Food Chemistry Advances 6 (2025) 100920

Contents lists available at ScienceDirect

Food Chemistry Advances

journal homepage: www.elsevier.com/locate/focha

Exploring the physicochemical and phytochemical properties of Boka Saul: An indigenous Assamese rice variety

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ARTICLE INFO

Keywords:
Boka Saul
Amylose
Amylopectin
Traditional rice
Functional foods

ABSTRACT

This study investigates the physiochemical and phytochemical properties of Boka Saul (BS) rice, an indigenous rice variety, its nutritional composition, agronomic potential, and crucial physicochemical attributes. The proximate analysis reveals key components such as carbohydrates (79.43 ± 0.42 g/100*g*), protein (6.92 ± 0.38 g/100*g*), low fat (0.57 ± 0.02 g/100*g*), and fiber content (8.86 ± 0.22 g/100*g*). Micronutrient levels, notably potassium (255.33 ± 1.53 mg/100 g), phosphorus (116.00 ± 1.73 mg/100 g), magnesium (30.33 ± 2.52 mg/100 g), calcium (7.43 ± 0.90 mg/100 g), and zinc (1.33 ± 0.21 mg/100 g), are also examined in detail. The physical characteristics of BS rice, encompassing 1000 grain weight (24.7 g), bulk density (734.3 kg/m^3), true density (1574.57 kg/m^3), porosity (53.33 %), and color value (whiteness: 22.86 %, transparency: 0.95), contribute to the rice's physical attributes. Gel consistency (25.5 mm), gelatinization temperature (69.54 °C), alkali spreading value (5), water uptake ratio (0.88), and cooking properties like length (940.00 ± 0.07 mm), breadth (340.00 ± 0.05 mm), cooking time (20 mins at 100 °C, 40–50 mins in normal water), and kernel elongation ratio (0.709) are analyzed. The amylose and amylopectin contents in BS rice was 21.63 ± 0.74 g/100 g and 78.40 ± 0.70 g/100 g respectively. This research offers a holistic understanding of the nutritional, physicochemical, and cooking properties of Boka Saul rice, contributing to its characterization and potential applications in food and agriculture.

1. Introduction

Rice is a valuable nutritional staple food that is widely consumed by over 90 % of the world's population (Fairhurst & Dobermann, 2002). Rice is the nutritional seed that is obtained from the grass species *Oryza sativa* (Asian rice) and the other is *Oryza glaberrima* (African rice). This food commodity in the agricultural sector is the third most produced crop around the world(Chauhan, Jabran, & Mahajan, 2017). The rice consumption rate has increased globally from about 437.18 million metric tons for the crop year 2008/2009 to approximately 520.5 million metric tons in the year 2023/2024 (USDA, 2023). In India, it is even more important as >50 % of the country's population depends on rice either directly or indirectly for their food. India is also one of the world's largest rice producers (Chang & Luh, 1991).

Rice has a vast genetic diversity throughout the world and India had about 110,000 rice varieties till 1970 (Rathna Priya et al., 2019). During the green revolution and its emphasis on modernity and hybrid crops, many traditional rice varieties have been lost and now India has only about 6000 rice varieties (Frankel, 2015). These existing non-hybrid traditional rice varieties are unpolished and have thick rice bran which has better nutritional aspects than polished rice. Traditional rice varieties are rich in antioxidants, phytochemicals, phytonutrients,

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https://doi.org/10.1016/j.focha.2025.100920
Received 17 May 2023; Received in revised form 28 January 2025; Accepted 8 February 2025
Available online 9 February 2025

vitamin E, protein and other nutrients required for the proper functioning of the immune system and to boost memory power in children (Bhat & Riar, 2015). The traditional rice varieties are available in various colors including black, red and brown. Black rice is rich in proteins, calcium, sodium, iron, vitamins and fiber content so it is recommended for cancer and cholesterol patients (Yao et al., 2013). The major anthocyanin component present in black rice is peonidin-3 glucisides and cyanidin-3 glycosides which have cancer treating characteristics (Yao et al., 2013). Red rice has high content of iron and zinc and they are more efficient for weight loss and provide relief for digestive problems (Nivedita et al., 2020). Some of the well-known regions where red rice grows include Matte of Kerala, Patni in Maharashtra, Jatu and Matali in Himachal Pradesh (Thakur & Kumari, 2020). Brown rice is highly nutritious as it has low calories and it is rich in fiber, vitamin B, magnesium, selenium, phosphorus, thiamin, niacin (Niacin) and other nutrients (Saleh et al., 2019; Zahra et al., 2020). Extracts of brown rice are also used as an energy drink for individuals, patients and in curing chronic gastric problems, hepatitis, dysenteric complaints, to increase lactation and nutrition in children. Brown rice extracts have been proclaimed as a remedy for breast and stomach cancer and warts (Zahra et al., 2020). Based on these aspects, colored rice has also been utilized in treating diabetes mellitus, obesity, hypertension, cancer, and cardiovascular problems (Mbanjo et al., 2020).

White rice is normally processed by the removal of the rice bran and the germ layer which in turn leads to a loss of various nutrients present in rice. To achieve this process, milling is done which results in the removal of about 85 % of fat content, 15 % of protein content and other essential nutrients such as calcium (90 %) and vitamin B (70 %) including B_1, B_2 and B_3 (RathnaPriya et al., 2019). This loss of phytochemical compound increases as the degree of milling process increases. This loss of nutrients by the milling process can be overcome by the consumption of traditional rice variety (RathnaPriya et al., 2019). Certain traditional varieties such as Navara and Rakthashali are said to possess medicinal benefits to humans for diabetes, in preventing premature hair loss and in rectifying illness affecting circulatory, respiratory and digestive systems (RathnaPriya et al., 2019).

Currently some of the traditional rice varieties that are grown regionally include Basmati, Sharbati rice and Sugandha rice from north Indian states such as Himachal Pradesh, Punjab and Uttarakhand, Asha, Rakthashali, Maapillai Samba, KattuYanam, Poongar from southern states of Tamil Nadu, Kerala and Karnataka, Katarni rice and Annada from the east Indian states of Bihar, Odisha and Jharkhand and Ambemohar, Kali Kusal and Ghansal from the western state of Maharashtra (Longvah et al., 2021; RathnaPriya et al., 2019; Devraj et al., 2020; Muttagi & Ravindra, 2020).

Boka Saul is an ancient paddy variety known by several names like-Magic Rice, Assamese Soft Rice, Komal Saul, etc. Boka in Assamese means mud (and the softness of it), and saul means rice. This variety is grown in some lower parts of Assam mostly in the districts of Baksa, Barpeta, Goalpara, Darang, Dhubri, Kamrup, Kokrajhar, Nalbari, and so on. It is planted in the third or fourth week in June and reaped in December. Therefore, this rice is also known as 'Xali' in the local language. This variety is cultivated in Assam for a very long time and the process of cultivation is purely traditional. It is believed that this variety of rice was first cultivated in the 17th Century by the Ahom Reign people during emergency while battling against the Mughal Army. This variety of rice does not need to be cooked for consumption (Parul Jauhari, 2020).

Each and every rice seed has two starch components, amylose, and amylopectin. Amylose provides the hardness of the rice, while amylopectin gives stickiness to the rice. Boka saul is glutinous rice, which in general has low amylose content and higher amylopectin content. Thus, this composition makes the rice variety soft and sticky. As per the research done at Guwahati University, this rice variety has a fiber content of 10.73 % and a protein content of 6.8 % (Parul, 2020). Owing to its numerous significances, Boka Saul rice has been issued Geographical Indication (GI) tag in 2019 on an application for GI made in 2016 by the Lotus Progressive Center (LPC) that is located in Nalbari district and the application was assisted by the Center for Environmental Education (CEE) while Assam Science Technology and Environmental Council provided the necessary potential (Boruah, 2021). The study aims to comprehensively characterize Boka Saul rice, an indigenous variety, by conducting proximate analysis to determine its macronutrient and micronutrient composition, with emphasis on carbohydrates, protein, fat, fiber, potassium, phosphorus, magnesium, zinc, and calcium. Additionally, the research investigates its physical attributes, including grain weight, density, porosity, and color, alongside physiochemical properties such as gel consistency, gelatinization temperature, and cooking characteristics. The study also delves into starch composition by analyzing amylose and amylopectin contents. Furthermore, it seeks to evaluate agronomic potential and sensory attributes, and assess the impact of various processing methods on nutritional quality and sensory attributes. Through these objectives, the study aims to provide insights into the nutritional, agronomic, and culinary potential of Boka Saul rice.

2. Materials and methods

2.1. RAW materials

The BS rice has been purchased from Assam based company "Miha Trading Solution", Kamrup, Guwahati- 781,001, Assam, India. The entire study was processed with the same rice.

2.2. Physical characteristics

2.2.1. L/B ratio

10 rice grains were randomly selected and their length and breadth were measured. Their individual mean was divided to obtain L/B ratio (Devraj et al., 2020).

2.2.2. 1000 grain weight

Thousand grain seed weight was determined by counting 100 kernels and weighing them in electronic weighing balance and then multiplied by 10 to give the mass of 1000 grains (Tiwari et al., 2017).

2.2.3. Bulk density

The bulk density of the grain sample is obtained simply by dividing the weight of the sample by the volume of the container (Eq. (1)). From the storage point of view, it is important to determine the effect of moisture content on the bulk density of grains because the bulk density of some grains increases with an increasing moisture content, whereas it decreases for some other grains (Tiwari et al., 2017).

$$\text{Bulk density } (\rho B) = \text{Mass of sample (kg)} / \text{Total volume } (m^3) \quad (1)$$

2.2.4. True density

50 mL toluene was filled in a 200 mL measuring cylinder and then same mass of sample that was taken for bulk density was put into the vessel containing toluene. The displacement of toluene level in the vessel on putting rice kernels was noted down. The ratio of the mass of rice kernels to the volume of displaced gave the true density (Tiwari et al., 2017) (Eq. (2)).

$$\text{True density } (\rho t) = \text{Mass of sample (kg)} / \text{Volume of displaced toluene } (m^3) \quad (2)$$

2.2.5. Porosity

It is calculated from the values of true density and bulk density by the Eq. (3) (Devraj et al., 2020).

$$\text{Porosity } (\varepsilon) = (\text{True density} - \text{Bulk density} / \text{True density}) \times 100 \quad (3)$$

2.2.6. Colour value

Whiteness of the rice samples were measured using a kett digital whiteness meter and colour was measured using colour difference meter (Model JC801, Japan) (Ponjanta et al., 2016).

2.3. Physicochemical analysis

2.3.1. Gelatinization temperature and alkali spreading value

Gelatinization temperature, a crucial characteristic of rice grains, was determined using a method adapted from Patindol and Wang (2003). To conduct the test, seven entire kernels of each landrace were carefully collected and placed in a Petri plate, with three replicates for each sample.

Subsequently, 20 mL of a 1.7 % potassium hydroxide (KOH) solution was added to each Petri plate. This solution was prepared by dissolving 1.7 g of potassium hydroxide in 100 mL of distilled water. The samples were then left undisturbed for a period of 23 h at a constant room temperature of 21 °C. Following the incubation period, the spreading behavior of each kernel was visually assessed using a 7-point numeric scale, with each replicate being scored independently. The spreading value for each replicate was determined by averaging the results obtained from the assessment of seven kernels, as outlined by Pokhrel et al. (2020).

2.3.2. Gel consistency

A test tube (13 mm × 100 mm) was filled with approximately 500 mg of rice flour from each rice genotype, with measurements performed in triplicate. To prevent the rice flour from clumping, 0.026 mL of 95 % ethanol containing 0.025 % thymol blue was added to each tube. The mixture was gently vortexed, followed by addition of 2 mL of 0.2 N KOH and vortexing again. Glass marbles were placed in each tube to prevent steam loss and sample reflux before heating in a boiling water bath at 92 °C for 6 mins. The tubes were then held at room temperature for 5 mins followed by placement in an ice bath for 15 mins. After 30 mins, the tubes were laid horizontally on graph paper on a flat laboratory surface, and the length of the blue gel was measured in millimeters from the bottom to the tip of each tube (Pokhrel et al., 2020).

2.3.3. Water uptake ratio

According to Bhattacharya and Sowbhagya, rice samples weighing 2 g in 20 mL of water were cooked for the ideal amount of time in a boiling water bath at 95 °C. After draining the remaining liquid, the cooked rice was placed on filter paper to soak up any surface water. For the purpose of determining the water intake ratio, the cooked samples were precisely weighed (Pokhrel et al., 2020) (Eq. (4)):

$$\text{Water uptake ratio} = \frac{\text{Weight of kernel after cooking (g)}}{\text{Weight of kernel before cooking (g)}} \quad (4)$$

2.4. Cooking characteristics

2.4.1. Optimum cooking time

2 g of rice sample was taken and along with that 20 mL of distilled water was taken and kept in a water bath at 90 °C (Pokhrel et al., 2020).

2.4.2. Cooked length-breadth ratio

The cooked length-to-breadth ratio was calculated as the cumulative length of 10 cooked kernels divided by the breadth of 10 cooked kernels.

The length-to-breadth ratio of cooked rice was represented by the Eq. (5) (Pokhrel et al., 2020):

$$\textit{Cooked length} - \textit{breadth ratio} = \frac{\textit{Length of cooked rice (mm)}}{\textit{Breadh of cooked rice (mm)}} \quad (5)$$

2.4.3. Kernel elongation ratio

The elongation ratio was calculated by dividing the difference between the cumulative length of 10 cooked rice kernels and the length of 10 uncooked raw kernels by the length of 10 uncooked raw kernels.

The Kernel elongation ration was calculated by the following Eq. (6),

$$\text{Kernel elongation ratio} = (X_L - Y_L)/Y_L \quad (6)$$

Where, X_L = length of 10 cooked kernels, Y_L = length of 10 uncooked kernels (Devraj et, al.,2020)

2.5. Proximate analysis

2.5.1. Moisture content

The moisture content of Boka Saul rice was determined using a hot air oven according to AOAC (2005) procedure (Devraj et al., 2020). The rice sample was pulverized to obtain flour particles of 100 μm size. Glass plates were pre-dried in the oven to remove residual moisture. Ten grams of rice flour was weighed in a pre-dried plate and recorded as W1. The sample was then placed in a hot air oven maintained at 105 °C for 24 h. After 24 h, the sample was weighed and recorded as W2. The moisture content was calculated using Eq. (7):

$$\text{Moisture Content (\%)} = (W1 - W2)/W1 * 100 \quad (7)$$

Where, W1 = initial weight of the sample (g) and W2 = final weight of the sample (g).

2.5.2. Ash content

Ash content in the rice sample was determined as per AOAC (2005) by weighing around 5 g of the sample placed in a previously oven-dried dish. The dish is heated in the muffle furnace at 550 °C overnight. Then the dish is cooled in the desiccator and the sample is weighed when it turned grey. The ash % was calculated using the Eq. (8)

$$\text{Ash (\%)} = (\text{Weight of ash} / \text{Weight of sample}) \times 100 \quad (8)$$

2.5.3. Total carbohydrates

The total carbohydrate content present in the rice sample was determined by the phenol sulfuric acid method (AOAC, 1999). 2 g of the sample was hydrolyzed with 2.5 N of HCl. Na_2CO_3 was used to neutralize the sample and then the volume is made up to 100 mL. The prepared solution is centrifuged at 9000 rpm for 10 mins at 4 °C. The supernatant is collected to determine the total carbohydrates content by obtaining optical density [OD] at 495 nm in a spectrophotometer (Microprocessor UV–VIS Double Beam Spectrophotometer –IR 513 D, INFRA DIGI, India).

2.5.4. Total protein content

Total protein content was determined using the Kjeldahl method (AOAC, 2000). A sample of rice (0.5–1.0 g) was placed in a digestion flask along with 5 g of Kjeldahl catalyst and 200 mL of concentrated H_2SO_4. The digestion flask was positioned at an incline and heated gently until frothing ceased. After cooling, 60 mL of distilled water was added to the flask. The mixture was then connected to a distillation column (KjelDIST, Tulin Equipments, India) and heated until complete distillation of NH_3. The excess standard acid in the distillate was titrated with standard NaOH solution. The protein content was calculated using Eq. (9).

$$\text{Crude Protein (\%)} = (((\text{mL of HCl} - \text{mL of blank}) \times \text{Molarity} \times 14 : 007 \times 6 : 25) / \text{mg test portion}) * 100 \quad (9)$$

2.5.5. Total fat content

Fat content present in rice samples was determined as per AOAC (2005) using Soxhlet Method (Eq. (10)) . The sample weighing 3–5 g was transferred to the extraction thimble and soxhlet. Petroleum ether measuring 250 mL was filled into the bottle and connected to the soxhlet

apparatus. The water is turned to cool them and then the heating mantle is switched on. The sample is heated for about 14 h (heat rate of 150 drop/min) and the solvent is evaporated using the vacuum condenser. The bottle is incubated at 80–90 °C until the solvent is completely evaporated and the bottle is completely dry. After drying, the bottle is transferred with a partially covered lid to the desiccator to cool and be weighed.

$$\text{Fat } (\%) = (\text{Weight of fat} / \text{Weight of sample}) \times 100 \quad (10)$$

2.5.6. Dietary fiber

Dietary fiber content was determined according to AOAC (2000) method. A 2 g sample of dry matter was weighed and defatted using Soxhlet extraction, then transferred to a 600 mL Erlenmeyer flask. The sample was boiled with 200 mL of H_2SO_4 solution (1.25 g H_2SO_4/100 mL; 0.255 N) under reflux for 30 mins. The mixture was filtered, and the filter paper was washed with hot water until neutral pH. The residue was carefully transferred from the filter paper to the Erlenmeyer flask using a spatula and 200 mL of boiling NaOH solution (1.25 g NaOH/100 mL; 0.313 N). The mixture was filtered through a pre-weighed filter paper or Gooch crucible, then washed sequentially with K_2SO_4 solution, boiling water, and 15 mL of 95 % ethanol. The filter paper containing the residue was dried at 110 °C until constant weight (1–2 h). The dietary fiber content was calculated using Eq. (11).

$$\%\text{Crude fiber} = ((B - C) / A) * 100\% \quad (11)$$

Where, A = Weight sample
B = Filter Paper + Fiber
C = Filter Paper

2.5.7. Mineral composition

The sample was dried in a microwave oven (Samsung MG 23A3515AK/TL) to remove moisture and the particle size was reduced through milling. The powdered sample was digested using NaOH. The digested product was then filtered using Whatman No.1 filter paper and used for analysis. The composition of minerals like Calcium, Iron, Magnesium, Potassium, Phosphorus, and Zinc are determined using the standard AOAC (2000) inductively coupled plasma-optical emission spectrometry method (5800 ICP-OES –Agilent, India).

2.5.8. Amylose and amylopectin content

Apparent amylose content was estimated after iodine complexation using the method of Morrison and Laignelet (1983). Amylopectin content was calculated by the difference of total starch minus amylose content.

Amylose content was determined based on simplified colorimetric method & ISO 6647- 2: (2015) with slight modifications. Initially, milled rice samples were ground to fine powder using a disk mill (FFC- 23, NETZSCH India) and sieved (180 μm pore size) using a sieve shaker (VS 100- LABINDIA ANALYTICAL, India). Sieved rice samples were packed in metalized pouches and stored at 4 °C. Prior to the analysis, samples were kept at room temperature for three hours and moisture content was measured using digital moisture analyzer (SHIMADZU-MOC63 u).

A prepared rice flour sample (100.00 ± 0.50 mg) was accurately weighed into a 100 mL conical flask. The sample was moistened with 1.0 mL of 95 % ethanol by gentle shaking. Nine milliliters of 1 N sodium hydroxide solution was then added to the flask, mixed thoroughly, and left overnight. The completely dispersed rice flour solution was transferred to a 100 mL volumetric flask and made up to volume with distilled water to prepare the initial stock solution. An aliquot of 5.0 mL of this stock solution was combined with 1.0 mL of 1 N acetic acid and 2.0 mL of 2 % iodide solution, then diluted to 100 mL. The mixture was stirred and allowed to stand for 20 mins before measuring the absorbance at 620 nm using a colorimeter. A calibration curve was prepared using standard starch solutions containing 0, 20, 40, 60, 80, and 100 % amylose, following the same procedure. The amylose content of the sample was calculated using the standard curve and expressed as a percentage (Jain et al., 2012).

Amylopectin content was calculated using the following Eq. (12). The average amylose content value was taken for the calculation.

$$\text{Amylopectin} = (100 - \text{Amylose } \%) \quad (12)$$

Amylose content and amylopectin content of rice variety were measured in every two weeks for a period of 14 weeks to determine the variations.

2.6. Phytochemical analysis

2.6.1. Sample extract preparation

Each powdered sample (10 g) was extracted for 8 h with 50 mL of acidified (HCl 8 N –0.5:40 mL) methanol in an electrical shaker (Stainless Steel Labsol VDRL Shaker, Labsol Enterprises, India) at 30 °C. The extract was centrifuged at 1000 g for 15 mins and the supernatant was stored in a sealed container at 4 °C until further use for analysis.

2.6.2. Total phenolic content

Total Phenolic Content of the sample was determined using Folin–Ciocalteu method using Gallic acid as standard. 10–100 μL of sample extract is added to distilled water. FCR reagent is added in a 1:10 ratio and is left for 5 mins at 25 °C. Then, 1.2 mL of Na_2CO_3 was added and the final volume was made up to 5 mL with distilled water. The absorbance at 760 nm was taken using a spectrophotometer (Microprocessor UV–VIS Double Beam Spectrophotometer –IR 513 D, INFRA DIGI, India) to determine the total phenolic content in mg/g (Colussi et al., 2014).

2.6.3. Total flavonoid content

Total flavonoid content of Boka saul was determined by the method designed by Zhishen et al., 250 μL of extract and standard quercetin was diluted with 1.25 mL of distilled water. To it, 75 μL of 5 % $NaNO_2$ was added and incubated at room temperature for 6 mins. After incubation, 150 μL of 10 % $AlCl_3$ was added and again kept for incubation for 5 mins and 0.5 mL of 1 M NaOH was added and the mixture solution was vortexes and the absorbance was taken immediately at 510 nm against blank (Reddy et al., 2016).

2.6.4. Fourier transform infra red (FTIR) spectroscopy analysis

The prepared samples were subjected to FTIR (FT/IR- 4600, JASCO, India) analysis to confirm the functional groups. In transmittance mode, in a particular scanning range of 4000–5000 cm^{-1} the sample along with potassium bromide (KBr) is given in the sample collection area. After specific number of scans (1–20 scans) the spectrum of the sample is obtained which is then compared with the standard peaks available (Md Noh et al., 2020).

2.7. Statistical analysis

The obtained results were analyzed using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test. The values were denoted as mean ± SD.

3. Results and discussion

3.1. Proximate analysis

3.1.1. Estimation of macronutrients of Boka Saul rice

The proximate analysis of Boka saul rice revealed the percentage of macronutrients present in it. Carbohydrate is the major constituent, contributing to 79.43 ± 0.42 g/100g of rice. Longvah et.al. (2021) reported 70.7, 68.06 and 72.27 % of carbohydrates in Assam rice varieties like Boka Joha, Konoklata and Basundara respectively. The highest carbohydrate content of 81.00 ± 2.88 % was found in Kichali Samba

followed by other rice varieties, 74.43 ± 1.98 % in Poongar followed by Navara (76.51 ± 0.86 %), Mapillai Samba (76.81 ± 1.42 %), and Karunguruvai (78.10 ± 2.29 %) (Devraj et al., 2020). The subsequent macronutrient includes protein which constitute to about 6.92 ± 0.38 g per 100 g of BS rice. Meera et al. (2019) had reported the protein content of few traditional rice varieties like kattuyanam, red kavuni, black kavuni, karudan samba and found to have 12.64, 11.81, 13.2 and 10.98 % respectively. Salem samba had 7.5 % of protein which was 0.7 % higher than normal milled rice (Ravi et al., 2012). The highest protein content of 9.61 ± 0.11 % was found in Navara followed by Mapillai Samba (9.16 ± 0.41 %), Poongar (9.07 ± 0.26 %), and Karunguruvai (8.46 ± 0.30 %) in comparison with white rice varieties which showed the least protein content of 6.86 ± 0.32 % in Basmati rice (Devraj et al., 2020). Also, the rice namely Rice berry, Phitsanulok, Brown jasmine and Red jasmine of Thailand had estimated the crude protein value of about 6.51–7.27 % Kraithong et al., 2017. Lahkar et al., 2019 investigated 22 different aromatic rice varieties and reported highest protein value of 17.3 % in the variety Krishna Joha.

Muttagi and Ravindra (2020) studied the chemical and nutritional composition of 20 traditional rice varieites of Karnataka and reported highest fat percentage of 2.92 in Rajmudi and similar percentage of fat (2.9 %) was reported by Kariyawasam et al. (2016) in Unakola samba a Sri Lanka traditional variety. Assam traditional variety Boka Saul comparatively yielded 0.57 % of fat making it much more nutritious than the other varieties.

One rice variety from Karnataka, Malgudi Sanna has total fibre content of 10.25 %, a bit higher compared to Boka Saul (8.9 %) (Muttagi & Ravindra, 2020). Few rice varieties from Sri Lanka yielded very low (0.9 –1.1 %) range of total fibre compared to Boka Saul (Kariyawasam et al., 2016) (Table 1).

3.1.2. Estimation of micronutrients of Boka Saul rice

The proximate analysis of Boka saul rice (Fresh weight) reveals the quantity of micronutrients present in the rice in which potassium was found to be present majorly of about 255.33 ± 1.53 mg/ 100 g of rice, phosphorous constitute about 116.00 ± 1.73 mg/ 100 g of rice, magnesium about 30.33 ± 2.52 mg/ 100 g of rice, calcium and zinc constitute about 7.43 ± 0.90 mg and 1.33 ± 0.21 mg/ 100 g of rice. The mineral contents of BS and a few traditional rice varieties of Kerala were found to be similar (Pillai et al., 2020). The mineral constituents such as phosphorous 230.00 ± 5.00 mg/100 g of rice, calcium 20.00 ± 3.00 mg/100 g of rice and zinc 3.00 ± 1.00 mg/100 g of rice were found to be in Karnataka rice varieties (Muttagi & Ravindra, 2020) (Table 1).

The ash content of Boka Saul (4.2 %) was found to be similar to Kunkuni Joha of Karnataka (Lahkar et al., 2019). The moisture content of BS rice was found to be 12.66 ± 0.45g/100 g of rice (Table 2). Similarly, there was a diverse level of moisture content 8.00 ± 2.00 g/100 g was found to be in various Karnataka traditional rice varieties (Muttagi & Ravindra, 2020).

Table 1
Macronutrients and micronutrients of Boka Saul.

Nutrients value (per 100 g)	
Carbohydrate (g)	79.43 ± 0.42
Protein (g)	6.92 ± 0.38
Fat (g)	0.57 ± 0.02
Fiber content (g)	8.86 ± 0.22
Potassium (mg)	255.33 ± 1.53
Phosphorus (mg)	116.00 ± 1.73
Magnesium (mg)	30.33 ± 2.52
Zinc (mg)	1.33 ± 0.21
Calcium (mg)	7.43 ± 0.90

Table 2
Ash and Moisture content of Boka Saul.

Ash and moisture content of Boka Saul (g / 100g)	
Ash Content	4.20 ± 0.13
Moisture Content	12.66 ± 0.45

3.2. Physical characteristics of Boka Saul rice

3.2.1. L/B ratio

From the result it was found that Boka Saul rice length measured 550.00 ± 0.05 mm and the breadth was found to be 250.00 ± 0.05 mm and has L/B ratio of 2.2. Also, similar result of BS was found to be in tandem with salem samba (2.5) which infers that these L/B ratio range rice falls under the category of medium slender grain (Ravi et al., 2012) (Table 3).

3.2.2. 1000 grain weight

The thousand-grain weight of Boka Saul was determined to be 24.7 g. From the study of Luh 1980, the 1000 grain weight values below 20 g indicate the presence of immature, damaged or unfilled grains. Thus, BS rice could be considered as less damaged and more matured grains doesn't undergo much damage during milling and other processes (Table 3).

3.2.3. Bulk density and true density

The bulk density and true density of the BS rice were 734.3 kg/m^3 and 1574.57 kg/m^3 (Table 3). Ravi et al., (2012) estimated the bulk density of Salem samba to be 575.45 kg/m^3. According to Bhattacharya et al., (1972), bulk density is related to the kernel shape, (i.e.) L:B ratio, the more round the kernel the greater the bulk density and since salem samba was classified under medium slender variety the bulk density can be claimed to be slightly low. Correa et al. (2007), noticed the increase in bulk density when the volume is reduced by processing, probably due to taking out the husk and by milling because the volume reduction is higher than the mass reduction assuming that the material taken out in each unity operation is of lower specific gravity.

3.2.4. Porosity

The porosity of the rice was said to be 53.33 % (Table 3), similar results were observed in the rice namely; mapillai samba, karunguruvai, sonamasuri (Devraj et al., 2020). The porosity of both traditional and white rice varieties depicted in Table 1, indicated the highest porosity of 66.58 ± 2.80 % in Basmati rice and the lowest porosity of 50.82 ± 1.32 % in Sona Masuri, respectively. In the case of traditional rice varieties, the highest porosity of 62.38 ± 0.75 % was noted in Poongar with the lowest porosity of 50.94 ± 1.84 % in Karunguruvai. The range of porosity values observed can be attributed to the characteristics of bulk and true density, which are influenced by various factors such as grain dimensions and other relevant aspects. (Qiu et al., 2015).

3.2.5. Colour value

The whiteness of rice was found to be 22.86 % and the transparency percentage was 0.95 (Table 3). The whiteness % for Salem samba rice

Table 3
Physical characteristics of Boka Saul.

Physical Characteristics	
Description	Values
L / B Ratio	2.2
1000 Grain weight (g)	24.7
Bulk Density (kg/m^3)	734.3
True Density (kg/m^3)	1574.57
Porosity %	53.33
Colour Value (Whiteness)%	22.86

was 22.7 %. The whiteness percentage of Salem samba (40.0) on milling is similar to the standard USDA value for raw polished rice (43.7 %).

3.3. Physicochemical characteristics

The gelatinization temperature value, a precise indicator of the starch gelatinization point in rice grains, is essential for evaluating cooking quality and texture, making it a critical parameter for rice breeders and processors. This is particularly relevant for Boka Saul riceknown for its unique gelatinization properties. Boka Saul, which can be consumed without cooking, relies heavily on its gelatinization temperature, distinguishing it from other rice varieties and contributing to its unique culinary and cultural significance. The Boka Saul rice is said to have intermediate gel consistency of about 25.5 mm and the gelatinization temperature was estimated to be 69.54 °C with an alkali score value of 5 (Table 4). Similar gel consistency result was observed in salem samba rice (25.43 mm) and similar alkali spreading value were noted in Dangor Joha, Nepali Joha and IR64 (Lahkar et al., 2019). The gelatinization temperature value help in cooking time determination and it depends on coarseness of the grains (Khare et al., 2014). Joha land races showed medium disintegration resulting in intermediate alkali digestion value and hence is classified under intermediate gelatinization temperature which is a highly desirable for grain quality (Bhonsle, 2010). The water uptake ratio of BS rice was determined to be 0.88 (Table 4) and in salem samba rice found to be 1.42. During cooking, the starch content of the milled rice kernel absorbs moisture and swells due to its gelatinization.

3.4. Cooking characteristics

The length and breadth of cooked rice was found to be 940.00 ± 0.07 mm and 340.00 ± 0.05 mm respectively (Table 5). The optimum cooking time of BS rice has been identified to be 20 mins at 100 °C and 40–50 mins in normal water (25 °C) (Table 5). During cooking, the starch content of the milled rice kernel absorbs moisture and swells due to its gelatinization. The maximum cooking time of up to 50.18 ± 1.44 min was noted in Karunguruvai with a minimum of 40.76 ± 0.40 min in the case of Navara. In the case of white rice varieties, Basmati took a minimum cooking time of 16.75 ± 0.75 min with a maximum of 28.96 ± 1.02 min in Kichali Samba. This difference in cooking time was mainly due to the presence of lipids, proteins, and pigments in traditional rice varieties which requires more time for cooking and the obtained results were in favor with the proceedings of Rosniyana et al. (2004). The kernel elongation ratio (KER) was estimated to be 0.709 (Table 5). It was observed highest KER in basmati rice of 2.89 ± 0.15 whereas in Sonamasuri and kichali samba it was reported as 2.06 ± 0.57 and 1.89 ± 0.10 respectively (Devraj et al., 2020). The decrease in KER could potentially be attributed to the existence of an outer layer comprising pigments and other nutrient components that stimulate volume expansion rather than elongation of the grains (Gujral & Kumar 2003).

3.5. Estimation of amylose and amylopectin content

Amylose and amylopectin analysis showed the presence of 21.63 ± 0.74 g of amylose in 100 g of rice and the amylopectin content was found to be 78.40 ± 0.70 g per 100 g of rice (Table 5). During cooking, rice granules absorb water and swell to much more than their original size. This granule expansion causes ruptures in the grain, leading to a decrease in the hardness. Furthermore, there is well-documented evidence that amylose and amylopectin molecules leach into the surrounding water above the gelatinization temperature (Cuevas et al., 2010). These leached amylose and amylopectin molecules are likely to contribute to the stickiness of cooked rice (Leelayuthsoontorn & Thipayarat, 2006).

The traditional aromatic rice varieties were characterized by a low amylose content. Rice with high amylose content does not result in sticky rice; instead, it expands and becomes firm upon cooling. Rice with moderate amylose content generally has a fluffy texture. On the other hand, rice with low amylose content produces sticky rice that appears shiny, does not expand significantly, and remains cohesive even after cooling. (Lahkar et, al.,2019).

The ratio between amylose and amylopectin and their respective structures have a significant influence on the physicochemical, thermal, functional, and rheological properties of starch. Moreover, this ratio also plays a role in determining the glycemic response associated with foods containing starch. (Muttagi & Ravindra, 2020).

Table 4
Physiochemical characteristics of Boka Saul.

Physicochemical Characteristics Characteristics	Value
Gel Consistency (mm)	25.5
Gelatinization Temperature (°C)	69.54
Alkali Spreading Value	5
Water uptake ratio	0.88

Table 5
Cooking characteristics of Boka Saul.

Cooking Characteristics	
Length of cooked rice (mm)	900 ± 0.07mm
Breadth of cooked rice (mm)	300 ± 0.05mm
Cooking time	20 mins at 100 °C and 40–50 mins in normal water (25 °C)
Kernel Elongation ratio	0.709
Amylose	21.63 ± 0.74 g / 100 g
Amylopectin	78.40 ± 0.70 g / 100 g

3.6. Phytochemical analysis

The non-nutritive plant chemicals that have a protective or disease-preventing property are known as phytochemicals. The phytochemical compounds are mainly accumulated in the pericarp and bran of the rice kernel. They prevent oxidative damage in foods and also have a wide spectrum of beneficial biological activities (RathnaPriya et, al.,2019).

3.6.1. Total phenolic content

The Total phenolic content present in BS rice was estimated to be 4.60 ± 0.20 mg/ 100 g rice. Meera et al. (2019) observed that the phenolic content in the range of 1.91–5.99 mg GAE/g of various rice. Phenolic compounds plays a vital role in combating chronic diseases such as cardiovascular diseases and type II diabetes. Phenols are the major contributors in determining the antioxidant potential of cereal grains. Cultivation techniques, growing conditions, genotype, degree of maturity, extraction, storage and ripening process could impact phenolic constituents of rice (Meera et al., 2019). Also, total phenolic content may vary because of moisture content.

3.6.2. Total flavonoid content

Flavonoids can counteract cancer cell growth, as well as promote antioxidant, anti-inflammatory activities (Rajendran et al., 2018). The total flavonoid content of BS rice was found to be 143.25 ± 2.08 mg / 100 g rice. The BS rice found to possess high flavonoid content when compared to certain Assam varieties (7.59 –105.16 mg GAE) (Lahkar et, al.,2019). Also, BS rice showed increased flavonoid content among ten traditional rice varieties (2.2 –7.18 mg / 100g) as investigated by Rajendran et al. (2018) and among seven rice varieties (30 –78 mg / g) explored by Devraj et al. (2020).

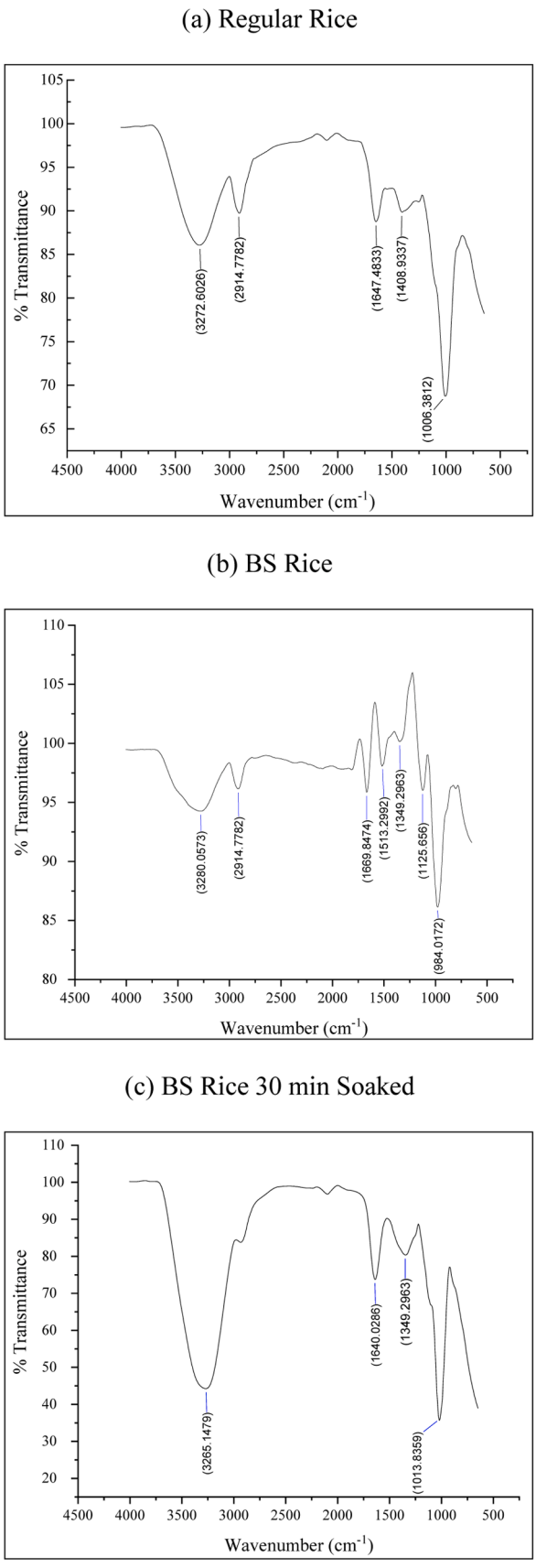

Fig. 1. FTIR spectrum of a) Regular rice, b) BS rice, c) BS rice after 30mins soaked in water.

Table 6a
FTIR table of a) Regular rice, b) BS rice, c) BS rice after 30mins soaked in water a) REGULAR RICE.

Peak no.	Wavenumber (cm^{-1})	Functional Groups
1	**3280**	RC═C—H (#C—H stretch), RCO—OH dimer OH, C = C—CO—OH dimer OH, ArO—H bonded, ArO- H-bonded
2	**2929**	RCH_2CH_3 CH stretch, RCO—OH dimer OH, C = C—CO—OH dimer OH, -CH_2-
3	**1640**	3-ring C = C stretch, $RCONH_2$, NH out of plane, RNH_2 NH_2 in plane bend, C = N
4	**1543**	RCONHR NH out of plane, N-O nitro comp. Alif. Nitro, N = O nitroso, N-O nitro comp, N-O asymmetrical. stretch
5	**1341**	R-F C-F stretch, Ar_2NH Ar-N stretch, S = O sulfone 1, S = O sulfonic acid, N-O nitro comp, N-O symmetrical stretch
6	**1148**	R-F C-F stretch, R-O-R C-O stretch, RNH_2 C-N stretch, R_2NH C-N, C = S thiocarbonyl, S = O sulfone 2, P-H phosphine P-H bending, P = O phosphine oxide, P = O phosphate, RCO-OH, C-O stretch, RCOOR C-O stretch
7	**998**	P-H phosphine, P-H bending, P-OR esters
8	**857**	1,3,5-trisub, C-H out of plane, 1,2,4,5-tetrasub, C-H out of plane, S-OR esters, RNH_2, R_2NH N-H wag amines

3.7. FTIR analysis

The regular rice and BS rice showed peaks at 3280 cm^{-1} and 3266 cm^{-1} (BS rice after 30 mins soaked in water), which is attributed to the vibration of OH stretching. This peak pronounced curve in BS rice after 30 mins soaked in water. Absorption peaks within this range are a frequent occurrence in polysaccharides, owing to the O—H bonds found in the glucopyranose rings (Indira et al., 2022). Also, at 2929 cm^{-1}, peak which can be attributed to CH bond stretching has been observed. There was a minor displacement observed at 2922 cm^{-1} in BS rice and 2937 cm^{-1} in BS rice soaked after 30 mins.

A new small peak (2109 cm^{-1}) has been observed in BS rice soaked after 30 mins which contributes to NH stretching. The starches of the BS, BS soaked in water and the regular rice showed the introduction of alkene group (C = C), being verified by the band at 1640 cm^{-1} (Fig. 1) with a slight modification noticed in BS rice (1662 cm^{-1}). The decrease in the peak of BS (Fig. 1b) at 1535 cm^{-1} when compared to regular rice (Fig. 1a.) (Table 6a) at 1543 cm^{-1} represents the presence of aromatic compounds in BS rice and also no peak was identified when the BS has been soaked for 30 mins for that particular intensity. However, variations in peak intensities and shifts are observed, particularly after soaking Boka Saul rice in water. This includes changes in the intensity of peaks related to dimer OH groups and C—O stretches, reflecting alterations in hydrogen bonding and hydration states due to water absorption. These findings align with previous studies indicating the influence of water content on rice grain structure and chemistry (Indhira et al., 2022; Soltani et al., 2023).

Understanding the influence of water content on rice grain structure and chemistry is essential for future research aiming to adapt this variety for product development (Smith et al., 2020; Johnson & Brown, 2019). By elucidating the molecular dynamics underlying these changes, researchers can optimize processing techniques and tailor product formulations to enhance the sensory attributes, nutritional content, and shelf-life stability of rice-based products. Additionally, insights gained from this study contribute to broader efforts in agricultural science aimed at improving crop resilience, sustainability, and market competitiveness (Lee et al., 2018).

The peaks 1341 cm^{-1} in the Fig. 1a and 1c corresponds to the sulphur-oxy compounds with sulphur ester and sulphonic acid structures which is absent in BS rice (Fig. 1b) (Table 6b). The peak of 1148 cm^{-1} of regular rice, BS and BS soaked after 30 mins shows C-F bond stretching

Table 6b
FTIR table of a) Regular rice, b) BS rice, c) BS rice after 30mins soaked in water **b) BOKA SAUL**.

Peak no.	Wavenumber (cm^{-1})	Functional Groups
1	**3280**	RC═C-H (#C-H stretch), RCO-OH dimer OH, C = C-CO OH dimer OH, ArO-H bonded, ArO- H-bonded
2	**2922**	RCH_2CH_3 CH stretch, RCO-OH dimer OH, C = C-CO-OH dimer OH, -CH2-
3	**1647**	$R_2C═CH_2$ C = C stretch, 6-ring C = C stretch, 7-ring C = C stretch, $RCONH_2$ C = O stretch (H-bond), RCONHR C = O stretch (H-bond), R $CONR_2$ C = O stretch, C = N C = N, conj. dienes
4	**1465**	RCH_2CH_3 CH_2 and CH_3, -CH_2- -CH2-, C-C in ring, Ar C-C stretch
5	**1408**	S = O sulfate, S = O sulfate ester, C-C in ring, Ar C-C stretch
6	**1237**	R-F C-F stretch, Ar-O-R C-O stretch, P-H phosphine P-H bending, P = O phosphonate P = O phosphonate, P = O phosphoramide P = O phosphoramide, N-O amine oxide, N-O aromatic, RCO-OH C-O stretch, RCOOR C-O stretch, CH_2X C-H wag (-CH_2X)
7	**991**	$RCH═CH_2$ =CH out of plane, P-H phosphine, P-H bending, P-OR esters, P-OR esters
8	–	

and P-H bending observed in Fig. 1a, 1b and 1c (Table 6c), P-H bending and S = O sulphonate indicates the presence of heteroxy compounds in the rice sample. The presence of common inorganic ions can be justified with the peaks 996 cm^{-1}, 984 cm^{-1} and 1006 cm^{-1}. There is a significant increase (931 cm^{-1}) in the peaks of the BS and BS rice that has been soaked for 30 mins on comparison with the regular rice.

4. Conclusion

In conclusion, the proximate analysis of Boka Saul rice revealed valuable insights into its nutritional composition. Carbohydrates are the predominant macronutrient, followed by protein, fat, and fiber. The rice also contains essential micronutrients such as potassium, phosphorus, magnesium, calcium, and zinc, making it a nutritionally superior choice compared to traditional rice varieties. These findings are crucial for promoting Boka Saul rice consumption and raising awareness about its nutritional benefits. Beyond macronutrients and micronutrients, the analysis unveiled specific characteristics of Boka Saul rice. Its amylose content is relatively low at 21.6 g/100 g, making it suitable for sticky rice dishes. In contrast, the amylopectin content is high at 78.4 g/100 g, imparting a gelatinous and sticky texture ideal for dishes like pudding and risotto. This information is valuable for food scientists and nutritionists, enabling the formulation of healthier products. Additionally, consumers can make informed choices about their dietary habits based on this comprehensive analysis of Boka Saul rice. Further research on this variety may lead to innovative food products with enhanced nutritional value, contributing to the advancement of nutritious food options.

Table 6c
FTIR table of a) Regular rice, b) BS rice, c) BS rice after 30mins soaked in water c) BOKA SAUL SOAKED AFTER 30 MINUTES.

Peak no.	Wavenumber (cm^{-1})	Functional Groups
1	**3265 (deep bend)**	RCO-OH dimer OH, C=C-CO-OH dimer OH, ArO-H bonded, ArO- H-bonded
2	**2937**	RCH_2CH_3 CH stretch, RCO-OH dimer OH, C=C-CO-OH dimer OH
3	**1640**	3-ring C=C stretch, $RCONH_2$ NH out of plane, RNH_2 NH_2 in plane bend, C = N C = N
4	–	–
5	**1341**	R-F C-F stretch, Ar_2NH, Ar-N stretch, S = O sulfone S = O sulfone 1, S = O sulfonic acid, N-O nitro compound, N-O symmetrical stretch
6	**1148**	R-F C-F stretch, R-O-R C-O stretch, RNH_2 C-N stretch, R_2NH C-N stretch, C = S thiocarbonyl, S = O sulfone, S = O sulfone 2, P-H phosphine, P-H bending, P = O phosphine oxide, P = O phosphate, RCO-OH C-O stretch, RCOOR C-O stretch
7	**1006**	R-F C-F stretch, P-H phosphine, P-H bending, P-OR esters, P-OR esters, Si-OR, Si-OR (broad), RCO-OH, C-O stretch, RCOOR, C-O stretch
8	**931**	P-OR esters, P-OR esters, =NOH oxime =NOH (N-O), RCO-OH, RCOOH O-H bend

CRediT authorship contribution statement

Udayamathi Mohan: Writing – original draft, Methodology, Conceptualization. **Shamitha Jayakumar:** Investigation, Formal analysis. **Sneha Nair Vasudevan:** Methodology, Formal analysis. **Rajamathanghi Rangaprabu:** Writing – review & editing, Data curation. **Hema MadhuriVeera:** Writing – review & editing, Data curation. **Yesodhaa Ravi:** Writing – original draft, Formal analysis, Data curation. **A Saravanaraj:** Validation. **Nadeem Siddiqui:** Validation. **Yuvaraj Dinakarkumar:** Validation, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors wish to thank the management of Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Avadi, Chennai, Tamil Nadu, India, Vels Institute of Science, Technology and Advanced Studies (VISTAS), Pallavaram, Chennai, Tamil Nadu, India and Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswram, Green Fields 522502, Andhra Pradesh, India for providing the necessary facilities and support.

Data availability

Data will be made available on request.

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