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Evaluation of the Soaking Conditions (Temperature and Time) on the Physicochemical Properties of Parboiled Rice: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Review Article

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ABSTRACT

Soaking is a temperature-dependent process, which determines the rate of water diffusion into the rice kernel. Similarly, soaking also leaches the fiber, fat, and mineral composition of the rice kernel, thereby changing their composition in rice grain. This review aims to evaluate the effect of soaking conditions (temperature and time) on the physicochemical properties of selected parboiled rice varieties. As a result of the NERICA-4 rice variety, soaking at 65°C for 6 hours was the ideal temperature and time. Under these conditions, the ideal response variables for hardness, cooking time, moisture, ash, protein, fat, carbohydrate, energy, magnesium, potassium, and phosphorous content were 375.37 N, 52 min, 12.3%, 1.24%, 13.86%, 2.17%, 3.2942%, 67.1171%, 343.5 kcal/100 g, 274.72 mg/100 g, and 268.31 mg/100 g, respectively. The soaking temperatures and time is an essential operation in the process and affects the quality characteristics of the rice, including its physical characteristics, chemical composition, starch characteristics, cooking characteristics, etc. The functional characteristics are conducted to identify and possibly better determine how new proteins, fats, fibers, and carbohydrates can perform in specific systems and demonstrate whether or not such proteins can be used to stimulate or replace conventional proteins. Finally, the results demonstrated that the research environment's optimal parboiling settings were used to process rice types, in particular NARICA 4 rice variety, for enhanced physical qualities, proximate composition, and mineral content.

Keywords: Soaking conditions; parboiling rice; physiochemical; functional properties.

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1. INTRODUCTION

"Rice is the staple food for over 3 billion people, constituting over half of the world's population" [1]. "The major key nutrient of brown rice such as fiber, antioxidants, phytoestrogens, minerals, and vitamins are concentrated in the bran layer which is removed during the milling process to improve the hardness and chewiness" (Das et al. 2008; Wang et al., 2013). "Rice bran constitutes 10% of total rice grain and contains the major part of nutrients and antioxidative components such as vitamin E (tocopherols and tocotrienols), phytosterols, phytic acid, phenols, γ-oryzanols, and tricin" (Leardkamolkarn et al., 2011). "Parboiling rice possesses unique functional and processing properties mainly due to its distinct starch composition" (Kim et al. 2013). "Parboiled rice has a higher nutritional value than its non-parboiled counterpart due to the migration of bran components (e.g., vitamins, minerals) into the endosperm during the hydrothermal treatment" (Bhattacharya, 2004). "Milling efficiency and grain quality of rice can be improved by various preprocessing treatments such as post-harvest tempering and parboiling to reduce the internal fissures and increase head rice yield" (Iguaz et al. 2006). "Rice soaking before parboiling is akin to the initial phase of germination when a large number of enzymatic activities take place. Soaking is a hydration process in which the diffusion-controlled water uptake migrates into the rice kernel, and subsequent heating leads to irreversible swelling and fusion of starch granules". [2] "The starch granules are gelatinized and retrograded as a result various changes occur in rice, which plays an important role in the subsequent processing operations, such as storage, milling, cooking, and in eating qualities" [3]. "The hydrothermally treated flour may find utility in products like soups and sauces due to its low tendency to retrograde" [4]. "These novel foods usually require rice flour of having known functional properties, which are known to influence the characteristics of food systems. The pasting profile is the most important characteristic and has been used to predict the end-use quality of various food products. On parboiling, considerable changes occur in the pasting parameters due to the order-disorder transitions taking place at the molecular level" [5]. Finally, this review aims to encourage the optimization needed to create reliable, high-quality rice to sustain commercial parboiled rice production on a wide scale and compete with imported rice. For improved physical qualities, near composition, and mineral content of rice types, this study promotes soaking conditions during parboiling.

2. LITERATURE REVIEW

2.1 Anatomy and Morphology of Rice

2.1.1 Anatomy of rice

The anatomy of mature raw rice is a brown kernel enclosed with a husk (complete grains with husks intact) (Juliano et al.,2007). The husk, also known as the hull, is the most prominent part of a crude rice grain. This hull covers the caryopsis' external layer and makes up 20-25 percent of the total weight, although it is not edible [6]. As shown in Fig. 1, "the hull serves as a safeguard against infestation and environmental influences. Sterile lemmas, rachilla, palea, and lemma are present in the shaft. The lemma covers two-thirds of the seed, with the edges of the palea fitting inside so that the two close tightly around the seed" [7]. "The caryopsis contains the embryo and starchy endosperm, surrounded by the seed coat (tegument) and the pericarp" [8,9].

"The caryopsis is comprised of three fibrous bran tissues: pericarp, tegument, and aleurone. Endosperm and embryo are also members of the caryopsis. The bran represents one-tenth of the raw cereal weight and is highly nutritious because it includes proteins, lipid fibers, and dietary fibers. The pericarp consists of small protein bran layers. The tegument contains a variety of fats" [7]. Endosperm and the embryo are covered by the aleurone. Its tissue is abundant in cellulose and protein. The embryo is the grain's reproductive organ and is very high in fat and protein. The endosperm, the largest ingredient in grain, consists primarily of starch granules with small quantities of protein, lipids, and water (Champagne et al., 2004).

2.1.2 Morphology of rice

Plant morphology is the physical form of a plant. It applied to any species and involves a complete study of vegetative and reproductive characteristics to shape plant profiles (Wyatt, 2016). "The morphology of the rice is separated into the vegetative phases (including the germination, seedling, and tilling phases) and the reproductive phases (including the initiation and flowering phases)" [11]. "The rice grain, commonly referred to as the seed, contains the real fruit or brown rice (caryopsis) and the hull, which encloses the brown rice. Brown rice mainly consists of the embryo and the endosperm. The surface contains several thin layers of differentiated tissue surrounding the embryo and the endosperm" [12]. The palea, lemmas, and rachilla are the indicia rice hulls [10].

The hull usually includes rudimentary glumes and a portion of the pedicel. One grain weighs about 10-45 mg at 0% moisture content (Wani et al., 2012), rice length, width, and thickness vary widely across varieties. The average hull weight is about 20% of the total grain weight. Most types of rice have a maximum depth of 1 m or deeper in soft upland soils. In flooded soils, however, rice roots rarely exceed 40 cm in depth.

2.2 Parboiling of Rice

"Rice parboiling is a special hydrothermal processing method and differences in parboiling steps and conditions also result in a variety of final product properties due to microstructural and molecular alterations in starch granules" [5]. "Parboiling treatment helps in preserving vitamins, minerals, losses of starch, destruction of infestation molds and insects, and inactivation of lipases, which further increases the shelf life of rice products" (FAO 2015). "Parboiling consists of three steps soaking, steaming, and drying. Rice parboiling has been a major processing technique in South Asian developing countries, particularly Indian subcontinents, for decades" (Bhattacharya 2004).

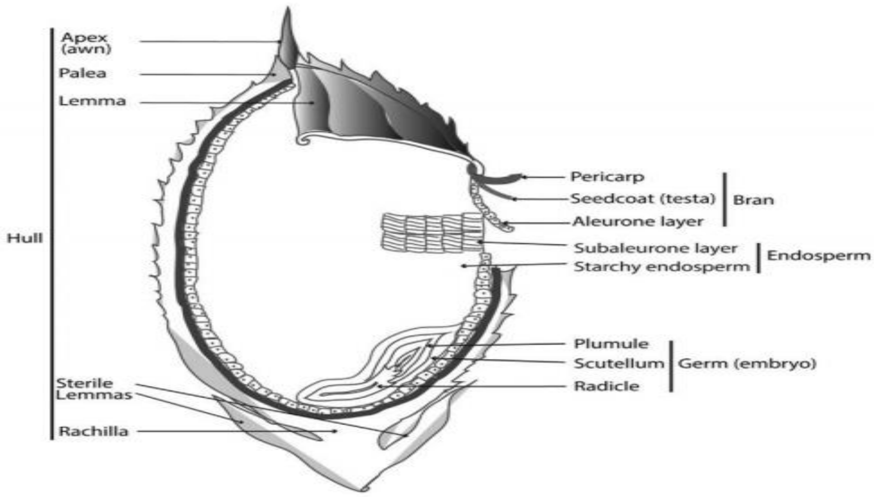

Fig. 1. Cross-section of a rice kernel [9]

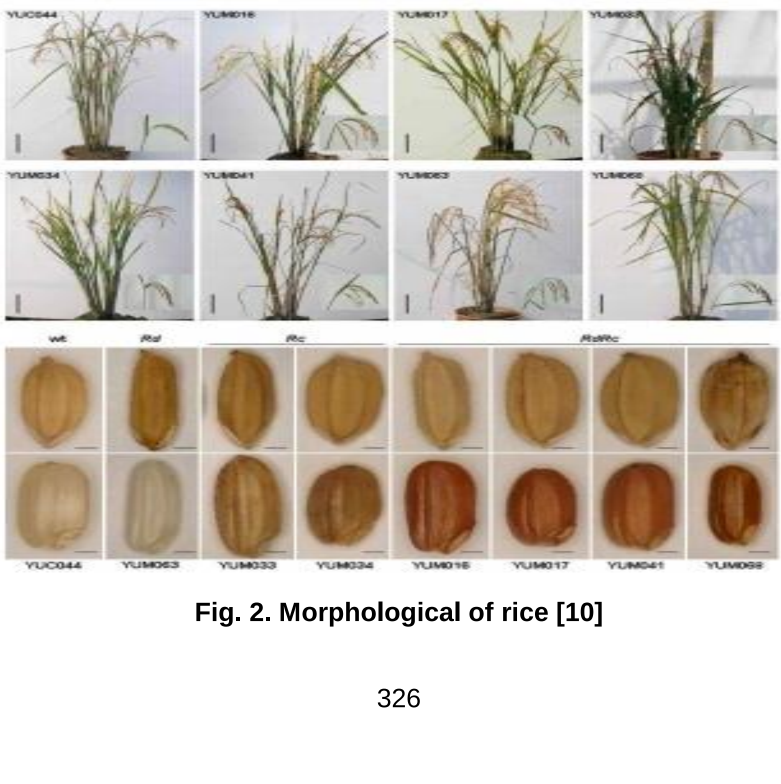

Fig. 2. Morphological of rice [10]

2.2.1 Process of parboiled rice

2.2.1.1 Soaking temperature

"The purpose of the rice-soaking step is to promote rapid and uniform water absorption and to increase moisture content (MC) to approximately 30%" [13]. "Soaking is a temperature-dependent process, which determines the rate of water diffusion into the rice kernel. Similarly, soaking also leaches the fiber, fat, and mineral composition of the rice kernel, thereby changing their composition in rice grain" [14,15]. Therefore, soaking is considered the most important as well as the critical step of parboiling (Igathinathane et al., 2005).

"In parboiling, soaking can be done either in a room or at elevated temperatures (up to approximately 70 °C). Thus, soaking is done at different temperatures (ambient to 80 °C) and for different periods (under, optimal, and oversoaking). Different studies suggested the optimum temperature for soaking different varieties of rice in the range of 60- 80ºC" (Odenigbo et al., 2013) [16]. "The soaking temperature is typically set within a few degrees below the gelatinization temperature of rice starch to ensure that the gelatinization process occurs during steaming. The rate of moisture absorption sharply increased after an initial slower phase and decreased the soaking time by several hours (up to 6 hours of soaking duration reduction when increasing 50ºC soaking temperature to 75ºC)" (Akhter et al., 2014).

2.2.1.2 Steaming

"The second parboiling step is steaming. Steaming temperatures (typically 100ºC) cause starch to gelatinize, converting granular crystals to a melted amorphous form" [17]. "Steaming is the process in which gelatinization occurs because the proper steam temperature is greater than the starch gelatinization temperature. Paddy rice needs to be heated until fully gelatinized to avoid white belly kernels in parboiled rice products. Another cause of white bellies is the imbalance of the last moisture equilibrium inside the grains after soaking. The amorphous starch fills tissues in the endosperm and seals them when cooled" [13]. "The steaming process also inhibits enzymes and increases storage characteristics, kernel firmness, and eating quality. Exact durations can vary depending on rice cultivars and prior processing pretreatments like soaking, but a standard duration is about 10 min at atmospheric pressure" [18].

2.2.1.3 Drying

"After soaking and steaming, the rice moisture content is usually between 30 and 40%" (Luh and Mickus, 1991). "The drying step of the parboiling process reduces MC to 12-14% for storage and milling. Sun drying in the shade outdoors with active stirring is a traditional method to dry wet rice that can be a multiple-day process. The parboiled rice was dried in temperature-controlled environments with regulated airflow and relative humidity to prevent fissuring caused by extreme loss of moisture in a short period" (Luh and Mickus, 1991). "The relative humidity is also dependent on rice cultivar and drying temperatures, but there are rice equilibrium moisture charts available that can recommend relative humidity conditions based on drying temperature to reach the kernel moisture content. In up to 80ºC, relative humidity should range between 55 – 65% to achieve optimal finished moisture" (Sadaka and Bautista, 2014). Drying parboiled rice is different from drying raw rough rice because the former's moisture content is high initially. Its starch granules are partially gelatinized.

2.3 Factors Affecting the Parboiling of Rice

Soaking temperatures and time is an essential operation in the process and affects the quality characteristics of the rice, including its physical characteristics, chemical composition, starch characteristics, cooking characteristics, etc. Ahromrit et al. (2006) reported "processing duration is a key factor affecting the cost of parboiling rice". "It is also a measure of the great versatility of rice and the wide diversity of its quality that rice varieties do not only vary in their property profile, but they also in turn influence the property of parboiled rice" (Bhattacharya, 2011). The use of infrared heat treatment during soaking was investigated to completely remove the steaming step and dry the gelatinized rice after an "enhanced" soaking step (Likitrattanaporn and Noomhorm, 2011). Properties affected by parboiling include ash content, gelatinization, and cooking properties.

According to Anuonye et al., 2016 observed that "there was a slight increase in the ash content of parboiled rice (0.49%) compared to milled, raw rice (0.39%)". "Water-soluble minerals spreading through the endosperm during the soaking and steaming steps of parboiling could have caused the ash to increase" (Jamila., et al 2015). "It was observed that the duration and temperature required to reach starch gelatinization were greater for parboiled rice compared to milled, raw rice" [19].

2.4 Physical Properties of Parboiled Rice

Kar et al., [20] established that "when parboiling brown rice the percentage of no opaque area in parboiled brown rice kernels increases with soaking time (from 1 to 4 h) and initial soaking temperature (from 70 to 100°C). An extrapolative trial was carried out to determine the time because long periods are not compensatory, neither economical nor concerning grain quality". "The initial soaking temperature is in agreement with the previously mentioned values. The temperature of the water to which the rough rice was added had to be calculated" (Amato et al., 2002), Paddy is soaked for 4–5hrs (depending on variety) at 65 °C. If a short soaking tempering method is used, the paddy is soaked for 60–75 min.

According to Cherati et al., [21] "there is a significant difference in the milling yields of the various tests and treatments performed". Sareepuang et al., [22] reported that "soaking at 50 °C for 3 hours most provided the desired stewed rice quality from a nutritional and sensory point of view". "Revisions based on qualitative changes in parboiled rice have concluded that intermediate soaking temperatures (60 ° C to 70 ° C) would be useful for soaking" [23]. There is a correlation between the soaking water temperature and the soaking time [13]. The higher the soaking water temperature, the lower the soaking time. However, the soaking water temperature should not exceed the freezing temperatures of the paddy rice starch.

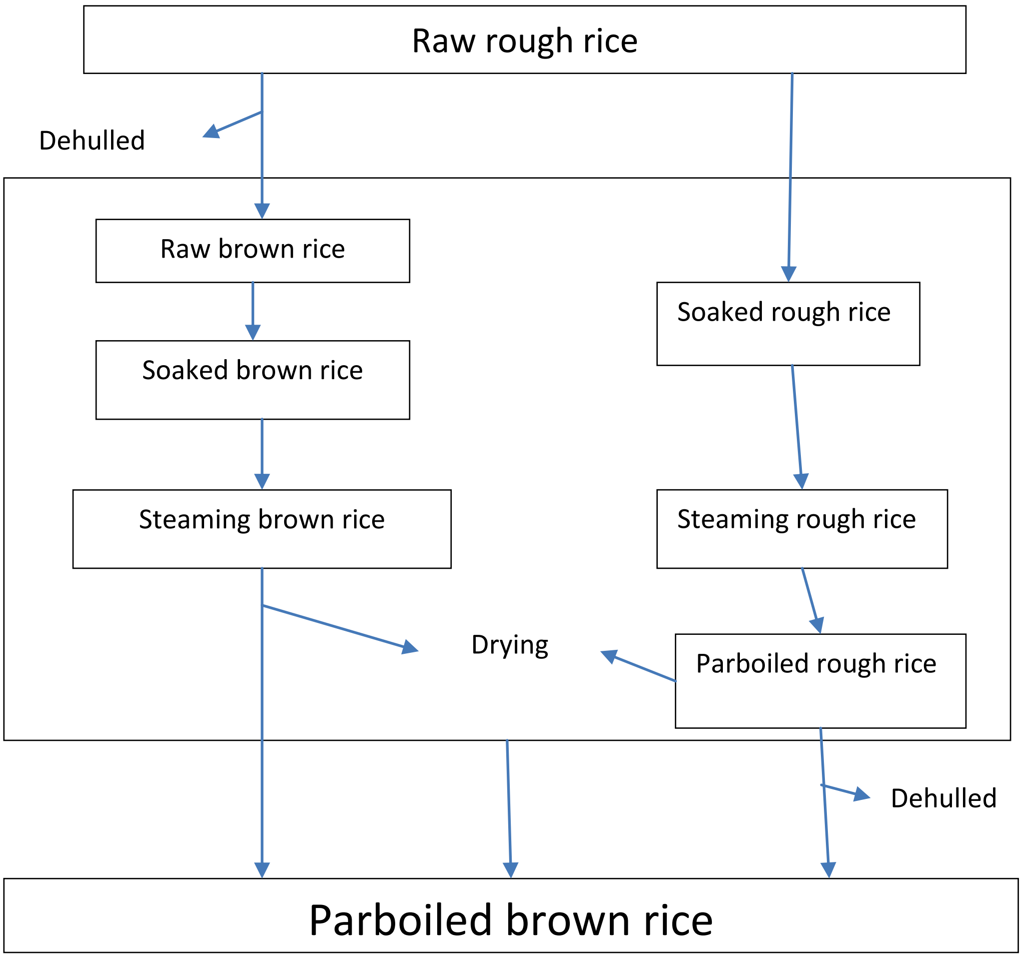

Fig. 3. Steps to convert raw rough rice to milled parboiled rice (Derycke and L. Lamberts, 2010)

2.4.1 Hardness

The hardness of rice is considered an important property of rice as it has a significant impact on the milling attributes of rice and it is the most important of the physical properties of parboiled rice [16]. Kernel hardness is a very important attribute, especially during the milling and storage of rice.

According to Chavan et al., [24] reported parboiling increased grain hardness from 6.63N for control to 9.52N for paddy parboiled by method 3 for 40 min. In addition, he reported that the hardness of rice parboiled for 60 min and 80 min ranges from 5.25-8.66N and 4.82-8.04 respectively. Bhattacharya, 2011 also found “the hardness of un-soaked raw and parboiled rice was 85 and 129 N, respectively. In addition, the study also reported that the parboiled rice required a much higher strength 149.8N than raw rice 75.5N for crushing the grain without presoaking treatment indicating the significantly higher hardness of the parboiled rice, and raw rice showed a gradual decrease in crushing strength from an initial crushing strength of 75.5N for un-soaked rice to 52.1N for rice soaked for 2hr. This indicates the hardness of rice as measured by crushing strength decreases with an increase in soaking time (moisture content of grain)”. According to Correa et al., 2006 “parboiling fills the void spaces and cements the cracks inside the endosperm, making the grain harder and minimizing internal fissuring and thereby breakage during milling”.

Mir et al., [2] also report “the highest hardness (131.41 N) among raw rice of different varieties remained practical to have the hardness increased to (163.71N), and (177.79N), with the increase in the temperature of soaking at 60°C and 70°C respectively. The variation in the compact arrangement of starch granules among rice varieties is due to the parboiling temperatures differing in the hardness of rice grains at different rice varieties”. “The hardness imparted to the kernels in parboiled rice is responsible for the starch gelatinization process and the adhesion between starch granules and protein bodies. Starch swelling completely cures rice grain cracks and chalkiness and improves its hardness” (Sahay et al 1995). “Hardness is an essential fundamental property of parboiled rice among all physical properties. It reduces breakage during milling, which also significantly impacts increasing market value and consumer acceptability. It is generally understood that cooked parboiled rice is more complicated and less sticky than raw, cooked rice” [25].

2.4.2 Cooking time

According to Sareepuang et al., [22], the cooking time was significantly decreased when rice was soaked at a lower soaking temperature (60°C). According to Vidal et al. 2007, “the size and shape of the endosperm (mainly thickness) are probably the most significant factors impacting the cooking time; however, rice with high ash content also showed long cooking time”. According to Bleoussi, (2010); Mo et al., [26] reported that “cooking time depended on different factors, including the parboiling process, storage duration, and variety”. “Brown rice was significantly harder than milled rice for both non-parboiled and parboiled rice for the cooking durations tested, ranging from 31 to 37 min and 43 to 52 min, respectively” [27].

According to Champagne et al., (2004), observed an increase in the cooking time decreased removal of the bran layer of brown rice affected the rice to gain more water cooked later, and decreased the length and width due to less diffusion of water into the starch molecules. According to Sareepuang et al., [22] reported that “the soaking temperature enhances the cooking quality of parboiled brown rice was decreased cooking time”. According to Otegbayo et al., (2001) reported that “parboiled rice has a longer cooking time than non-parboiled from 49-52 min respectively”.

2.4.3 Chalkiness

“Chalkiness or white portion is an undesirable quality of parboiled rice. Parboiling takes about changes in rice during which vitamins and minerals are moved from the aleurone and germ into the starchy endosperm” (Henrik et al., 2007). “These transformations are accompanied by a reduction in the white portion and give milled rice a more translucent appearance. A common problem with parboiling, especially by employing high temperature and pressure and longer processing time, is the darkening of the grain” (Bhattacharya, 1995). Also, the steaming operation, which brings about the gelatinization of starch, requires a lot of energy to produce steam for the process, it is, necessary to establish optimum processing conditions required to obtain better qualities of the finished product while saving energy and time. Marshall et al. (1993) studied “the relationship between the percentage of gelatinization and head yield (the primary parameter used to quantify rice milling quality given by the ratio of the weight of rice grains that are three-quarters intact to the total weight of milled parboiled rice) of parboiled rice" (Cooper and Siebenmorgen, 2005). They reported that maximum head rice yield could be achieved when the rice starch is 40% gelatinized during the parboiling of paddy and that extensive parboiling or extensive starch gelatinization is not required to obtain maximum head rice yields.

2.5 Nutritional Composition of Parboiled Rice

"The nutrients of rice are in large quantities in the outer layers than in the endosperm. Parboiled rice contains more protein, vitamins, and minerals" [28]. "Better nutrient availability in parboiled rice is attributed to the development of hydrothermal treatment steps" [24]. "The nutritional value-added of parboiled rice (mainly fiber and mineral content) is another quality feature that makes a significant difference at the time of purchase by consumers who are aware and more demanding" [14]. "The parboiling process was found to impart increased and decreased nutritional components such as protein, lipids, and an ash content of rice kernel that were affected by the different soaking temperatures and time" [24] (Otegbayo, 2001). "The chemical composition differed due to different parboiling processes. For example, parboiled rice produced with high soak water temperature and high soaking time was reported to be less in lipid content" [22]. "Higher in thiamine content but experienced higher starch leaching" [29,30].

2.5.1 Moisture content

The moisture content plays a significant role in determining foods' shelf life [31]. The moisture absorption process was facilitated by heating water to a soaking temperature of 40-100°C energizes molecules for faster movement across barriers into the rice kernel. Thus the longer the soaking period, the greater the moisture content of the soaked brown rice. The parboiled rice varieties' moisture content is variable from 7.1–11.6%, the moisture content of brown rice and milled rice is lower than other rice varieties. The soaking Process possibly enables paddy rice to imbibe water and become moist. Ibukun, [15], stated studied the effects of temperature and time on the moisture of parboiled rice and the increasing and decreasing moisture content of parboiled rice dependent on a range of smallest and largest recorded soaking temperatures and time on the moisture content. According to Roy et al., (2011); (Ibukun, [15] identified parboiled rice varieties showed an elevation amount of moisture content with an increase in soaking temperature that quickly passes through the bran layer of rice. According to Parnsakhorn and Noomhorm, [32] found that the moisture content of parboiled rises at soaking temperatures 70^{o}C and 80^{o}C, and soaking time from 1-4hr ranges from 33.96-39.55%.

2.5.2. Ash Content

Chavan et al., [24] reported that Ash content increased with the increase of soaking temperature at 65^{o}C -70^{o}C, and low soaking time with low temperature affected decreasing the Ash content. later reduced at higher temperatures of parboiling steps (soaking temperature and time) [30,23] (Oseh, 2009). Sareepuang et al., [22] found the maximum amount of ash (1.02 %) at the soaking temperature of 70℃ for brown rice and parboiled three brown rice varieties (Parboiled rice (PR40) soaked at 40°C, parboiled rice (PR50) soaked at 50°C and Parboiled rice (PR60) soaked at 60°C) presented similar ash contents, 1.25%, 1.34% and 1.30% respectively. USDA, 2004 and Ibukun, [15] reported increase in ash content of rice varieties with increase in parboiling duration. Sareepuang et al., [22] reported increase in the ash content (1.21 to 1.30) of rice by the process of increasing soaking temperature from 40-60^{o}C). According to Joseph et al., [19] the ash content of rice soaked at temperatures of 60, 65, and 70 ° C was 0.76% cent, 0.78, and 0.83%, respectively.

2.5.3 Proteins

"The protein bodies in the rice grain reported to be rupture during the steaming process. It was well documented that the solubility of rice protein was reduced after parboiling and the extent of reduction was proportional to the severity of the process" (Bhattacharya, 2011). Chavan et al., [24] reported that "parboiling sinks the protein bodies into compact mass and made it less extractible which resulted in reduced protein yield and he found protein content decreased from 9.62% for control to 9.14% for paddy parboiled". Rao and Juliano, (1970) stated "decrease in the protein content was attributed to the leaching of protein substances during soaking and rupturing of molecules during steaming"

The result obtained by Chukwu and Oseh, 2009, "there is a decrease in protein content of the parboiled rice samples (5.29%, 6.33%, and 4.25% at 80ºC, 100ºC, and 120ºC, respectively) compared to the non-parboiled sample (6.61%), which may be due to leaching of protein substances during soaking and rupturing that occurs in the molecules due to steaming". (Chukwu and Oseh, 2009) "there was no soaking or steaming process for the non-parboiled samples, hence it had higher protein content than the parboiled rice". Ale et al., [23] reported that a low soaking temperature 60^{o}C soaking could increase the protein content (8.5%) while increasing the soaking temperature have an effect on protein content and it decreases in the range of 8.56ºC at 65 to 8.31 at 70ºC.

According to Zohoun et al., 2018 reported parboiled rice (WITA4 and NERICA) records the highest protein content of 10.6% and 13.2% respectively. He reported that the protein content increased with parboiling compared to non-parboiled rice varieties. The significance of protein can be attributed to the effect of parboiling temperature. The high heat treatment such as high parboiling temperature treatment can reduce protein during soaking while the mild temperature treatment helps in retaining protein in rice under the soaking although this could be depending on soaking time. The soaking Temperature at 60-65 ℃ and a different time, a high % of protein (11.07-11.98) the migration to the outer layers to within the grain during the parboiling process [33]. The protein contents ranged from 5.71% to 7.42%, showing a decreasing trend in milled samples [34]. USDA, (2004), reported "Food composition tables assessed herein report protein contents for commercial rice from 7.02% to 8.3% for brown rice and 6.3–7.3 for milled rice with small variations in moisture contents".

2.5.4 Lipid

The composition of fat present in rice is dependent on the degree of bran and germ removal and cultivar. The higher the degree of bran and germ removal, the less the fat content of the cultivar because most of the oil content is present in the germ. Azuka et al., [35] reported that "the fat content of rice varieties range from 2.47- 3.17%, which was higher than the value reported by Alaka et al., (2011) who reported a fat content of 2.02-2.23% but within the range of value reported by Oko et al., (2012) of 0.5-3.0%". According to Zohoun et al., "2018 two parboiled rice varieties (WITA4 and NERICA) records 1.6% and 0.73% respectively. He reported that the lipid content increased with parboiling compared to non-parboiled rice".

According to Kale et al., 2015 reported that "the fat content was increased somewhat at lower temperatures, and decreased soaked at higher temperatures". Sareepuang et al., [22] also report "the chemical composition of rice differed due to different parboiling processes". According to Joseph et al., [19] "parboiled rice has fewer lipids content than the control (non-parboil) or partially parboiled rice. It oil contained in the embryo could be dissolved and diffused out of the grain during the steaming process to give it low fat content". According to Patindol et al., [3] reported "parboiling enhanced the interaction of bran lipids with endosperm starch and protein". According to Joseph et al., [19] stated "the lipids content, varietal differences, soaking temperature, and time, as well as interactions the significant effects, in the Nerica-14 variety, the total lipids ranged from 2.2 to 3.4%, and that of Jasmine-85 ranges between 2.5-3.4%".

Kale et al., (2015) reported that when the temperature is ranged between 60^{o}C to 70^{o}C the fat content decreases in a range of 2.59% to 2.58% respectively. The decrease in the fat content can be attributed to different factors, not only the rice varieties and culture. Ale et al., [23]; Chavan et al., [24] reported soaking temperatures between 60-70 ℃ are a more significant effect on crude fat content, and soaking increased the amount of fat slightly at lower temperatures but decreased at higher temperatures (≥ 75 °C).

2.5.5 Fiber

Ale *et al.,* 2015 reported that the fiber content increase in the range of 1.59 to 1.70 when the soaking temperature is higher and decrease at lower soaking temperature. The rice variety differences can affect the fiber content in bran and its microstructure. According to Ebuehi and Oyewole, [31], soaking significantly increases rice's crude fiber content, remarkably sustaining the digestive system healthily and functionally. "Crude fiber content, an essential nutritional parameter, of un-soaked brown and un-soaked polished rice was estimated as 1.52% and 0.83%, respectively, whereas soaked (at 65 °C) brown and soaked-polished rice had its value as 1.62% and 0.93%, respectively" [23]. According to Chavan et al., 2016 "reduction of crude fiber content from 1.58% for control samples to 0.80% for the optimum parboiled rice was because of the low heat capacity generated during parboiling to cause any degradation of the crude fiber present".

2.5.6 Carbohydrate and energy

Parboiling has a positive effect on the carbohydrate content of rice. According to Kale et al., 2015 reported that the percentage of the carbohydrate content of parboiled rice was growth when rice was soaked at 60-65^{o}C. According to Chukwu et al. [30] who reported the increased or reduced Carbohydrate content of rice might be affected by soaked temperature and time with rice varieties. According to Chavan et al., [24] reported that carbohydrate content increased from 72.98% to 75.71% for parboiling different processes and had no significant difference with the parboiling method. According to Thomas et al., (2013) who reported that parboiled rice could be considered as a good source of energy with higher carbohydrate content. According to Otegbayo et al., 2001 discovered that parboiling as a process increases the carbohydrate content of rice when compared to non-parboiled rice. According to Otegbayo et al., (2001), observed soaking temperature and a process that increases the carbohydrate content of rice when matched to non-parboiled rice. According to Ituen and Ukpakha (2011), who observed the rice soaked at higher temperatures and short time was analyzed as the best processing condition with a high amount of carbohydrate content.

The rice varieties' high percentage of carbohydrate contents shows that rice is a good energy source. The minimum carbohydrate content was 57.1 percent and 55.9 percent, while the maximum values were 70.3 percent and 69.5 percent for rice varieties after soaking. Among all the varieties, the maximum values were derived from non-parboiled (control) samples, while the smaller amounts were derived from extreme or parboiled rice [28].

2.5.7 Minerals

According to Joseph et al., [19] reported in "the parboiling process the water-soluble minerals present in the outer layer of the grain (bran), migrate to the starchy endosperm, causing increased levels of these components". Ibukun [15] reported "the mineral composition of non-basmati rice with an increase in the sternness of parboiling. It might be due to the leaching of minerals from the husk and bran into the starchy endosperm during the soaking process". Ale et al., [23] Joseph et al., [19] also reported minerals seeped into the soaking water, and diffused into the endosperm of rice, thus decreasing the mineral content of the husk and the corresponding increase in the bran rice paddy husk contains a large amount of mineral composition. The temperature increase/ decreases impact the mineral amount that exists in the husk and bran layer. If the soaking Temperature is higher for a long time, it could affect the rice quality, mainly minerals (Derycke et al., 2005). A significant difference between the mineral composition of the un-soaked paddy husk and that of the soaked at (70°C) paddy husk was observed attributed to the displacement of minerals from the husk during soaking.

According to the study of Scgerz et al., (2000) the contents of potassium, parboiled rice, intensely evaluated the potassium value of parboiled rice from 150-260 kg/100g. Ale et al., [23] recorded the removal of minerals from the rice bran to the endosperm whereas soaked at a different temperature and time. According to Joseph et al., [19] the decreasing soaking temperature and time for increasing potassium amount in the rice varieties. According to the work of (Marr et al.,1995), who reported the magnesium content, parboiled rice has considerably maximum magnesium values of soaking temperature and soaking time of rice varieties (100-130.8kg/100g).

Identifying these elements' natural genetic variability is of great importance for selecting nutritionally promising rice varieties for trading. The increase in rice mineral contents would make a significant contribution of K and P to the RDA [14].

2.5.8 Vitamins

"Parboiled rice has significantly more thiamine and niacin than white rice. These nutrients are essential for energy production. Furthermore, parboiled rice is higher in fiber and protein" (Shah et al., 2005). "Parboiled and white rice can sometimes be enriched with iron, thiamine, niacin, and folate, reducing some of these nutrient differences compared to brown rice. Still, brown rice is the best source of nutrients, overall" Oli et al. [36]. "Niacin (also known as vitamin B3) is one of the water-soluble B vitamins. Niacin is the generic name for nicotinic acid (pyridine-3-carboxylic acid), nicotinamide (niacinamide or pyridine-3-carboxamide), and related derivatives, such as nicotinamide riboside" (Bourgeois et al., 2010). Niacin is naturally present in many foods, added to some food products, and available as a dietary supplement.

Manful et al. (2007) reported that "the thiamine content in the parboiled rice increased gradually as the parboiling intensity was raised from the initial soaking temperature to 30°C -70°C. There was a sharp rise in thiamine when the soaking temperature was further increased by 90°C and steamed for 12 min. The gradual increase in thiamine content with the severity of heat treatment (during soaking and steaming) indicates the possibility of forming this vitamin during thermal treatment". "However, this hypothesis can only be concluded after proper investigation. The riboflavin level showed a different pattern because it increased with parboiling with increasing temperature of soak water up 70°C, but beyond that, it decreased" (Manful et al., 2007).

2.6 Functional Properties of Parboiled Rice Varieties

Functional properties are fundamental Physic-chemical properties that recognize the complex interaction between the composition, structure, molecular conformation, and physicochemical properties of food materials, together with the nature of the environment in which they are combined and measured (Siddiqi et al., 2009). Functional characteristics are conducted to identify and possibly better determine how new proteins, fats, fibers, and carbohydrates can perform in specific systems and demonstrate whether or not such proteins can be used to stimulate or replace conventional proteins [37].

2.6.1 Water absorption index

According to Elbert *et al*., 2000 soaking Temperature and Time have hugely influenced the rate of water absorption and nutritional and functional property of rice. the higher the Temperature of the soaking medium, the higher the rate of moisture absorption [38]. According to Mir et al., [2] who reported water absorption index increased with the increase in temperature, probably due to increased dextrinization at higher temperatures. According to Parnsakhorn and Noomhorm, [32] the lowering in water absorption of parboiled brown rice contributed to starch granules modified from the heating and parboiling process. Thus, a more substantial structure was obtained, and difficult for water penetration into the kernel. According to Ding et al., 2006 who reported Water absorption index decreased with increase in moisture content.

According to Mir et al.,[2] reported the variety difference in soaking temperature and time in water absorption index ranging from 2.15 in Jhelum to 2.41% in Pusa-3 were raw rice samples and found to be increased by 3.52%, and 4.68% at 60˚C, 3.68% and 4.60% at 70˚C, and 4.01% to 5.92% at 80˚C for parboiled Jhelum, and Pusa-3 respectively. The soaking temperature might be due to the more injured starch present in parboiled rice flour at different temperatures to imbibe and hold more water. The absorption potential at the start of soaking was optimum as the rice was dry and balanced and was easily set up (Amato, 2002).

2.6.2 Water solubility index

The water solubility index decreased initially and increased with an increase in temperature, which may be attributed to the similar variation of side extension of the extrudes with an increase in temperature [39]. According to Ding et al., 2005 who recorded the water solubility index increased initially with the increase in moisture content, which may be due to good gelatinization and a side increase of the starch WSI measures the number of soluble components released from the starch after extrusion. High WSI is an indicator of good starch digestibility as it implies the extent of gelatinization and dextrinization [39]. Parboiling the solubility enhanced in all rice varieties. According to [2] the water solubility of raw rice flour samples of different rice cultivars ranging from 1.50 to 2.60 was found to be varied from 2.33 ± 0.26-3.58 ± 0.20 at 60oC and 2.37 ± 0.21-3.64 ± 0.29a at 70℃. WS was found to increase due to the effect of parboiling in the present study, which could be supported by the observations of various cereal flours with an enhanced WS during different parboiling conditions [40].

2.6.3 Oil absorption capacity

According to Abdel-Aal et al 1992, the results on oil absorption capacity showed an increase with increased moisture and decreased temperature. Abdel-Aal and coworkers (1992) also observed that extrusion conditions had little effect on FAI when rice flour and fava bean protein

Table 1. Mineral composition of parboiled brown rice mg/100 g

Mg/100g	Juliano Bechtel (1985)	Wolnik et al. (1985)	Sotelo et al. (1990)	Marr et al. (1995)	Scgerz et al. (2000)	USDA (2004)	Abulude et al 2004
K	60-280	12.5-195	181-386	210-300	150-260	223	400-376
P	170-430	48-230	____	240-310	250-383	333	______
Mg	20-150	3.95-92	____	100-130	110-166	143	75-71

concentrate blend were used. The FAI range for products was 2.4–3.0 g/g. The oil absorption capacity of food protein depends upon intrinsic factors like amino acid conformation, protein conformation, and surface polarity or hydrophobicity. The ability of the proteins of these flours to bind with oil makes them useful in the food system where optimum oil absorption is desired. The OAI values of the rice flour were 1.11-1.34 g/g. Sarangapani et al. (2016) reported the oil absorption capacity of rice flour to be 0.88-1.39 g/g. High numbers of hydrophobic groups within starch molecules contribute to high values of OAI (Tharise et al., 2014). Improving mouth feel, flavor retention, and palatability in food products are stimulated by high OAI, rancidity happening in food products is boosted by higher values of OAI (Falade and Chirstopher, 2015).

2.6.4 Bulk density

Processing parameters and ingredients formulations on the effect of properties of extruded expanded rice products and found that moisture was the most important factor affecting bulk density (Pan and coworkers 1992). Bulk density is used to determine flour expansion and the porosity of products; it also indicates the volume of packaging material (Shafi et al., 2016). According to Bryant et al., [41] reported significant main effects for rice, temperature as well as a significant temperature by flow rate interaction and a significant rice-by-temperature interaction. Akubor and Obieguna (1999) reported that the bulk density of a sample could be used in determining its packaging requirements. Joy and Ledogo, [42] reported bulk density is dependent upon the particle size of the samples and can be described as a measure of the heaviness of a flour sample. Bulk density ranged from 1.34g/ml increased to 1.53 g/ml related to processing methods and rice varieties. Chandra, [43] reported the highest bulk density was observed for rice flour (0.914 g/ml, which revealed that bulk density depends on the particle size and initial moisture content of flours. Falade and Christopher 2015 reported a bulk density of 0.53-0.89 g/cm for Nigerian rice.

2.6.5 Water swelling index

The swelling power provides evidence of non-covalent bonding between starch molecules in the flour. Factors like amylose-amylopectin ratio, chain length, molecular weight distribution, degree/length of branching, and conformation determine the degree of swelling power and solubility. Swelling volumes also depend on the presence of various chemicals and treatments carried out on rice flour. High amylose content and the presence of a more substantial or a higher number of intermolecular bonds can reduce swelling in rice flour.

2.7 Sensory Properties of Parboiled Rice Varieties

The assessment of the sensory assessment showed that the aroma, texture, and taste of cooked parboiled rice were significantly better [44]. Parboiled rice scored for aroma, texture, and taste are high average for acceptability. According to Kar et al., [20] Parboiling has an obvious impact on the organoleptic properties of cooked rice. Also reported that cooked parboiled rice is hard and less sticky than non-parboiled cooked rice. The mean scores of appearance, aroma, texture taste, and overall acceptance of parboiled rice were between 4.4 and 6.6, while those of brown rice will be between 6.2 and 7.0. Sareepuang et al., [22] his report identified that rice soaked at 60^{o}C gave the lowest scores (5.95 out of 9) among all treatments but slightly lower than brown rice [45].

3. CONCLUSIONS

Rice processed and marketed in Ethiopia lacks desired product properties and unique quality parameters. This is mainly because of a lack of optimized parboiling conditions (soaking temperature and time). The purpose of this study was, therefore, to optimize parboiled conditions (soaking temperature and time) for better physicochemical, functional, and sensory properties of two rice varieties grown in eastern Ethiopia. Response surface method (RSM) experimental design was applied to optimize the effects of soaking temperature in the range of 60–70^{o}C and soaking time within the range of 4–6hrs. The results showed a significant difference ($P < 0.05$) in most of the measured quality parameters and indicated soaking time and temperature are the most factors influencing the physicochemical and sensory quality of paddy rice. Numerical optimization for physical, functional, and proximate composition making the independent variables in range was performed. According to better-quality rice in terms of determined physicochemical and sensory quality parameters obtained at soaking temperature, 65^{o}C, 70^{o}C, 65^{o}C, and soaking time 6hrs, 4hrs, and 5hrs respectively. It was observed that soaking temperature and time are the most significant factors to determine the quality of rice during parboiling. The soaking indicated a broader changeability in physical, nutritional, functional, and sensory properties and optimum soaking temperature assay.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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