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INSTANT GERMINATED VD20 RICE CULTIVATED IN VIETNAM: EFFECT OF COOKING CONDITIONS

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ABSTRACT

Instant rice is ideal for convenient use as a low-moisture, lightweight ration and emergency food in our fast-paced lifestyle. It has a longer shelf life and can be quickly rehydrated. This study examined the impact of various cooking circumstances, such as the ratio of rice to water and the kind and concentration of food additives, on the physical and sensory characteristics of quick germinated VD20 rice. Using the correct ratio of rice to water could decrease the percentage of broken cooked grains, increase porosity and volume expansion, and improve customer satisfaction. The study revealed that germinated VD20 rice cooked with a water-to-rice ratio of 1:2 had superior sensory qualities, as well as an appealing appearance when compared to both cooked and quick rice. Furthermore, the notable impact of food additives, specifically sodium bicarbonate and sodium chloride, on the characteristics of instant rice was noticed. Sodium bicarbonate adversely affects the organoleptic characteristics and causes structural damage and dark yellowing in instant rice. In a theoretical sense, the addition of 0.5% NaCl as a supplement can improve the physical characteristics of rice, resulting in instant rice with a well-formed structure and a higher rate of acceptance compared to the control sample which does not contain any food additives. This study is the first to explore the manufacturing of instant rice from germinated products. It aims to provide fundamental knowledge for future research on utilizing the high nutritional value of these sources and optimizing the production process.

1. Introduction

Germinated rice is a type of rice created from brown rice raw materials. Due to the germination process, rice is enhanced nutritional profiles, including vitamins E, PP, B1, B6, magnesium... especially gamma amino butyric acid (GABA). GABA is a free amino acid neurotransmitter, which have potential to regulates blood pressure, accelerates metabolism in the brain, prevents loss of control of some hormones during aging and perimenopause and beneficial for Alzheimer's patients. In addition to GABA compound, in germinated rice also contains γ-oryzanol, a ferulic acid with antioxidant effects that prevents skin aging and regulates blood cholesterol levels (Hepsomali et al., 2020). GABA is a water-soluble non-protein amino acid, it exists in small amounts in some plants used as food such as vegetables (spinach, potatoes, cabbage, asparagus, cauliflower and eggplant), sour fruits (apples and grapes), some grains (oats and corn) and in beans (Maqbool et al., 2017). GABA has been shown to have many benefits for animal bodies such as reducing blood pressure, reducing blood cholesterol (Inoue et al., 2003). Furthermore, it also has the effect of inhibiting neurotransmitter impulses in the central nervous system, effectively preventing pain, reducing stress and anxiety states as well as inhibiting the development of tumors of cancer cells (Huang et al., 2022). Therefore, research and development of GABA-rich food products has become a potential trend and is increasingly expanding.

Along with the continuous development of today's society, fast food products are becoming more and more popular and increasingly have a place in the hearts of consumers because of the convenience they bring. Rice is the main ingredient that needs to be supplied to the body every day. One of the rice varieties that has been successfully restored in Tien Giang is the VD20 rice variety, a rice variety with good quality thanks to its high quality, fragrant and sticky rice, suitable for consumer tastes. As mentioned earlier, germinated VD20 rice also has the potential to development into products, and one of them is instant rice. Instant rice is becoming increasingly popular as a result of people's hectic and fast-paced lifestyles (Loan et al., 2023; Yadav et al., 2023). Yadav et al. (2023) reported that the manufacturing techniques employed to produce instant rice are as follows: The three methods mentioned in the literature are as follows: (a) precooking the rice grain followed by sterilization; (b) precooking the rice grain followed by drying; (c) extruding rice flour followed by drying. The most easy method is the precooking and then drying (Lin & Li, 2023). When the rice kernel is boiled in extra water to attain full translucence, its swelling ratio is approximately 3–3.5, signifying that the rice kernel can absorb up to 2–2.5 times its weight in water. In a constrained water system (water-to-rice ratio of 1.4), all water is absorbed by the rice kernel. While comparable water absorption occurs for rice grains cooked for 12 minutes and 35 minutes, the distribution of water is more uniform with extended cooking duration (Hsu et al., 2015; Kasai et al., 2005). Consequently, the cooking temperature enhances the rate of water diffusion within the rice kernel. Moreover, the water absorbed by the starch granules leads to the substitution of hydrogen bonds between starch molecules with hydrogen bonds between starch and water molecules during gelatinization. Hot-air drying, a traditional and cost-effective method for dehydrating rice kernels, influences the quality and starch digestibility of rehydrated instant rice (Lin & Li, 2023). Limited research has systematically explored the effects of rice variety, cooking parameters, retrogradation, and annealing on the starch digestibility of instant rice. Especially, there was no study on production instant rice from the germinated grain. Therefore, the aim of this study was to determine the effect of cooking process (usage of water and effect of some food additives) on physical characteristics and sensory properties of instant germinated rice. Research on the process of producing instant rice from VD20 germinated rice is carried out with the aim of both meeting consumer needs, diversifying products and generating income for farmers from rich nutritional value material in Tien Giang province (Vietnam).

2. Materials and methods

2.1. Materials

A sample of VD20 rice varieties was obtained from a local farmer in Tien Giang province, Vietnam. The paddy sample underwent a comprehensive cleaning process to eliminate dust particles and was then de-husked using a Dehusker machine for subsequent analysis. The germination process followed the previous established method of our group (Loan & Thuy, 2019).

2.2. Experimental design

Weigh 300 g of germinated rice (for each treatment) and wash it with clean water. Then, add water at the rate according to the experimental setup (1:1, 1:1.25, 1:1.5, 1:1.75, 1:2 for ratio of rice and water), and cook with a rice cooker with a capacity of 1.2 liters (Sunhouse SHD8217W, Vietnam). Cooking time was determined when the pot turned on the "cook" button and the cooked rice was left to stabilize for another 5 minutes. After the rice was cooked, let it cool and then put it in the oven dryer at 60°C until the humidity was reached ≤13% (Loan et al., 2023). Sample was put in PA packaging to keep it stable for at least 3 days, then take 20 g for reconstituting with 45 ml of boiling water for a certain time and then determine the physical and sensory characteristics.

After selecting the appropriate conditions, the study of effect of sodium bicarbonate ($NaHCO_3$)/sodium clorua (NaCl) on the physical and sensory characteristics was conducted. 300 g germinated rice also was used for this study. The ratio of rice and water was chosen from previous experiment. In this study, different concentrations of $NaHCO_3$ (0.1, 0.2, 0.3%) and NaCl (0.5, 1.0, 1.5%) were added in the cooking water, sample without added additive consider as control sample. The cooking procedure also was same as earlier mentioned.

2.3. Analysis of nutritional profile of germinated VD20 rice

The proximate composition (moisture, protein, fat, ash and fiber) of the rice samples were estimated by standard AOAC protocols (AOAC, 2005). The carbohydrate content was estimated by difference method. Total starch content and amylose contents were estimated by Anthrone reagent and colorimetric methods, respectively (Sharma et al., 2024). The total polyphenol content of rice was analysis by Folin-Ciocalteu 10%, follow the procedure described by Loan and Thuy (2019).

2.4. Determination of physical properties

Volume expansion and hardness of instant rice were determined follow the method of Loan et al. (2023) and Chavan et al. (2018) to analysis the increasing volume of instant rice compare to the initial volume of rice and the change of structure of rice after processed.

2.5 Sensory evaluation

A sensory analysis of sample was conducted by a panel of 20 semi-trained members using a five-point Hedonic scale (Sivaranjani et al., 2024). The selection of panelist was based on their pre-existing expertise and enthusiasm for the sensory evaluation of instant rice. At first, the members received training on the quality characteristics of instant rice, the evaluation form, and the process of assigning scores. The samples were evaluated using a rating scale that ranged from "1 - Dislike extremely" to "5 - Like extremely" on 3 mainly attributes, including color, aroma and taste, and appearance and structure. The sample was provided in a randomized sequence at a temperature of 25–27°C, and the average mean score was utilized for comparison analysis.

2.6. Data analysis

The average statistics from three replications for each character were conducted. The repeated data underwent statistical analysis using the Analysis of Variance (ANOVA) method, utilizing the Statistical Package for Social Science (SPSS) software.

3. Results and discussions

3.1 Nutritional profile of germinated VD20 rice

Raw materials are an important factor that determines product quality. Depending on the origin and type of rice, the chemical composition may vary. Therefore, it is necessary to analyze the chemical composition of raw materials to determine the nutritional value of raw materials and find a reasonable processing process. The proximate composition of germinated VD20 rice was comparable with the reported of Bolarinwa et al. (2019). It also could be beneficial to produce the gluten-free product. The polyphenol content was observed at value of 32.3 mgGAE/100 g, which also could be potential to nutraceutical food as well as low glycemic index food by different mechanism (Ngo et al., 2023).

Table 1. Physicochemical properties of germinated VD20 rice

Parameters	Value
Moisture content	11.52%
Protein content	7.99%
Lipid content	2.29%
Carbohydrate content	69.47%
Ash content	4.33%
Polyphenol content	32.3 mgGAE/100 g

3.2 Effect of ratio of rice and water on the physical and sensory properties of instant rice

Adding water during cooking is very important. The water ratio during cooking has significant different effects on the structure of rice after gelatinization at the same cooking temperature conditions. After cooking, starch gelatinization occurs, causing rice grains to swell. The swelling phenomenon occurs first in the spore of starch granules, then spreads over the surface, causing their volume to increase many times until the starch granule tears and becomes an irregular shape, and then stop increasing volume (Briffaz et al., 2014). According to Reed et al. (2013), rice varieties will often differ in the thickness of the silk layer, structure, composition as well as gelatinization temperature and gelatinization degree. To completely gelatinize starch, it is necessary to use the appropriate amount of water. That directly affects the swelling and structure of reconstituted dried rice products (Bui et al., 2018).

Through the process of performing the experiment under the same conditions, the collected results were shown in Table 2 and Table 3. Specifically, for a rice: water ratio of 1:1, the cooking time was about 15 minutes, the rice is hard after cooking, with little loose grain expansion, the rice expansion after cooking is low at 21.56 cm^3 due to the supplemented water not being enough to gelatinize the rice. After cooking, the rice grains are quite dry and the rice hardness was measured at 1051 grams of force, which is mainly because the amount of water is small, so the grains do not absorb enough water to expand well. Therefore, after cooking, the rice is still hard and quite dry, but the grains still retain their original shape and are less likely to break (Figure 1). Amornsin (2003) reported that rice grains are not adequately moistened in the interior, the starch in the interior of the grain may not be fully gelatinized by heating. The color of the rice after cooking is still light yellow, with a light aroma (Figure 1). Therefore, the acceptable aroma and taste were low (3.53). Because the amount of water is low when cooking, the water evaporates faster during the drying process, and the drying time at 60^{o}C was short (about 220 minutes).

However, for a rice: water ratio of 1:1.25, the cooking time was about 20 minutes, which was longer than the sample is from ratio of 1:1. After being cooked, rice grains are still quite hard and swell less because the amount of water also was not enough to gelatinize the rice starch. Therefore, the expansion is relatively low at 22.37 cm^3, but still higher than that of ratio of 1:1. The grain structure recorded 1027 grams of force, showing that the rice was still quite hard which would affect the sensory properties and expansion when reconstituted. The acceptable value on color, aroma and taste, appearance and structure of instant rice were 4.54, 3.43, 4.15, respectively. After cooking, the rice still retains its good color, light aroma, and the grains are intact. Due to the same reason that the amount of water retain in rice is small, the water evaporates relatively quickly during the drying process, and the drying time was quite short (240 minutes). However, because the rice grains have not been completely gelatinized, after reconstitution the rice grains bloom less and are still hard

At a rice: water ratio of 1:1.5, the cooking time for rice increased to about 25 minutes. After cooking, the rice grains are cooked evenly and swell completely to an extent of 24.70 cm^3. The amount of water added is just enough, which led after cooking the rice was soft, the grains sticked together but not significantly and still retain their intact shape. The hardness of instant rice was about 997 grams of force. It has a decrease in hardness, comparing to rice: water ratios of 1:1 and 1:1.25. However, the appearance and structure acceptance were highest, reaching value of 4.98 out of 5. The drying time was about 260 minutes. After cooking, instant rice still retains its color, light aroma, and acceptable taste, which made the acceptance of color, and aroma reached value of 4.47 and 4.06, respectively.

Table 2. Effect of ratio of rice and water on hardness and volume expansion index of instant rice

Ratio of rice and water	Volume expansion (cm^3)	Hardness (g-force)	Color	Aroma and taste	Appearance and structure
1:1.0	21.56^{e}	1051^{a}	4.69^{a}	3.51^{b}	3.85^{e}
1:1.25	22.37^{d}	1027^{ab}	4.54^{b}	3.43^{c}	4.15^{c}
1:1.5	24.70^{c}	997^{b}	4.47^{c}	4.06^{a}	4.89^{a}
1:1.75	25.39^{b}	923^{c}	3.85^{d}	3.31^{d}	4.34^{b}
1:2.0	28.18^{a}	848^{d}	3.54^{e}	3.21^{e}	4.05^{d}

Note: Different superscript capital letters indicate significant difference within column ($p < 0.05$).

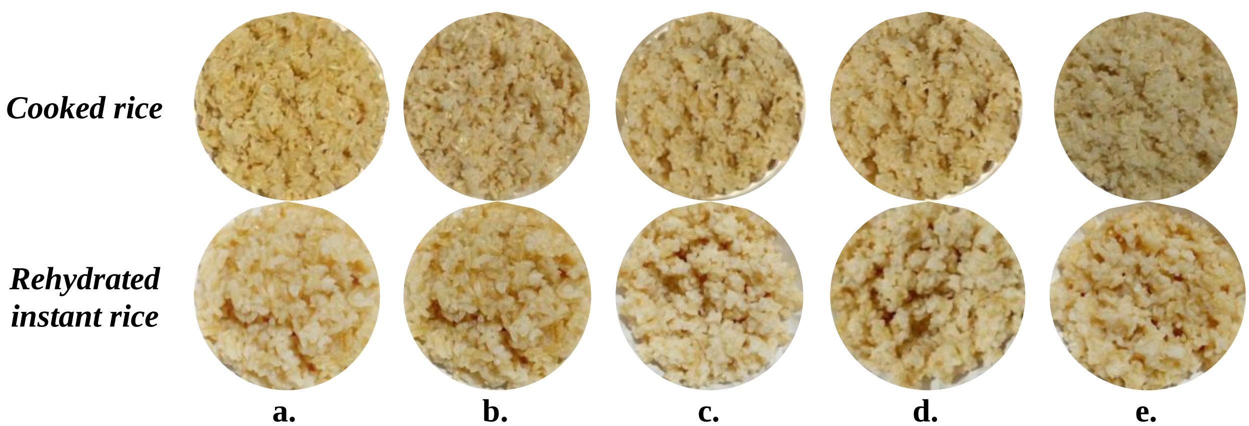

Figure 1. Appearance of cooked and dehydrated VD20 instant germinated rice under different ratio of rice and water: a. 1:1, b. 1:1.25, c. 1:1.5, d. 1:1.75, e. 1:2

It could be seen that with a rice: water ratio of 1:1.75 the cooking time increased due to large volume. By this ratio, the rice after cooking has a large expansion of 25.39 cm^3, which described as evenly cooked and soft. The expansion of the rice was quite large compared to the 3 ratios previously done. The structure of rice was recorded as 923 grams of force. Due to the amount of water was relatively high, led to undesirable properties as known as begin to appear mushy and grains stick together, some grains were broken. After cooking, the rice's color gradually fades due to the increased amount of water, the aroma is light, and the taste is quite delicious as can see from the value of acceptance in Table 3. When reconstituted, the rice grains swell evenly and quite sticky together. Moreover, the supplementary water ratio was high (2 times than weight of rice), led the rice after cooking was very mushy and too soft. The hardness recorded as 848 grams of force, showing that the rice is very soft compared to previous samples. The rice was evaluated as stick together, many broken grains and unable to retain its original shape. The drying process also took long time. The color of rice after cooking is no longer typical of VD20 rice due to too much water, the smell is very light, and the taste is quite bland. When reconstituted, the rice grains are too soft, many grains stick together, and the shape is not beautiful.

Different water ratios create rice with different blooms and textures. At a higher water ratio, the rice grains swell evenly and become soft, but the rice grains become mushy and stick together, making the drying process difficult (Wang et al., 2020). On the contrary, at a lower water ratio, the rice will not be cooked, the rice's bloom will be low, the rice grain structure will be hard due to not enough water to gelatinize the starch, the rice after reconstitution will be very hard and have low bloom or no bloom at all affects the swelling of rice after reconstitution (Loan et al., 2023). Besides, the color and flavor gradually decrease because the more water there is, the lighter the flavor and color become. From the research results, it shows that the sample with a rice: water ratio of 1:1.5 cooked rice quickly and the rice has a moderate expansion and structure that is neither too puffy nor too hard, most suitable compared to other rice varieties. The color and flavor of instant rice still retain quite well after cooking and reconstitution. The drying time was relatively short, the rice after reconstitution blooms quite well, was relatively uniform, and soft. This sample had a higher sensory evaluation than the remaining samples.

3.3. Effect of type and concentration of food additive on the physical and sensory properties of instant rice

The purpose of adding additives during the cooking process is to improve the structure, swelling and help the rice grains separate and not too much sticky after cooking without affecting the drying process (Sharma et al., 2024). Therefore, it is necessary to choose the most suitable additive type and additive ratio, thus that the product after cooking and reconstitution has the best sensory properties. Two types of additives used for the additive survey experiment were $NaHCO_3$ and NaCl.

3.3.1. Effect of sodium bicarbonate concentration on the physical and sensory properties of instant rice

The addition of sodium bicarbonate ($NaHCO_3$) during the cooking process significantly affects the structure, color and taste of rice after cooking and reconstitution, when cooked under the same conditions with the optimal rice: water ratio of 1:1.5. Table 4 and 5 showed that rice cooked using $NaHCO_3$ at different additive ratios, which led to the rice after cooking has different colors, flavors and structures as well as physical properties. Because of the amount of water and just enough time for the starch to gelatinize, the control sample has an expansion value of 25.60 cm^3 and hardness of 933 grams force. Due to rice grains were completely gelatinized, thus after reconstitution, the rice grains swell evenly, are soft and separate from each other. However, when cooking water added $NaHCO_3$ led to the volume expansion was increase, while the reduction in hardness was found. The cooked rice became to mushy and softer (Figure 2). The panelists evaluated that even though the percentage of $NaHCO_3$ added was small, the rice was still a bit mushy and became quite dark yellow brown and cannot retain its original shape. The textural qualities of cooked rice are frequently determined by measuring the hardness and stickiness of rice grains (Jung et al., 2016). As a results, the acceptance rate on color, aroma and taste, appearance and structure also reduced when the cooking water was supplemented with sodium bicarbonate. As increasing concentration of $NaHCO_3$, the acceptance value was remarkable decreased. Xu et al. (2022) also reported that sodium carbonated could significantly decrease the color of instant noodle. Although in Cai Lay black rice, using $NaHCO_3$ in making reconstituted dried rice is effective in improving the structure (Loan et al., 2023). However, when applying in production of instant germinated

VD20 rice, $NaHCO_3$ was not effective in improving the structure and sensory value of rice after reconstitution. As above explanation, the buffering and dispersing properties of sodium carbonate could potentially influence the solubility and stability of such products (Đorđević et al., 2022). However, the fully pregelatinization during cooking and drying process, it make the product not significant changed structure of product.

Table 3. Effect of sodium bicarbonate concentration on sensory properties of instant rice

Concentration of $NaHCO_3$ (%)	Volume expansion (cm^3)	Hardness (g-force)	Color	Aroma and taste	Appearance and structure
0	25.60^{d}	933^{a}	4.47^{a}	4.07^{a}	4.84^{a}
0.1	26.77^{c}	857^{b}	3.96^{b}	3.84^{ab}	4.30^{ab}
0.2	28.46^{b}	797^{c}	3.42^{c}	3.37^{bc}	3.80^{bc}
0.3	29.83^{a}	597^{d}	2.92^{d}	3.00^{c}	3.36^{c}

Note: Different superscript capital letters indicate significant difference within column ($p < 0.05$).

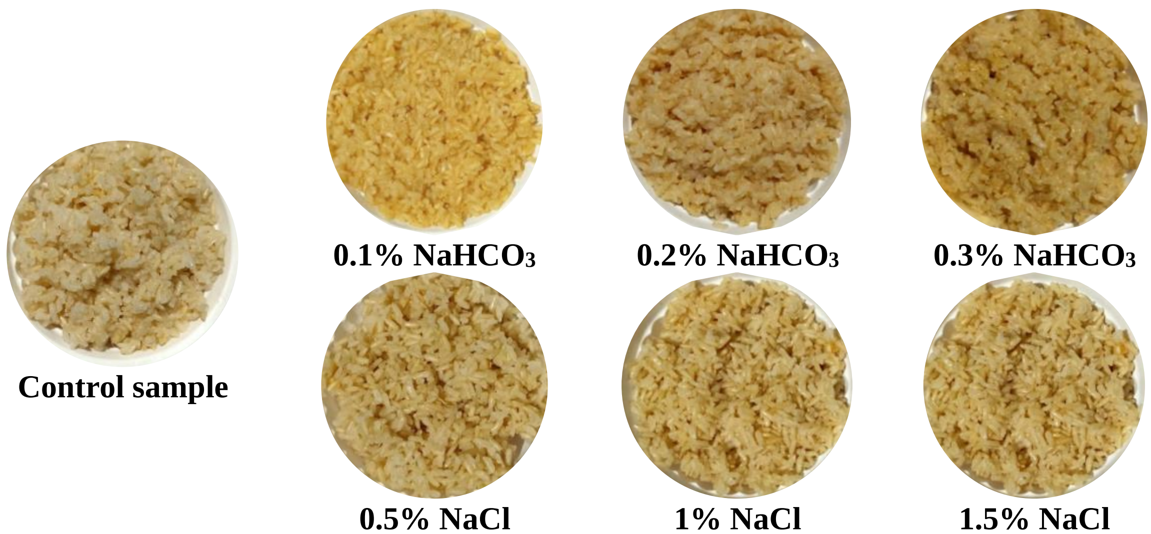

Figure 2. The appearance of cooked rice when supplementing different food additives with various concentration

3.3.2. Effect of sodium chloride concentration of food additive on the physical and sensory properties of instant rice

Sodium chloride (NaCl) is not only a familiar ingredient in cuisine but also greatly affects food from many different aspects. Salt is one of the basic tastes that humans are capable of sensing, the use of salt can enhance the flavor of food and make it more appealing. According to research by Sharma et al. (2024), have demonstrated the effects of salt treatments at different concentrations during the cooking process on the physicochemical, cooking and rehydration kinetics of instant rice. The application of salt pretreatment reduces bulk density and fraction of broken particles, while enhancing porosity, volumetric expansion rate, weight gain rate and rehydration properties.

Table 4 showed that different salt ratios resulted in instant rice with different flavors and structures. With the appropriate salt ratio, the rice grains swell well and rarely stick together. However, with a higher salt ratio, the rice bloom was quite poor, and the rice structure gradually increased in hardness. It was found that the highest hardness and lowest acceptance in appearance and structure from the sample was added 1.5% of NaCl (1049 g-forces and 3.31, respectively). The color and aroma of the rice are not much different, but the taste of the rice has changed. When adding salt to the cooking process of rice, the dried rice noodle could prevent the hardness and increase the elasticity of the cooked rice (Sangpring et al., 2015). At a low salt ratio, the rice swells well after cooking, is soft, the rice flavor is not too different in this study.

For a salt ratio of 0.5%, the rice is evenly cooked and soft, do not break after cooking, separate from each other. The swelling and structure of the rice are not too different from the control sample because the added salt ratio is low, so the aroma and sweetness are still retained during the cooking process. Therefore, the combination of salty and sweet tastes when eaten will stimulate taste receptors on the tongue. When both salty and sweet are combined, they create a unique taste. When reconstituted, the rice will still be golden brown in color, the grains will expand evenly, be soft, and the grains will less stick to each other.

Table 4. Effect of sodium chloride concentration on physical properties of instant rice

Concentration of NaCl (%)	Volume expansion (cm^3)	Hardness (g-force)	Color	Aroma and taste	Appearance and structure
0	25.60^{d}	933^{c}	4.65^{a}	4.22^{a}	4.54^{a}
0.5	26.36^{c}	961^{c}	4.26^{b}	4.13^{a}	4.52^{a}
1	27.76^{b}	1012^{ab}	3.85^{c}	3.42^{b}	3.85^{b}
1.5	28.80^{a}	1049^{a}	3.36^{d}	2.91^{c}	3.31^{c}
CV (%)	4.85	5.80	12.31	18.02	12.61

Note: CV is coefficient of variation; Different superscript capital letters indicate significant difference within column ($p < 0.05$).

For a salt ratio of 1%, the rice grains are separated from each other and are drier than the 0.5% ratio, so the rice grain is dry. Similarly for the salt ratio of 1.5%, the rice is evenly cooked, soft and the grains are not broken or separated. The expansion of rice is 28.80 cm^3 and the structure of rice is 1049 grams. The rice still retains its aroma, but the salt ratio is quite high, so the rice tastes salty after cooking. Rice after cooking still retains its golden-brown color (Figure 2). When reconstituted, the rice still has a golden-brown color, the grains swell evenly, are less soft, and the grains rarely stick together, but the salty taste greatly affects the sensory value.

Because the nature of $NaHCO_3$ is to create swelling and porosity, it is not suitable for selection as an additive to improve the structure of products (Kabiri et al., 2003). When using additional salt during the cooking process, the rice after cooking has a stable structure, the rice grains are neither too soft nor too hard, and the color and flavor are completely acceptable. Salt, in addition to improving the structure of the product, also reduces water activity, thereby helping to inhibit the growth of bacteria and fungi (Albarracín et al., 2011). Therefore, it prevents the growth of harmful agents and reduces product failure. Research results showed that salt at a rate of 0.5% shows that rice, after cooking and reconstitution, has good elasticity, is soft, has a beautiful golden-brown color, has a light aroma, and tastes good.

4. Conclusions

The current study examines the impact of the ratio of rice to water, as well as the types and quantities of food additives, such as sodium bicarbonate and sodium chloride, on the quality of instant rice when prepared for cooking. Significant changes in the cooking quality features of rice were reported in all tests. A ratio of 1 part rice to 2 parts waters can result in a sample that has the desired level of hardness and a high rate of acceptance. The use of food additives had a substantial impact on the physical, rehydration, and sensory properties of instant rice. Sodium bicarbonate has the potential to enhance the expansion of volume, decrease hardness, and alter sensory characteristics. Sodium chloride decreased the extent of damaged grains and improved the flavor of instant rice. Moreover, the method used to prepare instant rice is convenient for users, economical, does not require any specialized equipment, and can therefore be simply implemented on an industrial level. Thus, it is advisable for food enterprises that handle convenience and ready-to-eat food products to consider using a 0.5% sodium chloride treatment during the manufacture of instant rice.

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