusting the balance of colon microorganisms, modulating immunological response, and protection from diseases, such as antibiotic- associated diarrhea, and colon cancer. Furthermore, probiotics prevent infections of intestinal pathogens by creating antimicrobial agents and improving host health (de Vrese & Schrezenmeir, 2008; Havenaar & Huis in’t Veld, 1992; Markowiak & Śliżewska, 2017; Šuškovic et al., 2010). Moreover, oligofructose is a non-digestible sugar which can be fermented by the intestinal bacteria. Therefore, it is considered a dietary fiber for the body. It helps to improve the ecology of microorganisms in the gut (de Vrese & Schrezenmeir, 2008; Ziemer & Gibson, 1998). In this research, oligofructose was used as a prebiotic together with probiotics in the GBRD considered as a synbiotic drink. Synbiotics have been demonstrated to alter, modify, and reinstate the pre-existing intestinal microflora during the passage through the upper intestinal tract and it promote increasing survival, stimulate growth, and activate probiotic metabolism (Pandey, Naik, & Vakil, 2015).

The objectives of this research were to study the quantities of GABA and total sugar of the germinated paddy rice (GPR), GBR, and GBRD-PO and the physicochemical, biological and sensory properties of GBRD-PO during chilled storage.

MATERIALS AND METHODS

Materials

Thai Hom Mali (HM) brown rice (white), cleaved soybean, white sesame, and pure refined sugar were purchased from a supermarket in Bangkok, Thailand. Hom Lanna (HL) paddy rice and HL brown rice (purple) were purchased from the Agricultural Technology Research Institute, Rajamangala University of Technology Lanna, Thailand. Oligofructose (Orafti P95, Tienen, Belgium) with a degree of polymerization of 2-8 was received from the DPO (Thailand) Co., Ltd. Lactobacillus rhamnosus TISTR 047 (TISTR 047) was purchased from the Department of Bio-Science, Thailand Institute of Scientific and Technological Research.

Preparation of starter

TISTR 047 was inoculated in a sterilized flask of de Man, Rogosa and Sharpe (MRS) broth and incubated (Memmert UN 110, Germany) at 37 C for 24 hours. The standard curve was plotted for the probiotic numbers and the optical densities at 600 nm using UV/VIS spectrophotometer (Biochrom Libra S22, EU). The starter probiotics were prepared by incubating TISTR 047 (37 C, 18 hours); the numbers of starter bacteria were assayed by comparing with the standard curve for preparing fresh culture. They were then centrifuged (Digicen 21 R, Spain) at 3,000xg (4 C, 5 minutes), washed with 0.85% sterilized saline solution, and adjusted at 8 log CFU/ml into the drinks (Srisuvor, Chinprahast, Prakitchaiwattana & Subhimaros, 2013).

Preparation of GBRD-PO

HL paddy rice, and HM brown rice, HL brown rice were washed and soaked in water using a rice-to-water ratio of 1:3 (w/v) (paddy rice, 24 hours; brown rice, 4 hours). HM and HL brown rice were incubated for 6-8 hours. They were washed again, then incubated (paddy rice, 48 hours; brown rice, 14 hours) until sprouting 0.5-1.0 mm length. The soybeans were soaked in water for 6-8 hours and washed with water. The sesame seeds were roasted until brown and fragrant. All ingredients (Table 1) were blended with hot water in a high-speed blender (5 minutes). The mixture was boiled (70 C, 10 minutes), filtered, and pasteurized (70 C, 5 minutes). When the mixture cooled to 37 C, it was inoculated with 8 log CFU/ml of TISTR 047 starter (Srisuvor et al., 2013). The GBRD-PO was filled into 100 ml of polypropylene bottles; then refrigerated (4 C, 21 days).

Table 1. Ingredients of the GBRD-PO

Ingredients	Quantities (%)
GBR-HM	4.29
GBR-HL	1.84
Soybean	1.23
Sesame	1.23
Sugar	2.52
Oligofructose	3.00
Water	85.89
Total	100.00

From: Division of Rice Research and Development (2016); Srisuvor (2019)

Analysis of physicochemical properties

The quantities of GABA and different types of sugar, i.e., total sugar, fructose, glucose, sucrose, maltose, and lactose in the GPR, GBR and GBRD-PO were analyzed using TAS 4003 and AOAC method 982.14, respectively using high-performance liquid chromatography (Shimadzu LC-6A, Japan) (AOAC, 1995; TAS, 2012a). The quantities of GABA and total sugar in the GBRD-PO were analyzed at 0 and 21 days of storage. The physicochemical properties of the GBRD-PO were examined on 0, 7, 14 and 21 days of storage. The total soluble solids (TSS) were measured by a hand refractometer (Atago 2373 WO5, Japan), the total solid (TS) and moisture were analyzed by using a hot air oven (Memmert, UN 450, Germany), the pH was measured by a pH meter (SCHOTT Lab 850, Germany), the total acidity (TA) was assayed by the titration method (AOAC, 2012), and the apparent viscosity was measured using viscosity meter (Brookfield LVDV-II+P, USA).

Analysis of probiotic survival

The enumerations of probiotic cells were made cell spreading on the MRS agar at 0, 7, 14 and 21 days of storage by plate count technique. Total plates were incubated in an anaerobic jar (Merck) at 37 □ C for 72 hours.

Analysis of sensory properties

The GBRD-PO at 0 and 21 days were coded with 3 digit random numbers, served at 10°C, and evaluated by 45 semi-trained panelists (students of Department of Food Technology and Nutrition) for the preference test in the appearance, color, odor, flavor, taste, texture, and overall satisfaction. The sensory evaluations used preference scores with 7-point hedonic scale (7- like extremely, 6- like moderately, 5- like slightly, 4- neither like nor dislike, 3- dislike slightly, 2-dislike moderately, and 1- dislike extremely (Larmond, 1982).

Analysis of statistics

The Completely Randomized Design was used for the experimental design of physicochemical and biological properties, and the Randomized Complete Block Design was used for the evaluation of sensory properties. They were carried out over three replications. These results were assayed by the analysis of variance. Means were compared by Duncan' New Multiple Range Test (p □ 0.05).

RESULTS AND DISCUSSION

Quantities of the GABA and total sugar

Table 2. Quantities of GABA and types of sugar in the GPR, GBR, and GBRD

Categories	Quantities (mg/100g, WB)						
	GABA	Total sugar	Fructose	Glucose	Sucrose	Maltose	Lactose
GPR-HL	6.96	-	-	-	-	-	-
GBR-HM	0.20	Nd[a]	Nd[a]	Nd[a]	Nd[a]	Nd[a]	Nd[a]
GBR-HL	8.91	2,050	Nd[b]	650	Nd[b]	1,400	Nd[b]
GBRD-PO	0.27	4,090	Nd[b]	Nd[b]	3,060	1,030	Nd[b]

PONd[a]<100 mg/100g, Nd[b]<600 mg/100g

Table 2 shows the quantities of GABA and different types of sugar in the germinated paddy rice of HL variety (GPR-HL), germinated brown rice of HM variety (GBR-HM), germinated brown rice of HL variety (GBR-HL), and GBRD-PO. The quantities of GABA in the GPR-HL and GBR-HL were 6.95 and 8.91 mg/100g WB, or 9.21 and 9.57 mg/100g, DB, respectively (data not shown). These results correlate with Anawachkul and Jiamyangyuen's (2009) assertion that the GABA quantities of the GPR and germinated red rice were 1.5-13.1 and 2.6-21.3 mg/100g, DB, respectively at different germination time. The results showed that the germinated rice had a higher GABA quantities than the GPR due to the soaking of the rice germ in water. It meant that the germination ratio of rice was higher than the paddy rice due to water absorption and hydrolytic enzyme activity. The quantities of GABA increased as the time of germination was prolonged. Karladee and Suriyong (2012) reported that the quantities of GABA during incubation at 0 and 24 hours were 3.96-17.87 mg/100g, DB. At 24 hours, Khao Dawh Mali (white) and Kum Doi Saket (purple) rice displayed the highestGABA quantity (23 mg/100g, DB) of all 21 varieties. Tantakul (2009) showed that the GABA quantities of low-amylose rice (31-37 mg/100g) were higher than high-amylose rice (21-29 mg/100g), and the GABA quantities of glutinous rice (29-72 mg/100g) were higher than low-amylose rice. The conclusion was that the quantities of GABA depended on the types and cultivars of the germinated rice. This correlates with Chua, Koh, & Liu's (2019) assertion that the factors of high GABA quantities were the rice cultivars, steeping conditions, provided nutrients, germination duration, and novel techniques.

In this study, the GABA quantity in the GBR-HM was low since the rate of germination was less than 70% and it was

polished for more than 2 weeks (TAS, 2012b). Later results showed that the GABA quantity in the GBRD-PO was 0.27 mg/100g WB, because this drink contained GBR-HL at only 1.84% of total ingredients. Besides, the pasteurization of GBRD-PO may cause a decrease of GABA quantities from the initial GBR-HL. This result was consistent with the decrease of GABA quantities in all the cooking processes of germinated grains and yoghurt - containing paste of germinated red rice including canned GBR (Anawachkul & Jiamyangyuen, 2009; Jongyingcharoen & Cheevitsopon, 2016; Tiansawang, Luangpituksa, Varanyanond, & Hansawasdi, 2016). Therefore, the pasteurization of the GBRD-PO should use temperatures at □ 100 □ C for 10-20 minutes because the high temperature could inactivate GAD and protease inhibiting the raise of GABA (Parnsakhorn & Langkapin, 2018). Contrarily in GBR-HM, the quantity of GABA increased slightly when it was produced as GBRD-PO. The result may be due to the production of GABA through multiple GABA synthetic pathways. GABA may be synthesized by chemical synthesis from various bio-based or biological synthesis from microorganisms (Koubaa, Delbecq, Roohinejad & Mallikarjunan, 2019; Rashmi et al., 2018;). Therefore, increasing the quantities of GABA in the pasteurized drink, fermented food, or commercial food could be obtained by supplying probiotics with high GABA- producing ability (Anawachkul & Jiamyangyuen, 2009). Further study should investigate the steeping conditions, germination duration, and provided nutrients of rice to produce high GABA before the probiotic fermentation. It has been suggested that the amount of GABA used to decrease anxiety should be 300-600 mg/day (Thorne Research, Inc., 2007).

The total sugar, glucose, and maltose of the GBR- HL were found to be in reasonable quantities. The fructose, sucrose, and lactose of the GBR were undetected since they are usually found in fruits or milk rather than rice. However, the total sugar and sucrose were high in GBRD-PO because sucrose creates sweetness and is a carbon source for the probiotics. Lastly, the quantities of glucose and maltose slightly dropped in the GBRD-PO because the monosaccharide and disaccharide could be fermented by probiotics.

Physicochemical properties of the GBRD-PO

Figure 1 and 2 show the physicochemical properties of the GBRD-PO during chilled storage. The drinks showed no significant difference in TSS, apparent viscosity, moisture, or TA. The 7-21 day samples had more TS than on the production day. This may be due to the fact that the rice starch was hydrolyzed by β-amylase on α-1, 4 glycosidic linkages at the non-reducing ends to produce maltose (Evans, Li & Eglinton, 2009). This result correlates with the increased quantity of maltose on day 21 (Table 3) and it is associated with maintaining probiotics survival (Figure 3) by using sugar as a carbon source. The pH of the 0-day storage was higher than the 14-21 days since the probiotics fermented some glucose and sucrose in the drinks to produce lactic acids, decreasing the pH (Bonestroo, Kusters, de Wit & Rombouts, 1992; Costa, Fonteles, de Jesus & Rodrigues, 2013).

The effects of chilled storage of the GBRD-PO on the quantities of GABA and total sugar are presented in Table3. The quantity of GABA on day 21 increased about 2 times from the production day. This may be due to the fact that GABA is synthesized via GABA shunt, and the L-glutamate is catalyzed by GAD to form GABA (Rashmi et al., 2018; Shelp et al., 1999). Also, this drink was produced by supplementing TISTR 047, which could convert the L-glutamate to form GABA by GAD during incubation. Enhancing GABA production of the probiotics depends on the probiotic species, co-incubation strains, culture medium, L-glutamate concentration, GAD activity, pH, temperature, and time (Kim, Lee, Ji, Lee & Hwang, 2009; Lee, Shim, Yao, Kim & Kim, 2018; Li, Qiu, Huang & Cao, 2010; Shan et al., 2015). The quantities of sucrose decreased slightly by day 21 since it was used for the metabolism and activities of the probiotics (Costa et al., 2013). However, the maltose quantities of the GBRD- PO increased slightly by day 21. This may be due to the fact that β-amylase converted the starch in the drink into maltose (Cho & Lim, 2016).

Probiotic survival in the GBRD-PO

Figure 3 displays the survival of TISTR 047 in the GBRD-PO during 0-21 days. They averaged 8.26 log CFU/ml ($p > 0.05$). They can survive throughout the chilled storage. Probiotics live in the gut of the mammal host (de Vrese & Schrezenmeir, 2008). Their survival gradually reduced during chilled storage especially in non-dairy foods (Costa et al., 2013; Nematollahi, Sohrabvandi, Mortazavian & Jazaeri, 2016). However, combining the appropriate probiotics and prebiotics could improve the survival of probiotics in fermented products (Kailasapathy & Chin, 2000). Pimentel, Madrona, Garcia & Prudencio (2015) reported that oligofructose helped the survival of probiotics by preventing injuries from the environment and acidity during juice storage. Furthermore, Acevedo-Martínez, Gutiérrez-Cortés, García-Mahecha & Díaz-Moreno (2018) suggested that the 5% oligofructose could be used to protect cells from acidity in mango drink at 4□ C by providing a substrate for metabolismand it would help probiotics to survive in the gastrointestinal tract. There are several factors involved in enriching probiotic viability in food products, such as probiotic selection, inoculum level, microbial interaction, strain adaptation, food matrix, probiotic encapsulation, synbiotic combination, product formulation, processing conditions, packaging system, and storage temperatures (Karimi, Mortazavian, & Da Cruz, 2011; Terpou et al., 2019). In conclusion, these fermention conditions are suitable for the survival of TISTR 047 at >8 log CFU/ml with no loss of viability during chilled storage at 4C.

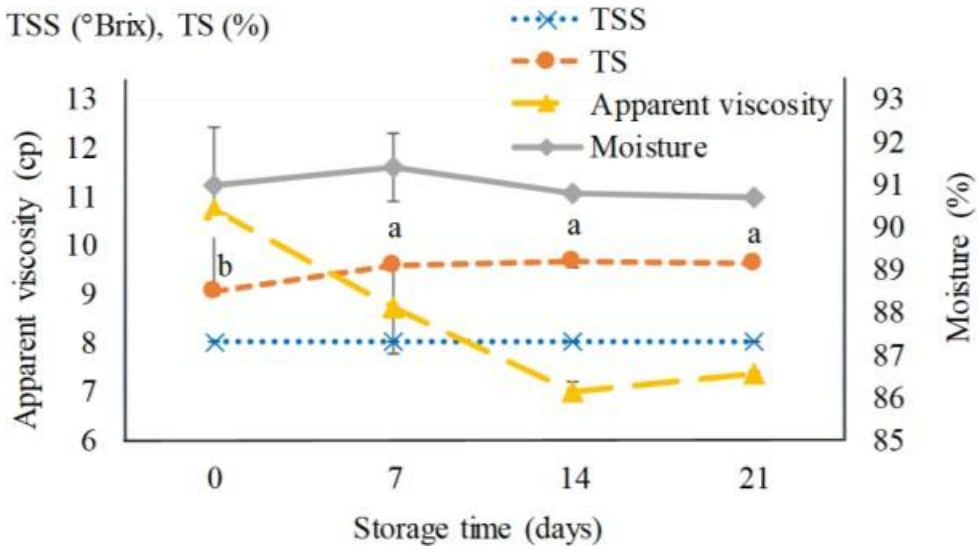

Figure 1. Total soluble solids (TSS), total solids (TS), apparent viscosity, and moisture levels of the GBRD-PO during chilled storage

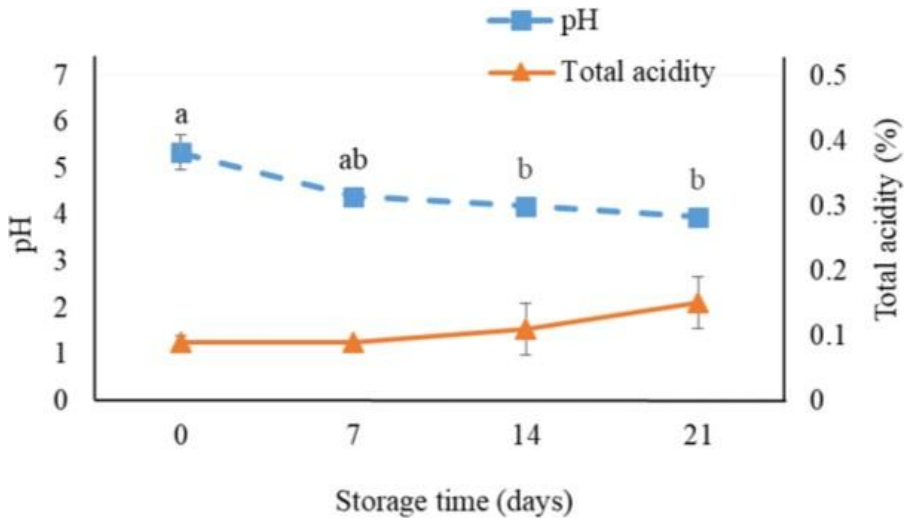

Figure 2. The pH and total acidity of the GBRD-PO during chilled storage

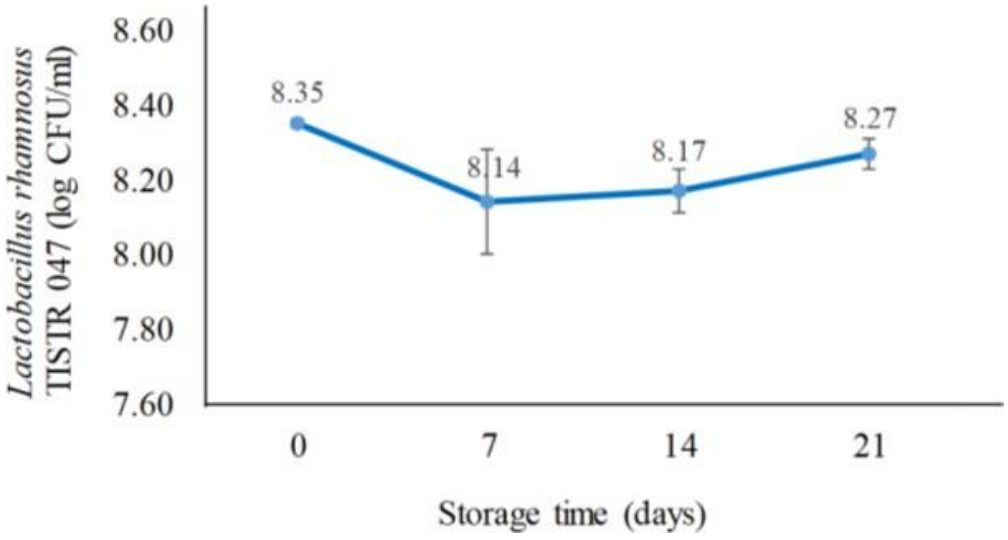

Figure 3. Survival of probiotics in the GBRD-PO during chilled storage

Sensory properties of the GBRD-PO

Figure 4 shows the sensory properties of the GBRD- PO during chilled storage. The preference scores on day 0 were all higher than on day 21, except for color. On the 21st day, the GBRD-PO had an increased sour odor and fermented rice taste causing a decrease in overall liking scores. These results correspond with the decrease of sucrose and pH (Table 3 and Figure 2). Supplementing probiotic and oligofructose did not influence the color of the GBRD-PO during chilled storage. The overall liking scores were in an acceptable range. However, this GBRD-PO needs to improve the sensory properties due to the fermented rice's sour odor and taste. The selection of probiotic species to produce less acid and better flavor is a way to improve the sensory properties of the product.

Table 3.Quantities of GABA and types of sugar in the GBRD-PO during chilled storage

Storage (days)	Quantities (mg/100g, WB)			
	GABA	Total sugar ns	Sucrose	Maltose
0	0.11 ± 0.00^{b}	4,910 ± 0.14	$3,860 \pm 0.12^{a}$	$1,050 \pm 0.23^{b}$
21	0.23 ± 0.00^{a}	4,485 ± 0.13	$2,840 \pm 0.13^{b}$	$1,645 \pm 0.01^{a}$

Fructose, Glucose, and Lactose<100mg/100g

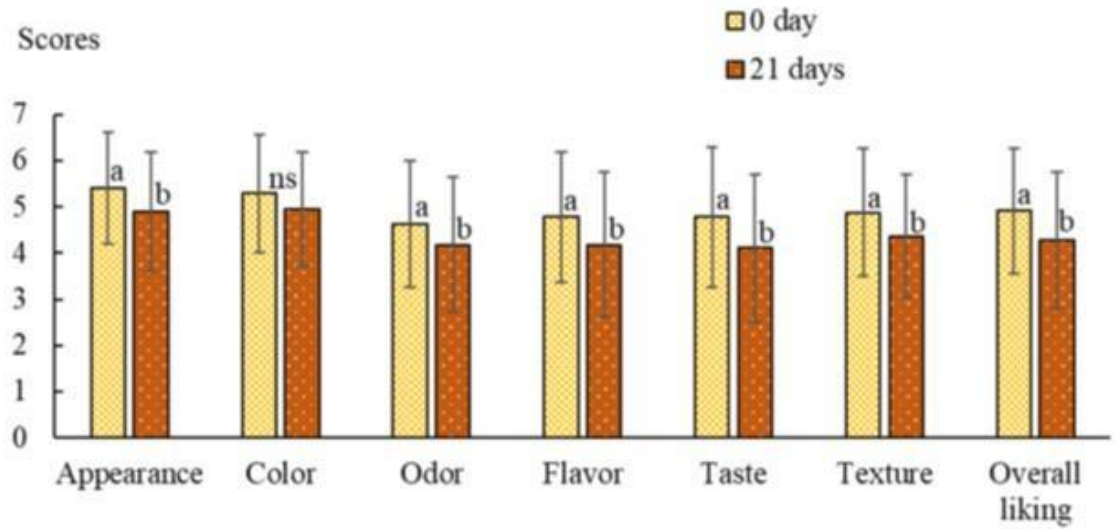

Figure 4. Sensory properties of the GBRD-PO during chilled storage

CONCLUSIONS

The quantities of GABA and total sugar in the GBR depend on the types and cultivars of rice. The GBRD-PO had an increase of GABA and TS quantities but a decrease of the sucrose and pH levels during chilled storage. The survival of probiotics was potentially suitable to be used in functional drinks (>8 log CFU/ml). It is an enriched drink from GBR which contains GABA as a synbiotic drink. Further studies are required to improve the GABA quantities and sensory properties of the GBRD-PO to be accepted as synbiotic fermented rice drink for health.

ACKNOWLEDGEMENTS

This research was funded by Rajamangala University of Technology Krungthep, Bangkok.

REFERENCES

[1]. Acevedo-Martínez, E., Gutiérrez-Cortés, C., García-Mahecha, M., & Díaz-Moreno, C. (2018). Evaluation of viability of probiotic bacteria in mango (Mangifera indica L. Cv. “Tommy Atkins”) beverage. Revista DYNA, 85(207), 84-92. doi:10.15446/dyna.v85n207.70578

[2]. Anawachkul, M., & Jiamyangyuen, S. (2009). The study of GABA content and development of GABA-enriched yogurt from germinated red rice (Munpu rice). Kasetsart Journal (Natural Science), 43, 224-231. Retrieved from http://kasetsartjournal.ku.ac.th/kuj_ files/2010/A1003081314396250.pdf

[3]. Association of Official Analytical Chemists (AOAC). (1995). Official Methods of Analysis (16th ed.). Washington, DC: Author.

[4]. Association of Official Analytical Chemists (AOAC). (2012). Official Methods of Analysis (19th ed.). Washington, DC: Author.

[5]. Assumption University. (2015). Petty Patent No.12346, Bangkok, Thailand: Department of Intellectual Property,

Ministry of Commerce. Retrieved from http://patentsearch.ipthailand.go.th/DIP2013/view_public_data.php?appno=11514600005

[6]. Banchuen, J., Thammarutwasik, P., Ooraikul, B., Wuttijumnong, P., & Sirivongpaisal, P. (2010). Increasing the bio-active compounds contents by optimizing the germination condition of Southern Thai brown rice. Songklanakarin Journal of Science and Technology, 32(3), 219-230. Retrieved from https://pdfs.semanticscholar.org/3779/d39db0548b5 96449 e2bf8039bc9610cbd2a6.pdf?

[7]. Mohan Raja Pulicharla, D. Y. (2023). Neuro-Evolutionary Approaches for Explainable AI (XAI). Eduzone: International Peer Reviewed/Refereed Multidisciplinary Journal, 12(1), 334-341.

[8]. Bonestroo, M. H., Kusters, B. J. M., de Wit, J. C., & Rombouts, F. M. (1992). Glucose and sucrose fermenting capacity of homofermentative lactic acid bacteria used as starters in fermented salads. International Journal of Food Microbiology, 15(3- 4), 365-376. doi:10.1016/0168-1605(92)90070-J

[9]. Bouche, N., Lacombe, B., & Fromm, H. (2003). GABA signaling: a conserved and ubiquitous mechanism. Trends in Cell Biology, 13(12), 607-610. doi:10. 1016/j.tcb.2003.10.001

[10]. Bown, A. W., & Shelp, B. J. (2016). Plant GABA: Not just a metabolite. Trends in Plant Science, 21(10), 811-813. doi:10.1016/j.tplants.2016.08.001

[11]. Chaiyasut, C., Sivamaruth, B. S., Pengkumsri, N., Saelee, M., Kesika, P., Sirilun, S., . . . Peerjan, S. (2017). Optimization of conditions to achieve high content of gamma amino butyric acid in germinated black rice, and changes in bioactivities. Food Science and Tehnology, Campinas, 37(Supplement 1), 83-93. doi:10.1590/1678-457x.33416

[12]. Cho, D., & Lim, S. (2016). Germinated brown rice and its bio- functional compounds. Food Chemistry, 1(196), 259-271. doi:10.1016/j.foodchem.2015.09.025

[13]. Chua, J-Y., Koh, M. K. P., & Liu, S-Q. (2019). 2-Gammaaminobutyric acid: A bioactive compound in foods. In H. Feng, B. Nemzer, & J. W. DeVries (Eds.), Sprouted grains: Nutritional value, production, and application (pp. 25-54). Duxford, England: Elsevier. Cornejo, F., Caceres, P. J., Martínez-Villaluenga, C., Rosell,

[14]. M., & Frias, J. (2015). Effects of germination on the nutritive value and bioactive compounds of brown rice breads. Food Chemistry, 173(15), 298- 304. doi:10.1016/j.foodchem.2014.10.037

[15]. Costa, M. G. M., Fonteles, T. V., de Jesus, A. L. T., & Rodrigues, S. (2013). Sonicated pineapple juice as substrate for L. casei cultivation of probiotic beverage development: Process optimization and product stability. Food Chemistry, 15(139), 261266. doi:10.1016/j.foodchem.2013.01.059

[16]. De Vrese, M., & Schrezenmeir, J. (2008). Probiotic, prebiotics, and synbiotics. Advances in Biochemical Engineering/Biotechnology, 111, 1-66. doi:10.1007/ 10_2008_097

[17]. Pulicharla, M. R. Explainable AI in the Context of Data Engineering: Unveiling the Black Box in the Pipeline.

[18]. Diana, M., Quílez, J., & Rafecas, M. (2014). Gamma- aminobutyric acid as a bioactive compound in foods: A review. Journal of Functional Foods, 10, 407-420. doi:10.1016/j.jff.2014.07.004

[19]. Division of Rice Research and Development. (2016). The production of germinated brown rice drink mixed with cereals. Retrieved from http://brrd. ricethailand.go.th/index.php/2016-07-15-05-29-43/ 47-2016-07-15-05-53-25

[20]. Evans, D. E., Li, C., & Eglinton, J. K. (2009). The properties and genetics of barley malt starch degrading enzyme. In G. Zhang & C. Li (Eds.), Genetics and improvement of barley malt quality (pp. 143-189). New York, NY: Zhejiang University.

[21]. Chi, K., Ness, S., Muhammad, T., & Pulicharla, M. R. Addressing Challenges, Exploring Techniques, and Seizing Opportunities for AI in Finance.

[22]. Gajcy, K., Lochyński, S., & Librowski, T. (2010). A role of GABA analogues in the treatment of neurological diseases. Current Medicinal Chemistry, 17(22), 2338-2347. doi:10.2174/092986710791698549

[23]. Havenaar, R., & Huis in't Veld, J. H. J. (1992). Probiotics: A general view. In B. J. B. Wood (Ed.). The lactic acid bacteria, Volume 1: The lactic acid bacteria in health and disease (pp. 151-170). London, England: Elsevier.

[24]. Jongyingcharoen, J. S., & Cheevitsopon, E. (2016). Development of UV-treated cooked germinated brown rice and effect of UV-C treatment on its storability, GABA content, and quality. LWT-Food Science and Technology, 71, 243-248. doi:10.1016/ j.lwt.2016.03.044

[25]. Kailasapathy, K., & Chin, J. (2000). Survival and therapeutic potential of probiotic organisms with reference to Lactobacillus acidophilus and Bifidobacterium spp. Immunology and Cell Biology, 78(1), 80-88. doi: 10.1046/j.1440-1711.2000.00886.x

[26]. Karimi, R., Mortazavian, A. M., & Da Cruz, A. G. (2011). Viability of probiotic microorganisms in cheese during production and storage: A review. Dairy Science and Technology, 91(3), 283-308. doi:10. 1007/s13594-011-0005-x

[27]. Karladee, D., & Suriyong, S. (2012). □-Aminobutyric acid (GABA) content in different varieties of brown rice during germination. ScienceAsia, 38(1), 13-17. doi:10.2306/scienceasia1513-1874.2012.38.013

[28]. Kayahara, H., Tsukahara, K., & Tatal, T. (2001). Flavor, health and nutritional quality of pre-germinated brown rice. In A. M. Spanier, F. Shahidi, T. H. Parliment, C. Mussinan, C.-T. Ho, & E. Tratras Contis (Eds.), Food Flavors and Chemistry: Advances of the New Millennium (pp. 546-551). Cambridge, England: RSC Publishing. doi:10. 1039/9781847550859-00546 Kim, J. Y., Lee, M. Y., Ji, G. E., Lee, Y. S., & Hwang, K. T.

[29]. Production of gamma-aminobutyric acid in black raspberry juice during fermentation by Lactobacillus brevis GABA 100. International Journal of Food Microbiology, 130(1), 12-16. doi:10.1016/j.ijfoodmicro.2008.12.028

[30]. Koubaa, M., Delbecq, F., Roohinefad, S., & Mallikarjunan, K. (2019). Gamma-Aminobutyric acid. In V. Peter, M. Laurence, & S. Fereidoon (Eds.), Encyclopedia of Food Chemistry, Volume 3 (pp. 528-534). Cambridge, MA: Elsevier. doi:10.1016/B978-0-08- 100596-5.22412-8
[31]. Pulicharla, M. R. (2024). Data Versioning and Its Impact on Machine Learning Models. Journal of Science & Technology, 5(1), 22-37.
[32]. Armond, E. (1982). Laboratory methods for sensory evaluation of food. Publication No. 1637. Ottawa, Canada: Food Research Institute, Canada Department of Agriculture. Lee, K. W., Shim, J. M., Yao, Z., Kim, J. A., & Kim, J. H.
[33]. Properties of kimchi fermented with GABA- producing lactic acid bacteria as a starter. Journal of Microbiology Biotechnology, 28(4), 534-541. doi:10.4014/jmb.1709.09011
[34]. Li, H., Qiu, T., Huang, G., & Cao, Y. (2010). Production of gamma-aminobutyric acid by Lactobacillus brevis NCL912 using fed-batch fermentation. Microbial Cell Factories, 9(1), 85-91. doi:10.1186/1475-2859-9-85
[35]. Lin, Y., Pao, C., Wu, S., & Chang, C. (2015). Effect of different germination conditions on antioxidative properties and bioactive compounds of germinated brown rice. BioMed Research International, 2015(4), 1-10. doi:10.1155/2015/608761
[36]. Markowiak, P., & Śliżewska, K. (2017). Effects of probiotics, prebiotics, and synbiotics on human health. Nutrients, 9(1021), 1-30. doi:10.3390/nu9091021
[37]. Nematollahi, A., Sohrabvandi, S., Mortazavian, A. M., & Jazaeri, S. (2016). Viability of probiotic bacteria and some chemical and sensory characteristics in cornelian cherry juice during cold storage. Electronic Journal of Biotechnology, 21, 49-53. doi:10.1016/j.ejbt.2016.03.001 Ng, L. T., Huag, S. H., Chen, Y. T., & Su, C. H. (2013).
[38]. Changes of tocopherols, tocotrienols, γ-oryzanol, and γ-aminobutyric acid levels in the germinated brown rice of pigmented and nonpigmented cultivars. Journal of Agricultural and Food Chemistry, 61(51), 12604-12611. doi:10.1021/jf403 703t
[39]. Ohtsubo, K., Suzuki, K., Yasui, Y., & Kasumi, T. (2005). Bio- functional components in the processed pre-germinated brown rice by a twin-screw extruder. Journal of Food Composition and Analysis, 18(4), 303-316. doi:10.1016/j.jfca.2004.10.003
[40]. Pulicharla, M. R. (2023). Hybrid Quantum-Classical Machine Learning Models: Powering the Future of AI. Journal of Science & Technology, 4(1), 40-65.
[41]. Olsen, R. W. (2002). GABA. In K. L. Davis, D. Charney, J. T. Coyle & C. Nemeroff (Eds.), Neuropsychopharma cology: The fifth generation of progress (pp. 159- 168). Philadelphia, PA: Lippincott, Williams and Wilkins.
[42]. Pandey, K. R., Naik, S. R., & Vakil, B. V. (2015). Probiotic, prebiotics and synbiotics-A review. Journal of Food Science and Technology, 52(12), 7577-7587. doi:10.1007/s13197-015-1921-1
[43]. Parnsakhorn, S., & Langkapin, J. (2018). Effects of drying temperatures on physicochemical properties of germinated brown rice. Songklanakarin Journal of Science and Technology, 40(1), 127-134. doi:10. 14456/sjst-psu.2018.11
[44]. Patil, S. B., & Khan, M. K. (2011). Germinated brown rice as a value added rice product: A review. Journal of Food Science Technology, 48(6), 661-667. doi:10. 1007/s13197-011-0232-4 Pimentel, T. C., Madrona, G. S., Garcia, S., & Prudencio, S.
[45]. (2015). Probiotic viability, physicochemical characteristics and acceptability during refrigerated storage of clarified apple juice supplemented with Lactobacillus paracasei ssp. paracasei and oligofructose in different package type. LWT-Food Science and Technology, 63(1), 415-422. doi:10. 1016/j.lwt.2015.03.009
[46]. Rashmi, D., Zanan, R., John, S., Khandagale, K., & Nadaf, A. (2018). □-aminobutyric acid (GABA): Biosynthesis, role, commercial production, and applications. In
[47]. R.S. Atta-ur-Rahman (Ed.), Studies in Natural Products Chemistry, Volume 57 (pp. 413-452). Cambridge, MA: Elsevier. Shan, Y., Man, C. X., Han, X., Li, L., Guo, Y., Deng, Y., . . .
[48]. Jiang, Y. J. (2015). Evaluation of improved □- aminobutyric acid production in yogurt using Lactobacillus plantarum NDC75017. Journal of Dairy Science, 98(4), 138-149. doi:10.3168/jds. 2014-8698
[49]. Shelp, B. J., Bown, A. W., & McLean, M. D. (1999). Metabolism and functions of gamma-aminobutyric acid. Trends in Plant Science, 4(11), 446-451. doi:10.1016/s1360-1385(99)01486-7
[50]. Singh, K., Simapisan, P., Decharatanangkoon, S., & Utama- ang, N. (2017). Effect of soaking temperature and time on GABA and total phenolic content of germinated brown rice (Phitsanulok 2). Current Applied Science Technlogy, 17(2), 224-232. Retrieved from https://www.tci-thaijo.org/index. php/cast/article/view/128531/96675
[51]. Srisuvor, N. (2019). Preliminary properties of probiotic drinks with oligofructose. In RMUTCON (Ed.), The 10th Rajamangala University of Technology International Conference 2019 Proceedings (pp. 254-258). Chiang Mai, Thailand: Research and Development Institute of Rajamangala University of Technology Lanna.
[52]. Srisuvor, N., Chinprahast, N., Prakitchaiwattana, C., & Subhimaros, S. (2013). Effect of inulin and polydextrose on physicochemical and sensory properties of low-fat set yoghurt with probioticcultured banana purée. LWT-Food Science and Technology, 51(1), 30-36. doi:10.1016/j.lwt.2012.10.018
[53]. Šuškovic, J., Kos, B., Beganovic, J., Pavunc, A. L., Habjanič, K., & Matošic, S. (2010). Antimicrobial activity-The most important property of probiotic and starter lactic acid bacteria. Food Technology and Biotechnology, 48(3), 296-307. Retrieved from https://pdfs.semanticscholar.org/a600/47ca461d122544d92a9b1f6c7089a114b2b3.pdf?_ga=2.146413245.809777321

[54]. Tantakul, P. (2009). Pre-germinated GABA-Rice. Food Focus Thailand. Retrieved from http://library.dip.go.th/ multim6/edoc/2553/18907.pdf
[55]. Terpou, A., Papadaki, A., Lappa, I. K., Kachrimanidou, V., Bosnea, L. A., Kopsahelis, N. (2019). Probiotics in food systems: Significance and emerging strategies towards improved viability and delivery of enhanced beneficial value. Nutrients, 11(7), 1591-doi:10.3390/nu11071591
[56]. Thai Agricultural Standard (TAS 4003). (2012a). Germinated Brown Rice. Bangkok, Thailand: National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives.
[57]. Thai Agricultural Standard (TAS 4404). (2012b). Good manufacturing practices for germinated brown rice. Bangkok, Thailand: National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives.
[58]. Thao, N. T. T. (2018). Effect of germinated colored rice on bioactive compounds and quality of fresh germinated colored rice noodle. KMUTNB International Journal of Applied Science and Technology, 11(1), 27-37. doi:10.14416/j.ijast.2017.12.008
[59]. Thorne Research, Inc. (2007). Gamma-Aminobutyric Acid (GABA). Alternative Medicine Review, 12(3), 274-
[60]. Retrieved from http://www.altmedrev.com/ archive/publications/12/3/274.pdf
[61]. Tiansawang, K., Luangpituksa, P., Varanyanond, W., & Hansawasdi, C. (2016). GABA (γ-aminobutyric acid) production, antioxidant activity in some germinated dietary seeds and the effect of cooking on their GABA content. Food Science and Technology, 36(2), 313-321. doi:10.1590/1678- 457X.0080 Wu, F., Yang, N., Toure, A., Jin, Z., & Xu, X. (2013).
[62]. Germinated brown rice and its role in human health. Critical Reviews in Food Science and Nutrition, 53(5), 451-463. doi:10.1080/10408398.2010.542259
[63]. Ziemer, C. J., & Gibson, G. R. (1998). An overview of probiotics, prebiotics and synbiotics in the functional food concept: Perspectives and future strategies. International Dairy Journal, 8(5-6), 473-
[64]. 479. doi:10.1016/S0958-6946(98)00071-5