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The effect of soaking temperature and time on the qualitative and marketability of parboiled rice *Shiroudi* variety

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ABSTRACT

This research aims to examine the effects of soaking temperature and steaming time on the qualitative properties, head rice yield, cooking properties, and marketability of parboiled rice of *Shiroudi* variety. The paddy was soaked at three temperatures of 55, 65, and 75°C and then steamed at 100°C for 5, 10 and 15 min. The samples were dried in an oven at 30°C and then hulled. Physical properties, color quality, head rice yield, internal structure, and cooking quality of parboiled rice were measured and compared. The results showed that head rice yield increased significantly ($p<0.01$) in the parboiled process by about 83.24% compared to non-parboiled rice by about 58.65%. The highest head rice yield was obtained at 65°C soaking temperature and 15 min steaming time treatment. By increasing the soaking temperature and steaming time, the lightness of the rice decreased and the color value increased. Parboiled rice at 55°C soaking temperature had the highest lightness and lowest color value than other treatments. By increasing the soaking temperature and steaming time, the amount of water uptake ratio, cooking time, and volume expansion of parboiled rice decreased. By considering microscopic (SEM) results, it can be found that the parboiled process could be able to increase the head rice yield. It was due to the cohesion of starch granules together. Increasing of soaking temperature and be a major cause of more longitudinal expansion and porosity reduction of starch granules as the water molecules do not have enough space to locate between them. The volume expansion ratio decreased by increasing the soaking temperature. The panel test results showed that the panelist liked the taste, texture, and cooking expansion of the rice after cooking, but the color and especially the odor of parboiled rice were not satisfied.

1- Introduction

Rice is an annual plant from the cereal family that is cultivated in both dry and irrigated conditions and is considered one of the most important agricultural products in the world, and in Iran, too. More than half of the world's people have chosen it as their primary food, and it provides the highest number of calories, fiber, protein, vitamins, and minerals in human food [1]. Based on the increase in population in Iran, it is predicted that the need for rice will reach approximately 4 million tons by 2020 [2].

Low production efficiency, limited cultivated area, water resources, high costs of rice production, lack of stability and security in the domestic rice purchase market are the main problems of rice farmers. Increasing production will not compensate for the problem of low conversion efficiency. The percentage of healthy rice in Shiroodi variety is not as high as in other rice varieties. Among these, one way that can significantly help reduce waste and increase conversion efficiency is the use of the parboiling technique [3].

Parboiling is a hydrothermal process applied to paddy rice. This technique consists of three stages: soaking, steaming, and drying, and can be implemented in rice milling industries before the milling process, with no use of any chemical substances [4,5]. This method has been recommended as an effective, practical, and reliable approach to reducing rice breakage, which plays a significant role in achieving rice self-sufficiency. Parboiling the paddy increases its moisture content to 35% on a wet basis, leading to starch gelatinization [6]. This process will have a considerable effect on reducing the percentage of rice breakage [7]. Parboiling also leads to changes in the physical and chemical properties of rice and improves its quality attributes [8,9,10].

Nasirahmadi et al. (2014) investigated the effects of steaming duration and soaking temperature in the parboiling process on the milling recovery and head rice percentage of Mazandaran rice varieties. These researchers applied the parboiling process at three soaking temperatures of 25, 50, and 75 °C and three steaming times of 10, 15, and 20 minutes at 100 °C under atmospheric pressure on two paddy cultivars, Tarom and Fajr. Based on the measurements of milling recovery and head rice yield, it was determined that increasing the steaming time caused an increase in milling recovery and head rice yield in both varieties [11].

Latifi and Alizadeh (2014) subjected three paddy cultivars Tarom Mahalli, Shiroudi, and Fajr to the parboiling process and compared the head rice yield, cooking quality, and hardness of rice obtained from parboiled and non-parboiled methods. The findings of these researchers indicate that the percentage of broken rice in the parboiled Shiroudi and Fajr varieties decreases significantly. Parboiling was identified as an effective factor in reducing whiteness, changing cooking characteristics including reducing solid losses and increasing the hardness [12].

Ebrahim Taghinejad et al. (2017), through experiments conducted on the Fajr rice cultivar, found that the use of an intermittent dryer, while reducing the drying time, substantially increases the head rice yield compared with a continuous dryer [13].

Some researchers, in studies aimed at determining the effects of parboiling on rice characteristics, have stated that parboiled rice can also retain desirable attributes similar to raw rice in terms of taste and color. This attribute depends on the parboiling technique, soaking temperature, steaming conditions, and the pH of the water used in the process [14].

Soaking temperature and steaming duration have a significant effect on the color of rice [15]. During parboiling, the color of rice changes to brown due to the Maillard reaction, and processing conditions can influence the intensity of this color change throughout the parboiling process. In addition, the pigments from the bran layer diffuse into the endosperm during soaking [16,17].

Sichaya Sitipod (2014), in examinations conducted on scanning electron microscopy (SEM) images of parboiled rice processed at 70°C, observed that in non-parboiled rice, fractures were present in the polygonal starch granules at the central region of the grain. In contrast, in parboiled rice, almost no fractures were observed, and the granules, while retaining their polygonal shape, were fused with their boundaries merged [18].

Sari-Pong et al. (2008) measured cooking time and water absorption at soaking temperatures of 40, 50, and 60 °C. They found that as the soaking temperature increased, cooking time decreased, and water absorption also declined [15]. Kari-Kam et al. (2012) conducted a sensory evaluation on parboiled and non-parboiled rice. The assessment showed that after consumers were informed about the benefits of parboiled rice, 50% of the panelists expressed a strong willingness to consume this type of rice [19].

Shiroudi rice is a high-yielding cultivar grown in the northern regions of Iran. Morphologically, it is very similar to Tarom Hashemi variety, although it ranks lower in terms of aroma and flavor. It also possesses acceptable cooking quality compared with other high-yielding varieties. Due to its high productivity and desirable taste, it holds a notable position in the dietary pattern of Iranian households. Evaluating the effect of an optimized parboiling process on Shiroudi rice can potentially enhance milling recovery as well as its nutritional value. Therefore, in this study, the effects of different soaking temperatures and steaming durations on milling recovery, cooking quality, color, internal structure (using scanning electron microscopy, SEM), and marketability of parboiled Shiroudi rice were investigated.

2-Materials and Methods

1-2- Sample preparation

For the purpose of conducting the experiment, the high-yielding Shiroudi rice variety grown in the paddy fields of the National Rice Research Center in Amol was used. The average initial moisture content of the paddy grains was approximately 12% (w.b.).

2-2- Parboiling process

As shown in Fig. 1, the soaking equipment consisted of a temperature-control system and a tank. The temperature-control system maintained the water temperature at a constant level. At first, putting the paddy into the tank, then, soaking was carried out at three temperature levels 55, 65, and 75°C until the moisture content of the paddy reached 35% (w.b.). After the completion of soaking, the steaming process was performed at 100°C for 5, 10, and 15 min. Finally, the paddy was dried under ambient conditions at 30°C until its moisture content reached 12% (w.b.).

Figure 1. Setup of parboiling system

2-3. Milling Operation

After completing the parboiling process, a laboratory-scale roller rice huller (YANMAR, Japan, 50ST) was used for dehusking and converting it into brown rice. For the whitening operation, an abrasive whitener (SATAKE, TM, Japan) was employed for two minutes.

2-4. Head Rice Yield

For determining head rice yield (HRY), a 10-g sample was weighed. Grains with a length greater than 75% of that of a full-length head rice kernel were classified as head rice. Grains shorter than this threshold were manually separated. The percentage of HRY was calculated by dividing the weight of the head rice kernels by the total weight of the paddy [21].

2-5. Cooking Quality

The quality attributes of rice are classified into two main categories: grain-related traits and grain-quality traits. Grain-quality traits are further divided into four major groups: (1) milling quality, (2) appearance quality (grain color and whiteness, chalky spots, and aroma), (3) cooking and eating quality (elongation and volume expansion), and (4) nutritional quality (nutritional value) [22, 23].

2-5-1. Determination of Water Uptake Ratio

To measure this parameter, 10 g of head rice kernels were immersed in 150 mL of water at 80°C for 15 min then placed on a mesh screen for one min to drain the surface water. The water uptake ratio (WUR) was subsequently determined using Equation (1) [15].

$$WUR = \frac{W_2}{W_1}$$

(1)

where W_1 is the sample weight before soaking and W_2 is the sample weight after soaking.

2-5-2. Determination of Cooking Time

The Ranghino test was used to determine the cooking time. A 250 mL beaker was filled with 100 mL of distilled water and placed on an electric heater until the water reached boiling temperature. Once boiling, 10 g of head rice kernels were added to the beaker. After 10 minutes of cooking, every minute, ten kernels were removed from the beaker, placed between two clean glass plates, and gently pressed (Fig. 2). The cooking time was recorded when at least 90% of the kernels exhibited a non-opaque core. The rice was then allowed to simmer for an additional two minutes to ensure complete gelatinization of the kernel cores. The final cooking time was considered as the recorded time plus the additional two minutes of simmering [24].

Figure 2. Samples after compaction between two glasses

2-5-3. Determination of Volume Expansion

Volume expansion was determined using the ratio of the height of the cooked rice to the height of the uncooked rice. The samples were placed in a wire cylinder, and their initial height was measured. The rice inside the wire cylinder was soaked in 100 mL of distilled water for one hour, and then transferred into a beaker containing 300 mL of boiling distilled water. After 20 min of cooking, the cylinder was removed, and the height of the cooked rice was measured. Volume expansion was calculated using Equation (2) [25].

$$VER = \frac{h_f - h_i}{h_i} \qquad (٢)$$

VER is the volume expansion ratio, where (h_i) is the initial height and (h_f) is the final height of sample after cooking.

2-6. Lightness and Color Value

The degree of whiteness was measured using a colorimeter (Abzarkaran FAN-POUYA Shomal, 13074) (Fig. 3). The rice kernels were placed in a glass container with a diameter of 2 cm and a height of 1 cm, ensuring that the bottom surface was completely covered. Images of the samples were then captured and analyzed using ImageJ software, along with the images obtained from the colorimeter, to quantify the color parameters. By substituting these values into Equation (3), the overall color value was calculated [26].

$$\Delta E = [(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2]^{1/2} \qquad (3)$$

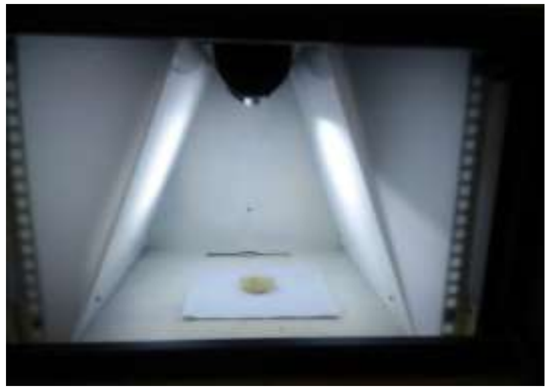


Figure 3. Color gram Equipment

2-7. Scanning Electron Microscopy

Scanning electron microscopy (SEM) is one of the most powerful analytical techniques widely used across various scientific fields. In this experiment, an SEM instrument (S-3500N, Hitachi Science Systems, Ltd., Japan) was employed, operating at an accelerating voltage of 15 kV and a magnification of 500 µm [18]. The samples were first thoroughly dried in an oven. The cross-sections were then cut and coated with a very thin conductive layer, such as gold or gold/palladium. After coating, the samples were placed in the SEM chamber. When the electron beam strikes the sample surface, electrons accumulate, leading to a phenomenon known as charging, which simultaneously causes deviation of the electrons from their direct path. This effect appears as very bright spots on the monitor, allowing imaging and analysis of the samples.

2-8. Sensory Evaluation

Appearance quality, along with cooking quality are key attributes influencing the marketability of rice. Sensory evaluation was therefore conducted to assess these traits. The samples were cooked and evaluated by a trained panel. Eight trained panelists (four female and four male) participated in the assessment and responded to the questions presented in Table 1.

Table 1. Amount of interest in panel test

Amount of interest	score	aroma	taste	color	height	texture
like so much	9					
very like	8					
like	7					
like a little	6					
don't like, don't hate	5					
don't like a bit	4					
do not like	3					
don't like so much	2					
hate	1					

2-9. Statistical Analysis

A factorial experiment was conducted in a completely randomized design with three replications. The treatments consisted of soaking at three temperature levels (55, 65, and 75 °C) and steaming at three durations (5, 10, and 15 min). Data analysis was performed using GenStat software, and graphs were generated using Microsoft Excel.

3-Results and Discussion

3-1. Head Rice Yield

According to Fig. 4, which illustrates the interaction effect of soaking temperature and steaming time, the head rice yield in the parboiling process increased significantly (at the 1% level) to 83.24%, compared with 65.58% in the non-parboiled sample. The highest HRY (83.24%) was obtained at a soaking temperature of 65°C and a steaming duration of 15 min. The increase in HRY may be attributed to starch gelatinization and uniform dehydration of the kernels during the soaking stage. During steaming, the starch granules fuse and the structural integrity of the kernels is strengthened, resulting in a higher proportion of head rice kernel during milling [7,28].

The lowest HRY was obtained at the soaking temperature of 75°C combined with steaming durations of 10 and 15 min. It appears that at high temperatures, starch granules lose their structural integrity and cohesion. Moreover, excessive moisture absorption at high temperatures leads to partial cooking of the kernels, which increases the breakage during milling [1,6]. Therefore, the parboiling process improves the HRY of the Shiroudi variety compared with its non-parboiled, which is consistent with the findings reported by Saripong et al. (2008) [15].

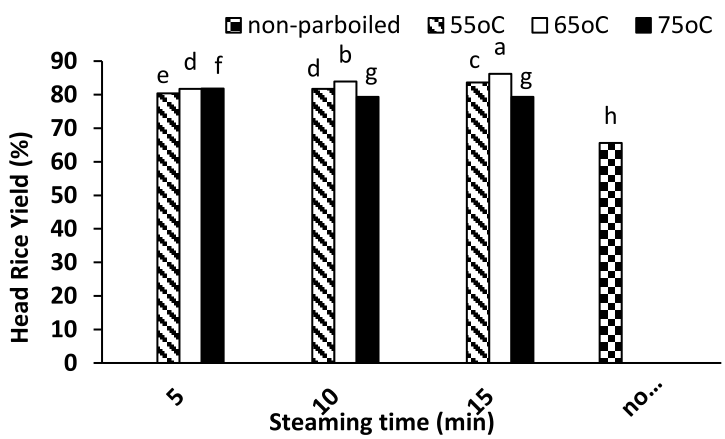


Figure 4. The interaction of soaking temperature and steaming time on Head rice yield

3-2. Cooking Quality

3-2-1. Rehydration Ratio

The rehydration ratio, or the amount of water absorbed by rice kernels, is one of the key factors influencing the marketability of the product. Waxy rice varieties, which exhibit high water absorption and develop a pasty and sticky texture after cooking, are generally not preferred in many regions of the world. According to Table 2, the rehydration ratio of non-parboiled rice was 1.6 which decreased to 1.5–1.4 in the parboiled samples. During the soaking stage, as rice kernels absorb water, starch molecules swell, and the void spaces and air pockets between them decreased. The higher the soaking temperature, the greater the water uptake and, consequently, the more pronounced the swelling of starch granules in the Shiroudi cultivar. This swelling is irreversible [14,16]. With increasing soaking temperature, water absorption decreased, and the non-parboiled sample exhibited a higher rehydration ratio compared with the parboiled samples. This is because the intermolecular spaces are reduced during the parboiling process. Moreover, extending the steaming duration does not play a significant role in rehydration, which is consistent with the findings reported by Hinman et al. (2005).

3-2-2. Determination of Cooking Time

Cooking time is an important parameter in terms of energy consumption and processing efficiency. According to Table 2, the longest cooking time (about 17 min) was observed at the soaking temperature of 55°C combined with a steaming duration of 15 min, whereas the shortest cooking time occurred at the soaking temperature of 75°C (about 13 min). As the soaking temperature increases, starch granules absorb more water and approach the gelatinization point. During cooking, when the kernels are placed in boiling water, an initial period is required for gelatinization to occur, after which the kernels begin to soften, or "cook." The higher the soaking temperature, the greater the extent of pre-gelatinization, resulting in a shorter time required for complete gelatinization during cooking; thus, the kernels begin to cook more quickly. Steaming duration had no significant effect on cooking time, with only a few seconds of variation among treatments [14].

Table 2. Water uptake ratio and cooking time

Treatments	non-parboiled	55	65	75
Cooking time (min & sec.)	17±0.1	15±0.1	14±0.2	13±0.16
Water uptake ratio	1.61±0.02	1.5±0.03	1.46±0.015	1.41±0.014

2-3-2. Determination of Volume Expansion

Volume expansion (VE) is one of the key marketability attributes and is commonly referred to as the "cooking quality" of rice, indicating the extent to which the kernels expand after cooking. A greater increase in volume generally reflects a more desirable product. Kernel thickness and amylose content can influence volume expansion; however, since only one rice variety was used in this study, these factors cannot be considered responsible for the observed differences in VE ratio. According to Fig. 5 and 6, the highest VE ratio in the parboiled samples was obtained at a soaking temperature of 55°C and a steaming duration of 5 min (2.7), whereas the lowest ratio (2.65) was observed at a soaking temperature of 75°C and a steaming duration of 15 min. It appears that samples soaked at higher temperatures absorbed more water and experienced greater starch-granule swelling, bringing them closer to the gelatinization point. Consequently, during the volume-expansion test, these samples absorbed less additional water due to the reduced intermolecular void spaces. In contrast, samples soaked at lower temperatures absorbed more water, resulting in higher VE ratios. An inverse relationship was observed between soaking temperature and steaming duration with volume expansion, such that increasing either parameter led to a decrease in the VE ratio [14,16].

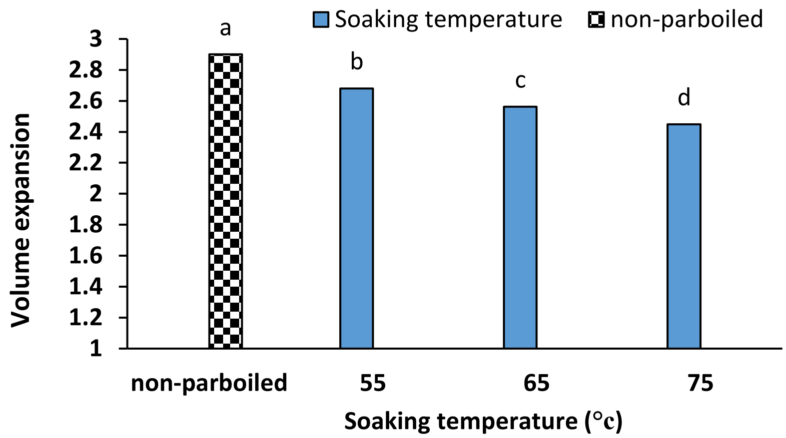


Figure 5. Soaking temperature in volume expansion ratio

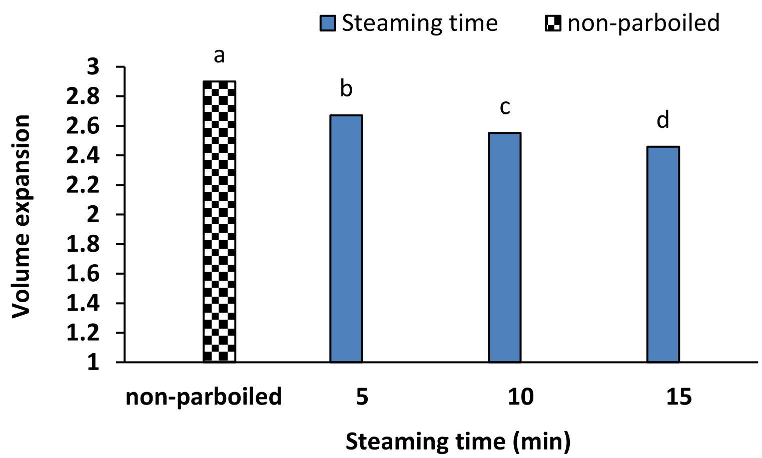


Figure 6. Steaming time in volume expansion ratio

3-3. Lightness and Color Value

Color is a key determinant of rice marketability, and brighter kernels are generally more appealing to consumers. According to Fig. 7–10, the most favorable treatment was soaking at 55°C followed by 5 min of steaming, which resulted in higher lightness values and lower color difference compared with the other treatments. As the soaking temperature and steaming duration increased, the lightness (L) decreased while the color value (ΔE) increased, indicating a darker appearance of the rice.

These observations are consistent with the findings reported by Islam et al. (2003, 2004) [29,30]. During soaking and heat treatment of Shiroudi rice with the husk intact, vitamins, minerals, and the reddish-brown pigments present in the bran layer diffuse into the endosperm. As a result, the color of the final product shifts toward a brownish appearance. In contrast, non-parboiled rice does not undergo heat treatment, and its husk is removed and polished during the early post-harvest stages, preventing such pigment migration.

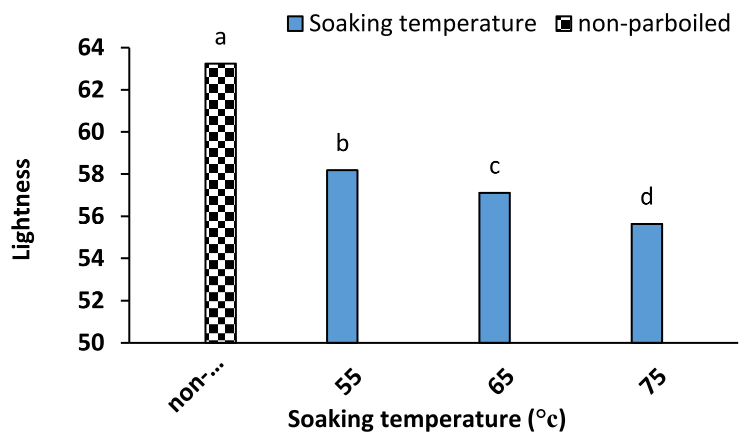


Figure 7. Soaking temperature on the lightness

Therefore, the lower color quality of parboiled Shiroudi rice occurs at higher soaking temperatures and longer steaming durations. In general, higher lightness values and lower color differences indicate a more desirable rice color. These results are consistent with the findings of numerous researchers, including Lambert et al. (2008), Taghinejad et al. (2015), and Naqavi-Marmati et al. (2011) [17,31,32].

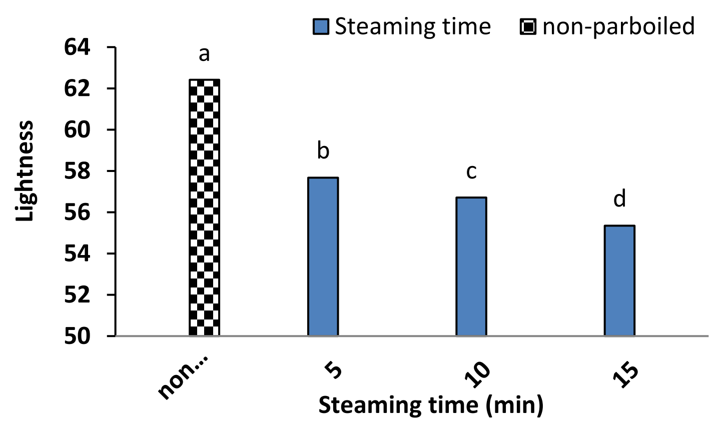


Figure 8. Steaming time in lightness

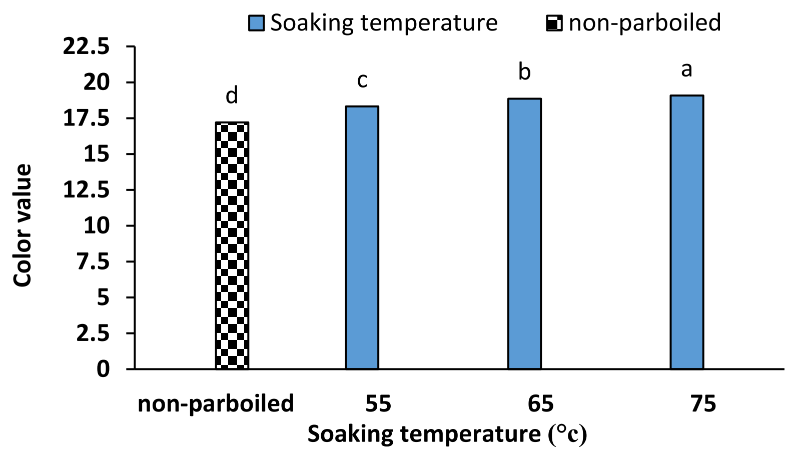


Figure 9. Soaking temperature in Color value

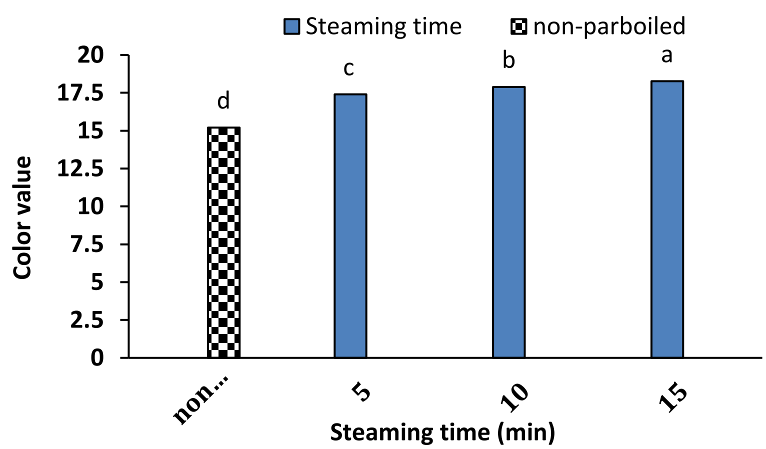


Figure 10. Steaming time in Color value

3-4. Scanning Electron Microscopy

Microstructural views of the rice kernels obtained using scanning electron microscopy (SEM) at different magnifications are presented in Fig. 11–13. With increasing soaking temperature and steaming time, the microscopic structure of rice changed significantly. In the non-parboiled sample (Fig. 11), the starch granules appear irregular and peak-shaped, with numerous voids and considerable porosity between granules, and little structural cohesion.

While it seems that in the parboiled samples, with increasing soaking temperature and steaming time, the porosity gradually decreases and the surface of the rice becomes smooth and integrated. Moreover, the starch granules, which exhibited irregular and peak-like structures in the non-parboiled sample, became more uniform and slightly rounder in the parboiled kernels.

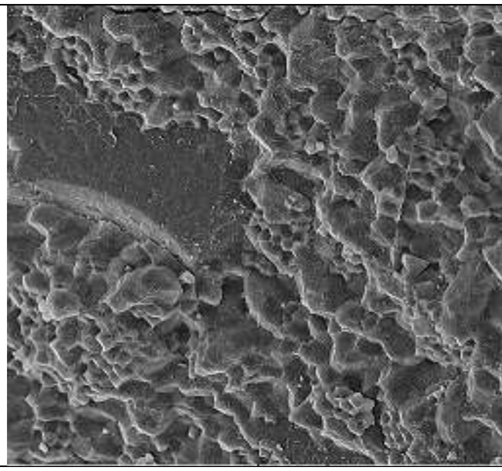
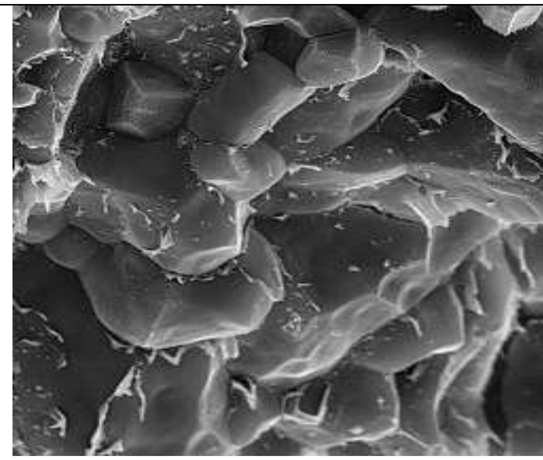
	1kx	5kx
Non-parboil rice		

Figure 11. SEM cross-section of non-parboiled rice in 55, 65, and 75 ˚c and 5, 10, and 15 min in different zoom

Soaking leads to water absorption by the starch granules, resulting in irreversible swelling and structural transformation of the starch. Consequently, this longitudinal expansion fills the internal spaces of the endosperm, reduces porosity, and allows the starch granules to align more closely, increasing their cohesion and structural integrity. As shown in Fig. 12 and 13, the parboiling process enhances the HRY, which is attributed to improved continuity and bonding among starch granules. At 65°C, where the highest HRY was observed compared with the other soaking temperatures, this granule cohesion is clearly visible, as the kernels are closer to the gelatinization temperature.

As shown in Fig. 12 and 13, increasing the soaking temperature results in greater longitudinal expansion and a reduction in porosity and the void spaces between the starch granules. Consequently, there is insufficient space for additional water molecules to penetrate, which emphasizes that higher soaking temperatures result in lower VE ratios. These findings are consistent with the results reported by Swamy *et al.* (2008) and Bognhaut *et al.* (2013) [۳۳،۳۴].

kx	5	10	15

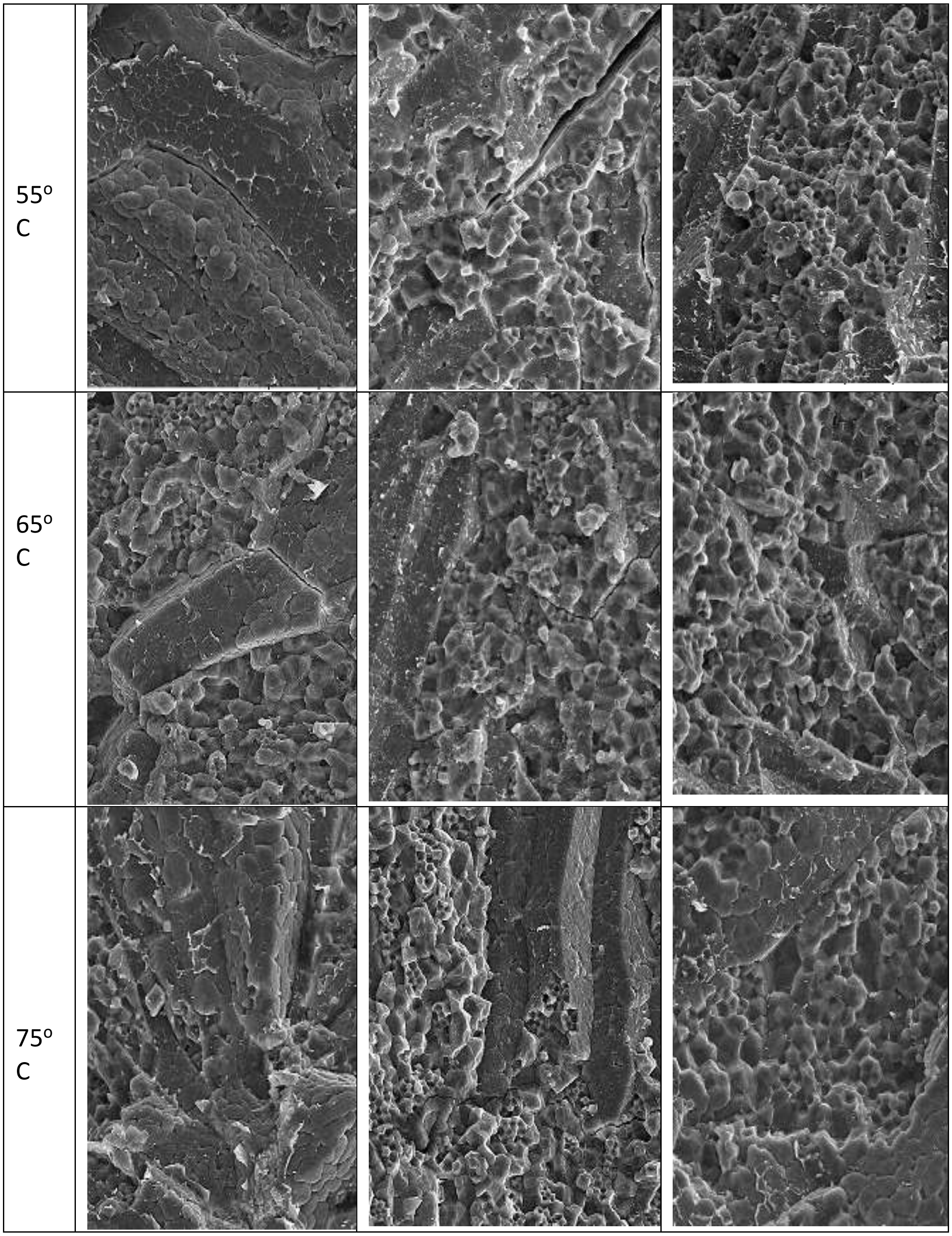


Figure 12. SEM cross-section of parboiled rice in 55, 65, and 75 ˚c and 5, 10, and 15 min in 1 Kx

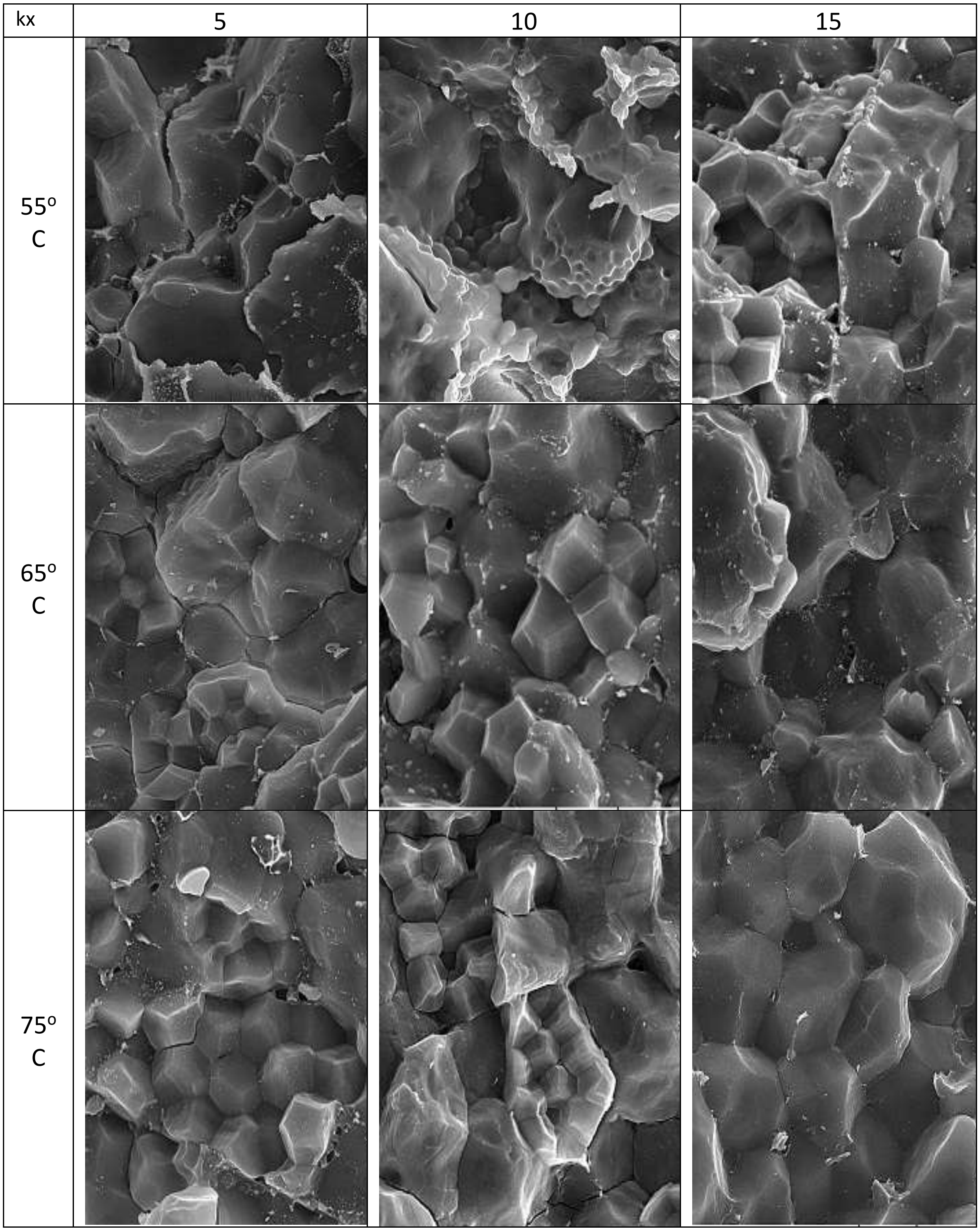


Figure 13. SEM cross-section of parboiled rice in 55, 65, and 75 ˚c and 5, 10, and 15 min in 5 Kx

3-5. Sensory Evaluation

In the sensory evaluation, attributes such as consumer liking and disliking related to taste, texture, flavor, and color were assessed by the panelists (Table 1). The panelists favored the taste, texture, and grain elongation of the cooked rice, but the color and especially the unpleasant smell of the parboiled rice were not satisfactory to them. The panelists did not perceive noticeable differences in taste or texture among the samples with respect to soaking temperature or steaming duration. Approximately 50% of the panelists indicated that they would be willing to substitute parboiled rice for regular (non-parboiled) rice, while the remaining half were unwilling to do so due to the undesirable odor.

In Iran, consumers generally prefer white and well-polished rice, and parboiled rice is less popular and is produced in small quantities due to families' lack of awareness about its properties. During the post-evaluation discussion, the panelists were informed about the nutritional and functional benefits of parboiled rice, after which they were asked again whether they would be willing to substitute it for regular (non-parboiled) rice. Their responses were encouraging; almost all people were willing to make the switch due to the many benefits of parboiled rice [19].

4-Conclusion

In this study, the yield of healthy rice, cooking quality, color, and sensory evaluation of Shiroodi rice variety were investigated under different soaking and steaming conditions. Treatment at 65°C and 15 min had the highest efficiency. The results showed that the water absorption ratio, cooking time and volume expansion ratio decreased with increasing soaking temperature. The best color was obtained at an soaking temperature of 55°C and a steaming time of 5 min.

Increasing the soaking temperature led to reductions in rehydration ratio, cooking time, volume expansion, and lightness, while simultaneously increasing color value; which indicates that the color of the rice becomes darker and has a negative impact on the marketability of parboiled rice. Iranian people are more interested in white and crisp rice, and parboiled rice has been less popular due to families' ignorance about its characteristics.

SEM observations further confirmed that higher soaking temperatures and longer steaming time reduced porosity and improved granule cohesion, which in turn contributed to higher HRY and as porosity decreases, the volume expantion ratio decreases.

Finally, to choose the best treatment for parboiled rice, different treatments can be considered depending on the priorities. Because if only efficiency is considered, a treatment with a soaking temperature of 65°C and a steaming time of 15 min has the best performance, but if color and marketability are the priorities, a treatment with a soaking temperature of 55°C and a steaming time of 5 min is the best.

The findings of this study demonstrate that soaking temperature and steaming duration exert significant effects on the physicochemical, structural, and sensory properties of parboiled Shiroudi rice. These changes can be attributed to enhanced water absorption, irreversible starch-granule swelling, and partial gelatinization occurring during the parboiling process.

Data Availability

The data used to support the finding of this study are available from the corresponding author upon request.

Conflict Of Interest

The authors have no conflicts interest to report.

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تاثیر غوطه‌وری و زمان بخاردهی بر خواص کیفی و بازارپسندی برنج نیم‌جوش (رقم شیرودی)

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چکیده

در این پژوهش اثر دمای غوطه‌وری و زمان بخاردهی بر خواص کیفی، راندمان تبدیل، خواص پخت و بازارپسندی برنج نیم‌جوش رقم شیرودی مورد بررسی قرارگرفت. بدین منظور، شلتوک در سه سطح دمایی ۵۵، ۶۵، ۷۵ درجه سانتی‌گراد غوطه‌ور شده و در دمای ۱۰۰درجه سانتی‌گراد طی زمان‌های۵،۱۰و ۱۵دقیقه بخاردهی گردید. نمونه‌ها در آون با دمای۳۰ درجه خشک شده و طی فرایند پوست‌کنی به برنج سفید تبدیل شدند. راندمان برنج سالم،کیفیت رنگ، مشاهده تغییرات ساختار درونی برنج با میکروسکوپ الکترونی (SEM)، خواص فیزیکی وکیفیت پخت برنج نیم‌جوش مورد بررسی قرارگرفت و با برنج غیرنیم‌جوش مقایسه‌گردید. نتایج نشان داد که راندمان برنج سالم در فرایند نیم‌جوش با ٪ ۸۳/۲۴ در مقایسه با نمونه غیرنیم‌جوش با میزان ٪ ۶۵/۵۸ بطور معنی‌داری ($p<0.01$) افزایش‌یافت. بیشترین راندمان برنج در دمای غوطه‌وری ۶۵ درجه و زمان بخاردهی ۱۵دقیقه بدست‌آمد. با افزایش دمای غوطه‌وری و زمان بخاردهی، روشنایی برنج نیم‌جوش کاهش و ارزش رنگ افزایش یافت. برنج نیم‌جوش در دمای غوطه‌وری ۵۵ درجه و زمان بخاردهی ۵ دقیقه، بالاترین شدت روشنایی و کمترین ارزش رنگ را نسبت به بقیه تیمارها داشت. با افزایش دمای غوطه‌وری و زمان بخاردهی، میزان جذب آب، زمان پخت و نسبت انبساط حجمی برنج نیم‌جوش کاهش‌یافت بطوری‌که بیشترین مقدار این پارامترها مربوط به برنج غیرنیم‌جوش بود. با مشاهده حاصل از (SEM) به‌راحتی می‌توان نتیجه‌گرفت که فرایند نیم‌جوش‌کردن موجب افزایش راندمان تبدیل می‌شود و این بدلیل پیوستگی و اتصال گرانول‌های نشاسته می‌باشد. افزایش دمای غوطه‌وری، باعث افزایش انبساط طولی و کاهش تخلخل بین گرانول‌های نشاسته می‌شود، بطوری‌که مولکول‌های آب فضای کافی برای قرارگیری بین آن‌ها نخواهندداشت و نشان می‌دهد با افزایش دمای غوطه‌وری، نسبت افزایش‌حجم کاهش پیدامی‌کند. در ارزیابی، ارزیاب‌ها طعم، بافت و بلندی قد برنج پس‌از پخت را دوست داشتند؛ اما رنگ و مخصوصا بوی نامطبوع برنج نیم‌جوش راضی‌کننده نبود.