Impact of parboiling on physicochemical and nutritional properties of selected rice varieties

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DECLARATION BY STUDENT

I hereby declare that the data presented in this dissertation report entitled, **"Impact of parboiling on physicochemical and Nutritional properties of selected rice varieties"** is based on the results of investigations carried out by me in Botany Discipline at the School of Biological Sciences & Biotechnology (SBSB), Goa University under the supervision Dr. Siddhi K. Jalmi and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University will be not be responsible for the correctness of observations/ experimental or other findings given the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report **"Impact of parboiling on physicochemical and Nutritional properties of selected rice varieties"** is a bonafide work carried out by **Mr. Rupesh Ratnakar Velip** under my supervision in partial fulfilment of the requirements for the award of the degree of Master of Science in the Botany Discipline at the School of Biological Sciences & Biotechnology (SBSB), Goa University.

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PREFACE

In the amazing world, the journey of food from farm to table involves various processes shaping its final quality. In rice one of the most important post harvesting method is Parboiling. In this study we have studied how parboiling technique affect the physicochemical properties of rice and what is the best parboiling method that can be adopted by the farmer. This preface introduces our exploration into how parboiling influences rice, and its science and implications.

Rice, consider for its versatility and cultural importance, undergoes a transformative journey from fields to plates. Parboiling, practiced for centuries, enhances rice texture, taste, and nutrition. However, it's some of most important effects remain underexplored from Goan rice stain. Through meticulous research, I aim to uncover how parboiling impacts rice characteristics. By subjecting specific rice varieties to controlled parboiling, I seek to understand changes in physical, chemical, cooking traits and alongside an assessment of nutritional parameters including total crude carbohydrates, total protein content, reducing sugar levels, and total anthocyanin content.

My findings not only advance rice processing science but also inform agricultural practices, food processing, and dietary choices. I extend gratitude to farmers, Botany Discipline, Dr. Siddhi k. Jalmi and others and readers for their contributions. May this exploration deepen our understanding of food systems, beauty and their connection to humanity and nature. Enjoy the journey of food world!

Rupesh R. Velip

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Rupesh R. Velip

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ABBREVIATION

Abbreviation	Entity
%	Percent
>	Greater Than
AF	Assgo Farmer Parboiled
APBD	Assgo Parboiled Direct Method
APBID	Assgo Parboiled Indirect Method
ARR	Assgo Raw Rice
°C	Celsius
DOM	Degree of Milling
Fig.	Figure
g	Grams
GC	Gel Consistency
GT	Gelatinization Temperature
HCl	Hydrochloric Acid
HYV	High Yielding Variety
ICAR	Indian Council of Agriculture Research
JaPBD	Jaya Parboiled Direct Method
JaPBID	Jaya Parboiled Indirect Method
JaRR	Jaya Raw Rice
JyPBD	Jyoti Parboiled Direct Method
JyPBID	Jyoti Parboiled Indirect Method
JyRR	Jyoti Raw Rice
kg	Kilogram

Km	Kilometre
KPBD	Korgut Parboiled Direct Method
KPBID	Korgut Parboiled Indirect Method
KRR	Korgut Raw Rice
LV	Local Variety
mg	Milligrams
mL	Millilitre
Mm	Millimetre
PBD	Parboiled Direct Method
PBID	Parboiled Indirect Method
RR	Raw Rice
TAC	Total Anthocyanin Content (mg equivalent cyanidin-3-O-glucoside per g)
TCC	Total Carbohydrates Content
TPC	Total Protein Content
TRSC	Total Reducing Sugar Content

ABSTRACT

Parboiling (PB), an age-old rice processing technique, was examined in South Goa district to understand its impact on rice quality. Traditional parboiling methods, namely the indirect method (PBID) with soaking and the direct method (PBD) without soaking, were studied. Physicochemical characteristics were assessed for white variety Jaya (Control) and brown varieties Jyoti, Assgo, and Korgut across Raw rice (RR), PBD, and PBID treatments. Results revealed significant varietal differences across treatments. Assgo showed the highest Degree of Milling (DOM) in PBD and Korgut in PBID, whereas it was lowest in Jaya in RR. Korgut showed increased anthocyanin content in PBID, while Jaya showed decreased under PBD. Jaya exhibited superior cooking characteristics, with high elongation and expansion in PBID. However, Assgo displayed inadequate cooking traits, with low elongation and expansion in PBID. Both parboiled methods yielded intermediate Alkali Spreading value (AVS) and Gelatinization Temperature (GT) in Assgo and Korgut. Highest gel consistency (GC) recorded in Jyoti in PBD and lowest in Jaya under RR. Total Anthocyanin Content (TAC) was increased in Assgo under RR and Total Carbohydrate Content (TCC) increased in all varieties under PBID, with Jaya recorded as the highest and lowest in Korgut under RR. Total Protein Content (TPC) decreases with parboiling and the lowest is found in Korgut PBD, where it shows an increase in Jaya under RR, while Jaya, Jyoti, and Korgut had the lowest in RR. In this study, significant differences were observed across all treatments, highlighting the need for further research on the parboiling process. PBID showed a positive impact on physicochemical properties compared to PBD and RR. Jaya and local varieties displayed superior effects on rice quality. This study can inform farmers and policymakers on adapting and modifying parboiling methods and promoting local rice varieties.

Key Words: Parboiling; Physico-chemical properties; Grain Quality; Brown rice

CHAPTER 1: INTRODUCTION

1.1. Background

Rice, scientifically known as *Oryza sativa*, belonging to the Poaceae family and is predominantly cultivated in warm climates, particularly in Asia, where it holds immense cultural and economic importance. As a cereal grain, it serves as a primary food source for a significant portion of the world's population, providing carbohydrates, essential nutrients, and energy.

Rice in a global dietary staple assumes pivotal significance in ensuring food security and nutritional well-being, particularly in regions like India (FAO, 2021). India, known as the second-largest producer of rice worldwide, showcases a diverse array of rice varieties that contribute significantly to the nation's agricultural heritage (ICAR, 2019). Goa, located in the western-southern part of India, presents a fascinating, boasting a rich tapestry of indigenous rice varieties that are deeply connected with the cultural fabric of local communities (Local Government Authority of Goa, 2020).

1.1.1. Status of Rice Production

1.1.1.1. India

In India, rice production is of prime importance, with the country being one of the 2nd world's largest producers and consumers of rice. According to 3rd Advance Estimates of Production of Food grains for 2022-23, all India rice production estimate was 135.54 million tonnes. Several states in India, including West Bengal, Uttar Pradesh, Punjab, Andhra Pradesh, and Telangana, are prominent rice-producing regions due to favourable climatic conditions and agricultural practices.

India's also play role in rice exports significantly to the global rice trade, with the country being a major exporter of rice to various international markets (USDA, 2023). Conversely, India also imports rice to meet domestic demand, particularly for specific varieties or during periods of production shortfall (Directorate General of Foreign Trade, Government of India, 2023) shown in **Table 1.1**. The balance between rice exports and imports, based on domestic production levels, international market dynamics, and government policies aimed at ensuring food security.

1.1.1.2. Goa

Rice stands as the primary staple crop in Goa and cultivated across the goa sate with 42,973 hectares, yielding an annual production of 155,818 metric tons. With an average productivity of 3,399 kilograms per hectare, rice farming is practiced in three distinct topographical settings, namely, rainfed uplands or "Morod," rainfed lowlands or "Kher," and coastal saline lands or "Khazans" (Director, ICAR-Central Coastal Agricultural Research Institute, Old Goa).

This cultivation occurs in both the kharif (Sod) and rabi (Vaigon) seasons, with approximately 67% of the area dedicated to kharif and 33% to rabi cultivation. During the rabi season, the average productivity relatively higher to 4,052 kilograms per hectare, compared to 3,781 kilograms per hectare in the kharif season. Despite the higher yields, rice cultivation faces various challenges in Goa. The average landholding size is notably small, with 95% of holdings less than one hectare in size, often fragmented across parcels. This fragmentation poses logistical challenges and hampers efficient farming practices.

South Goa, characterized by its wonderful and beautiful greenery and fertile lands, boasts a rich tradition of rice cultivation. Here, agriculture intertwines with local customs, shaping the rhythm of life in rural communities. The cultivation of traditional rice varieties forms the backbone of agriculture and farming practices, fostering a connection to the land and preserving age-old practices.

Local varieties such as Assgo and Korgut are cherished for their unique flavours, adaptability to local environmental conditions, and cultural significance (Bhonsle & Krishnan, 2010). These traditional rice varieties not only offer diversity in taste and texture but also possess inherent resilience to pests, diseases, and adverse climatic conditions, so preserve the unique genetic character is most important. Their cultivation reflects a deep-rooted relationship between farmers and their land, passed down through generations.

The cultivation of traditional rice varieties intertwines with the practice of parboiling, a method deeply drive into in Goan rice processing. Parboiling, the process of partially boiling rice in the husk, enhances the nutritional profile and shelf life of rice while also imparting a unique aroma and texture (Sujatha et al. 2003). In Goa, parboiling is not purely a technological process but a cultural tradition passed down through generations. The local rice varieties, carefully cultivated in the region's diverse landscapes of south Goa, undergo the parboiling process, further enhancing their nutritional richness and culinary appeal.

Scientifically, the diversity in topographical settings for rice cultivation in south Goa provides unique environments for studying the adaptability of different rice varieties to varying soil and water conditions. Additionally, the contrasting productivity levels between the kharif and rabi seasons offer insights into the seasonal dynamics of rice growth and the factors influencing yield fluctuations.

1.1.3. Parboiling and Traditional Methods

1.1.3.1.Parboiling History, Process & Benefits

Parboiling is the process of partially boiling rice in the husk, has a rich history dating back thousands of years. Its origins can be traced to ancient civilizations in regions such as Asia and Africa, where it served as a method of food preservation and enhancement of nutritional value Historical records suggest that parboiling was practiced in ancient India as early as 2000 BCE (Kar et al., 1999). In India, this technique was primarily used for processing rice, a staple crop in the region. Parboiling involved soaking the rice in water and then subjecting it to partial boiling, often in large pots or vessels. This process not only helped in cleaning the rice but also led to the gelatinization of the starches in the grains, making them more digestible. Additionally, the parboiling facilitated the retention of certain nutrients, particularly vitamins and minerals, in the rice grains, thus enhancing their nutritional value (Choudhury, 2006).

Over time, parboiling spread to other parts of Asia, including Southeast Asia and China, where it became an integral part of rice processing techniques. Similarly, in Africa, particularly in regions such as West Africa and the Sahel, parboiling emerged as a traditional method of rice processing among various ethnic groups and also improved with the time. Here, parboiling was often combined with sun-drying to further enhance the quality and storability of the rice (Roy, 2008).

The practice of parboiling continued through the centuries, evolving with advancements in technology and agricultural practices. In the modern era, parboiling has become a standardized process in rice milling industries worldwide (Madramootoo & Broughton, 1990). With the advent of mechanization and industrialization, parboiling techniques have been refined and optimized for efficiency and quality control. Today, parboiled rice is widely consumed across the globe and is valued for its nutritional benefits, extended shelf life, and versatility in cooking. Its historical significance as a traditional food processing method underscores its enduring importance in culinary traditions and agricultural practices.

Parboiling is a crucial step in rice processing, involves several distinct stages. Initially, the raw rice grains are cleaned to remove impurities and debris. Then, the cleaned rice is soaked in water, allowing for hydration and swelling of the grains. Following soaking, the rice undergoes a partial boiling process, typically conducted under controlled temperature conditions (Lamberts et al., 2006).

During the soaking and boiling process of parboiled rice, with specific temperature conditions induce a series of biochemical and physical changes within the grain kernel structure. The initial soaking phases accelerate water absorption, causing the outer bran layer to swell. Subsequent boiling under controlled temperature conditions initiates gelatinization of the starch granules in the endosperm, resulting in the release of soluble nutrients and other bioactive compounds from the bran into the surrounding starchy matrix which shown in the **Fig. 1.1** (Bhar et al., 2022).

These phenomenon allows for the migration of various nutrients, such as vitamins, minerals, and phytochemicals (Reddy & Chakraverty, 2004**)**, from the bran layer to the endosperm, thereby enriching the overall nutrient profile of the grain. However, it is important to note that during the parboiling process, some of these nutrients may also be subjected to degradation or leaching into the cooking water. This loss of nutrients, albeit minimal, occurs due to factors such as heat exposure, prolonged cooking times, and water-solubility of certain compounds (Brown, 2020).

In comparison to raw rice, which retains its bran layer intact and undergoes minimal processing, parboiled rice may experience a slight reduction in certain nutrients due to the aforementioned factors. However, the nutritional composition of parboiled rice remains highly favourable, with retained levels of essential nutrients and enhanced digestibility. Therefore, while there may be some loss of nutrition during the parboiling process, the resultant product still offers considerable nutritional benefits compared to its raw counterpart.

1.1.3.2. Traditional Relationship of Rice from South-Goa

Indeed, the relationship between parboiling and local rice cultivars is deeply intertwined with the livelihoods of farmers in rice-producing regions like South-Goa. Parboiling, often practiced using traditional methods passed down through generations is not just a processing technique; it's a crucial aspect of the local agricultural economy and community life.

For farmers cultivating traditional rice varieties, parboiling offers a means of adding value to their produce. By employing age-old techniques to parboil their harvest, farmers transform raw paddy into a product with enhanced nutritional value and unique sensory attributes. This added value translates into increased market opportunities and better returns for farmers, thereby contributing to the economic viability of rice cultivation.

Moreover, the practice of parboiling reinforces the cultural significance of local rice cultivars within the community. As farmers engage in the meticulous process of parboiling, they honour the traditions and knowledge passed down through generations, preserving a cultural heritage deeply rooted in the land.

1.2. Scope and Hypotheses

Reflecting on the significance of parboiling in South Goa's rice cultivation prompts fundamental inquiries regarding its traditional methods' nutritional implications and the imperative of studying and conserving these indigenous practices amid contemporary agricultural paradigms. Hypothesizing, we posit that traditional parboiling techniques with local rice, augment the nutritional composition of rice through processes such as enhanced bioavailability of micronutrients and preservation of phyto-chemicals.

Moreover, preserving these local procedures amidst modern agricultural practices is deemed crucial for sustaining biodiversity, preserving cultural heritage, and fostering food security. These traditional methods, honed over generations, not only contribute to the nutritional richness of rice but also foster a deeper connection to local ecosystems and cultural identity. Furthermore, exploring the intricate interplay between traditional methods, local rice varieties, and nutritional attributes may not only provide insights into sustainable agricultural practices but also offer pathways for addressing global challenges such as malnutrition and food insecurity. As such, investigating and preserving traditional parboiling methods in South Goa stand as integral steps towards achieving holistic and resilient agricultural systems that benefit both local communities and the broader global community.

1.3. Aim And Objectives

Thus, the entire study focuses on the two objectives:

1. **Examine the current status of native rice varieties from South Goa.**
2. **Study the impact of Parboiling on Physicochemical and Nutritional Properties of selected rice varieties.**

CHAPTER 2: LITERATURE REVIEW

2.1. Current Status of Rice Varieties

TOI (article), Jun 6, 2012, 02:39 IST, had published research paper by Goa University's Department of Botany highlights 28 traditional rice varieties unique to the region, some suitable for saline areas like *Khazan* lands. Authors Prof. S. Krishnan and Dr. Shilpa Bhonsle aim to promote these varieties over chemically altered ones. Out of 50 documented varieties, 28 are indigenous to Goa. Challenges faced by farmers include low profits and lack of technical knowledge. The paper suggests using indigenous varieties for biotechnological research to improve yield and quality. It also documents physical, chemical, and cooking characteristics of traditional rice varieties, emphasizing their importance for ecological balance and food security.

Ayamdoo et al., (2013), had conducted preliminary survey in northern Ghana aimed to understand processors' understanding of parboiling principles and its effects. Results showed that processors, mainly women with limited education, were unaware of parboiling nutritional impact but recognized its flavour enhancement and practical benefits. Further studies are recommended to assess parboiling nutritional impact, and training for processors on its scientific advantages is advised to improve practices.

Bello et al., (2023), study in Kano State assessed local parboiling practices and constraints. Manual methods with soaking temperatures of 55°C to 70°C were common. Lack of modern technology and understanding were major issues they found. However, potential benefits exist, especially for women, with improved technologies leading to better quality rice and livelihoods.

Roy et al., (2013), evaluated local parboiling processes (vessel, small-boiler, and medium-boiler) through physical monitoring and surveys. Parboiled rice from boiler processes had higher market value but required more initial investment. Boiler processes were less labourintensive and provided better working conditions. Head rice yield was highest for the small-boiler process. Medium-boiler consumed the least energy. Cost analysis showed all processes were economically viable, with the small-boiler being the most attractive economically. Adoption of the medium-boiler process could improve energy consumption and rice market value.

Balbinoti et al., (2018), explores the parboiling process and its significance, considering its physical, nutritional, environmental, and social aspects. It also examines the consumption and health benefits of parboiled rice. Additionally, it presents a pioneering review of new technologies and mathematical modelling for optimization. Bhonsle & Krishnan, (2011), study focuses on the grain quality characteristics of traditionally cultivated salt-tolerant rice varieties in the khazan lands of Goa, India. 10 rice varieties were collected and studied for their physical, chemical, and cooking characteristics. The results showed that varieties Bello, Korgut, Khochro, and Kalo Novan had good grain quality characteristics. The study highlights the potential of these traditional rice varieties for breeding programs and improving grain quality traits.

2.2. Parboiling Processes and Techniques

Dutta et.al., (2014), studied an ancient rice processing technique, enhances rice quality. Assam, India, produces diverse rice varieties, some processed into unique parboiled rice products like Hurum, Komal Chaul, Bhoja chaul, and Sandahguri, with cultural and potential commercial significance. Despite extensive research on parboiled rice, these specialty products and their techniques remain underexplored. The research highlights the need for further research on parboiled rice, focusing on Assam's specialty products, to preserve cultural heritage and explore commercial opportunities. Adnan et al., (2023), focused on producing high-quality parboiled rice from the MRQ 107 variety using Response Surface Methodology. Results indicated that selected parameters consistently yielded a milling percentage of 69-70% and Head Rice Yield (HRY) of 84%-97%.

Bhattacharya & Subba Roa, (1966), highlights the critical factors affecting the cooking quality and colour of parboiled rice. The severity of heat treatment during soaking and steaming plays a crucial role. Optimal conditions include soaking at low temperatures and minimal steaming, followed by quick cooling. Discoloration during parboiling primarily results from non-enzymatic browning, influenced by factors such as bran embedding and husk pigment diffusion. The pH of the soaking medium also impacts colour. Further research is needed to fully understand these processes and optimize parboiling techniques for desired rice characteristics.

Sareepuang et al., (2008), examined the effect of soaking temperature on physical, chemical, and cooking properties of parboiled KDML 105 rice. Results indicated that soaking at 50°C for 3 hours prior to steaming and drying significantly improved milling yield, increasing it from 51% in brown rice to 60-80% in parboiled rice. Additionally, the parboiling process led to significant increases in protein, lipid, and ash contents. Overall, soaking at 50°C for 3 hours resulted in the most desirable quality of parboiled rice in terms of nutritional quality and sensory properties.

2.3. Impact of parboiling on rice grains

Han et al., (2016), study explored parboiling impact on milling, physicochemical, and textural properties of medium and long-grain rice after varying germination durations. Parboiling reduced broken grains and whiteness, while increasing γ-aminobutyric acid (GABA), notably after the initial germination phase. It also decreased amylose content and pasting viscosities, with Jupiter rice showing higher viscosities than Wells. Cooked parboiled germinated rice was softer, with Wells maintaining firmer texture compared to Jupiter. Overall, combining parboiling and germination enhanced nutritional and milling properties without compromising texture for both cultivars. Thammapat et al., (2016), examines traditional and alternative parboiling methods' effects on fatty acids and bioactive compounds in glutinous rice. Parboiling increases γ-oryzanol and phenolic acid while reducing vitamin E and polyunsaturated fatty acids. The new process enhances bioactive compounds, but optimization is needed to minimize nutrient loss.

Sujatha et al., (2004), found significant variations in nutritional and physical characteristics among forty-eight rice samples collected from Jaya and Kayame varieties cultivated in Dakshina Kannada across different seasons and stages of parboiling over two years. The analysis revealed differences in carbohydrate, protein, fat, sugar, fibre, amylose content, and physical traits between varieties, seasons, and processing stages. Jaya variety exhibited superior quality across multiple parameters, particularly during the rainy season. Moreover, correlation analysis unveiled significant associations between physicochemical properties and cooking quality within and between varieties, seasons, and parboiling stages.

Islam et al., (2001), effects of different processing conditions on the quality of parboiled rice, focusing on its physical properties and the correlation among various quality indicators. Key physical properties assessed included maximum viscosity, hardness of brown rice, hardness and adhesion of cooked rice, volume expansion ratio, and solid content. By employing a first-order kinetic model, the study successfully predicted how processing conditions influenced maximum viscosity and brown rice hardness, providing insights into the rate of change of quality. Notably, the duration of steaming emerged as a significant factor affecting indicators of cooked rice quality, such as adhesion, volume expansion ratio, and solid content. The study also revealed strong linear correlations between gelatinization property and cooking quality, as well as between adhesion and solid content, suggesting implications for the final product's texture.

Pakuwal & Manandhar, (2021), compared the nutritional quality of different rice varieties, finding Jumli Marsi rice to haves of raw and parboiled paddy rice at various moisture contents. For raw paddy, thousand grain weight, bulk density, and angle of repose increased with moisture content, while true density and porosity decreased. Parboiled paddy exhibited similar trends. Both types showed linear dependency on moisture content. Raw paddy had an average length, breadth, and thickness of 9.81 mm, 2.47 mm, and 1.93 mm, respectively, at 8.4% moisture content. Reddy & Chakraverty, (2006), investigated the physical properties Marsi rice exhibited the highest antioxidant and phenolic content, while TR rice had the highest reducing sugar content. Phytochemical analysis revealed various compounds present in all varieties, with pigmented rice showing higher nutritional components. Jumli Marsi rice stood out for its color and nutritional richness.

Luh & Mickus., (1991), evaluates rice varietal differences, focusing on shape, size, and cooking characteristics. Rice is categorized by length into extra-long, long, medium, and short grains by the FAO. The caryopsis structure, especially in the Indica group, affects suitability for parboiling. Long-grain rice cooks dry and separate, while medium and short grains are moister and stickier. Varietal disparities in amylose content and gelatinizing temperature further distinguish rice types, impacting culinary applications. Understanding these differences aids in optimal rice selection and utilization in food industries.

Manful et al., (2009), provides an overview of parboiled rice production techniques, physicochemical qualities, health benefits, and waste processing methods. Parboiling methods include soaking, steaming, and drying, altering starch structure and increasing nutrient diffusion. Parboiled rice has stable starch, lipids, and protein levels and a low glycemic index, making it suitable for dietary consumption and biomedical use. Effluent from production can be minimized through water conservation and recycling, with treatment options available. However, darker coloration is a drawback of intensive operations. Future research should focus on developing parboiled rice with high resistant starch and improved appearance, while promoting its health benefits and expanding niche markets worldwide.

Parnsakhorn & Noomhorm, (2012), investigated the impact of storage temperature on the physical and chemical properties of Thai brown rice (BR), parboiled brown rice (PB), and parboiled paddy (PP) over six months. Storage at lower temperatures (4°C) slowed down changes in moisture content, water absorption, b-value, and hardness, while storage at higher temperatures (25°C and 37°C) accelerated these changes. After six months, starch granule structure changed in PB and PP stored at higher temperatures, affecting the texture of cooked rice. Short-term storage at temperatures below room temperature is recommended to maintain the quality of parboiled rice.

Peres et al., (2023), demonstrates that parboiling can enhance wild rice quality by increasing anthocyanin content. Parboiling pressure significantly affects bioactive compound accumulation, with intermediate pressures yielding the highest levels. Starch digestibility decreases with increased pressure. Extreme parboiling conditions lead to higher ash, lipid, and phenolic compound contents. However, other parameters like colour, texture, thermal properties, and protein content show no significant differences.

Lamberts et al., (2006), found that during the parboiling process, rice colour changes from white to amber due to various factors. Colour parameters reveal that yellow bran pigments leach out during soaking, with the levels of Maillard precursors (reducing sugars and free amino nitrogen) dependent on soaking temperature and time. Enzymatic formation compensates for long soaking times, but proteolytic activity may not suffice for free amino nitrogen leaching. Enzymatic colour changes during soaking are minimal. Parboiled rice, both brown and milled, appears darker and more red and yellow, with the severity of parboiling conditions influencing the effect. Steaming affects rice colour more significantly than soaking, with changes opposite to those observed during soaking. Maillard type reactions occur during brown rice steaming, confirmed by analyses of furosine levels. Bran pigments diffuse into the endosperm during parboiling, contributing to the colour of parboiled rice.

Parnsakhorn & Noomhorm, (2018), examined the production of parboiled brown rice using Thai rice varieties with varying amylose content. Brown rice was soaked at different temperatures and times, followed by steaming and drying. Physicochemical properties and sensory analysis were conducted. Parboiled brown rice showed intermediate characteristics between milled rice and commercial parboiled paddy, with high acceptance in sensory evaluation. However, some vitamins were lost during the parboiling process. Whereas the Lamberts et al., (2006), study investigated the effects of soaking and steaming in rice parboiling on colour changes and reducing sugar levels. During soaking, red and yellow bran pigments diffused into the endosperm, increasing brightness due to compound migration. Increasing brown rice moisture content (MC) led to higher reducing sugar levels after soaking.

Nath et al., (2022), assessed morphological traits, cooking quality, proximate compositions, phyto-chemical capacity, and mineral contents of ten rice accessions from the Eastern Himalayan zone. Results showed significant variations among accessions in these parameters. Manipuri Black Rice exhibited the highest phyto-chemical capacity and mineral content. Such distinctiveness can aid in market differentiation and support farmer decision-making.

Muttagi et al., (2017), evaluated twenty traditional rice varieties from Karnataka for cooking characteristics and sensory attributes. Varieties showed significant differences in gelatinization temperature, gel consistency, cooking time, water uptake ratio, elongation ratio, volume expansion ratio, and dispersed solids. Organoleptic tests revealed variations in appearance, cohesiveness, tenderness, taste, aroma, and overall acceptability. Rajmudi was the most favoured variety, followed by Salem sanna and Jeerige sanna, while Krishnaleela and Anandi were least favoured. Whereas Islam et al., (2002), found that using a sample size of 200 g, with a 10 mm thick layer of rough rice, yielded favourable quality. Parboiled rice prepared at lower steaming temperatures (80–100°C) exhibited better quality compared to higher temperatures (110 and 120°C). Recommended steaming conditions included temperature-time combinations of 80°C-40 min, 90°C-30 min, and 100°C-20 min. Rice produced under these conditions showed adequate lightness and colour intensity, along with 4.0 to 7.5% higher milling yield and hardness values of 55 to 80 N compared to untreated samples. This proposed parboiling method is expected to be beneficial for both household and commercial production of high-quality parboiled rice.

Bhar et al., (2022), review, suggest that parboiled rice (PBR) may offer better control of postprandial blood glucose (PPBG) levels compared to regular brown rice (BR), benefiting both healthy individuals and those with type 2 diabetes mellitus (T2DM). This is likely due to PBR's higher calcium, selenium, and vitamin B6 content, along with lower phytic acid levels. These findings could have significant implications for global health, especially in regions with high rates of malnutrition and diabetes. Further research is needed to confirm these benefits, but developing a fortified parboiled rice variant could be a promising solution.

Feng et al., (2024), examined the effects of different parboiling times (4-20 min) on the structural and physicochemical properties, cooking quality, and zinc retention ratio of Zn-fortified germinated brown rice. The results showed that longer parboiling times exacerbated the disruption of microstructure and decreased relative crystallinity and enthalpy change. Cooking time was reduced with longer parboiling, improving palatability without significant differences in zinc retention ratio. A parboiling time of 16 minutes was recommended to achieve desired palatability, colour, and zinc content, making parboiling an effective technique for modifying the physical structure and properties of Zn-fortified germinated brown rice.

Doesthale et al., (1979), investigated the impact of milling on the mineral and trace element composition of raw and parboiled rice grain samples from 16 varieties. Varietal, locational, and seasonal differences in the nutrient composition of brown rice were observed. Parboiling itself did not affect the composition of brown rice. However, the degree of milling and the initial concentration of nutrients in the grain determined the magnitude of loss during milling. Parboiling altered the distribution of some nutrients in rice grain, except for zinc, magnesium, and copper. Milling losses for nutrients were significantly lower in parboiled rice compared to raw rice.

Buggenhout et al., (2013), examined how different parboiling conditions impact the extractability and molecular weight distribution of proteins in brown rice. Various soaking and steaming conditions were applied to parboil the rice. Protein extractability was assessed using different extraction media, and size exclusion-high performance liquid chromatography was used to analyze molecular weight distribution. Results showed that protein extractability varied depending on parboiling conditions, with more severe steaming leading to reduced extractability, indicating denser protein networks. Glutelins were particularly affected by severe steaming, undergoing polymerization.

Pal et al., (2018), assessed the changes in chemical content, total phenolic content, and antioxidant capacity of various landrace rice genotypes under parboiling conditions to identify suitable varieties for parboiled rice production. Parboiling reduced fibre content, total phenolic content, and antioxidant capacity in rice grains, while ash and protein content remained unaffected. Medmakham and Gum Leamphea varieties exhibited superior total phenolic content and antioxidant capacity in both brown and parboiled rice. Glam Feang had the highest protein content but lower phenolic content and antioxidant capacity.

David et al., (2020) investigated the impact of parboiling on the nutritional composition and levels of toxic metals in locally produced rice in Nigeria. Results showed that parboiling led to significant increases in ash and fibre contents, while lipids decreased significantly compared to unparboiled rice. Essential amino acids and vitamins were also reduced by parboiling. Moreover, parboiling resulted in significant reductions in aluminium, nickel, chromium, and manganese levels, while cadmium, lead, and arsenic levels increased significantly. These findings suggest that parboiling can alter the nutritional profile and toxic metal content of cooked rice, potentially impacting health.

CHAPTER 3: METHODOLOGY

The present study was carried out for the Master Programme in the Botany Discipline, School of Biological Sciences and Biotechnology (SBSB), Goa University during the period from November 2023 to April 2024. The detailed methods and methodology used for study is presented in this chapter.

3.1. Study Area

South-Goa is one of the two districts from Goa with an area of 1,996 sq.km. South Goa District encompasses the entire southern region of Goa state, bordered by the Arabian Sea to the west, North Goa district to the north, and Uttar Kannada district of Karnataka to the east and south. Geographically, South Goa is situated between the latitudinal parallels of 15°29′32″ N and 14°53′57″ N, and the longitudinal parallels of 73°46′21″ E and 74°20′11″ E. The district spans approximately 86 km from north to south and 40 km from east to west.

Goa, situated within the Konkan region, boasts diverse geographical features comprising hills, lowlands, and plateaus, which collectively shape its distinctive landscape. The Low Lands, stretching approximately 110 km along the coastal areas, epitomize Goa's scenic coastline adorned with numerous beaches. Fertile land characterized by rivers flowing from east to west traverses this region, fostering lush vegetation and dense population clusters.

The Mountainous Region, dominated by the Sahyadri mountain range to the east of South Goa, offers a verdant landscape blanketed by dense forests. Steep peaks such as Chandranath in Paroda, Dudhsagar in Sanguem taluka, and Cormolghant in Canacona taluka define this rugged terrain. Numerous streams and rivers, including the Zuari, Talpona, Sal, and Galgibag, originate from these mountains, enriching the lowlands below. In addition to providing a scenic backdrop, the mountainous region plays a vital role in Goa's economy, with inland waterways facilitating the transportation of mineral ores, including iron, bauxite, and manganese, from mining sites in Sanguem taluka to the Mormugao harbour for export to various international markets.

Goa experiences a hot tropical climate with minimal temperature fluctuations throughout the year. Monsoon season occurs from June to September or sometimes October, bringing heavy rainfall primarily to mountainous regions. From October to January, the climate becomes cooler and more temperate. Rice is the primary crop, thriving in the warm and humid coastal regions. Following the monsoon, crops like chillies and onions are cultivated. Cash crops such as Cashew, Coconut, Mangoes, Areca palm, Kokum, and Jackfruit are also grown, contributing to agricultural diversity and local livelihoods (Official site, South-Goa; https:https://southgoa.nic.in/).

3.2. Collection and Documentation of Rice Varieties from South-Goa

During the study period, the field survey was carried out in all part of South-Goa, for collection of rice varieties and parboiled process and its significance. The traditionally cultivated rice varieties were collected, clean, dried and stored. At the same time parboiled rice also collected and kept for analysis. The high yielding rice variety Jaya had been collected from Agriculture Department of Margao, South-Goa. And all other hybrid and high yielding varieties were dried and store at room temperature.

3.3. Parboiling of selected rice varieties

During the field survey, it was observed that farmers employed two distinct methods for parboiling rice, namely indirect and direct methods. Both traditional processes were utilized in the preparation of samples for subsequent analysis. Samples were pre-cleaned thoroughly to remove the chaffy and other foreign particles including inorganic (sand, metallic pieces, gravel, dirt, etc) and organic matters (husk, chaff, weeds seeds & etc).

3.3.1 Direct Method of parboiling:

A 1 kg clean and dry sample of rice was subjected to the parboiling process using electrical induction until the husks were opened. Subsequently, the parboiled rice was left to sundry for duration of 3-4 hr, during which periodic stirring was performed to ensure uniform drying. Following sun drying, the rice was air-dried for 24-48 hr to allow for further hardening of the rice grains. This methodological approach aligns with traditional practices and was employed to prepare the rice samples for subsequent analysis. This same procedure was repeated for the selected samples for study shown in **Plate 3.1**.

3.3.2 Indirect Method of Parboiling:

A 1 kg clean and dry sample was immersed in 1.5 L of distilled water within a steel container and allowed to soak for a period of 12-14 hr. Subsequently, the soaked sample underwent boiling until the husks opened. Following this, the parboiled rice was subjected to sun drying for 3-4 hr while simultaneously stirring to ensure uniform drying. The dried rice was then air-dried for duration of 24-48 hr before being stored for subsequent analysis. This methodological procedure adheres to established scientific protocols and was employed to prepare the rice samples for further investigation

3.4. Rice Grain Quality – Physical Characteristics

3.4.1. Degree of Milling (DOM) [Raw Rice (RR), Parboiled Direct (PBD), Parboiled Indirect (PBID)]

A 100-gram sample of paddy was precisely weighed and subsequently subjected to de-husking using a standard de-husker apparatus at the Maina milling site. Following the de-husking process, the resulting de-husked kernel underwent thorough cleaning. The weight of the de-husked kernel was then measured, and the percentage of de-husking was calculated utilizing the formula specified in the literature (Anonymous, 2004).

$$\textbf{Degree of milling (DOM): } \frac{\textbf{Weight of the de-husked kernel}}{\textbf{Weight of Paddy}} \textbf{ x 100}$$

3.5. Rice Grain Quality – Chemical Characteristics:

3.5.1. Alkali spreading and Clearing Test

Six de-husked rice kernels in triplicate in Petri plates and adding 10 mL of 1.7% potassium hydroxide (KOH) to each sample. The incubation took place at room temperature (27-30°C) for 23 hours, after which the spreading and clearing of the kernels were observed and scored on a 7-point scale. The scores were averaged across the six kernels. The scoring scale ranged from 1 (no spreading or clearing) to 7 (highly noticeable spreading or clearing with extremely distinct boundaries), providing a standardized method for evaluating the impact of the potassium hydroxide treatment. (**Table 3.1**) (Perez and Juliano, 1978). Based on the alkali spreading value, gelatinization temperature was determined (**Table 3.2**).

3.5.2. Gel Consistency (GC)

The rice samples underwent a milling process to achieve a fine powder consistency, employing either an electrical grinder or mortar and pestle. Subsequently, the powdered rice was subjected to sieving using a 1 mm sieve. For experimentation, 100 mg of the milled rice flour was dispensed into long test tissue culture tubes, with three replicates utilized for each sample. To these tubes, 0.2 mL of an ethanol solution containing 0.025% thymol blue was added. Following this, 2.0 mL of 0.2N potassium hydroxide (KOH) solution was introduced into each tube and thoroughly mixed using a vortex mixer. The mixture was then subjected to a boiling water bath for duration of 6 minutes, after which it was allowed to cool at room temperature for 5 minutes. Subsequently, the tubes were transferred to an ice bath and maintained for duration of 15 minutes to induce gelation.

Upon completion of the gelation process, the test tubes were positioned horizontally on a graph paper surface. The gel consistency of each sample was determined by measuring the length from the inner bottom of the test tube to the gel front. This parameter serves as an indicator of the gel properties of the rice samples. Classification of gel consistency is provided in **Table 3.3**.

3.6. Rice Grain Quality – Cooking Characteristics:

3.6.1. Volume Expansion Ratio and Elongation Ratio.

2 grams of rice were added to 10 mL of water in 15 mL graduated centrifuge tubes, and the initial volume increase (Y) was measured, followed by soaking for 10 minutes and noting the subsequent volume (Y-10). After cooking for 20 minutes on a water bath, cooked rice kernels' length was measured to compute the kernel length after cooking (KLAC). Then, all cooked rice was transferred to a 25 mL distilled water in 50 mL measuring cylinder, and the volume increase (X) and the volume raise (X-25) were recorded after cooking. The volume expansion ratio was calculated as the ratio of X to Y, and the elongation ratio was determined as KLAC to the initial length of rice kernel (Villota et al., 2016).

Volume expansion: $\frac{\textbf{Increase in volume after cooking (X}-\textbf{15)}}{\textbf{Increase in volume before cooking (Y}-\textbf{15)}}$

Elongation ratio: $\frac{\textbf{Kernel length after cooking (mm)}}{\textbf{Kernel lenght before cooking (mm)}}$

Where;

Y = Increase in volume after adding 2 g of rice

Y-10 = Increase in volume before cooking

X = Increase in volume of cooked rice inn 25 mL of water

X-25 = Increase in volume after cooking

3.6.2. Water Uptake

2 grams of rice sample were placed in graduated test tubes containing 10 mL of water and soaked for 30 minutes. Following this, the rice samples were boiled for 45 minutes at a controlled temperature range of 77 to 80°C in a constant temperature water bath. The tubes were then promptly immersed in a beaker filled with cold water to facilitate rapid cooling. Upon cooling, the supernatant, i.e., the liquid above the settled rice, was carefully poured into a graduated cylinder, and the water level was precisely noted (Reddy & Chakraverty, 2004).

$$\textbf{Water uptake ratio} = \frac{\textit{weight of cooked rice}}{\textit{Weight of uncooked rice}}$$

3.7. Biochemical Analysis:

3.7.1. Total Carbohydrates

100 mg of rice samples were subjected to hydrolysis by immersion in a boiling water bath for 3 hours with 5 mL of 2.5 N HCl. Following hydrolysis, the samples were cooled to room temperature and neutralized with solid sodium carbonate until effervescence ceased.

Then, the volume was adjusted to 100 mL, and filtration was performed to obtain clear solution. Aliquots of 0.5 mL and 1 mL were extracted from the supernatant for analysis.

For the preparation of standards, 50 mg of standard glucose dissolved in 50 mL of distilled water and aliquots of 0, 0.2, 0.4, 0.6, 0.8, and 1 mL were drawn from the working standard, with O serving as the blank. Each test tube, including sample tubes, was adjusted to 1 mL volume by adding distilled water. Subsequently, 4 mL of Anthrone reagent (2 g /1000 mL of H_2SO_4) was introduced, and the mixture was heated for 8 min in a boiling water bath. After rapid cooling, the resultant green to dark green colour was measured at 630 nm using a spectrophotometer. To quantify the carbohydrate content in the samples, a standard graph was constructed by plotting the concentration of the standard on the X-axis against the absorbance on the Y-axis. Utilizing this standard graph, the amount of carbohydrate present in the samples was determined following the method outlined by Yemm and Willis (1954).

3.7.2. Total Anthocyanin Content (mg equivalent cyanidin-3-O-glucoside per g)

0.5 g of rice sample was mixed with 10 mL acidified methanol (methanol: 1 N HCl, 85:15v/v), in triplicate. Absorbance of the solution was measured at 535 nm (Abdel-Aal and Hucl, 2003). Total anthocyanins wereexpressed as mg equivalent cyanidin-3-O-glucoside per 1000 g of sample and calculated by:

$$\frac{Abs}{e} x \frac{(Vol)}{100} xMWx \frac{1}{RW} x10^6$$

Where:

Abs: Sample absorbance at 535 nm;

e: Molar absorbance (cyanidin-3-glycoside = 25965 cm-1 M-1);

Vol: Total volume of anthocyanins extract;

MW: Molecular weight (cyanidin-3-glycoside = 449);

RW: *Rice Weight*

3.7.3. Total Proteins Content

Preparation of Phosphate buffer:

A: 0.2 M monobasic sodium phosphate weighs 27.8g of NaH_2PO_4 in the volumetric flask and adjusts 1 L with distilled water.

B: 0.2M Dibasic sodium phosphate Na_2HPO_4 $7H_2O$, 53.6gm/L

C: Prepare the extraction buffer (0.1 M, pH 7.9), 16mL (A) + 84mL (B) to 200mL with D.W.

Estimation of protein

Prepare standard by taking 0.2, 0.4, 0.6, 0.8 & 1mL and 0.1 and 0.2 mL sample extract + 1 mL of distilled water (blank). Add 5mL reagent C, mix well and allow standing for 10mn.Add 0.5mL of reagent D (Folin-ciocalteau reagent), mix well incubate at room temperature in dark for 30 min (blue colour will develop)

Measure the absorbance using spectrophotometer at 660nm. Using standard graph calculates fine the amount of protein present **(Lowry Method, 1951)**.

3.7.4. Total Reducing Sugar Content (TRSC) by DNS reagent

Weigh 100mg of the sample and extract the sugars with hot 80% ethanol twice (5m each time).Collect the supernatant and evaporate it by keeping it on a water bath at 80°C.Add 10mL water and dissolve the sugars. Pipette out 0.5 to 3mL of the extract in test tubes and equalize the volume to 3mL with water in all the tubes. Add 3mL of DNS reagent. Heat the contents in a boiling water bath for 5min. When the contents of the tubes are still warm, add 1mL of 40% Rochelle salt solution. Cool and read the intensity of dark red colour at **510nm**. Run a series of standards using glucose (0 to 500µg) and plot a graph.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Result

The present examined delineates the outcomes derived from an extensive survey, procurement, and systematic documentation pertaining to both conventionally cultivated and high-yielding varieties of rice within the South-Goa district. (i) Throughout the duration spanning from May 2023 to April 2024, comprehensive field surveys and collection excursions were undertaken across various location within the South-Goa district. The primary objectives of these endeavours encompassed the acquisition of traditionally cultivated, introduced, and hybrid rice strains, alongside a meticulous exploration of the indigenous parboiling methodologies aimed at augmenting rice quality.(ii) The selected rice cultivars, namely *Jaya*, *Jyoti*, *Assgo*, and *Korgut*, underwent rigorous evaluation to discern their grain quality attributes, particularly concerning parboiled and unprocessed grains. This evaluation aimed to elucidate the impact of parboiling on rice grain characteristics comprehensively. Parameters such as physical and chemical characteristics, along with an assessment of nutritional parameters including total crude carbohydrates, total protein content, reducing sugar levels, and total anthocyanin content, are crucial for evaluating the quality and nutritional value of food

The comparison was anchored upon Jaya variety, chosen as the control, distinguished by its whitish kernel, against the brown rice varieties, high-yielding *Jyoti*, and *Assgo* and *Korgut* are traditionally cultivated.

4.1.1. Study Area

The study encompassed the entirety of South Goa district, which includes 6 talukas out of the total 12, namely Canacona, Quepem, Sanguem, Salcete, Dharbandora, and Mormugao.

Field surveys and collection expeditions were conducted across various regions of South Goa, with the study sites depicted in **Fig 4.1**.

During these field surveys, it was noted that rice cultivation in South Goa occurs n fewer than three distinct conditions: Morod or lateritic uplands, Kher or midlands, and Khazan lands. Interactions with local farmers and residents revealed a declining trend in the cultivation of traditionally grown rice varieties, with a significant portion of the populace abstaining from paddy cultivation altogether. Notably, certain traditional rice strains such as Korgut, Sal, and Assgo are increasingly scarce. The current status of both traditional and high-yielding rice varieties is detailed in **Fig. 4.2, 4.3, 4.4, 4.5, and 4.6**, respectively. Furthermore, it was observed that two primary methods of parboiling are practiced in South Goa: (i) Direct parboiling method (without soaking) and (ii) Indirect parboiling method (with soaking), as illustrated in **Fig 4.7**.

4.1.2. Collection and Documentation of Rice Varieties.

During the study duration, a total of 8 rice varieties were procured from diverse sources including local farmers, villagers, and the Margao Agriculture Department. Among these, 3 rice varieties were identified as traditional cultivars, representing local rice varieties, while 4 were recognized as high-yielding varieties, with 1 introduced variety originating from Karnataka found in Netravelium, Sanguem Goa. Each traditional rice variety exhibited distinctive characteristics in terms of shape and coloration. Comprehensive grain morphology documentation of all selected rice varieties, including parboiled rice, is provided in **Plates 4.2 & 4.3**.

Following collection, the harvested varieties underwent preliminary cleaning procedures and were subsequently stored at the Botany Discipline, SBSB, Goa University, to facilitate further analytical investigations. Parboiled rice samples obtained during fieldwork were also collected and stored within the Botany Discipline for subsequent analysis.

Plate 4.3 offers detailed insights into the traditional practices of threshing, winnowing, and drying adopted by local farmers prior to parboiling, providing a comprehensive overview of the preparatory stages. Local farmers are now shifting on machinery equipment which is provided by the policy maker or any other sector, which is positive impact on the production. But 10 year ago farmers use the ox for threshing now they substituted modern agriculture, which had a negative impact on the household animals said farmers. Furthermore, **Plate 4.4** provides intricate details concerning the traditional parboiling practices prevalent in South Goa, elucidating the methodologies employed in this region. **Plate 4.5** furnishes a visual depiction of the diverse equipment utilized by local farmers throughout the parboiling process, showcasing the array of tools essential for this traditional practice**.** Furthermore, **Table 4.1, 4.2, 4.3.a & 4.3.b**, furnishes comprehensive data on both extinct, traditionally cultivar and high yielding rice varieties, along with their respective growing conditions and seasonal preferences. This tabulated information serves as a valuable reference, encapsulating the diversity of rice cultivars prevalent in the region and their inherent adaptability to local environmental conditions.

4.1.3. Rice Grain Quality – Physical Characteristics:

In **Table 4.4,** a detailed examination of physical characteristics between unprocessed (raw) rice and rice subjected to parboiling through both direct and indirect methods is presented. These findings are juxtaposed against the high-yielding white rice variety, Jaya, serving as a control. The comparison highlights significant disparities in coloration, size, and degree of milling, and ash content, important indicators of rice quality and consumer preference.

4.1.3.1: Degree of Milling (DOM)

DOM percentage was calculated for all the rice varieties including parboiled treated **(Table 4.4)**. The de-hulling of rice is one of the important post harvest processes. A higher Degree of Milling (DOM) is often considered desirable as it signifies that less of the outer layers of the rice grain have been removed during the milling process. These outer layers, namely the bran and germ, contain valuable nutrients such as fibre, vitamins, and minerals. Therefore, rice varieties with higher DOM tend to retain more nutritional value compared to those with lower DOM.

The Degree of Milling (DOM) percentages ranged from 75.87% to 80.83% among the selected rice varieties and treatments, which included direct (PBD) and indirect parboiling methods (PBID). The milling processes applied to different rice varieties were analyzed, particularly comparing raw rice (RR) to those subjected to parboiling via direct (PBD) and indirect (PBID) methods. Jaya, representing the control white rice variety, consistently exhibited the lowest DOM across all treatments, indicating minimal milling (RR: 75.87%, PBD: 80.13%, PBID: 79.46%). On the other hand, Korgut consistently displayed the highest DOM under the raw rice treatment (79.31%), suggesting more extensive milling.

Interestingly, under the parboiled direct (PBD), treatment Jyoti recorded the lowest DOM (79.56%), while Assgo demonstrated the highest (80.83%). However, in the parboiled indirect treatment, Assgo consistently exhibited the highest DOM (80.72%).

4.1.3.2. Total Ash Content

The total ash content, measured in mg/g, was examined across different rice varieties subjected to various treatments, including raw rice (RR), and parboiling methods via direct (PBD) and indirect (PBID) approaches. The results revealed notable variations in total ash content among the rice varieties and treatments, and ranging from 13.77mg/g to 29.03 mg/g recorded in **Table 4.5 and Fig 4.8.b.**

Across the treatments, Jaya consistently displayed relatively lower total ash content compared to the other rice varieties. In the raw rice (RR) treatment, Jaya exhibited a total ash content of 17.2 mg/g, which decreased to 13.775 mg/g under the PBD treatment, and subsequently increased to 24.01 mg/g in the PBID treatment. Conversely, Korgut consistently showed relatively higher total ash content across all treatments. In the RR treatment, Korgut had a total ash content of 15.875 mg/g, which remained relatively similar in the PBD treatment (15.75 mg/g), but significantly increased to 29.0725 mg/g in the PBID treatment and given in (**Fig 4.8.a**).

Comparing the parboiling methods, it is evident that both direct and indirect parboiling influenced the total ash content differently across the rice varieties. For instance, Assgo exhibited a higher total ash content under the PBD treatment (22.25 mg/g) compared to the PBID treatment (24.602 mg/g). Conversely, Jyoti displayed a lower total ash content under the PBD treatment (16.15 mg/g) compared to the PBID treatment (26.175 mg/g).

4.1.4. Rice Grain Quality – Chemical Characteristics:

4.1.4.1. Alkali spreading and Cleaning test

The alkali spreading values and gelatinization temperatures of various rice varieties at different processing stages were analyzed to understand their characteristics and the same are summarized in **Table 4.6 and Plate 4.6 & 4.7**. Raw rice (RR), parboiled rice (PBD), and parboiled using the indirect method (PBID) were the three main categories considered. Results indicated the following categories of alkali spreading value: low, intermediate and high. Low alkali spreading value means the gelatinization temperature is high (75-79℃). If intermediate spreading value means the gelatinization temperature is intermediated (70-74℃) and high alkali spreading value the gelatinization temperature is low (55-69℃).

In terms of alkali spreading values, the JaRR variety displayed intermediate spreading, followed by JyRR, ARR, and KRR, all showing low spreading. Among parboiled rice varieties, JaPBD and JaPBID had high spreading values, while JyPBD and JyPBID showed intermediate spreading, and APBD and APBID displayed intermediate spreading as well. KPBD and KPBID had intermediate spreading values similar to the aforementioned varieties.

Regarding gelatinization temperature, JaRR, JyRR, ARR, and KRR exhibited high gelatinization temperatures ranging from 75 to 79 ℃. In contrast, JaPBD, JaPBID, JyPBD, and JyPBID displayed low gelatinization temperatures between 55 and 69 ℃. The remaining varieties, APBD, APBID, KPBD, and KPBID, showed intermediate gelatinization temperatures ranging from 70 to 74 ℃.

4.1.4.2. Gel Consistency (GC)

The gel consistency (GC) is measured into soft, medium and hard. The length of the gel in millimetres (mm) ± standard deviation, ranging from 28.3 to 93.4 mm and the corresponding gel consistency were recorded in **Table 4.7**. Among the Raw Rice (RR) varieties, JaRR exhibited a gel length of 28.3±1.9 mm, characterized by a hard consistency. Conversely, JyRR displayed a significantly longer gel length of 92.2±0.8 mm, with a softer consistency observed. Moving to the Parboiled Rice (PBD) varieties, JaPBD and JyPBD exhibited gel lengths of 55.9±1.3 mm and 93.4±1.4 mm, respectively, both displaying a soft consistency. Similarly, APBD and KPBD also demonstrated soft gel consistencies, with gel lengths of 92.8±1.6 mm and 83.3±0.95 mm, respectively.

Transitioning to the Parboiled Indirect Method (PBID) varieties, JaPBID displayed a gel length of 67.2±1.55 mm, while JyPBID showed a gel length of 83.6±1.3 mm, both exhibiting a soft gel consistency. Additionally, APBID and KPBID displayed soft gel consistencies, with gel lengths of 81.6±1.1 mm and 75.4±1.4 mm, respectively in **fig 4.9**.

4.1.5. Rice Grain Quality –Cooking Characteristics:

4.1.5.1. Volume Expansion and Elongation Ratio

The cooking characteristics of rice grains, including elongation (%) and expansion (%), were evaluated across various treatments, encompassing Raw Rice (RR), Parboiled Direct Method (PBD), and Parboiled Indirect Method (PBID), ranging from 104.35 to 139.19 % and 6.4 to 39.15 %, were recorded in **Table 4.8**.

Among the Raw Rice (RR) varieties, JaRR and JyRR demonstrated elongation percentages of 108.25% and 107.54%, respectively, accompanied by expansion percentages of 8.252% and 7.54%, respectively. ARR exhibited slightly lower values with elongation and expansion percentages of 104.35% and 4.35%, respectively, while KRR showed percentages of 106.41% and 6.4%, respectively. Moving to the Parboiled Direct Method (PBD) varieties, JaPBD and JyPBD displayed elongation percentages of 110.03% and 111.52%, respectively, with expansion percentages of 10.03% and 11.82%, respectively. APBD and KPBD exhibited elongation percentages of 106.93% and 104.13%, respectively, accompanied by expansion percentages of 6.93% and 9.68%, respectively (**Fig.4.10.a & b**).

Transitioning to the Parboiled Indirect Method (PBID) varieties, JaPBID demonstrated significantly higher elongation and expansion percentages of 139.19% and 39.159%, respectively, while JyPBID exhibited percentages of 126.63% and 30.25%, respectively.

Similarly, APBID and KPBID showed elongation percentages of 118.87% and 129.84%, respectively, with expansion percentages of 22.09% and 29.84%, respectively.

4.1.5.2. Water Uptake

The water uptake of rice grains across various treatments, including Raw Rice (RR), Parboiled Direct Method (PBD), and Parboiled Indirect Method (PBID), was examined (**Table 4.8**). Among the Raw Rice (RR) varieties, JaRR and JyRR exhibited water uptake percentages of 6% and 5%, respectively. ARR displayed a slightly higher water uptake percentage of 9.5%, while KRR demonstrated a water uptake of 7.5%.

Moving to the Parboiled Direct Method (PBD) varieties, JaPBD and JyPBD showed notably higher water uptake percentages of 27% and 28.5%, respectively. APBD and KPBD displayed water uptake percentages of 12.5% and 18%, respectively. Transitioning to the Parboiled Indirect Method (PBID) varieties, JaPBID exhibited a water uptake percentage of 26.5%, while JyPBID showed the highest water uptake percentage of 41%. APBID and KPBID displayed water uptake percentages of 20.5% and 13%, respectively (**Fig.4.10.c**).

4.1.6. Biochemical Analysis:

4.1.6.1. Total Anthocyanin Content (mg equivalent cyanidin-3-O-glucoside per g)

The total anthocyanin content where mg equivalent cyanidin-3-O-glucoside per g, rice grains across different treatments, including Raw Rice (RR), Parboiled Direct Method (PBD), and Parboiled Indirect Method (PBID), was examined and ranging from 1.03 mg to 22.6 mg (**Table 4.9**). In the Raw Rice (RR) treatment, Jaya exhibited a total anthocyanin content of 6.57 mg/g, while Jyoti, Assgo, and Korgut displayed contents of 19.7 mg/g, 22.6 mg/g, and 19.7 mg/g, respectively (**Fig. 4.11**).

Under the Parboiled Direct Method (PBD) treatment, Jaya showed a total anthocyanin content of 1.03 mg/g, while Jyoti, Assgo, and Korgut demonstrated contents of 4.84 mg/g, 4.84 mg/g, and 6.9 mg/g, respectively. In the Parboiled Indirect Method (PBID) treatment, Jaya exhibited a total anthocyanin content of 0.61 mg/g, while Jyoti, Assgo, and Korgut displayed contents of 5.18 mg/g, 5.53 mg/g, and 4.49 mg/g, respectively.

4.1.6.2. Total Carbohydrates Content (TCC)

The total carbohydrate content was analyzed across selected rice varieties for different rice treatments namely; Raw Rice (RR), Parboiled Direct method (PBD), Parboiled Indirect method (PBID), and rice brought directly from farmers (Far), and also calculated the percentage of TCC given in **Table 4.10 & Fig.4.12**. Among the varieties studied, with Jaya serving as the control, the carbohydrate percentages varied. The highest carbohydrate content percentage was in the PBID method across all varieties, with Jaya registering at 84.24%, Jyoti at 83.11%, Assgo at 82.25%, and Korgut (not available in the farmer-sourced rice). However, the lowest carbohydrate content was observed in the Korgut variety, particularly in the RR treatment, with a percentage of 77.617%. The Korgut variety was not included (From farmer collection).

4.1.6.3. Total Protein Content (TPC)

The analysis of total protein content across different rice treatments revealed significant variations shown in **Table 4.10 and Fig.4.13**. The highest protein content was observed in the Raw Rice (RR) treatment for the Jaya variety at 8.45%, followed by 7.86% for the Korgut variety under the same treatment. Among the parboiled methods, the Parboiled Indirect method (PBID) consistently showed relatively high protein content across all varieties. For instance, in the PBID treatment, Jaya exhibited 5.2%, Jyoti 4.9%, Assgo 5.1%, and Korgut 5.61% protein content. Conversely, the Parboiled Direct method (PBD) generally yielded lower protein levels compared to RR and PBID methods. Notably, the lowest protein content was recorded in the

PBD treatment for the Jyoti variety at 4.118%. In the farmer-sourced rice, protein content ranged from 4.96% for Jaya to 5.57% for Assgo.

4.1.6.3. Total Reducing Sugar Content (TPC)

The total sugar content across selected rice varieties for different rice treatments, including Raw Rice (RR), Parboiled Direct method (PBD), and Parboiled Indirect method (PBID), revealed distinct patterns given in **Table 4.10**. In this study, the Jaya variety was maintained as the control for comparative purposes. The results indicated minor variations in sugar content across treatments and rice varieties. Among the treatments, the PBID method consistently demonstrated slightly higher sugar content compared to RR and PBD methods. For instance, under the PBID treatment, the Jaya variety exhibited the highest sugar content at 0.338%and followed closely by 0.35% for the Jyoti variety and 0.45% for the Assgo variety. However, the lowest sugar content was observed in the PBD treatment for both the Jaya and Korgut varieties, at 0.233% and 0.21%, respectively (**Fig.4.14**).In particular, the sugar content remained relatively consistent across rice varieties within each treatment, with minor variations observed.

4.2. Discussion

Rice stands as the fundamental staple food for the populace of Goa, yet its cultivation faces a threat due to the escalating cost of production over the years. The State of Goa dedicates approximately 52,191 hectares to rice cultivation, with 34,261 hectares during the Kharif season and the remaining 17,930 hectares during the Rabi season, with South Goa emerging as a significant contributor. Notably, around 90% of the kharif season and the entire Rabi season area are devoted to high-yielding rice varieties (Manjunath et al., 2009). However, the introduction of high-yielding varieties has led to the gradual disappearance of locally traditional varieties (Bhonsle and Krishnan, 2012).

The current study aimed to address this issue by systematically collecting both traditionally cultivated and high-yielding rice varieties from the South Goa district. Additionally, efforts were made to document the traditional knowledge associated with the parboiling process and its intrinsic relationship with the local culture. The collected rice varieties were meticulously evaluated for their grain quality in both raw and parboiled states, utilizing both direct and indirect parboiling methods.

This study holds immense significance in enhancing profitability through improved processing techniques and seed quality enhancement. By understanding the local parboiling process and nutritional profiles, it enables stakeholders to make informed decisions regarding rice cultivation and processing methods. Through the evaluation of grain quality attributes, including physical, chemical, and nutritional parameters, this study provides insights into which parboiling method is most suitable for processing rice, thereby contributing to the sustainable development of rice cultivation in Goa.

4.2.1. Collection and Documentation of Rice Varieties.

The collection of 8 rice varieties from diverse sources during the study period, including local farmers, villagers, and agricultural departments, highlights the importance of studying local rice varieties. Traditional cultivars, representing indigenous rice varieties, were identified alongside high-yielding varieties, including an introduced variety from Karnataka. This diversity underscores the significance of preserving traditional rice cultivars, as they often possess unique characteristics that may offer resilience to local environmental conditions and cultural significance.

The introduction of high-yielding rice varieties in the market has led to the gradual disappearance of traditional cultivars, as mentioned by Bhonsle and Krishnan (2012). This shift in cultivation practices may result in the loss of genetic diversity, potentially impacting food security and adaptability to changing environmental conditions. Moreover, the reliance on high-yielding varieties may lead to a reduction in the cultural heritage associated with traditional rice cultivation practices.

The study also delves into traditional parboiling practices prevalent in South Goa, shedding light on the methodologies employed and the equipment utilized by local farmers. This knowledge is crucial for understanding the gaps in traditional practices and identifying areas for improvement or innovation. Additionally, the impact of parboiling on the physical and physicochemical properties of rice grains underscores the need to differentiate between parboiled and raw rice.

In **Plate 4.3, 4.4** and **Plate 4.5** provide visual insights into the preparatory stages and parboiling practices, respectively, offering valuable documentation of traditional knowledge. However, gaps in local farmers' understanding of parboiling techniques may exist, highlighting the importance of conducting surveys and updating knowledge on locally found rice varieties. **Table 4.3a** and **4.3b** further underscores the diversity of rice cultivars and their adaptability to local environmental conditions, emphasizing the need for conservation efforts to preserve genetic diversity and cultural heritage.

Understanding the differences between parboiled and raw rice is essential for optimizing processing methods and enhancing rice quality. Parboiling not only alters the physical properties of rice grains but also enhances their nutritional profile and cooking characteristics. Therefore, studying the impact of parboiling on rice grains is crucial for improving processing techniques and promoting the utilization of traditional rice varieties in the market.

4.2.2. Rice Grain Quality – Physical Characteristics:

The selected rice varieties, the details examination of physical characteristics between unprocessed (raw) rice and rice subjected to parboiling through both direct and indirect methods is presented. These findings are compared against the high-yielding white rice variety, Jaya, serving as a control. The comparison highlights significant disparities in coloration, size, and degree of milling, and ash content, pivotal indicators of rice quality and consumer preference (Mir et al., 2015 & Bhattacharya et al., 1966).

4.2.2.1: Degree of Milling (DOM)

This study focused on analyzing the Degree of Milling (DOM) in various rice varieties subjected to different treatments, including direct and indirect parboiling methods. These treatments compared with raw rice and used Jaya as a control, a commonly cultivated white rice variety in across South Goa. DOM is a crucial parameter in rice processing as it reflects the extent of removal of the outer layers of the rice grain during milling (Rani et al., 2008). These layers contain valuable nutrients such as fibre, vitamins, and minerals, making higher DOM desirable to retain nutritional value (Bhar et al., 2022).

The DOM percentages ranged from 75.87% to 80.83% among the selected rice varieties and treatments. Our findings revealed notable variations in DOM across treatments and rice varieties. Jaya consistently exhibited the lowest DOM across all treatments, indicating minimal milling (RR: 75.87%, PBD: 80.13%, PBID: 79.46%). Conversely, Korgut consistently displayed the highest DOM under the raw rice treatment (79.31%), suggesting more extensive milling (**Fig.4.8.a).**

Under the direct parboiling treatment, Jyoti recorded the lowest DOM (79.56%), while Assgo demonstrated the highest (80.83%), this may because Direct parboiling (PBD) involves subjecting rice grains to boiling without prior soaking, which may result in less uniform gelatinization compared to indirect parboiling methods (PBID) involving soaking.. However, in the indirect parboiling treatment (PBID), Assgo consistently exhibited the highest DOM (80.72%). These results suggest that the parboiling process, particularly indirect parboiling, can influence the milling intensity, with Assgo showing a higher degree of milling across treatments. The indirect parboiling method (PBID), which involves soaking the rice for 10-14 hours before processing, may have led to optimal gelatinization of the rice grain, making it easier to mill (Itoh et al., 1985).

The extended soaking period could have facilitated the loosening of the outer layers, allowing for more efficient milling (Taghinezhad et al., 2015). So comparing all the treatments, it observed that parboiling indirect method (PBID) have greater influence on the degree of Milling (DOM). Comparing to Jaya variety has lesser impact on the parboiling may be due to the genetic factors among the varieties and environmental factor during cultivation such as soil composition, climate, and agronomic practices. And also suggest that local (Assgo & Korgut) varieties have the good impact on parboiling on DOM.

4.2.2.2. Total Ash Content

Ash content is another important component of physical characteristics. This study investigated the total ash content, measured in mg/g, across various rice varieties subjected to different treatments, including raw rice (RR) and parboiling methods via direct (PBD) and indirect (PBID) approaches. The results revealed significant variations in total ash content among the rice varieties and treatments, ranging from 13.77 mg/g to 29.03 mg/g shown in **Fig 4.8.b.**

Throughout the treatments, Jaya consistently displayed relatively lower total ash content compared to the other rice varieties to the mineral present in rice, which co-related to the DOM which influence and it also indicates that the parboiling have more impact on conservation of trace elements/inorganic elements in the rice kernel. For instance, in the RR treatment, Jaya exhibited a total ash content of 17.2 mg/g, which decreased under the PBD treatment (13.775 mg/g), and increased in the PBID treatment (24.01 mg/g). Conversely, Korgut consistently displayed relatively higher total ash content across all treatments, with a notable increase observed in the PBID treatment compared to the RR and PBD treatments (Sujatha et al., 2004).

Comparing the parboiling methods, it is apparent that both direct and indirect parboiling influenced the total ash content differently across the rice varieties. For instance, Assgo exhibited a higher total ash content under the PBD treatment (22.25 mg/g) compared to the PBID treatment (24.602 mg/g), which state the effect of soaking of rice (Alexandre et al., 2020). Conversely, Jyoti displayed a lower total ash content under the PBD treatment (16.15 mg/g) compared to the PBID treatment (26.175 mg/g), the effect DOM on the rice kernel.

When comparing all treatments, the PBID method shows superior results compared to others, followed by RR and PBD. In the PBD method, the lower results are due to the absence of soaking during parboiling. When soaking is applied, water-soluble elements are transferred to the endosperm, which helps conserve rice minerals (Bhar et al., 2022). Conversely, RR results are lower due to a lower DOM, while PBID shows higher levels, indicating a positive impact of soaking in water for 10-14 hours. The higher results observed in PBID for local rice (Assgo & Korgut) varieties may be attributed to environmental and genetic factors under specific conditions.

4.2.3. Rice Grain Quality – Chemical Characteristics:

4.2.3.1. Alkali spreading and Cleaning test

Juliano etal., (1964); Tang et al., (1989) concluded that amylase decides the firmness and stickiness after cooking, while rice with low GT requires low temperature, less water and time to cook than those with or intermediated GT. These two properties have highest effect on cooked rice rice kernel quality and play major role in consumer's preference. The Alkali spreading Value (ASV) and Gelatinization values (GT) are calculated and given in the **Table 4.6**.

The result show that JaRR exhibited intermediate ASV, while JyRR, ARR, and KRR showed low ASV, suggesting higher gelatinization temperatures for these varieties and among parboiled rice varieties, JaPBD, JaPBID, JyPBD, and JyPBID displayed high ASV, indicating lower gelatinization temperatures. APBD, APBID, KPBD, and KPBID exhibited intermediate ASV, indicating moderate gelatinization temperatures similar to JaRR (**Plate 4.6 & 4.7**) this is because gelatinization temperature (GT) and time of parboiled rice were generally higher than in raw-milled rice. The longer gelatinization time for the parboiled rice might be largely due to the reduced swelling ability of starch granules (Damir, 1985). While Parboiling the starch granules have a higher amylase activity because of that they more resistant to disintegration, reflecting its greater resistance to burst during cooking (Kamal et al., 1963).

Among all the varieties the PBID treatment had mark all the characteristic of best quality cooking and has good AVS value due to the changes in the structure of starch and also due to the soaking effect which make the better. The AVS is directly connected to the amylose content in the rice varieties, better amylose have been absorbed in the parboiled rice, which state that the parboiling have good impact on the quality with respect to the chemical characteristics (Damir, 1985). Most of customers prefer the intermediated rice for eating, so traditionally cultivated rice makes the required GT when they parboiled direct method or indirect method.

4.2.3.2. Gel Consistency (GC)

The gel consistency (GC) was measured into soft, medium and hard (Pandey et al., 2007), which is an important character of good rice. In the study, the gel consistency (GC) was measured as soft, medium and hard with reference to gel length value which is mentioned in the **Table 4.7**. It was observed that the soft and medium gel consistency, parboiled indirect method (PBID) and Parboiled direct method (PBD) as compare to raw rice. For Jaya variety, lower gel length value found (28.3 (RR) to 67.2 mm (PBID)) as compare to other varieties.

It may be effect of rate of drying which affect the change in variation and parboiling effect (Cagampang et al., 1973). Parboiled Indirect Method (PBID) varieties, JaPBID displayed a gel length of 67.2±1.55 mm, while JyPBID showed a gel length of 83.6±1.3 mm, both exhibiting a soft gel consistency (**Fig.4.9**). And foe traditionally cultivated rice APBID and KPBID displayed soft gel consistencies, with gel lengths of 81.6±1.1 mm and 75.4±1.4 mm, respectively, which showed the positive correlation with carbohydrates content and reducing sugar. However, the significant negative correlation with total protein content. From all the treatment PBID method has increased the length of gel, due to the starch gelatinization and also may be the effect of drying and soaking (10 to14 h). Starch, gel consistency and non-reducing decrease with elevated temperature (Pandey at al., 2007).

4.2.4. Rice Grain Quality –Cooking Characteristics:

4.2.4.1. Volume Expansion and Elongation Ratio

Horigane et al., (2006) showed using (MRI) that water penetrated in the centre of endosperm in milled rice grain during soaking, this is due to lose packing of amyloplasts in the central region of endosperm compared to the lateral side, even in the normal grain. In the present study, highest percentage of expansion was in JaPBID (39.159 %) followed by KPBID (29.84%), JyPBID (30.25%) and APBID (22.09%) shown in **Fig.10.a & b**. The expansion ratios, along both the length and breadth of parboiled rice, were lower than the raw cooked rice, due to more expansion of breadth in parboiled rice, compared to raw rice. The relatively greater expansion of parboiled rice along its breadth after cooking gives it a characteristic short and plump appearance (Sujatha et al., 2004).

It was observed that control variety Jaya had the highest expansion volume percentage as compare to other brown varieties, because Jaya variety has fine quality rice and the grains are white, slender and better in cooking quality, than the local variety (Assgo & Korgut), which has short &plump. Also the PBID method shown greater difference in all the varieties may be because of soaking at the at time of parboiling which help to penetrated the loose the amyloplasts region and drying effect made them more water up take and better for cooking. As compare to Parboiled directed and indirect method it was observed that mild increase in the percentage then the raw rice. This indicates the effect of soaking on the cooking. Volume expansion percentages show the positive correlation with elongation water uptake.

Whereas the study focused that the highest elongation percentage observed in Jaya (139.19) variety followed by the Korgut varieties which shown in **Table 4.8** and **Fig.4.10**. As compare to high yielding variety Jaya had shown the highest elongation percentage in all treatment as compare to brown rice variety Jyoti and local varieties Assgo and korgut because greater expansion and positive correlation with water uptake. Lower percentage found in the Assgo variety in all the treatments, which indicate the length and breadth of kernel influence to the elongation and expansion of the rice grain. While Jyoti variety have shown increased in all treatments from raw rice (107.54%) to Parboiled indirect method (126.63%).

All the rice varieties shown greater effect on the Parboiled indirect method (PBID) which state that parboiling with soaking with optimal temperature make the cooking characteristic better then raw rice (Reedy et al., 2004).

4.2.4.2. Water Uptake

Water absorption is also one of the important factors of cooking characters (Sujatha et al., 2004). The percentage of water uptake recorded in JaPBID (26.5 %) method in 30 min. The time was constant to all the varieties and lowest in JyRR (5 %). In all the treatments compare to Jaya variety the Assgo variety have the better absorption capacity then Korgut and Jyoti. While compare all the treatments, the parboiled method shown better result with some difference between parboiled direct and indirect method. For Jyoti (28.5%) variety Parboiled direct method show better result than other treatment, this may be due to environmental and parboiling effect on the Jyoti variety or this method is good for Jyoti variety as compare to there. While Assgo and Korgut show better result in PBID method, this variation in water uptake among the PBID treatment may be influenced by soaking duration and grain characteristics (Tan et al., 2000).

Whereas, the APBD and KPBD shown intermediated water uptake percentage of 12.5% and 18% respectively. Direct parboiling method (PBD) involves immersion in hot water, which partially gelatinised the starch and increases the surface of kernel which helps in rapid water absorption. The result defined the water uptake among treatments reflect the combined effects of processing methods and inherent characteristics of rice varieties. Direct and indirect parboiling methods (PBD & PBID) significantly increase water uptake due to starch gelatinization and increased surface of the kernel. Raw rice varieties exhibit lower water uptake percentages, reflecting their intact grain structure which influence in low absorption rate. These findings underscore the importance of processing methods in altering rice hydration characteristics, with implications for cooking properties.

4.2.5. Biochemical Analysis:

4.2.5.1. Total Anthocyanin Content (mg equivalent cyanidin-3-O-glucoside per g)

Anthocyanins are natural pigments found in rice, it can vary significantly based on various factors including genotypes and processing methods (Zaupa et al., 2015) also mentioned that when cyaniding-3-O-glucoside in decreased with the parboiling method due to water soluble anthocyanin compound. The present study, reveal that amount of TCA which equivalent to cyaniding-3-O-glucoside ranging from 0.61 to 19.7 mg/g in all the treatments.

Where in raw rice Jaya variety show the minimum amount (6.57 mg/g) of TCA due to the white variety and environmental factors. Whereas in Jyoti, Assgo and Korgut show the higher amount of TAC which were 19.7, 22.6, and 19.7 mg/g respectively (**Table 4.9**), which state that the brown colour rice varieties have the greater amount of TCA then the white rice variety. While comparing with hybrid brown to local variety, shown that is difference in the TAC content, where Assgo show greater amount of TAC followed by korgut. These suggest that they have higher amount of antioxidant properties (Goufo & Trindade, 2017).

In Parboiling process both Direct and Indirect methods had shown very less amount of TAC content. Direct parboiling method have higher amount of TAC in all rice varieties compare to the indirect method. This may because of soaking effect where the water solved anthocynanin had dissolved in the parboiled water which causes the decrease in the amoint of TAC refer to Fig.4.11.Parboiling, significantly impact the anthocyanin content in rice grains. While raw rice generally exhibits higher anthocyanin levels, parboiling leads to a reduction in content across all varieties tested. However, the extent of reduction varies depending on the specific variety and the parboiling method employed, which indirectly affect the antioxidant properties of rice.

4.2.5.2. Total Carbohydrates Content (TCC)

Carbohydrate is the primary component and rice grain normally content 67-87 % depending on factor such rice variety and processing methods and also the main source of energy in the human diet, (Bhonsle & Krishnan, 2010). This study, the carbohydrate content (TCC) and percentage of TCC were analysed across the selected rice varieties for different treatments, including Raw Rice (RR), Parboiled Direct method (PBD), Parboiled Indirect method (PBID), and directly parboiled rice from farmers (Far).

Among the varieties, lowest carbohydrate found to in Korgut (77.61%) raw rice or unprocessed rice compare to Jaya variety and other and overall raw rice had the lowest percentage of TCC as compare to all the treatments (**Fig.4.12**). Typically comparing the Jaya variety to all the brown variety including local and high yielding, it found to be more in all following treatments. In parboiling methods the TCC increased in all rice varieties or had slight variation may be attributed to differences in starch composition and gelatinization efficiency the parboiling process.

While comparing to both Parboiled (PBD) and Parboiled indirect method (PBID) it shown that PBID method have slight difference then PBD, may be due to involving the soaking step which help the starch gelatinization compare to the PBD method, so the PBID treatment highlights the effectiveness of this method in preserving or enhancing carbohydrate content in rice grains.

4.2.5.3. Total Protein Content (TPC)

The protein content is an essential nutritional component in rice because it is taken as a staple food throughout the world. High protein content in rice helps to fulfil the protein deficiency often observed in economically weaker sections (Nath et al., 2022). The total Protein content (TPC) in rice grains can vary depending on factors such as rice variety, environmental factors and processing methods. In this study, protein percentage was ranging from 4.9% - 8.45 %. Among, all the varieties Jaya (8.45%) variety had shown the higher percentage of TPC in Raw rice treatment, followed by Assgo (7.86 %) (**Table 4.10** & **Fig. 4.13)**. The higher protein content in Jaya variety (RR) suggests that genotype-specific difference in protein accumulation. Assgo also relatively high in protein content under this treatment (RR), indicating the inherent genetic characteristics contributing to protein synthesis.

In parboiling both treatments show the show the lower percentage of TPC, but compare to PBD method the PBID method show the slightly higher percentage of TPC, Jaya (5.2 %). Jyoti (4.9%), Assgo (5.1 %) and korgut (5.61%), respectively. But some paper state that there is increase (1-2%) in the protein content with respect to parboiling ((Nath et al., 2022), and also some paper states that the statement is wrong due to the some reason (Rao & Juliano, 1970), concluded that during parboiling, the protein content in rice slightly decreases, likely due to the leaching out of non-protein nitrogen and albumin. Additionally, the extractability of all protein with globulin being the most affected on a percentage basis and glutelin on a weight basis. However, Raw and parboiled brown rice displayed differences in the amino acid pattern between whole and residual protein after serial protein extraction. The residual protein had lower levels of arginine and lysine but higher levels of alanine (Palmiano et al., 1968) glutamic acid, leucine, methionine, serine, and threonine. The absence of cystine may have been due to alkaline decomposition during glutelin extraction. It was depends upon the parboiling process and time of soaking and other important factor like time and temperature. So parboiling both methods have the negative impact on the rice varieties.

4.2.5.3. Total Reducing Sugar Content (TPC)

Reducing is one of the important bioactive components of rice which has the aldehydes and ketone group which act has reducing reagent. The TRSC content in raw rice varied slightly among varieties, with Jaya, Jyoti, and Assgo and Korgut have similar level ranging from 0.21% to 0.22% (**Table 4.10** and **Fig.4.14**). Typically raw rice exhibits relatively lower sugar compare to parboiled rice due to the absence of processing steps that lead to sugar accumulation or modification.

Where, PBD method has lower percentage than PBID method. In PBD Jaya and Korgut varieties showed 0.23 % and 0.21% respectively. Whereas in PBID method has slightly higher TRSC compare to RR and PBD, where Jaya variety exhibited higher sugar content at 0.338%, followed closely by Jyoti and Korgut and Assgo 0.45% compare to Jaya its higher in PBID method. The Parboiled method involves the soaking for 10-14 and then streaming, which may contribute to better retention or modification of sugar content compare to the direct method. The higher sugar levels observed in PBID-treated rice suggest that this method may enhance sugar accumulation or preservation during processing.

Sugar content remained relatively consistent across rice varieties within each treatment, with minor variations observed, the overall pattern of sugar accumulation or modification was consistent across different rice processing methods. Varietal differences in sugar metabolism or composition may contribute to the minor variations observed (Reddy et al., 2004).Varietal differences and processing methods play important role in determining sugar content in rice grains, with implications for flavour, texture, and nutritional quality.

CHAPTER 5: CONCLUSION

Rice is the main food for the people of Goa and rice cultivation occupies an area of about 52.191 ha. During the study period 8 rice varieties are collected including 3 local rice varieties and 5 are high yielding. Out of 9 local varieties mentioned by Bhonsle and Krishnan, 2012, only 3 varieties had been collected. This is because of introducing the hybrid rice varieties, the farmers are not focussed on the local rice varieties which has different and useful genetic traits. On the other hand, they maintain the local parboiled process (age-old process) which makes the rice more valuable in the market. In south Goa district traditional parboiling methods, namely the indirect method (PBID) with soaking and the direct method (PBD) without soaking, were studied. Physicochemical characteristics such as physical, chemical, cooking & biochemical were assessed for white variety Jaya (Control) and brown varieties Jyoti (high yielding), Assgo and Korgut are both local cultivars, across Raw Rice (RR), Parboiled Direct (PBD) and Parboiled Indirect (PBID) treatments. Results revealed significant varietal differences across treatments. Assgo showed the highest Degree of Milling (DOM) in PBD and Korgut in PBID, whereas it was lowest in Jaya in RR. Korgut showed increased anthocyanin content in PBID, while Jaya showed decreased under PBD. Jaya exhibited superior cooking characteristics, with high elongation and expansion in PBID. However, Assgo displayed inadequate cooking traits, with low elongation and expansion in PBID. Both parboiled methods yielded intermediate (preferred by most consumers) Alkali Spreading value (AVS) and Gelatinization Temperature (GT) in Assgo and Korgut and the highest gel consistency (GC) recorded in Jyoti in PBD and lowest in Jaya under RR. Total Anthocyanin Content (TAC) was increased in Assgo under RR, while Jaya showed a decrease in PBD. Biochemical analyses reveal distinct patterns in sugar and protein content, emphasizing the influence of parboiling on nutritional composition. Notably, Assgo demonstrates higher reducing sugar content under PBID, suggesting potential implications for taste and texture.

Total Carbohydrate Content (TCC) increased in all varieties under PBID, with Jaya recorded as the highest and lowest in Korgut under RR. Total Protein Content (TPC) decreases with parboiling and the lowest is found in Korgut PBD, where it shows an increase in Jaya under RR. In this study, significant differences were observed across all treatments, highlighting the need for further research on the parboiling process. PBID showed a positive impact on physicochemical properties compared to PBD and RR. Jaya and local varieties displayed superior effects on rice quality. In local varieties Assgo and Korgut are better than the Jyoti rice variety. Further in detail work should want to understand the exact chemical phenomena rice grain. And need to understand soaking effect on rice grain, this study concluded that the soaking rice is good then the without soaking rice. Overall, this study can inform farmers and policymakers on adapting and modifying parboiling methods and promoting local rice varieties and culture which may help to consumer preferences and stakeholders which can make informed decisions to sustain and enhance the rice industry in South Goa.

REFERENCES

Abdel-Aal, E. S. M., Young, J. C., & Rabalski, I. (2006). Anthocyanin composition in black, blue, pink, purple, and red cereal grains. *Journal of agricultural and food chemistry*, *54*(13), 4696-4704.

Adnan, A. S. M., Karruppan, J., Hosni, H., Abdullah, E. H. E., Sulaiman, S. A., Sanusi, N., ... & Sabar, M. I. A. (2023). Evaluation of Physical Quality Characterization MRQ 107 Parboil Rice Production Using Selected Parameter. *Advances in Agricultural and Food Research Journal*, *4*(2).

Alexandre, N., Paul, H. J., & Gerardine, N. (2020). Effect of parboiling technique on the nutritional quality of rice. *Glob. J. Nutr. Food Sci*, *2*, 1-13.

Ayamdoo, J. A., Demuyakor, B., Dogbe, W., & Owusu, R. (2013). Parboiling of paddy rice, the science and perceptions of it as practiced in Northern Ghana.

Azuka, C. E., Nkama, I., Eze, C. R., Danbaba, N., & Asoiro, F. U. (2020). Cooking and functional properties of parboiled milled local rice marketed in the south-east zone of Nigeria. *International Journal of Food Studies*, *9*(2).

Balbinoti, T. C. V., Nicolin, D. J., de Matos Jorge, L. M., & Jorge, R. M. M. (2018). Parboiled rice and parboiling process. *Food engineering reviews*, *10*, 165-185.

Bello, M. M., Abubakar, M. S., & Lawan, I. (2015). Rice parboiling practices and technologies in Kano state. *Journal of Engineering and Technology*, *10*(2), 52-59.

Bello, M. O., Tolaba, M. P., & Suarez, C. (2007). Water absorption and starch gelatinization in whole rice grain during soaking. *LWT-Food science and Technology*, *40*(2), 313-318.

Bello, M., Tolaba, M. P., & Suarez, C. (2004). Factors affecting water uptake of rice grain during soaking. *LWT-Food science and Technology*, *37*(8), 811-816.

Bhar, S., Bose, T., Dutta, A., & Mande, S. S. (2022). A perspective on the benefits of consumption of parboiled rice over brown rice for glycaemic control. *European Journal of Nutrition*, 1-10.

Bhattacharya, K. R., & Subba Roa, P. V. (1966). Effect of processing conditions on quality of parboiled rice. *Journal of Agricultural and Food Chemistry*, *14*(5), 476-479.

Bhonsle, S. J., & Krishnan, S. (2010). Grain quality evaluation and organoleptic analysis of aromatic rice varieties of Goa, India.

Bhonsle, S. J., & Krishnan, S. (2010). Grain quality evaluation of traditionally cultivated rice varieties of Goa, India.

Bhonsle, S. J., & Krishnan, S. (2011). Traditionally cultivated salt tolerant rice varieties grown in khazan lands of Goa, India and their grain quality characteristics.

Bhonsle, S. J., & Krishnan, S. (2016). Molecular genetic diversity of landraces, cultivars and wild relatives of rice of Goa. *Current Science*, 1675-1679.

Buggenhout, J., Brijs, K., & Delcour, J. A. (2013). Impact of processing conditions on the extractability and molecular weight distribution of proteins in parboiled brown rice. *Journal of Cereal Science*, *58*(1), 8-14.

Cruz, N. D., & Khush, G. S. (2000). Rice grain quality evaluation procedures. *Aromatic rices*, *3*, 15-28.

Damir, A. A. (1985). Comparative studies on the physicochemical properties and microstructure of raw and parboiled rice. *Food chemistry*, *16*(1), 1-14.

Damir, A. A. (1985). Comparative studies on the physicochemical properties and microstructure of raw and parboiled rice. *Food chemistry*, *16*(1), 1-14.

David, E. E., Nwobodo, V., Famurewa, A. C., Igwenyi, I. O., Egedeigwe-Ekeleme, C. A., Obeten, U. N., ... & Emeribole, M. N. (2020). Effect of parboiling on toxic metal content and nutritional composition of three rice varieties locally produced in Nigeria. *Scientific African*, *10*, e00580.

Derycke, V., Veraverbeke, W. S., Vandeputte, G. E., De Man, W., Hoseney, R. C., & Delcour, J. A. (2005). Impact of proteins on pasting and cooking properties of nonparboiled and parboiled rice. *Cereal Chemistry*, *82*(4), 468-474.

Doesthale, Y. G., Devara, S., Rao, S., & Belavady, B. (1979). Effect of milling on mineral and trace element composition of raw and parboiled rice. *Journal of the Science of Food and Agriculture*, *30*(1), 40-46.

DUTTA, H., & MAHANTA, C. L. (2014). Traditional parboiled rice-based products revisited: Current status and future research challenges. *Rice Science*, *21*(4), 187-200.

Feng, R., Wang, R. M., Chen, P., Gao, Q., Tao, H., & Zhang, B. (2024). The impact of parboiling on physical structure, physicochemical properties and zinc status of Zn-fortified germinated brown rice. *LWT*, 115952.

Fofana, M., Wanvoeke, J., Manful, J., Futakuchi, K., Van Mele, P., Zossou, E., & Bléoussi, T. M. R. (2011). Effect of improved parboiling methods on the physical and cooked grain characteristics of rice varieties in Benin. *International Food Research Journal*, *18*(2).

Ghosh, M. (2007). Review on recent trends in rice bran oil processing. *Journal of the American oil chemists' society*, *84*, 315-324.

Goufo, P., & Trindade, H. (2017). Factors influencing antioxidant compounds in rice. *Critical reviews in food science and nutrition*, *57*(5), 893-922.

Han, A., Jinn, J. R., Mauromoustakos, A., & Wang, Y. J. (2016). Effect of parboiling on milling, physicochemical, and textural properties of medium-and long-grain germinated brown rice. *Cereal Chemistry*, *93*(1), 47-52.

Heinemann, R. J. B., Fagundes, P. D. L., Pinto, E. A., Penteado, M. D. V. C., & Lanfer-Marquez, U. M. (2005). Comparative study of nutrient composition of commercial brown, parboiled and milled rice from Brazil. *Journal of Food Composition and Analysis*, *18*(4), 287-296.

Hossain, M. A., Saha, S. C., Ahmmed, M. G., & Mazumder, M. A. R. (2019). Effect of cooking methods on the solid loss of rice. *Journal of Rice Science*, *1*(1), 1-3.

https://timesofindia.indiatimes.com/city/goa/goa-has-28-varieties-of-patentable-rice/articleshow/13858497.cms

Hu, Z., Tang, X., Liu, J., Zhu, Z., & Shao, Y. (2017). Effect of parboiling on phytochemical content, antioxidant activity and physicochemical properties of germinated red rice. *Food Chemistry*, *214*, 285-292.

Islam, M. R., ROY, P., SHIMIZU, N., & KIMURA, T. (2002). Effect of processing conditions on physical properties of parboiled rice. *Food Science and Technology Research*, *8*(2), 106-112.

Islam, M. R., Shimizu, N., & Kimura, T. (2001). Quality evaluation of parboiled rice with physical properties. *Food Science and Technology Research*, *7*(1), 57-63.

Itoh, K., Kawamura, S., & Ikeuchi, Y. (1985). Processing and milling of parboiled rice. *Journal of the Faculty of Agriculture, Hokkaido University*, *62*(3), 312-324.

Jane, J. L., & Chen, J. F. (1992). Effect of amylose molecular size and amylopectin branch chain length on paste properties of starch. *Cereal Chemistry*, *69*(1), 60-65.

Juliano, B. O. (1979). The chemical basis of rice grain quality. *Chemical aspects of rice grain quality*, *69*, 90.

Kamal, M. A., Refai, F. Y., & Tawfik, M. A. (1970). Effect of cooking upon the biochemical constituents of rice. *Con. Agri. Res*, 24-26.

Kanan, M. K. A., Nahar, T., Islam, N., Rahman, M. J., Ahmed, S., Kabir, M. S., & Ahmed, M. (2024). Impact of soaking and cooking treatments on the physicochemical and antioxidant properties of parboiled and non-parboiled rice (Oryza sativa L.). *Food Science and Technology International*, *30*(2), 160-168.

Korikanthimath, V. S., & Manjunath, B. L. (2009). Integrated farming systems for sustainability in agricultural production. *Indian journal of Agronomy*, *54*(2), 140-148.

Korikanthmath, V. S., Manjunath, B. L., & Manohara, K. K. (2010). Status paper on rice in Goa. *ICAR Res. Complex Goa*, *23*, 1-23.

Kumar, G., Singh, P., Basak, N., Kumar, A., & Sanghamitra, P. (2021). The Impact of Cooking on the Total Antioxidant Activity, Protein Content and Total Soluble Sugar in Pigmented and Non-Pigmented Rice.

Lamberts, L., & Delcour, J. A. (2008). Carotenoids in raw and parboiled brown and milled rice. *Journal of Agricultural and Food Chemistry*, *56*(24), 11914-11919.

Lamberts, L., Brijs, K., Mohamed, R., Verhelst, N., & Delcour, J. A. (2006). Impact of browning reactions and bran pigments on color of parboiled rice. *Journal of agricultural and food chemistry*, *54*(26), 9924-9929.

Lamberts, L., De Bie, E., Derycke, V., Veraverbeke, W. S., De Man, W., & Delcour, J. A. (2006). Effect of processing conditions on color change of brown and milled parboiled rice. *Cereal chemistry*, *83*(1), 80-85.

Lee, M. K., Park, J. S., & Na, H. S. (2010). Physicochemical properties of Olbyossal (parboiled rice). *Korean Journal of Food Preservation*, *17*(2), 208-213.

Luh, B. S., & Mickus, R. R. (1991). Parboiled rice. In *Rice: Volume I. Production/Volume II. Utilization* (pp. 470-507). Boston, MA: Springer US.

Luh, B. S., Barber, S., & Benedito de Barber, C. (1991). Rice bran: chemistry and technology. *Rice: Volume I. Production/Volume II. Utilization*, 732-781.

Mahoney, R. R., & Ramsay, M. (1992). A rapid tyrosinase test for detecting contamination of durum wheat. *Journal of cereal science*, *15*(3), 267-270.

Manful, J. T., Abbey, L. D., & Coker, R. D. (2009). Effect of artisanal parboiling methods on milling yield and cooked rice textural characteristics. *Journal of food quality*, *32*(6), 725-734.

Manjunath, B. L., Paramesh, V., Mahajan, G. R., Reddy, K. V., Das, B., & Singh, N. P. (2018). A five years study on the selection of rice based cropping systems in Goa, for west coast region of India.

Meng, F., Wei, Y., & Yang, X. (2005). Iron content and bioavailability in rice. *Journal of trace elements in medicine and biology*, *18*(4), 333-338.

Metcalf, S. L., & Lund, D. B. (1985). Factors affecting water uptake in milled rice. *Journal of Food Science*, *50*(6), 1676-1679.

Mir, S. A., Bosco, S. J. D., Shah, M. A., Mir, M. M., & Ganai, S. A. (2015). Rice: Parboiling and milling properties. *International journal of food engineering*, *11*(6), 777-787.

Muchlisyiyah, J., Shamsudin, R., Kadir Basha, R., Shukri, R., How, S., Niranjan, K., & Onwude, D. (2023). Parboiled rice processing method, rice quality, health benefits, environment, and future perspectives: A review. *Agriculture*, *13*(7), 1390.

Muttagi, G. C., Usha Ravindra, U. R., & Rajanna, M. P. (2017). Cooking qualities of traditional rice varieties of Karnataka.

Nath, S., Bhattacharjee, P., Bhattacharjee, S., Datta, J., & Dolai, A. K. (2022). Grain characteristics, proximate composition, phytochemical capacity, and mineral content of selected aromatic and non-aromatic rice accessions commonly cultivated in the North-East Indian plain belt. *Applied Food Research*, *2*(1), 100067.

Otegbayo, B. O., Osamuel, F., & Fashakin, J. B. (2001). Effect of parboiling on physico-chemical qualities of two local rice varieties in Nigeria. *Journal of Food Technology in Africa*, *6*(4), 130-132.

Pakuwal, E., & Manandhar, P. (2021). Comparative study of nutritional profile of rice varieties in Nepal. *Nepal Journal of Biotechnology*, *9*(1), 42-49.

Pal, P., Singh, N., Kaur, P., & Kaur, A. (2018). Effect of parboiling on phenolic, protein, and pasting properties of rice from different paddy varieties. *Journal of food science*, *83*(11), 2761-2771.

Park, W. J., Shelton, D. R., Peterson, C. J., Martin, T. J., Kachman, S. D., & Wehling, R. L. (1997). Variation in polyphenol oxidase activity and quality characteristics among hard white wheat and hard red winter wheat samples. *Cereal Chemistry*, *74*(1), 7-11.

Parnsakhorn, S., & Noomhorm, A. (2008). Changes in physicochemical properties of parboiled brown rice during heat treatment. *Agricultural Engineering International: CIGR Journal*.

Parnsakhorn, S., & Noomhorm, A. (2012). Effects of storage temperature on physical and chemical properties of brown rice, parboiled brown rice and parboiled paddy.

Peres, B. B., Cañizares, L. D. C. C., do Nascimento, L. Á., da Silva Timm, N., Meza, S. L. R., Siebeneichler, T. J., ... & de Oliveira, M. (2023). Parboiling process improves the phytochemical, chemical, and technological properties of wild rice (Zizania sp.). *Biocatalysis and Agricultural Biotechnology*, *50*, 102718.

Pinta, W., Aninbon, C., Kaewtaphan, P., & Kunyanee, K. (2024). Effects of Parboiling on Chemical Properties, Phenolic Content and Antioxidant Capacity in Colored Landrace Rice. *Foods*, *13*(3), 393.

Puri, S., Dhillon, B., & Sodhi, N. S. (2014). Effect of degree of milling (Dom) on overall quality of rice—A review. *International Journal of Advanced Biotechnology and Research*, *5*(3), 474-489.

Rani, N. S., Rao, L. V., Pandey, M. K., Sudharshan, I., & Prasad, G. S. V. (2008). Grain quality variation for physicochemical, milling and cooking properties in Indian rices (O. saliva L.). *Indian Journal of Crop Science*, *3*(1), 133-136.

Reddy, B. S., & Chakraverty, A. (2004). Physical properties of raw and parboiled paddy. *Biosystems Engineering*, *88*(4), 461-466.

Roy, P., Shimizu, N., Shiina, T., & Kimura, T. (2006). Energy consumption and cost analysis of local parboiling processes. *Journal of food engineering*, *76*(4), 646-655.

Sairam, S., Gopala Krishna, A. G., & Urooj, A. (2011). Physico-chemical characteristics of defatted rice bran and its utilization in a bakery product. *Journal of food science and technology*, *48*, 478-48

Sareepuang, K., Siriamornpun, S., Wiset, L., & Meeso, N. (2008). Effect of soaking temperature on physical, chemical and cooking properties of parboiled fragrant rice. *World Journal of Agricultural Sciences*, *4*(4), 409-415.

Shih, F., King, J., Daigle, K., An, H. J., & Ali, R. (2007). Physicochemical properties of rice starch modified by hydrothermal treatments. *Cereal chemistry*, *84*(5), 527-531.

Shittu, T. A., Olaniyi, M. B., Oyekanmi, A. A., & Okeleye, K. A. (2012). Physical and water absorption characteristics of some improved rice varieties. *Food and Bioprocess Technology*, *5*, 298-309.

Stuart, A. M., Pame, A. R. P., Silva, J. V., Dikitanan, R. C., Rutsaert, P., Malabayabas, A. J. B., ... & Singleton, G. R. (2016). Yield gaps in rice-based farming systems: Insights from local studies and prospects for future analysis. *Field crops research*, *194*, 43-56.

Sujatha, S. J., Ahmad, R., & Bhat, P. R. (2004). Physicochemical properties and cooking qualities of two varieties of raw and parboiled rice cultivated in the coastal region of Dakshina Kannada, India. *Food chemistry*, *86*(2), 211-216.

Sultana, S., Faruque, M., & Islam, M. R. (2022). Rice grain quality parameters and determination tools: a review on the current developments and future prospects. *International Journal of Food Properties*, *25*(1), 1063-1078.

Taghinezhad, E., Khoshtaghaza, M. H., Minaei, S., & Latifi, A. (2015). Effect of soaking temperature and steaming time on the quality of parboiled Iranian paddy rice. *International journal of food engineering*, *11*(4), 547-556.

Thakur, A. K., & Gupta, A. K. (2006). Water absorption characteristics of paddy, brown rice and husk during soaking. *Journal of Food Engineering*, *75*(2), 252-257.

Thammapat, P., Meeso, N., & Siriamornpun, S. (2016). Effects of the traditional method and an alternative parboiling process on the fatty acids, vitamin E, γ-oryzanol and phenolic acids of glutinous rice. *Food Chemistry*, *194*, 230-236.

Thayumanavan, B., & Sadasivam, S. (1984). Physicohemical basis for the preferential uses of certain rice varieties. *Plant foods for human nutrition*, *34*, 253-259.

van Handel, E. (1968). Direct microdetermination of sucrose. *Analytical biochemistry*, *22*(2), 280-283.

Veluppillai, S., Nithyanantharajah, K., Vasantharuba, S., Balakumar, S., & Arasaratnam, V. (2009). Biochemical changes associated with germinating rice grains and germination improvement. *Rice Science*, *16*(3), 240-242.

Verma, D. K., & Srivastav, P. P. (2020). Exploring the physicochemical and cooking properties of some Indian aromatic and non-aromatic rice (Oryza sativa L.) cultivars. *ORYZA-An International Journal on Rice*, *57*(2), 146-161.

Villota, S. M. A., Tuates Jr, A. M., & Capariño, O. A. (2016). Cooking Qualilites and Nutritional Contents of Parboiled Milled Rice. *Asian Journal of Applied Sciences*, *4*(5).

Zaupa, M., Calani, L., Del Rio, D., Brighenti, F., & Pellegrini, N. (2015). Characterization of total antioxidant capacity and (poly) phenolic compounds of differently pigmented rice varieties and their changes during domestic cooking. *Food chemistry*, *187*, 338-347.

Zhou, H., Xia, D., & He, Y. (2020). Rice grain quality—traditional traits for high quality rice and health-plus substances. *Molecular Breeding*, *40*, 1-17.

APPENDIX I

Chapter 3: 3.2. Questionnaire used to collect the field data.

Survey on Rice Varieties of South Goa
Conducted by
School of Biological Sciences and Biotechnology
Botany Discipline

1. Name of crop:
2. Variety:
3. Local name:
4. Village name:
5. Farmers name:
6. Grain color:
7. Husk colour:
8. Source of Grain:
9. Growing season:
10. Harvesting period:
11. The total area under production:
12. How do you process seeds and fields before sowing?
13. Do you use chemical fertilizers and pesticides?

If yes which all:

14. Do you have any unused agricultural land?

if yes why and how much:

15. Production has increased or decreased and why so?

16. How do you store the grains?

17. Is there any specific occasion for consumption?

18. Does the grain possess any medicinal properties?

19. Do you use the grain for yourself or sell it.

if yes where:
price per kg:

20. Which other crops do you grow in the same field?

21. Any other information:

APPENDIX II

3.7.3. Preparation of regents

Reagent A: 2% Sodium carbonate in 0.1 N Sodium hydroxide

Reagent B: 0.5% Copper sulphate ($CuSO_4$) in 1% Potassium sodium tartrate

Alkaline copper solution: 50ml of reagent A mixed to 1 mL reagent B prior to use

Reagent C: Folin-ciocalteau reagent

Standard protein solution (Stock solution): 50 mg of bovine serum albumin and dissolved in 50ml distilled water in conical flask.

Working solution: Dilute 10 mL stock solution 50ml D.W.

Preparation of Phosphate buffer:

A: 0.2 M monobasic sodium phosphate weighs 27.8 g of NaH_2PO_4 in the volumetric flask and adjusts 1 L with distilled water.

B: 0.2M Dibasic sodium phosphate Na_2HPO_4 $7H_2O$, 53.6g/L

C: Prepare the extraction buffer (0.1 M, pH 7.9), 16 mL (A) + 84 mL (B) to 200 mL with D.W.

3.7.4. Preparation of regent

3,5-Dinitrosalicylic acid Reagent (DNS Reagent): Dissolve by stirring 1g 3,5-Dinitrosalicylic acid, 200 mg crystalline phenol and 50 mg sodium sulphite in 100 mL 1% NaOH. Store at 4°C.

Since the reagent deteriorates due to sodium sulphite, if long storage is required, sodium sulphite may be added at the time of use.

40% Rochelle salt solution (Potassium sodium tartrate).

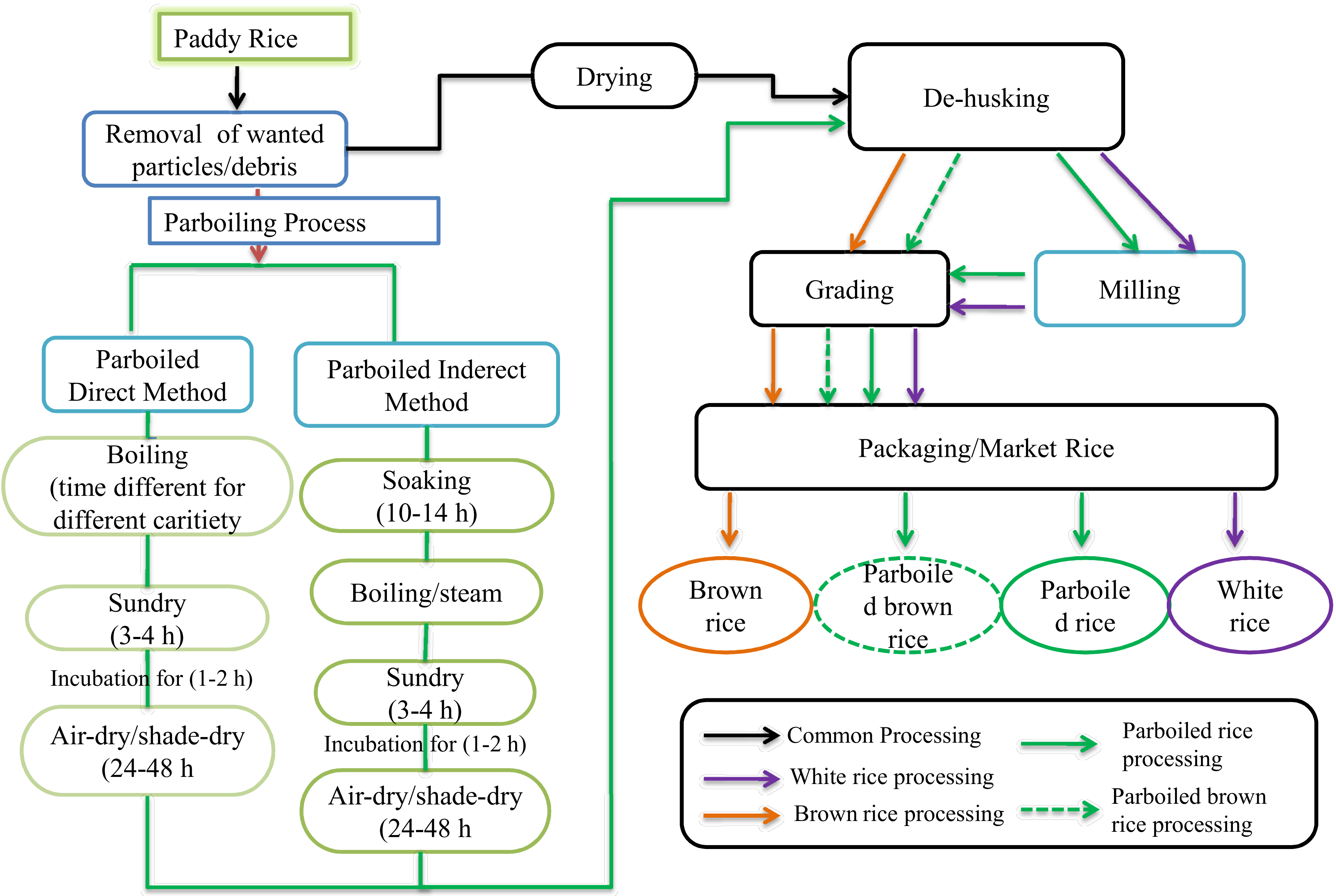


Fig 4.7. Schematic representation of post-harvest processing of rice to produce brown rice, parboiled brown rice, Parboiled rice and white rice.

Table 4.1. High yielding rice varieties with their s special features and present status in south Goa

Sr No.	Varieties	Landscape/Habitat	Local Status Present		Special Features	Cropping Season	Uses	Source of Seeds/Plantlates	Community/Knowledge holder
			Past	Present					
1	Karjat	Morod and Kherlands	NO	YES	Less water nad fast Maturing	Kharif, Rabi(Vaigan)	Food, Fav(Flattened rice)	Self Maintained from older crop, Agriculture Department from near by office	Village Peoples
2	Jyoti	Khazan Land, Morod and kherlands(mildlands)	NO	YES	Less water nad fast Maturity	Kharif, Rabi(Vaigan)	Food, Fav(Flattened rice)	Self Maintained from older crop, Agriculture Department from near by office	Village Peoples
3	Jaya	Morod Land and Kherlands	NO	YES	Need more water and late maturity	Kharif, Rabi(Vaigan)	Food, Fav(Flattened rice)	Self Maintained from older crop, Agriculture Department from near by office	Village Peoples
4	Punam	Morod Land and Kherlands	NO	YES	Good Production	Kharif (rainy) & Rabi	Food	Agriculture Department from near by office	Village Peoples

Table 4.2. Traditionally cultivated/ Local rice varieties with their special features and present status in south Goa

Sr No.	Varieties	Landscape/Habitat	Local Status Present		Special Features	Cropping Season	Uses	Source of Seeds/Plantlates	Community/Knowledge holder
			Past	Present					
1	Assago(Kusha Bhat)	Khazan Land or Saline water land	YES	YES	Khazan Land and salt tolerant Grains	Kharif (rainy)	Food	Self Maintained from older crop	Village Peoples
2	Korgut(Kusha Bhat)	Khazan Land or Saline water	YES	YES	Khazan Land and salt tolerant Grains are brown and has the Awns	Kharif (rainy)	Food	Self Maintained from older crop	Village Peoples
3	Sal Bath	Morod lands	YES	YES(limited)	Good Smell and very small	Rabi(vaigan), Kharif	Food, Lahyo(Popped rice)	Self Maintained from older crop	Village Peoples

Table 4.3.a. Extinct rice varieties with their cropping season and landscape and present status in south Goa

Sr No.	Varieties	Landscape/Habitat	Local Status Present		Special Features	Cropping Season	Uses	Source of Seeds/Plantlates	Community/Knowledge holder
			Past	Present					
1	Itti	Morod	YES	NO	-	Kharif	Food	Self Maintained from older crop	Village Peoples
2	Paniyo	Morod lands	YES	NO	-	Kharif, Rabi(Vaigan)	Food	Self Maintained from older crop	Village Peoples
3	Mangala	Morod Land and Kherlands	YES	NO	-	Kharif	Food	Self Maintained from older crop	Village Peoples
4	Annapurna	Morod land kherlands	YES	NO	-	Kharif , Rabi	Food	Self Maintained from older crop	Village Peoples
5	Sulaksha	Morod land kherlands	YES	NO	-	Kharif , Rabi	Food	Self Maintained from older crop	Village Peoples
6	Manayo	Morod land kherlands	YES	NO	-	Kharif , Rabi	Food	Self Maintained from older crop	Village Peoples
7	Kolyo	Morod, Mountain	YES	NO	Good for eating and grown in mountain area like Ragi	Kharif (rainy)	Food	Self Maintained from older crop	Village Peoples
8	Damgo	Kherlands	YES	NO	-	Kharif	Food	Self Maintained from older crop	Village Peoples

Table 4.3.b. Extinct rice varieties with their cropping season and landscape and present status in south Goa

Sr No.	Varieties	Landscape/Habitat	Local Status Present		Special Features	Cropping Season	Uses	Source of Seeds/Plantlates	Community/Knowledge holder
			Past	Present					
	Kotmirisal	Morod lands, Kherlands	YES	NO	small grains	Rabi(vaigan)	Food	Self Maintained from older crop	Village Peoples
	Bhangara Kadi	Morod Lands	YES	NO	Goldern Colour	Kharif	Food	Self Maintained from older crop	Village Peoples
	Tai chu/chaina	Morod lands, Kherlands	YES	NO	-	Kharif	Food	Self Maintained from older crop	Village Peoples
	Kalo/Tamdo Panyo	Morod Lands	YES	NO	Redish black in colour	Kharif, Rabi(Vaigan)	Food	Self Maintained from older crop	Village Peoples
	Jeevan	Morod Land, Kherland	YES	NO	-	Rabi	Food	Self Maintained from older crop	Village Peoples
	Patni	Morod, Kherlands	YES	Not conform	-	Kharif	Food	Self Maintained from older crop	Village Peoples

Fig. 4.1. Map of Goa state depicting the study sites

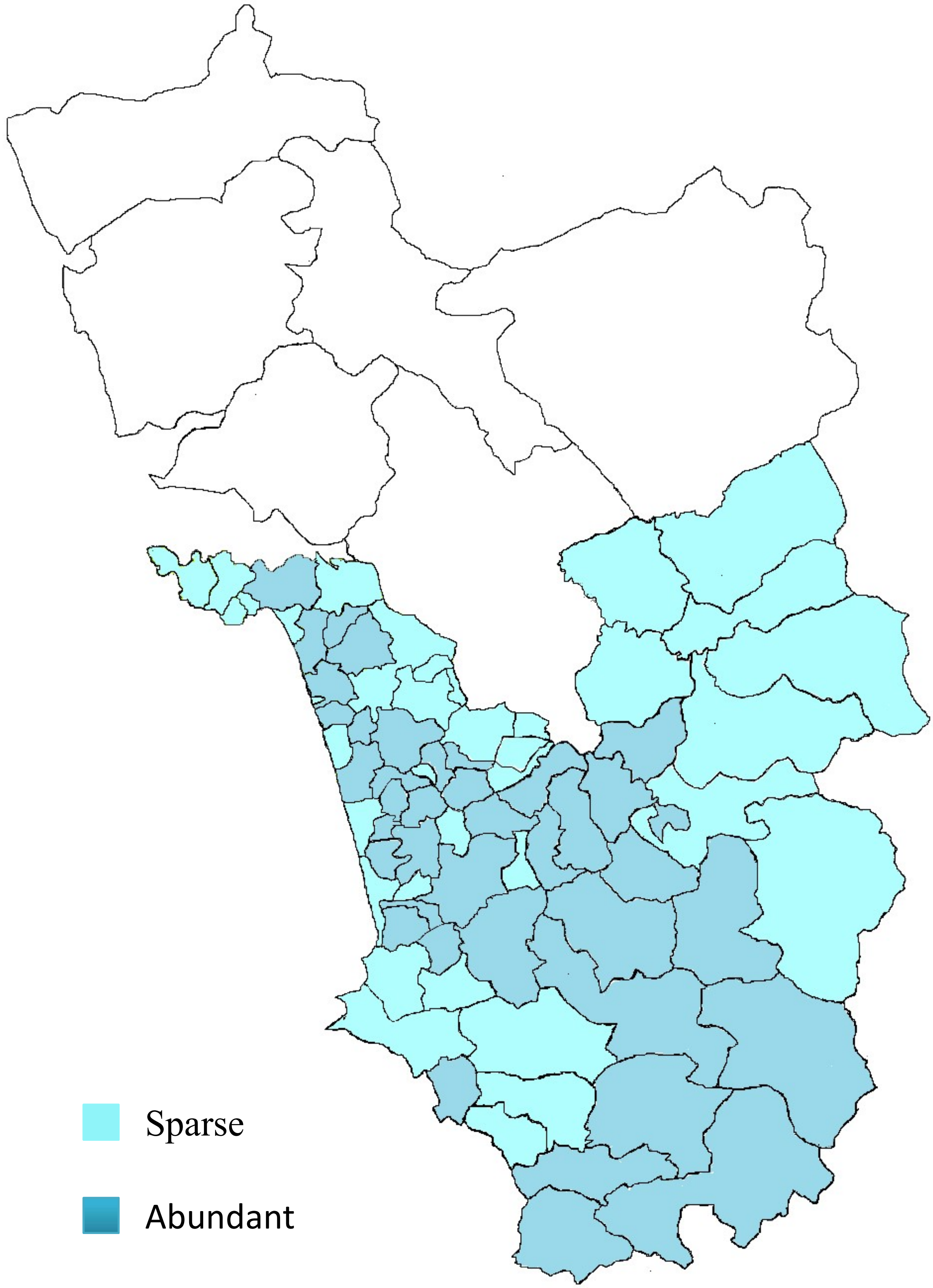


Fig. 4.2. Map depicting the current distribution of *Jaya* (HYV) rice in South Goa

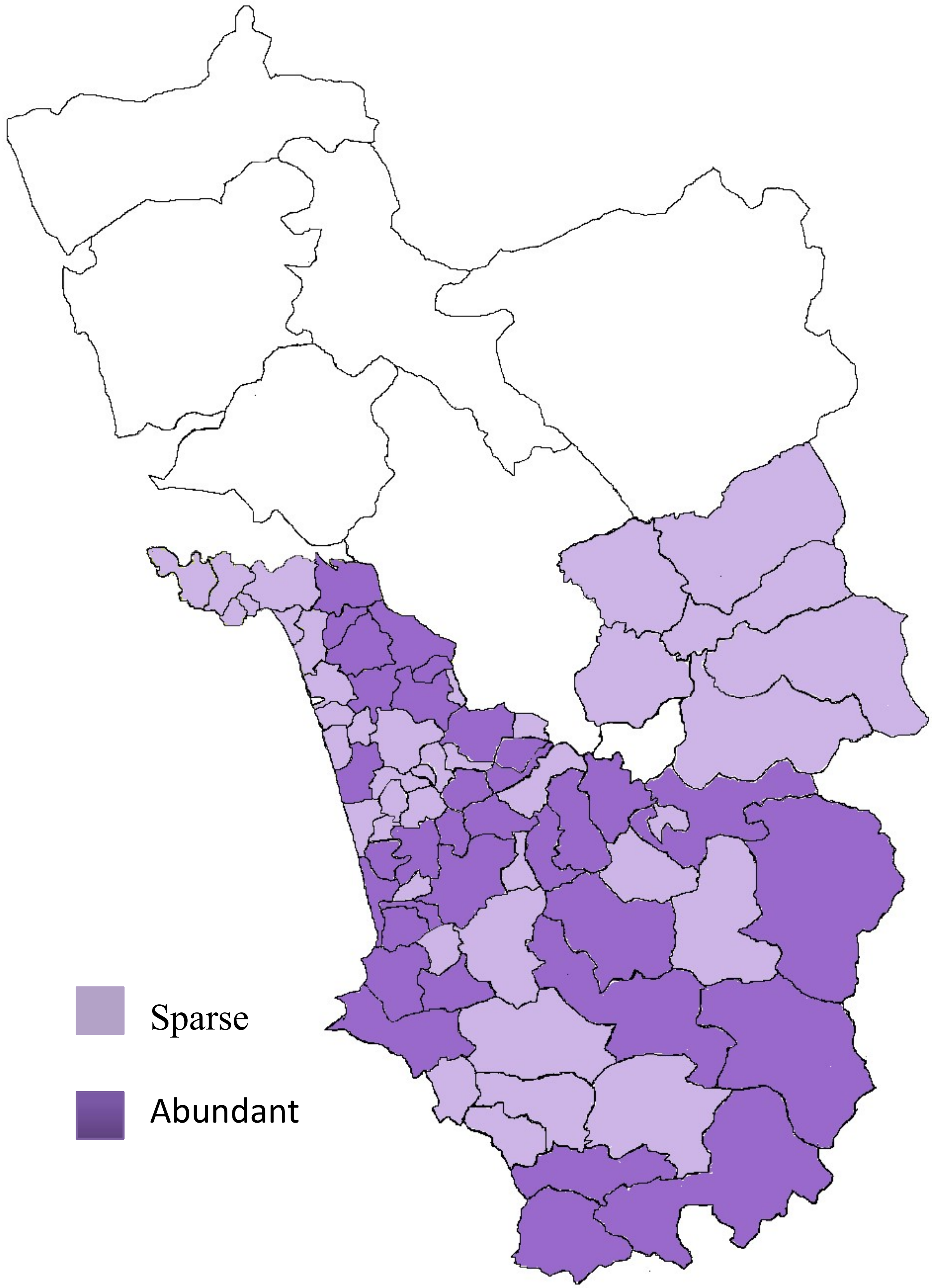


Fig. 4.3. Map depicting the current distribution of *Jyoti* (HYV) rice in South Goa

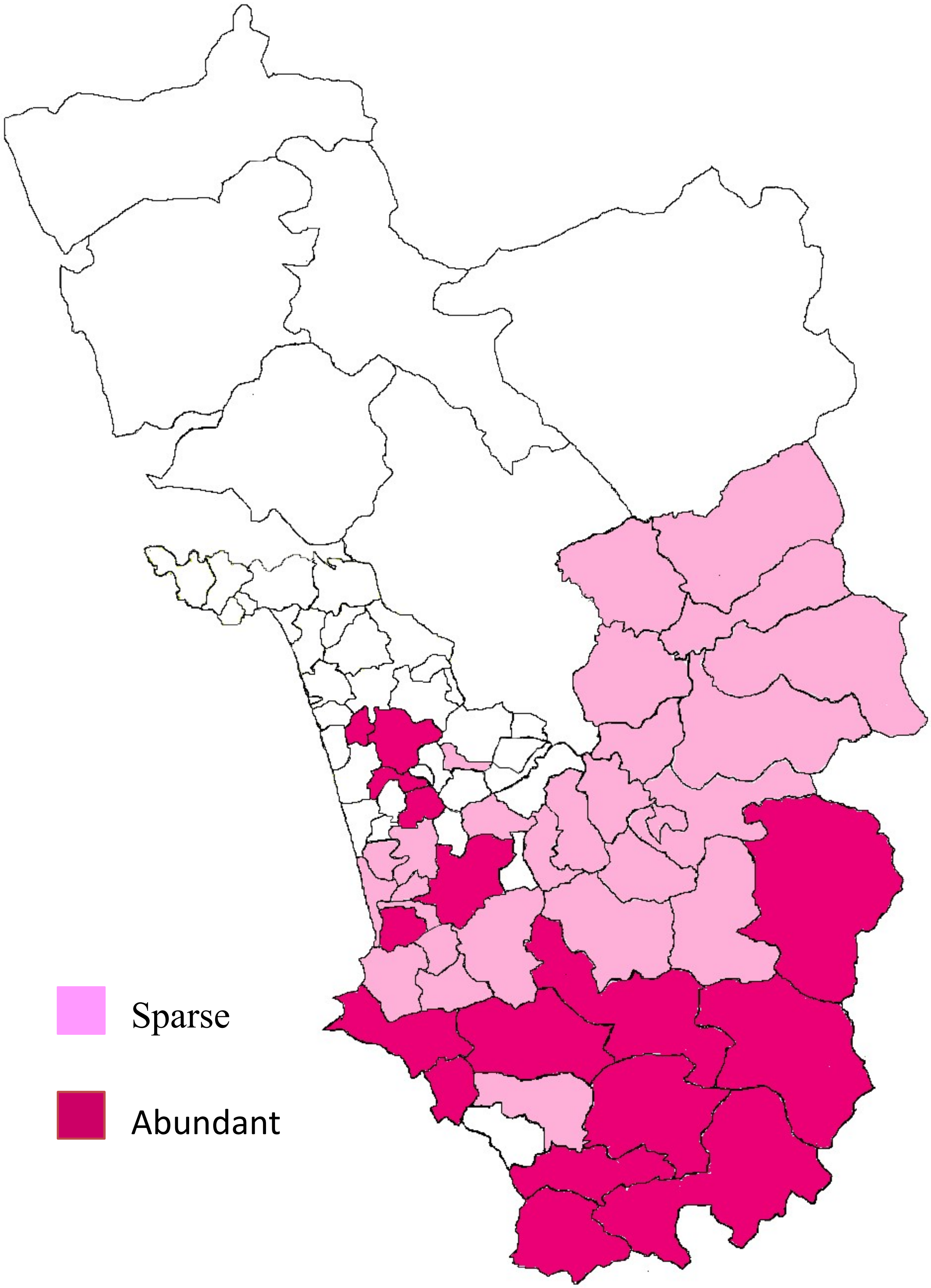


Fig. 4.4. Map showing the current distribution of *Karjat* (HYV) Rice in South Goa

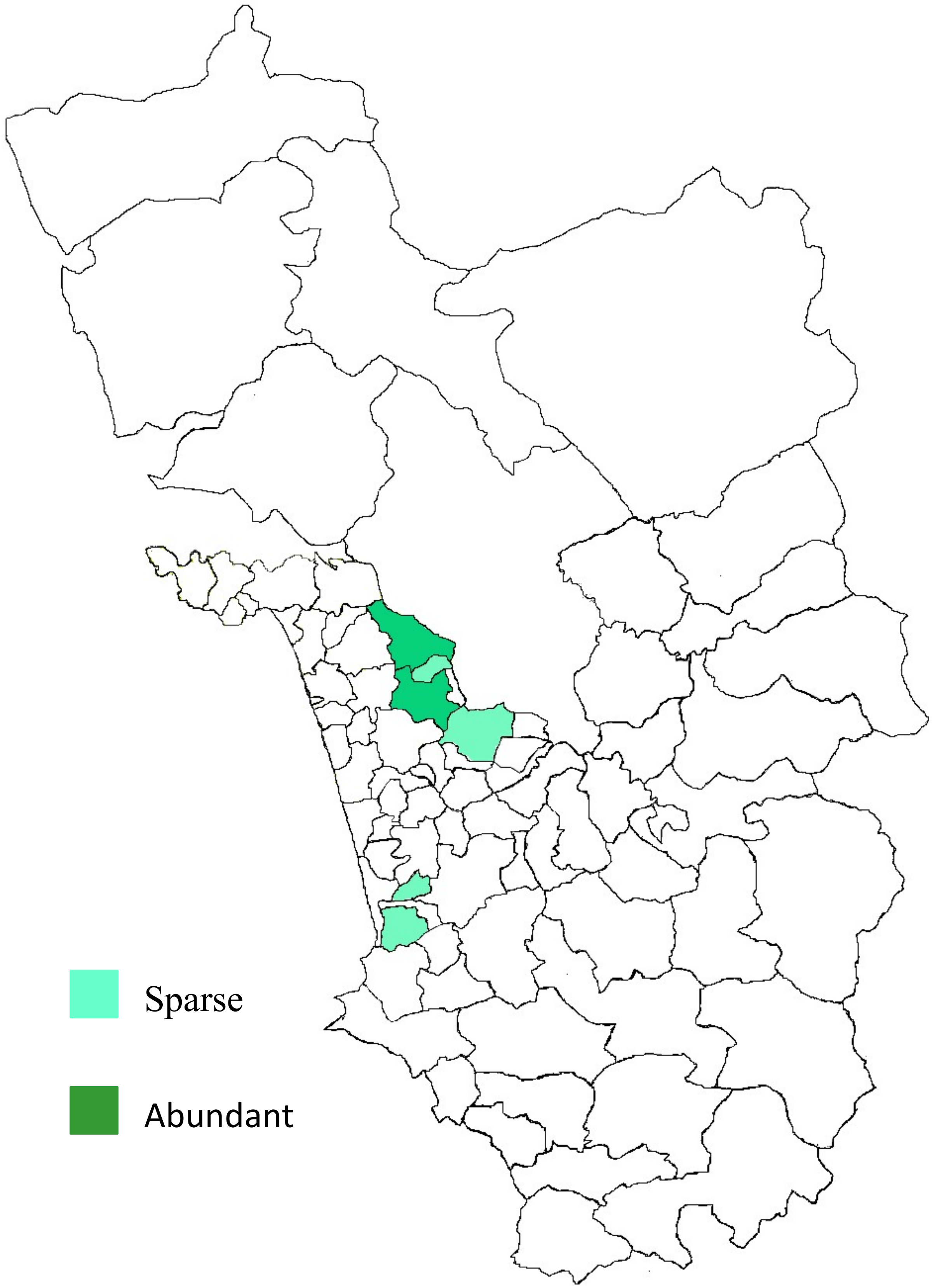


Fig. 4.5. Map depicting the current distribution of *Korgut* (LV) Rice in South Goa

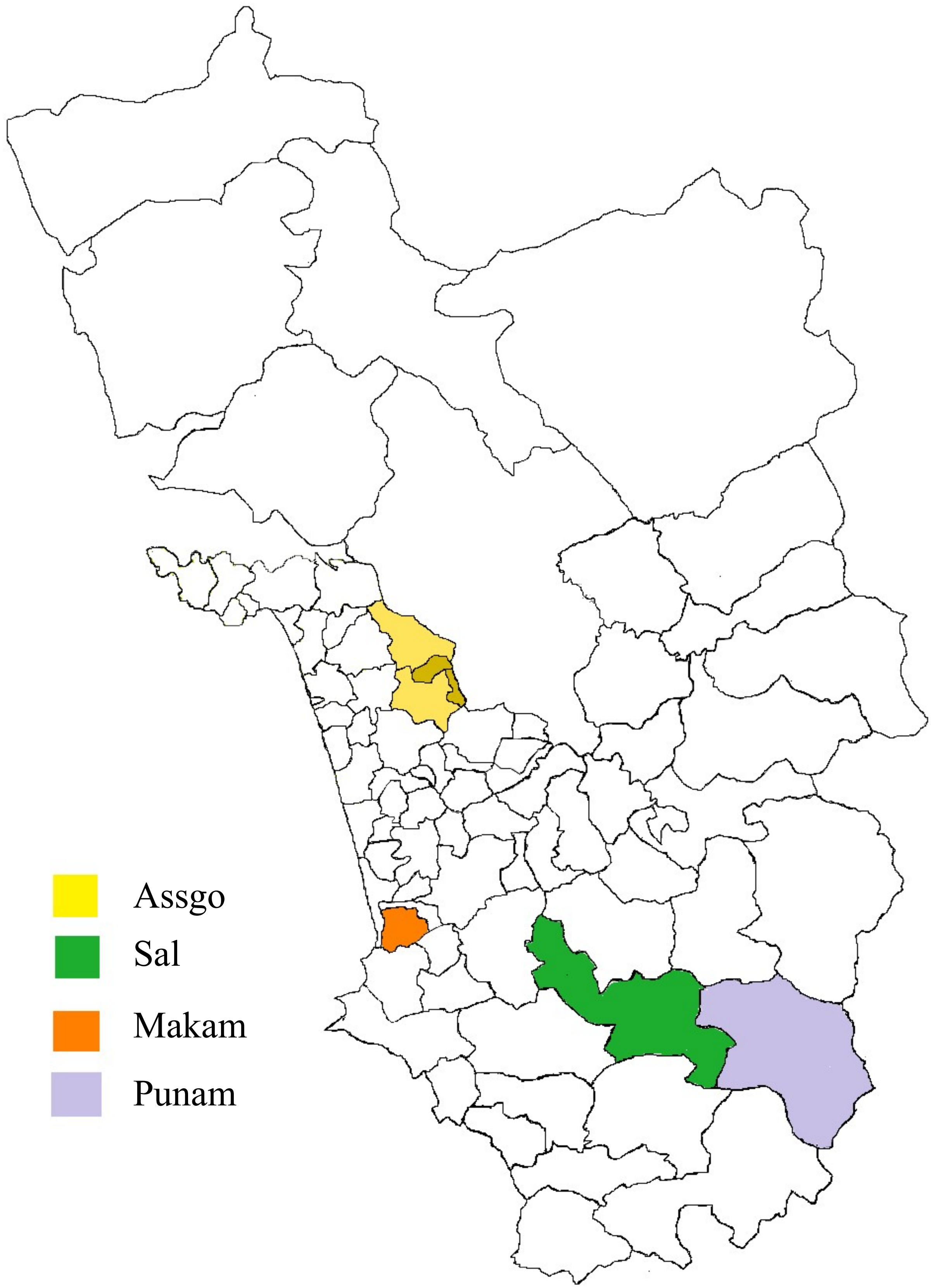


Fig. 4.6 Map depicting the current distribution of *Assgo* (LV), *Sal* (LV), *Makam* (HYV) & *Punam* (HYV) Rice in South Goa

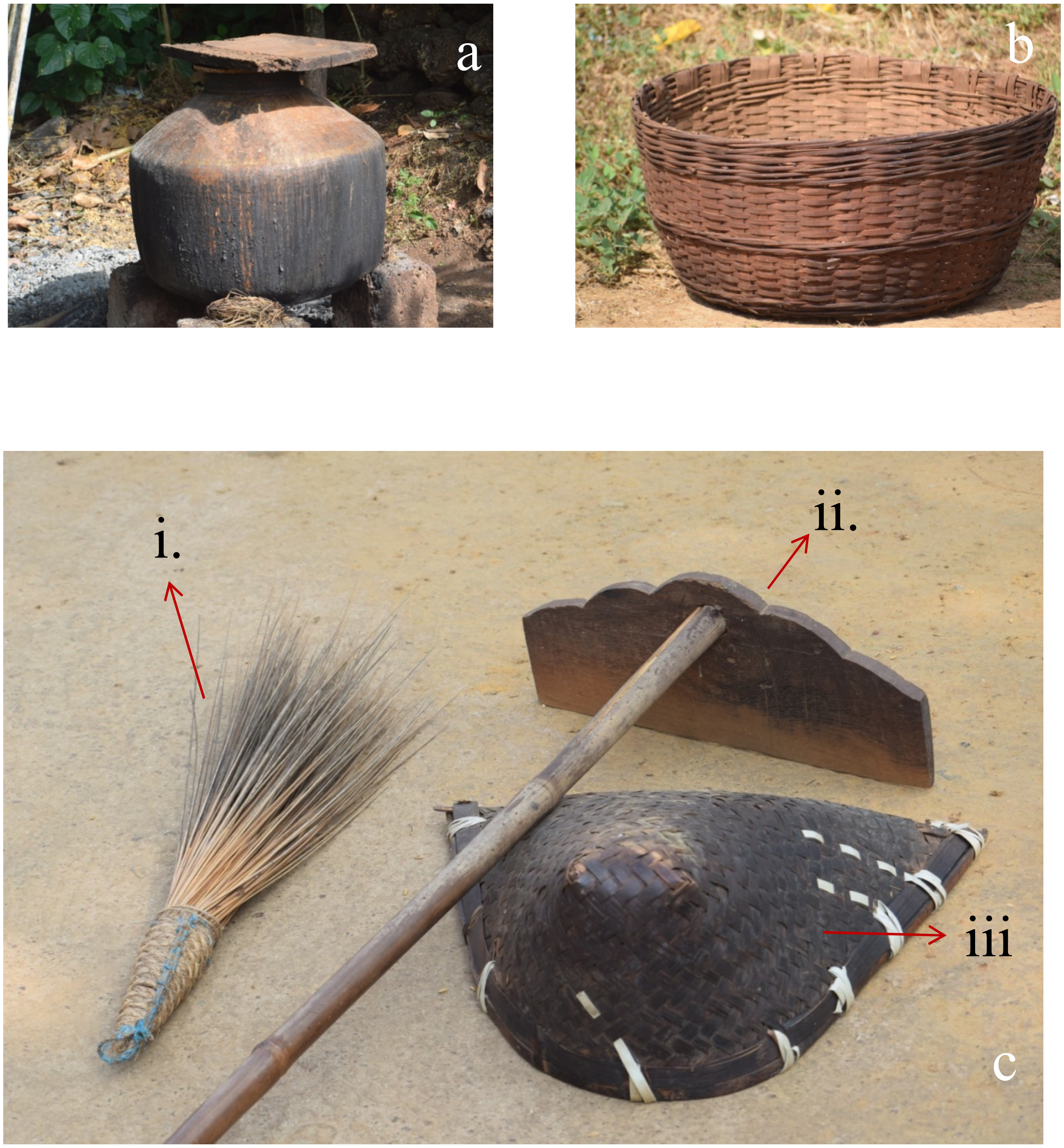


Plate 4.5. Traditional equipment/materials used for Parboiling, **“Cooper Vessel”** [Modki or Banddo (a)]; **“Bamboo Basket”** [Pateh (b)]; i. **“Broom”** (San), ii. Nivalo, iii. **“Bamboo Basket”** (Sup) (c).

Plate 4.3. Traditionally rice processing after harvesting. Threshing (a-e); Winnowing (f) & Drying and Storing (g & h).

Plate 3.1. Parboiling process for selected rice varieties. a: Washing and soaking; b: Boiling; c: Parboiled rice; d: Sun drying for 3 hr; e: Air drying/shade drying (36-48hr). f: After air dried.

Plant 4.4. Local/Traditional Parboil Process. Soaking & Boiling (a); Sun-drying (b-d); incubation (e); Shade dry or Air dry (f); Milling (g); final product rice kernel (h).

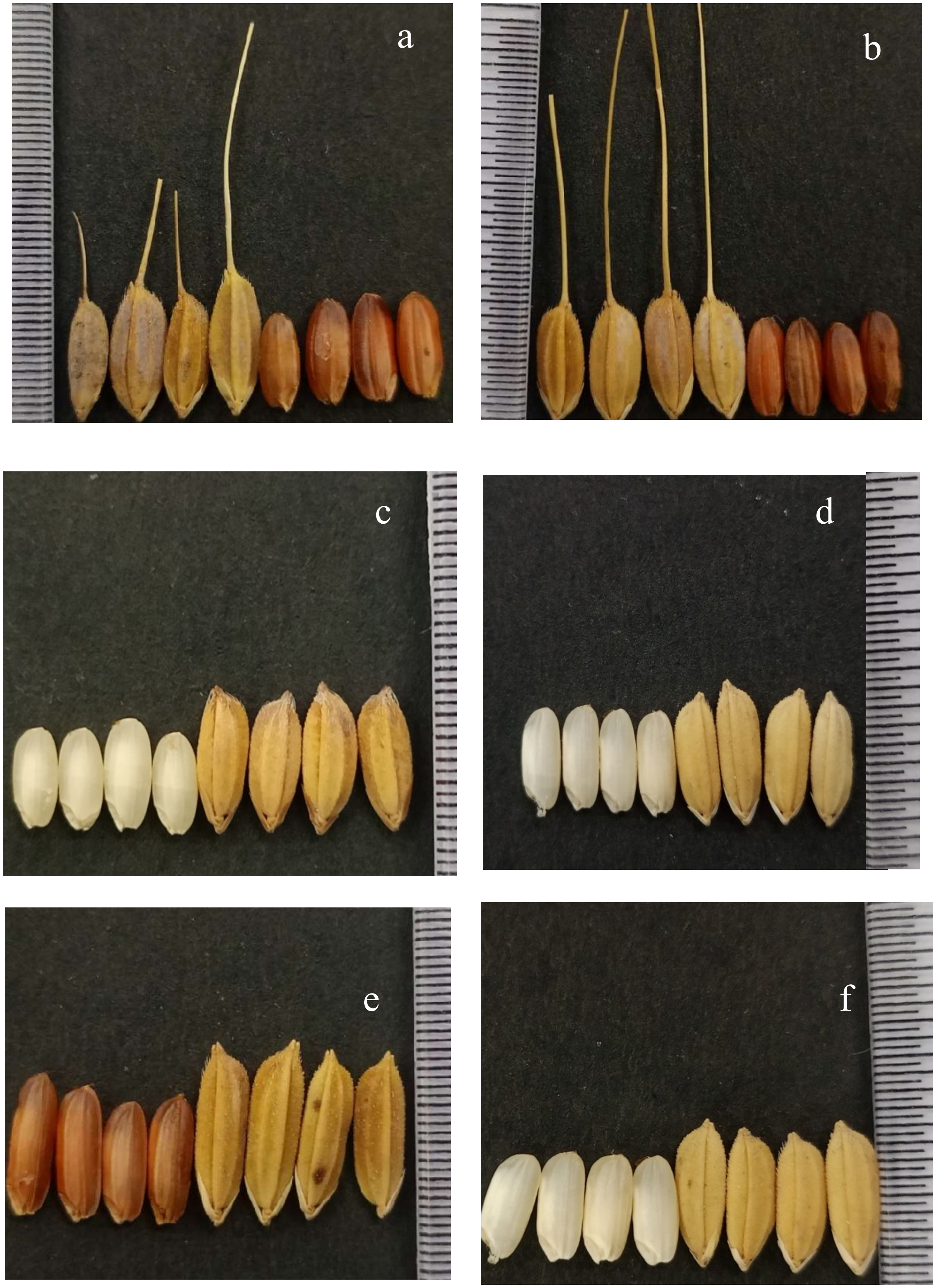


Plate 4.1. Indigenous/traditionally cultivated local (3) and High yielding (3) varieties with husk & de-husked. *Assgo* (a); *Korgut* (b); *Sal bhaat* (c); *Jaya* (d), *Jyoti* (e); *Karjat* (f).

Plate 4.2. High yielding varieties (2) and parboiled (4) varieties with husk & de-husked. *Makam* (a); *Punam* (b); *Assgo* (c); *Korgut* (d); *Jaya* (d), *Jyoti* (e).

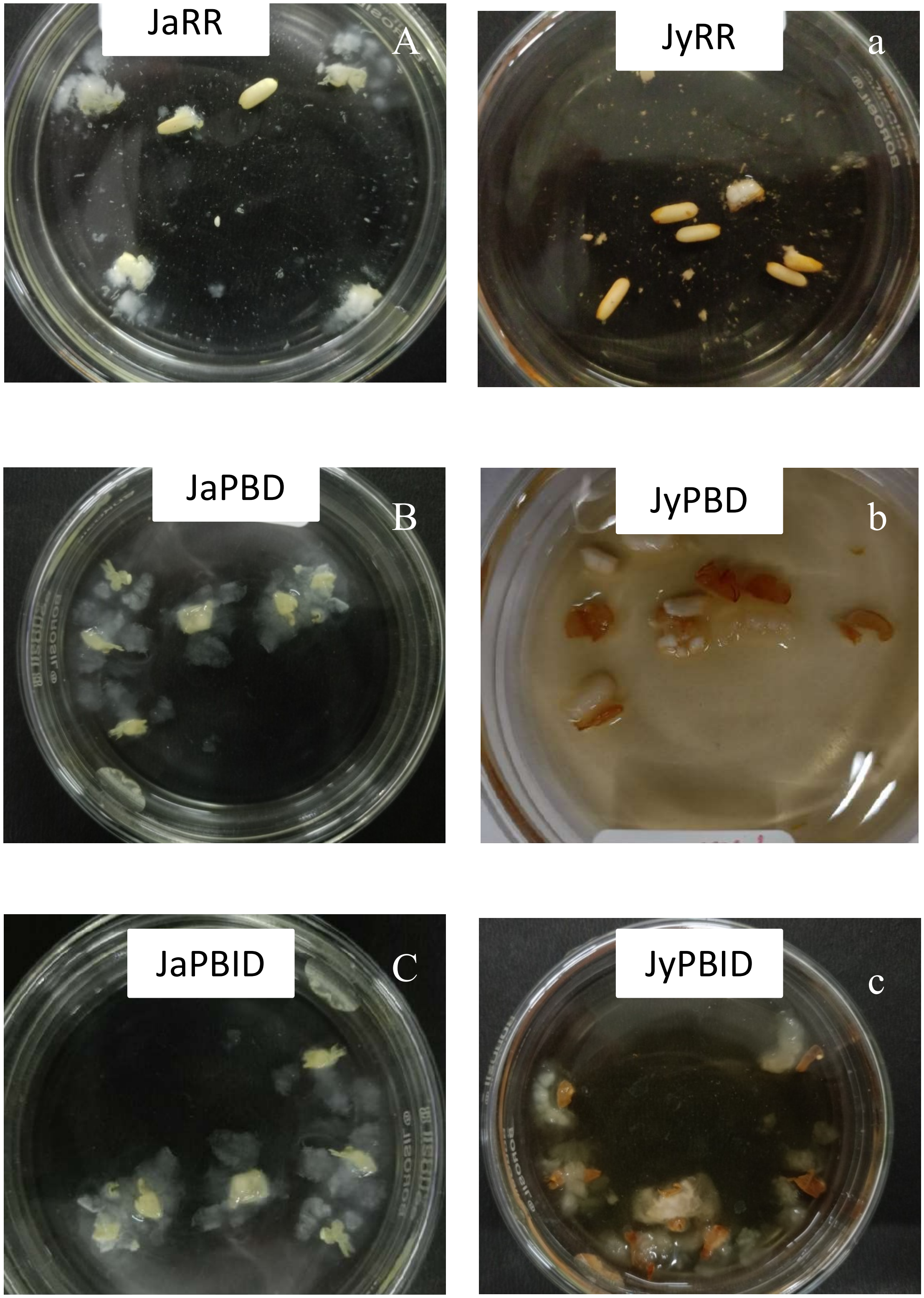


Plate 4.6. High yielding varieties showing alkali spreading value. A: Jaya Raw rice; B: Jaya Parboiled Direct method; C: Jaya Parboiled indirect method; a: Jyoti Raw rice; b: Jyoti Parboiled direct method; c: Jyoti Parboiled indirect method

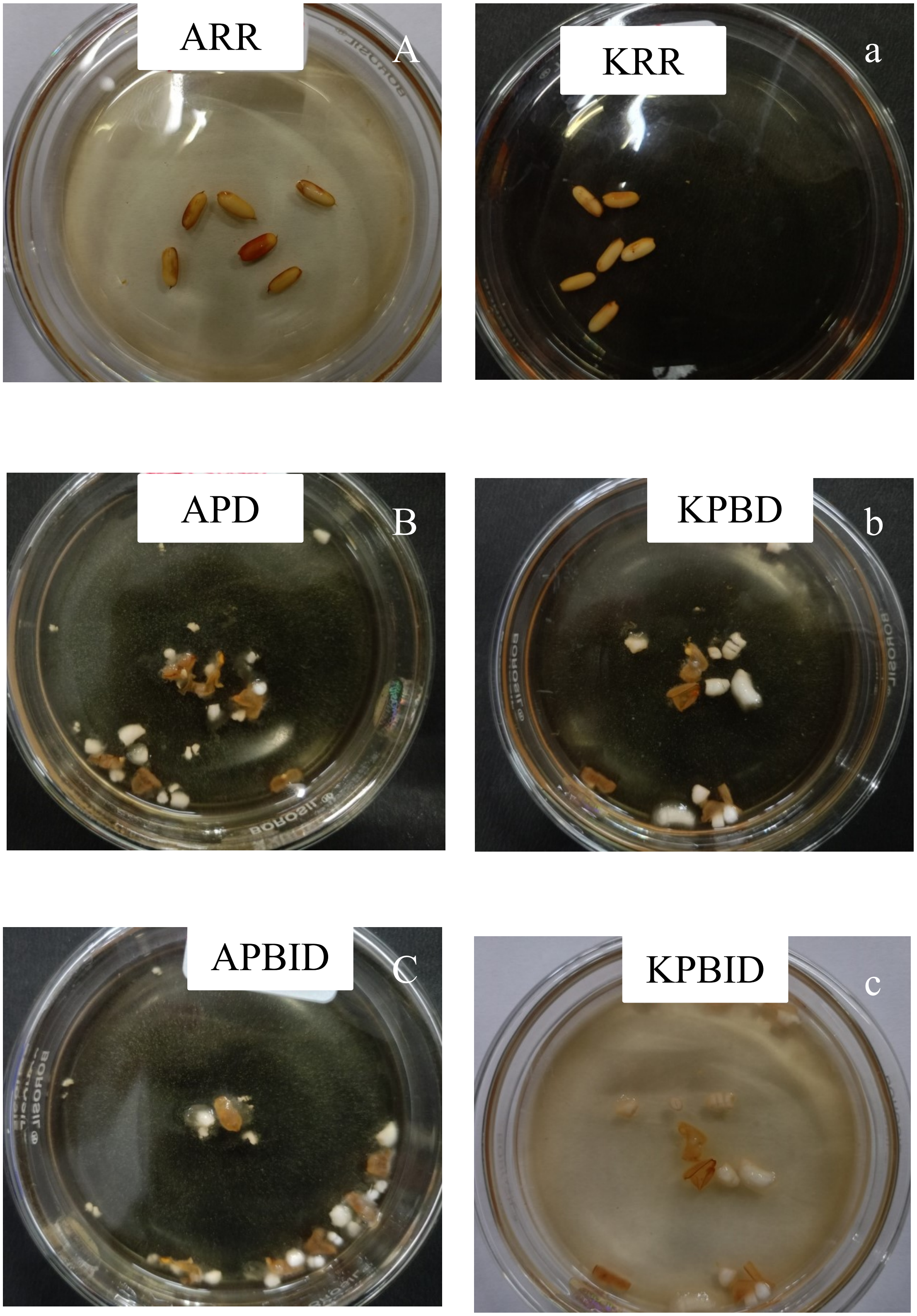
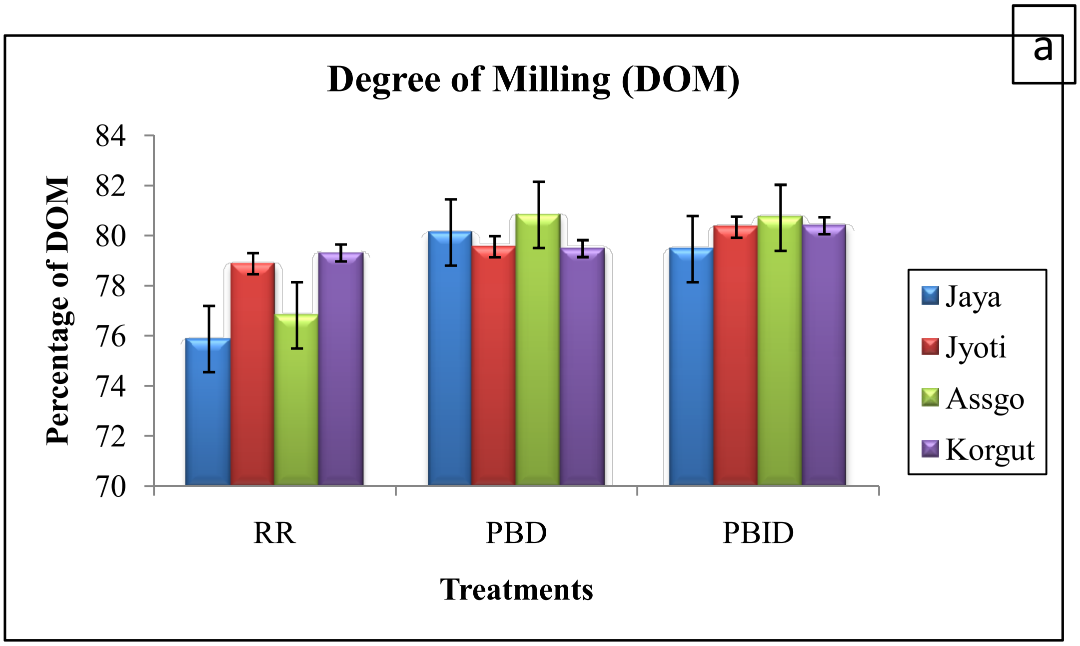


Plate 4.7. **Traditional/local rice varieties showing Alkali spreading value.** A: Assgo Raw rice; B: Assgo Parboiled Direct method; C: Assgo Parboiled indirect method; a: Korgut Raw rice; b: Korgut Parboiled direct method; c: Korgut Parboiled indirect method



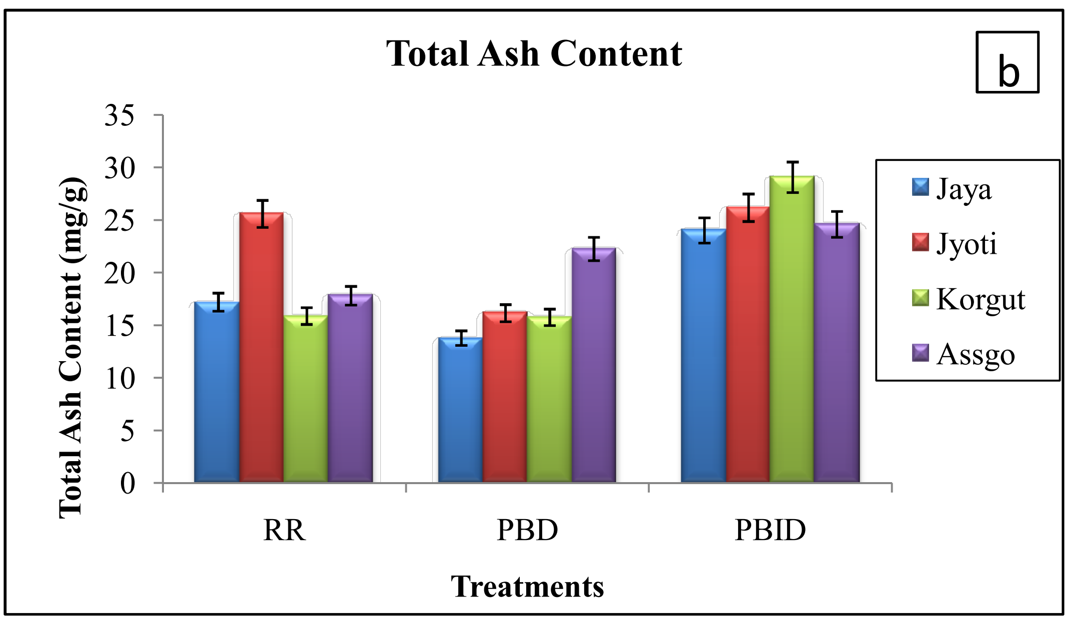
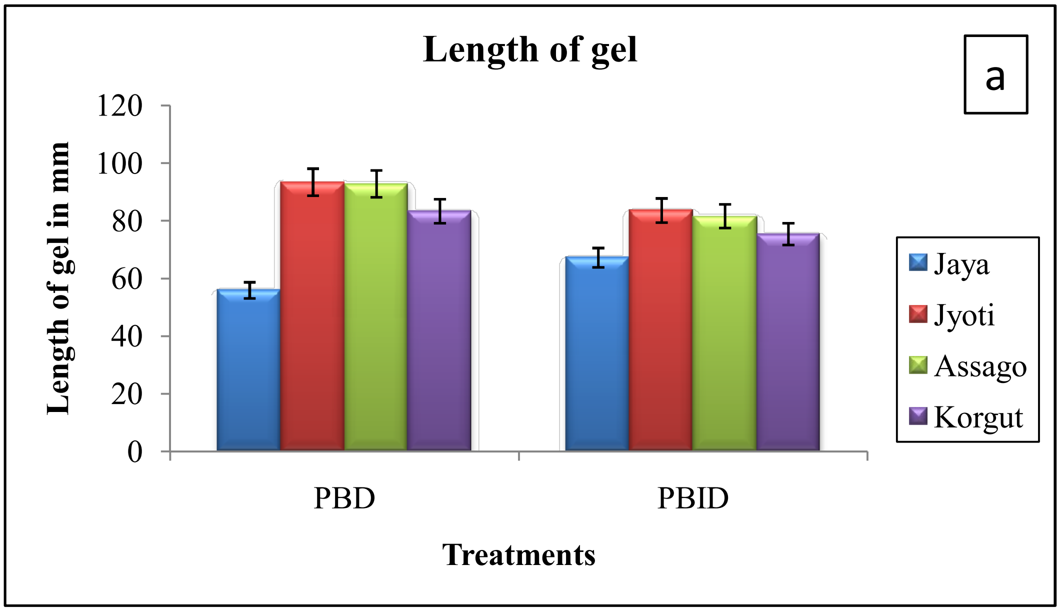


Fig 4.8. Comparative evaluation of Degree of Milling (DOM) & Total ash Content. a.: Degree of Milling (DOM); b: Total Ash Content (TAC).



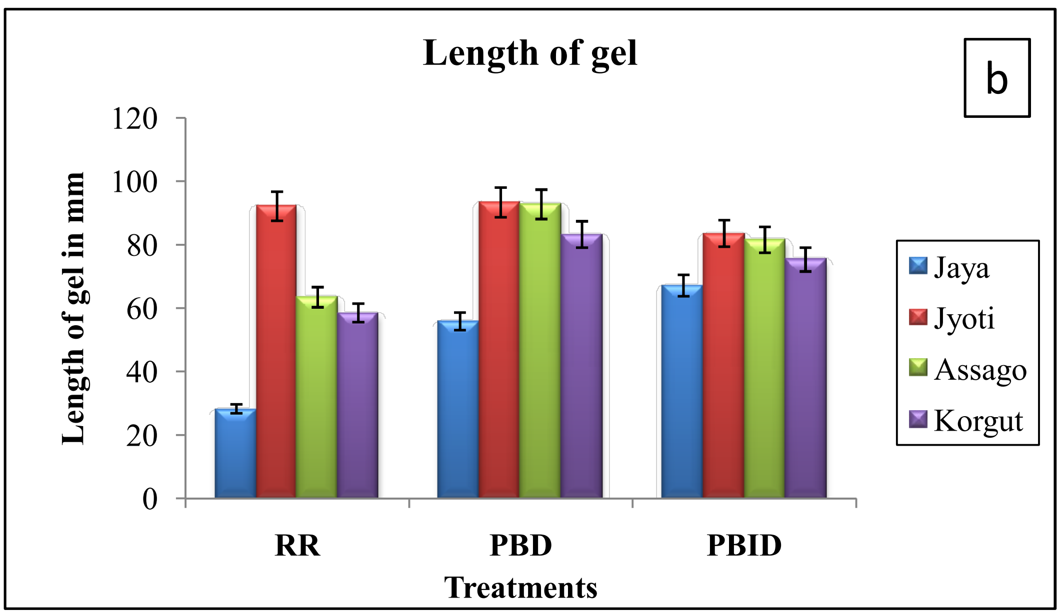


Fig 4.9. Comparative evaluation of Length of Gel. a: Parboiled Direct Method (PBD) v/s Parboiled Indirect Method (PBID); b: Raw Rice (RR), PBD and PBID treatments

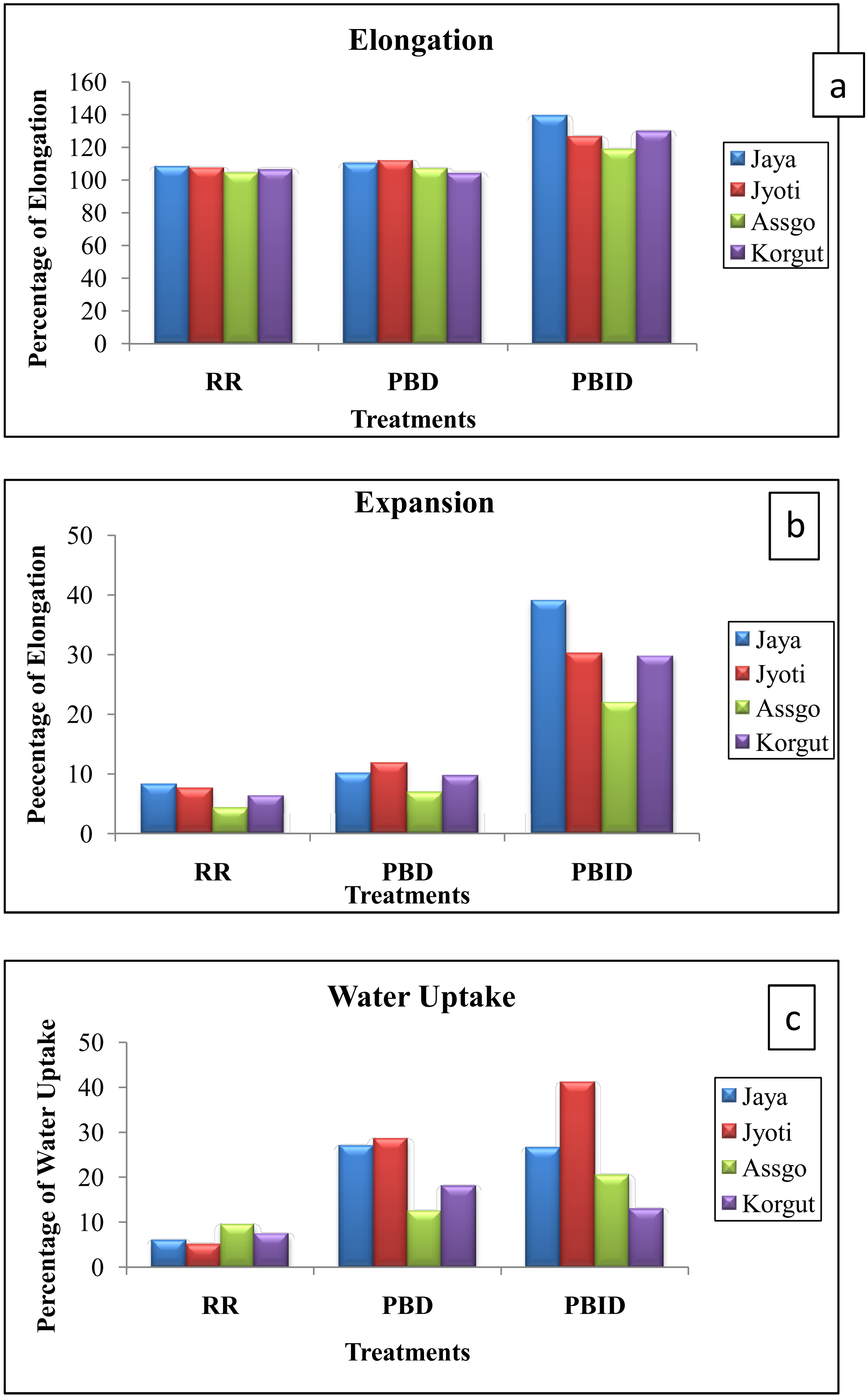
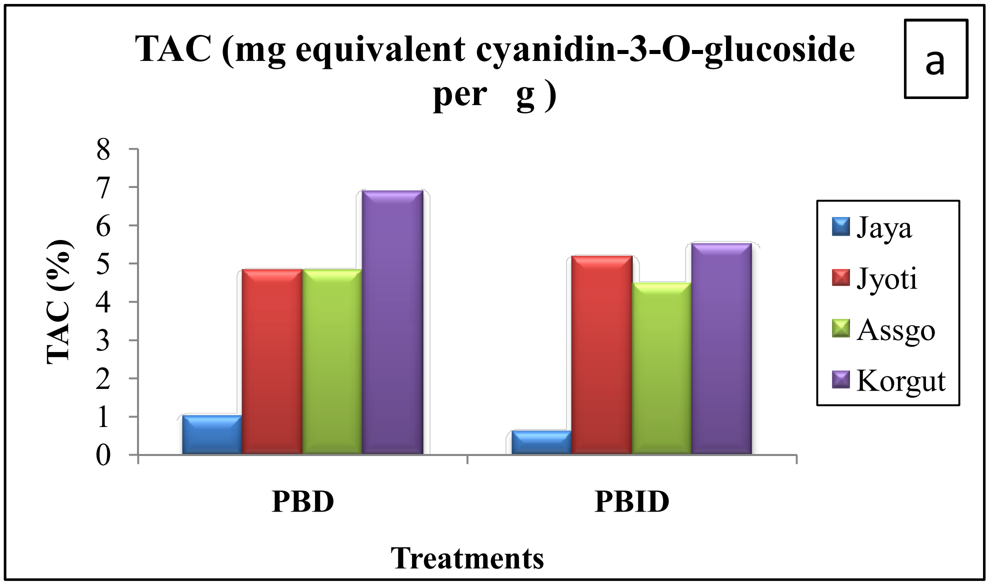


Fig 4.10. Comparative evaluation of cooking characteristics of Grains. a: Volume elongation percentage; b: Expansion percentage; c: Total water uptake percentage.



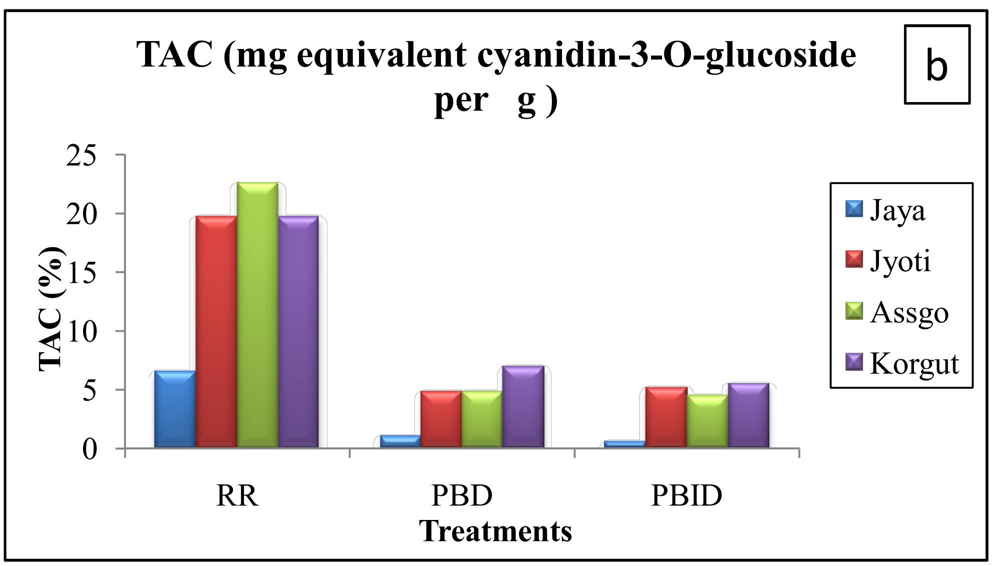


Fig.4.11. Comparative analysis of Total Anthocyanin (mg equivalent cyanidin-3-O-glucoside). a: Parboiled Direct Method (PBD) v/s Parboiled Indirect Method (PBID); b: Raw Rice (RR), PBD and PBID treatments.

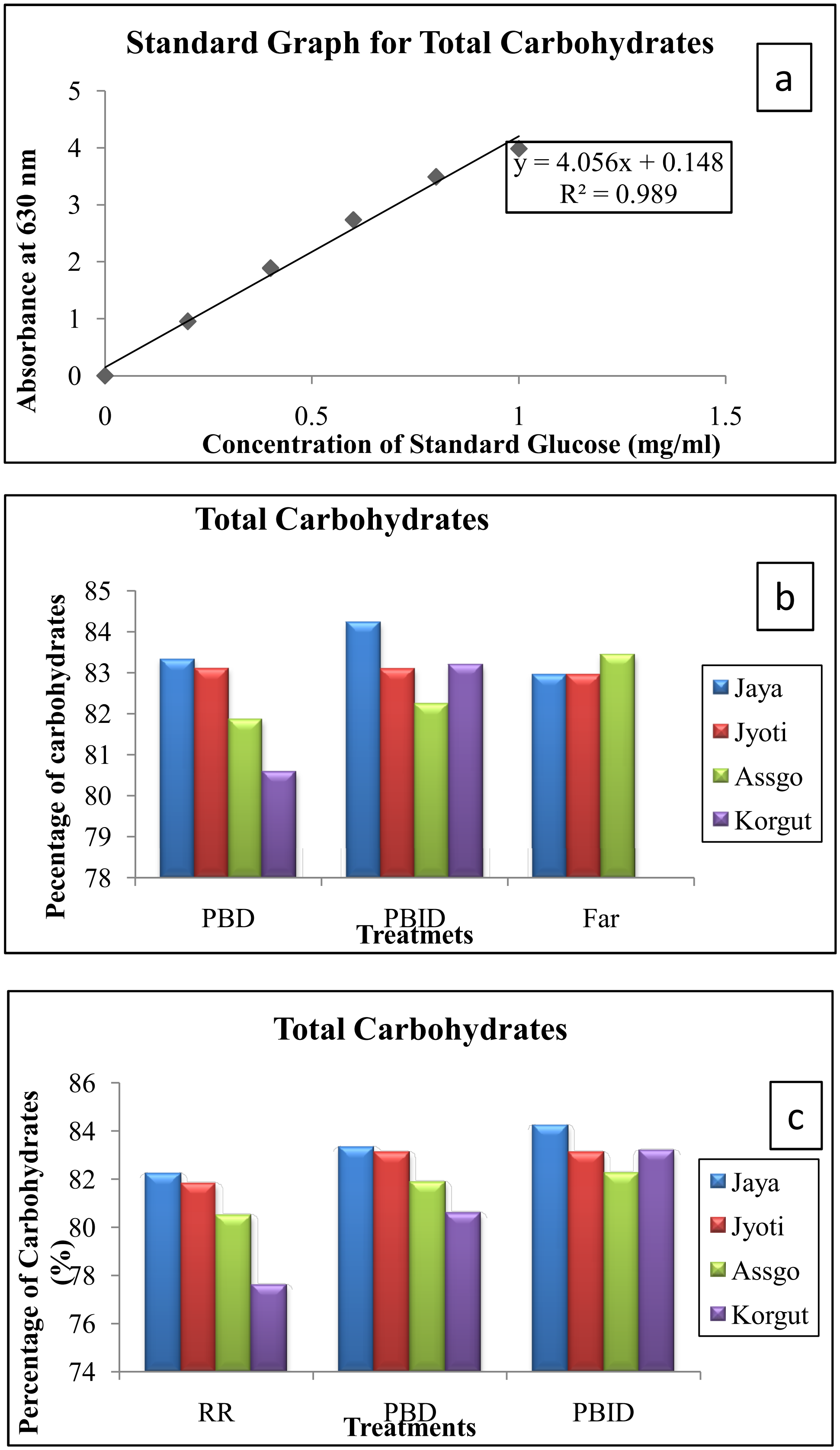


Fig 4.12. **Comparative analysis of Total Carbohydrates Content (TCC).** a: Standard Graph for Carbohydrates; b: Parboiled Direct Method (PBD), Parboiled Indirect Method (PBID) and Farmers(treated); c: Raw Rice (RR), PBD and PBID treatments.

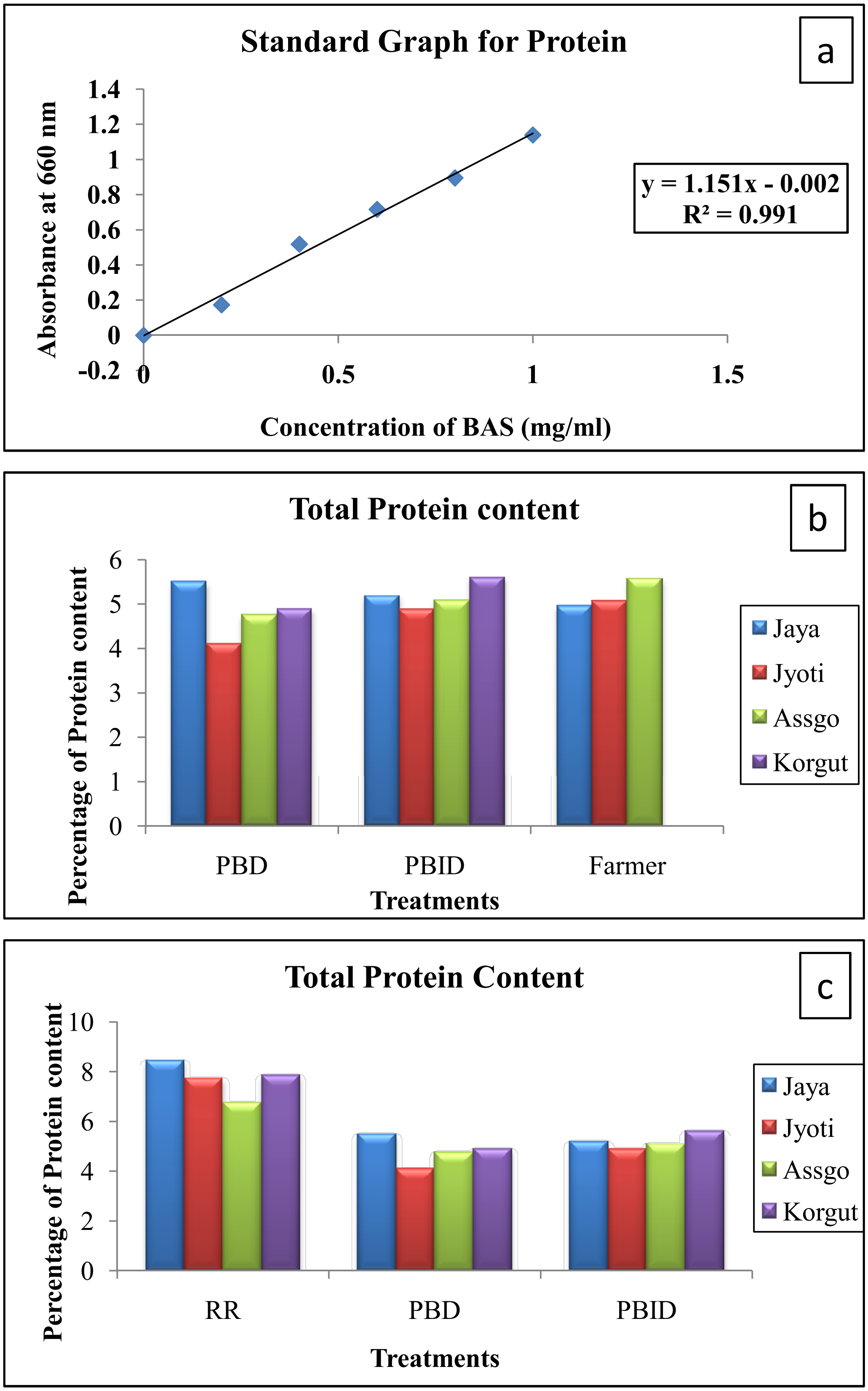


Fig 4.13. Comparative analysis of Total Protein Content (TPC). a: Standard graph for Protein; b: Parboiled Direct Method (PBD), Parboiled Indirect Method (PBID) and Farmers(treated); c: Raw Rice (RR), PBD and PBID treatments.

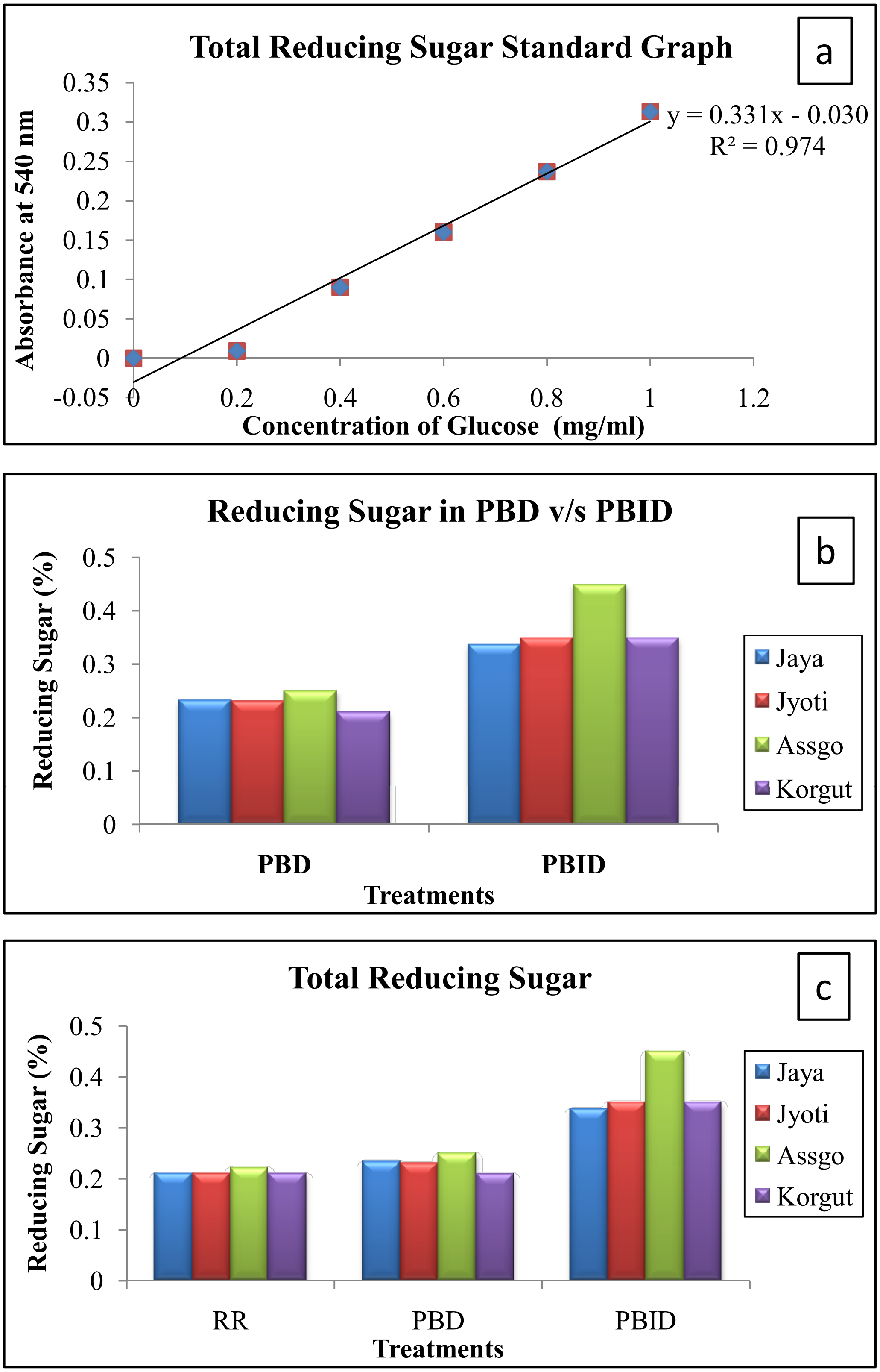


Fig 4.14. Comparative analysis of Total Reducing Sugar Content (TRSC). a: Standard Graph for TRSC; b: Parboiled Direct Method (PBD) and Parboiled Indirect Method (PBID) ; c: Raw Rice (RR), PBD and PBID treatments.

Table 1.1. Area of cultivation, Yield and Production of rice in India

Market	Area	Milled Production	Rough Production	Yield
Year	**(1000 Ha)**	**(1000 Tons)**	**(1000 Tons)**	**(T/Ha)**
2013/2014	44,136	106,646	159,985	3.6
2014/2015	44,110	105,482	158,239	3.6
2015/2016	43,499	104,408	156,628	3.6
2016/2017	43,994	109,698	164,563	3.7
2017/2018	43,774	112,758	169,154	3.9
2018/2019	44,156	116,484	174,743	4.0
2019/2020	43,662	118,870	178,323	4.1
2020/2021	45,769	124,368	186,571	4.1
2021/2022	46,279	129,471	194,226	4.2
2022/2023	47,832	135,755	203,653	4.3
2023/2024	48,000	134,000	201,020	4.2
5-year Average 2018/19 - 2022/23	**45,540**	**124,990**	**187,503**	**4.1**

(Source: India Ministry of Agriculture, Directorate of Economics and Statistics, Market Year 2017/18-2019/2020 data by districts)

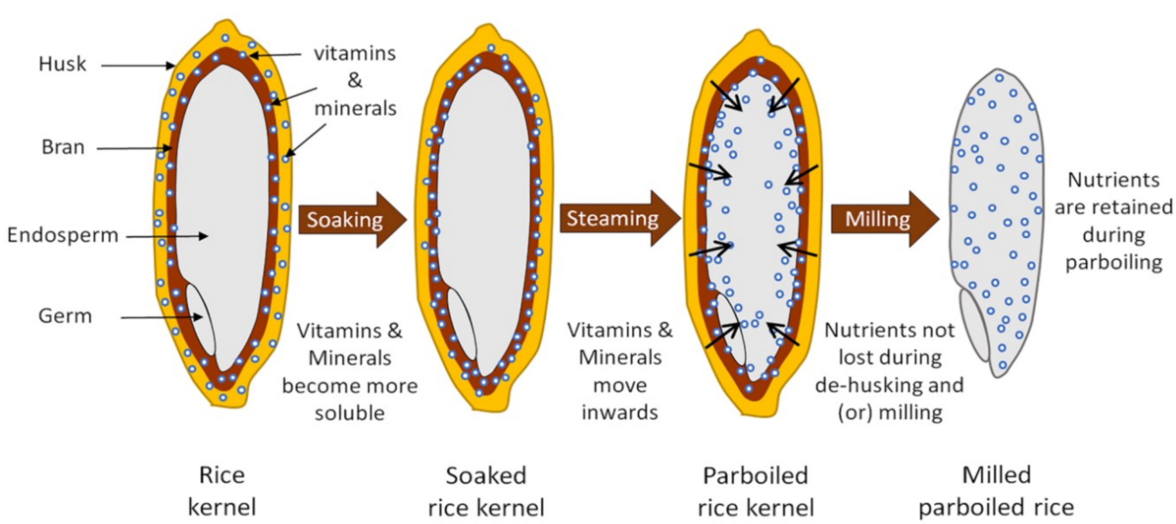


Fig. 1.1: Schematic representation of Nutrient infusion into rice endosperm during the parboiling process (Bhar et al., 2022)

Table 4.4. Physical characteristics of raw rice (RR) & Parboiled rice (Direct method & Indirect method). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirect method);Ja (*Jaya* variety); Jy (*Jyoti* variety); A (*Assgo* variety);K (*Korgut* Variety).

Sl.No.	Varieties (RR, PBD & PBID)	Colour of husk	Colour of Kernel	Awns	Lenght of Kull Grain (mm)	Lenght og Kernel (mm)	Degree of Milling (%)
1	JaRR	Light brown to brown	Creamy White	Absent	8.13±0.0116	6.166±0.16	75.87
2	JyRR	Dark brown to brown	Brown to light brown orange	Absent	0.9±0.1	7.1±0.2	78.87
3	ARR	Brownish- light Black shade	Orange to Brown	Present	8±0.2	6.3±02	76.81
4	KRR	Dark brown to brown	Light Brown to Orange	Present	9±0.2	6.6±0.2	79.31206
5	JaPBD	Light brown to brown	Creamy White to mild Y ellow	Absent	8.1±0.0117	6.525±0.15	80.12852
6	JyPBD	Dark brown to brown	Brown to light brown orange	Absent	0.9±0.2	7±0.15	79.56
7	APBD	Brownish- light Black shade	Brown to Chocolate brown	Present	8±0.3	6.52±0.375	80.83
8	KPBD	Dark brown to brown	Brown to Chocolate brown	Present	9±0.3	6.25±0.25	79.46
9	JaPBID	Light brown to brown	Creamy to mild brwunish yellow	Absent	8.13±0.0118	6.05±0.325	79.46
10	JyPBID	Dark brown to brown	Brown	Absent	0.9±0.3	6.57±0.45	80.33
11	APBID	Brownish- light Black shade	Dark brown to dark chocolate	Present	8±0.4	6.25±0.1	80.71
12	KPBID	Dark brown to brown	Dark brown to dark chocolate	Present	9±0.4	6.37±022	80.39

Table 4.5. Total Ash content in Raw rice (RR) & Parboiled rice (Direct method & Indirect method). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirect method);Ja (*Jaya* variety); Jy (*Jyoti* variety); A (*Assgo* variety);K *(Korgut* Variety).

Sl. No.	Varieties (RR, PBD & PBID)	Total Ash Content (mg/g)
1	JaRR	17.2±1.2
2	JyRR	25.595±1.145
3	ARR	17.8±0.2
4	KRR	15.875±0.575
5	JaPBD	13.775±3.375
6	JyPBD	16.15±3.375
7	APBD	22.25±2.021
8	KPBD	15..75±3.125
9	JaPBID	24.01±1.39
10	JyPBID	26.175±2.175
11	APBID	24.6026±1.548
12	KPBID	29.0725±1.0325

Table 4.6. Chemical characteristics of Raw rice (RR) & Parboiled rice (Direct method & Indirect method) showing Alkali spreading value (ASV) & Gelatinization temperature (GT). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirectmethod); Ja (*Jaya* variety); Jy (*Jyoti* variety); A (*Assgo* variety)K (*Korgut* Variety).

Sl. No.	Varieties (RR, PBD & PBID)	Alkali spreading Value	Gelatinization temperature
1	JaRR	Intermediate	Intermediate (70-74 °C)
2	JyRR	Low	High (75-79 °C)
3	ARR	Low	High (75-79 °C)
4	KRR	Low	High (75-79 °C)
5	JaPBD	High	Low (55-69 °C)
6	JyPBD	Intermediate	Intermediate (70-74 °C)
7	APBD	Intermediate	Intermediate (70-74 °C)
8	KPBD	Intermediate	Intermediate (70-74 °C)
9	JaPBID	High	Low (55-69 °C)
10	JyPBID	High	Low (55-69 °C)
11	APBID	Intermediate	Intermediate (70-74 °C)
12	KPBID	Intermediate	Intermediate (70-74 °C)

Table 4.7. Chemical characteristics of Raw rice (RR) & Parboiled rice (Direct method & Indirect method) showing the Gel consistency(GC). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirect method); Ja (*Jaya* variety); Jy (*Jyoti* variety);A (*Assgo* variety); K (*Korgut* Variety).

Sl.No.	Varieties (RR, PBD & PBID)	Length of gel in mm	Gel Consistency
1	JaRR	28.3±1.9	Hard
2	JyRR	92.2±0.8	Soft
3	ARR	63.5±1.2	Soft
4	KRR	58.6±1.05	Medium
5	JaPBD	55.9±1.3	Medium
6	JyPBD	93.4±1.4	Soft
7	APBD	92.8±1.6	Soft
8	KPBD	83.3±0.95	Soft
9	JaPBID	67.2±1.55	Soft
10	JyPBID	83.6±1.3	Soft
11	APBID	81.6±1.1	Soft
12	KPBID	75.4±1.4	Soft

Table 4.8. Cooking characteristics of Raw rice (RR) & Parboiled rice (Direct method & Indirect method) showing Elongation, Expansion & water up take (%). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirect method);Ja (*Jaya* variety); Jy (*Jyoti* variety); A (*Assgo* variety); K (*Korgut* Variety).

Sl.No.	Varieties (RR, PBD & PBID)	Cooking Characteristics		Water Up take At 30 min (%)
		Elongation (%)	Expansion(%)	
1	JaRR	108.25	8.252	6
2	JyRR	107.54	7.54	5
3	ARR	104.35	4.35	9.5
4	KRR	106.41	6.4	7.5
5	JaPBD	101.03	10.01	27
6	JyPBD	111.52	11.82	28.5
7	APBD	106.93	6.93	12.5
8	KPBD	104.13	9.68	18
9	JaPBID	139.19	39.159	26.5
10	JyPBID	126.63	30.25	41
11	APBID	118.87	22.09	20.5
12	KPBID	129.84	29.84	13

Table 4.9. TAC (mg equivalent cyanidin-3-O-glucoside per g) in Raw rice (RR) & Parboiled rice (Direct method & Indirect method). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirect method); Ja (*Jaya* variety); Jy (*Jyoti* variety); A (*Assgo* variety); K (*Korgut* Variety)

Sl. No.	Varieties (RR, PBD & PBID)	TAC (mg equivalent cyanidin-3-O-glucoside per g)
1	JaRR	6.57±0.00125
2	JyRR	19.7±0.0021
3	ARR	22.8±0.006
4	KRR	19.7±0.0015
5	JaPBD	1.03±0.00025
6	JyPBD	4.84±0.00015
7	APBD	4.84±0.00025
8	KPBD	6.9±0.0005
9	JaPBID	0.61±0.00015
10	JyPBID	5.18±0.00015
11	APBID	4.49±0.0002
12	KPBID	5.53±0.0002

Table 4.10. Total Carbohydrates (TCC), Total Protein (TPC) & Total Reducing Sugar (TRSC) in Raw rice (RR) & Parboiled rice (Direct method & Indirect method). RR (Raw Rice); PBD (Parboiled Direct method); PBID (Parboiled Indirect method); Ja (*Jaya* variety); Jy (*Jyoti* variety); A (*Assgo* variety); K (*Korgut* Variety).

Sl. No.	Varieties (RR, PBD & PBID)	Total Carbohydrates %	Total Protein %	Total Reducing Sugar %
1	JaRR	82.229	8.45	0.21
2	JyRR	81.829	7.74	0.21
3	ARR	80.49	7.86	0.22
4	KRR	77.617	6.76	0.21
5	JaPBD	83.33	5.5	0.233
6	JyPBD	83.11	4.118	0.231
7	APBD	81.87	4.9	0.25
8	KPBD	80.59	4.76	0.21
9	JaPBID	84.24	5.2	0.338
10	JyPBID	83.11	4.9	0.35
11	APBID	82.25	5.61	0.45
12	KPBID	83.21	5.1	0.35
13	JaF	82.96	4.96	-
14	JyF	82.96	5.07	-
15	AF	83.45	5.57	-

Table 3.1. Spreading and clearing of kernels noted on 7-point scale.

Scale	Spreading Scale	Clearing Scale
1	Kernel not affected	Kernel chalky
2	Kernel swollen	Kernel chalky, collar powdery
3	Kernel swollen, collar incomplete and narrow	Kernel chalky, collar cottony or cloudy
4	Kernel swollen, collar complete and white	Centre cottony, collar cloudy
5	Kernel split or segmented, collar complete and wide	Centre cottony, collar clearing
6	Kernel dispersed, merging with collar	Centre cottony, collar, cleared
7	All kernels dispersed and inter mingled	Centre and collar cleared

Table 3.2. Classification on the bases of gelatinization temperature (GT)

Classification	Alkali spreading value (ASV)	Gelatinization temperature (GT)
1-2	Low	High (75-79°C)
3-5	Intermediate	Intermediate (70-74°C)
6-7	High	Low (55-69°C)

Table 3.3. Classification of gel consistency test

Length of gel	Gel consistency
26-40 mm	Hard gel consistency
41-60 mm	Medium gel consistency
61-100 mm	Soft gel consistency