Traditional Parboiled Rice-Based Products Revisited: Current Status and Future Research Challenges

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Abstract: Parboiling is an age old technique carried out to improve rice quality. Different grain parboiling techniques have been traditionally followed and scientifically developed for preparation and industrialization of rice. The state of Assam, India produces a large number of rice varieties, some of which are traditionally processed into peculiar parboiled rice products like Hurum, Komal chaul, Bhoja chaul and Sandahguri, which are of both ethnic and possible commercial importances. In spite of extensive research carried out on parboiled rice, these products and their special parboiling techniques have not been sufficiently explored. The status of research on parboiled rice as a whole with special attention to these lesser known speciality products of Assam is extensively reviewed. Future scope of research on these products is also identified.

Key words: rice; parboiling; rice product; technique

Rice (Oryza sativa L.) is staple food for more than half of the world’s population. The International Rice Genebank of the International Rice Research Institute (IRRI) has a collection of more than 117 000 types of rice, comprising of modern and traditional varieties, also including wild relatives of the plant. The north-eastern states of India are very rich in biological as well as ethnic diversity. Among the north-eastern states of India, Assam is unique in terms of a mixed culture as well as both hilly and low land vegetation. Located between 24º to 28º4’ North latitude and 89º4’ to 96º East longitude, the state shares international borders with Bangladesh and Bhutan. More than 15 distinctly different tribes dwell in the land and each has its own food and social habits. Anthropological study by Bordoloi et al (1987) elaborated that many of these tribes migrate from Tibet, China and Burma. Hence, the agro-climatic location and continuous migration of the different Mongolian races from South-East Asia as well as Aryans from the Indian subcontinent and abroad have brought the unique racial intermixing and cultural exchange visible in Assam. This also causes extensive transfer of crop germplasm, resulting in a rich agricultural biodiversity. Assam produces numerous varieties of rice from time unknown. Ahmed et al (2011) have elaborated the varieties and recent growing patterns of rice in Assam.

Rice grain is principally composed of starch granules with very small size (about 2–5 µm). Starch is the natural source of energy in plants and is primarily composed of two molecular fractions: amylose and amylopectin. On the basis of the apparent amylose content, Juliano (1979) classified rice into high amylose (> 25%), intermediate amylose (20%–25%), low amylose (7%–20%) and waxy or glutinous (1%–2%) groups. The cooking properties of rice grains vary considerably from one group to another. Another classification method was proposed by Bhattcharya et al (1980), they classified hundreds Indian rice varieties collected from different parts of the country into eight groups. Group I cooks flaky and hard, while group VIII cooks extremely sticky and soft. Group IV consists of the aromatic rice varieties. It was observed that only Assam produced varieties from all the eight groups. Glutinous rice varieties of Assam and its adjoining states are unique in India.

Parboiling is an age-old technique used for post-harvest processing of rice grains. About 60% of the total production of paddy rice grains is parboiled in India. The country has more than 5 000 large scale mills with parboiling facilities. The parboiling technique is known to originate in India in the fourth or fifth century AD (Bhattacharya, 1985). The basic and
conventional parboiling process involves soaking rough rice for 2-4 d or longer in water at ambient temperature to attain saturation, followed by boiling the steeped rice till the grain expands and the hull’s lemma and palea start to separate. The grains are then air- or sun-dried to a desirable moisture level and milled. Advancement to the conventional parboiling method is pressure parboiling, involving application of high pressure and temperature to partially hydrate rice, which reduces the processing time and increases plant turnover. Another form of traditional parboiling method called dry-heat parboiling involves brief conduction heating of the soaked rice grains with or without very hot sand (Bhattacharya and Ali, 1985). Fig. 1 gives the schematic diagram of the three types of parboiling processes. Modern parboiling technologies and equipments have been developed by research institutes like Indian Institute of Technology, Kharagpur and Central Food Technological Research Institute, Mysore, etc (Kachru, 2010). Many variations in processing conditions and techniques have also developed and been studied. Introduction of modern dryers, microwaves, fluidized hot beds, etc. have made the parboiling process more efficient in recent times (Cheenkachorn, 2007; Sangdao and Krairiksh, 2008; Fofana et al, 2011).

This article reviews the rice parboiling techniques, their effects on the properties of the grain and utilization of parboiled rice products supported by research findings. The research possibilities on Assamese traditional rice products which have unexplored commercial and scientific significance are specially mentioned.

**Parboiled rice**

Research on parboiled rice dates back to the early 1960s (Mecham et al, 1961; Bhattacharya and Subba Rao, 1966; Bhattacharya, 1969). Although various aspects of parboiled rice have been studied by numerous researchers, most of the works revolve around the physicochemical attributes of the products. Parboiling results in easier processing (by hand), improves nutritional profile, and changes texture. However, mechanical processing becomes more difficult (Gariboldi, 1984). Suitably parboiled rice should always give 100% intact grains upon milling. Kaddus Miah et al (2002) observed a large reduction in fissured grains on hot soaking. Their study suggested that due to parboiling, the void spaces in the endosperm are filled and cracks are cemented, making the grain harder. Hence, it requires greater force and time for milling and polishing and therefore the nutritive epidermal layers of the rice grains are partially retained even after milling. Insect infestation is also reduced due to the hardness. Ibukun (2008), however, reported that prolonged steaming leads to the loss of nutrients in parboiled milled rice. The changes that occur in the rice grains on parboiling are broad in its morphological (grain surface and internal biological arrangements), structural (crystallinity change), physical (grain dimension, density, translucence, colour, hardness, porosity, flow and packing properties, milling quality, etc) and most importantly, the physicochemical and nutritional aspects (paste viscosity, texture, polymerization and polymorphism, thermal properties, proximate composition is widely used in the world. However, soaking of paddy rice grains for days in ground water or tap water has major drawbacks, making them unsuitable for consumption. Long soaking periods result in potent growth of microorganisms arising from the water source or soil attached with the paddy husk (Karunaratne, 2010). As rice seeds are hydrated and the activities of hydrolytic enzymes like amylase, protease, phosphatase and β-glucosidase increase, simpler sugars and proteins are formed and released into the soaking unit (Xavier and Anthoni Raj, 1995). This makes the system an ideal medium for yeasts and bacteria to grow. These microorganisms further form certain flavour and odour compounds that are considered unacceptable by many consumers. In addition, certain parboiled products like Ofada of Nigeria are relished due to the organoleptic flavour and nutritional enhancement on account of the microbial

![Fig. 1. Three basic parboiling processes.](image-url)
activity during soaking (Ebuehi and Oyewole, 2007). Use of microbial starter cultures for quality enhancement of such products has hence been practiced (Adeniran et al, 2012). The increased phenol content in the rice grains during soaking may lead to minor enzymatic colour development (Ramalingam and Raj, 1996). The modern process, therefore involves soaking of rice grains at elevated temperatures (around 70 ºC) for a few hours that saturates the grains fully or partially, followed by open or pressure steaming for a brief period (Tirawanichakul et al, 2012). Igathinathane et al (2005) developed a combination of soaking procedures which resulted in 67% reduction in soaking time as compared with single stage soaking at 70 ºC. They used initial soaking at 80 ºC for 45 min followed by 70 ºC for 3.25 h. The combination is dependent on the gelatinization temperature of the starch of any specific rice variety. The traditional method of parboiling also involves prolonged boiling under atmospheric pressure. Work of Himmelsbach et al (2008) dealt with changes in starch properties of rice with variable soaking and steaming temperatures. They reported that soaking at 90 ºC followed by steaming for 12 min results in enough gelatinization to prevent grain damage during milling. The characteristic amber colour of parboiled rice is mainly due to Maillard type browning reaction between reducing sugars and amino acids that leads to formation of Amadori coloured compounds (Messia et al, 2012). Colour development has been suggested as an important parameter for determining steaming severity by Lamberts et al (2006). The husk pigments also play an important role in determining the colour intensity as they migrate inwards into the endosperm during steaming (Lamberts and Delcourt, 2008). A non-uniform steaming leads to a non-uniform product colour. Other than that, parboiling severity alters the gelatinization temperature and reduces the gelatinization enthalpy of starch due to developed amorphousness (Wirakartakus and Lund, 1978). A laboratory-scale parboiling technique developed in our laboratory involving special treatments resulted in lowered cooking time of low amylose rice (Dutta and Mahanta, 2014). However, it is against the general findings due to the developed grain integrity and hardness, and the cooking time is increased after parboiling (Soponromarit et al, 2008; Tirawanichakul et al, 2012). Ong and Blanshard (1995b) did not find any relations between gelatinization temperature and texture of cooked rice. Their extensive study (Ong and Blanshard, 1995a, b) reported that the texture of cooked rice has strong correlations with the apparent amylose content and fine structures of amylopectin. The proportion of the longest (DP = 92–98) and shortest (DP < 25) amylopectin chains primarily determine the cooked rice texture. Intermediate (DP = 43–68) chains do not have any effects on texture. Cooked grains with harder texture are high in amylose and with longer chains of amylopectin that bind with other non-starch components. The changing status of viscosity of rice paste on cooking in excess of water and subsequent cooling as measured with a rapid viscosity analyser (RVA) gives the idea of the occurrence of starch gelatinization and retrogradation. The ratio of amylose and amylopectin of the rice flour plays the principal role in determining different viscosity parameters (Reddy et al, 1994). Our previous work on four rice varieties indicated that a high amylose variety forms a harder gel than glutinous ones (Dutta and Mahanta, 2012). In addition, amylopectin chain length, moisture content, protein content, lipid content and mineral content play significant roles in the pasting properties of rice flour and starch (Suzuki et al, 2006; Dautant et al, 2007; Ascheri et al, 2012). Hence, varietal and cultivar differences can be considered as the major factor behind differences in cooking behaviour of rice (Ashogbon and Akintayo, 2012). Prominent changes in the starch molecular arrangement as well as migration and restructuring of other components are suggested by the RVA patterns (Himmelsbach et al, 2008). Lowering of starch swelling at the heating phase indicated by lowered peak viscosity and other parameters was evident, which confirmed the findings of Bhattacharya and Ali (1985) that part of the gelatinised starch had retrograded during slow drying of the rice grains. The molecular re-association during retrogradation explains the phenomenon of longer cooking time of parboiled rice in boiling water. In addition, a major part of the starch is gelatinised in the parboiled rice grains, such rice grains absorb water faster at temperatures below the gelatinisation temperature of the rice. In a related study, Lai et al (2001) proposed a relationship between pasting properties and starch rigidity upon hydrothermal treatment. Parboiling also affects the level of disulphide bonds in proteins (Derycke et al, 2005). The protein network formed after parboiling restricts the swelling capacity of parboiled rice flour when heated, thereby also contributing to the lower peak viscosity values. The viscosity studies by different authors also suggested changes in gelatinization onset temperature after the hydrothermal treatment (Shih et al,
2007; Himmelsbach et al, 2008). Thermal behaviour of rice flour can be better understood by the differential scanning calorimetry (DSC) of rice slurry. Heating of starch slurry in the DSC melts any forms of crystallite present. Along with the reduction in total crystallinity as measured by X-ray diffractometry, newer crystallites are also formed during retrogradation. The native A-type X-ray diffraction spectra of raw rice starch changes partially to B-type due to differences in water content and newer arrangement after recrystallization (Mahanta et al, 1989). Amylose-lipid complexes give V-type X-ray diffraction pattern and additional endothermic peaks in the DSC thermograms. The formation of these new crystalline polymorphs depends largely on the rice variety and the parboiling conditions applied (Manful et al, 2008). Lamberts et al (2009) have reported the formation of amylose crystallites in parboiled rice.

**Popular parboiled rice products**

Asia as a whole is the major producer and consumer of steam parboiled rice. Parboiled rice is industrially produced, consumed and exported from almost all Asian countries. African countries like Nigeria, Ghana, Egypt, Niger and Benin are also significant producers of rice, and parboiling is a very common technique practiced in African households that plays an important role in fighting undernourishment and food loss (Tomlins et al, 2005). More recently, extensive research on African parboiled rice has been carried out (Demont et al, 2012). Amongst the dry-heat parboiled products, the most popular are the puffed rice and flaked rice (Fig. 2). The processing methods for both these products have been upgraded (Bhattacharya and Ali, 1985).

**Puffed rice**

Paddy rice grains are soaked in warm water overnight and the soaked grains are then roasted in sand on a Bhatti in small batches to produce dry-heat parboiled paddy rice grains. The paddy rice grains are allowed to dry in mild sun or in air after spreading out. The dried paddy grains are then milled in a huller. The milled parboiled grains are gently heated on the Bhatti without sand to reduce the moisture content to the appropriate level, then taken out and mixed with a proper amount of salt solution. After holding for some times, the parboiled rice grains are again roasted on the Bhatti in small batches with sand on a strong fire for a few seconds to produce the puffed rice. The improved process has been developed by the Central Food Technological Research Institute, Mysore, India (Chinnaswamy and Bhattacharya, 1983). It is found that dry-heat parboiling gives better puffing expansion of rice than steam parboiling, and pressure parboiling gives better puffing expansion than dry-heat parboiling. Paddy rice grains are first washed with water, followed by pressure parboiling at 2.0–2.5 kg/cm² for

![Image of parboiled rice products](image-url)
15 min. The parboiled grains are then dried either in sun or mechanical drier and milled. Before puffing, the parboiled grains are mixed with saturated salt solution (3–4 mL of saturated salt solution per 100 g of rice grains), and thereafter the moisture content of parboiled grains is brought down to 10.5%–11.0% and puffed in 10 times of its weight with sand at 250 °C for 10–11 s. Pressure parboiled rice gives slightly coloured puffed rice. To reduce the colour, the paddy grains are washed with 2% sodium bisulfite solution. Hoke et al (2005) reviewed the optimum conditions set for different types of rice puffing (dry-heat, microwave and gun-puffing) from different works. Effects of amylose and protein content are also evident in the quality of puffed rice, suggesting varietal differences to be considered for puffing rice (Chinnaswamy and Bhattacharya, 1983; Villareal and Juliano, 1987). A more recent and sophisticated analysis on the same variety by Mahanta and Bhattacharya (2010) clarified the earlier doubts on the variable product qualities with processing conditions. The study indicated that the puffing is promoted by gelatinization and amylose-lipid complex formation, and retarded by amylose retrogradation and probable starch breakdown due to high temperature conduction heating. Addition of different salt solution increases the starch breakdown due to high temperature conduction and retarded by amylose retrogradation and probable gelatinization and amylose-lipid complex formation, described then. Mujoo and Ali (1998) suggested that rice roasting resulting in gelatinization, causes exposure of starch component to enzymatic digestion. However, the additional step of roller flaking for rice flake preparation causes the formation of certain starch-protein complexes with molecular weights greater than 4 × 107 kDa. These complexes decrease the susceptibility of the product to enzymatic hydrolysis (Mujoo et al, 1998).

The Central Food Technological Research Institute at Mysore, India has conducted extensive studies on dry-heat parboiled rice. An early work by Ali and Bhattacharya (1976a) suggested that roasted rice gives higher degree of gelatinization than conventional parboiled samples as indicated by alkali degradation test. It also shows higher values of saturated equilibrium moisture content. The impact of retrogradation is minimised as the water required for retrogradation is insufficient due to rapid dehydration during roasting. Progressive retrogradation of starch in the roasted rice grains occurs only when stored at room temperature at above 18% moisture content (Ali and Bhattacharya, 1976b). They proposed that the high rate of moisture absorption by dry-heat parboiled rice is due to gelatinization effects, and the properties of conventional parboiled rice are due to retrogradation. The authors also developed a sedimentation test for pre-gelatinized rice products (Bhattacharya and Ali, 1976). Roasted rice gives high sedimentation volume in a dilute acidic solution. Fine and coarse brown rice grains were roasted by Guha and Ali (1998) where clear differences were observed between the two. Bran layers might have behaved as partial insulators during the process. The products exhibit lesser cooking time than steam parboiled rice due to high water absorption characteristics developed. Chitra et al (2010) worked on in vitro starch digestibility of popped rice, expanded rice and flaked rice prepared by sand

### Flaked rice

For flaked rice, soaked rice grains are precooked by roasting followed by flaking in an edge runner. The process also removes the brittle outer husk. One major drawback of passing through the edge runner is the low yield (63%–65%). In the edge runner, the roasted grains have to pass between the roller and pan edge repeatedly round and round for a minute. So, even the dehusked and flattened grains pass through the edge runner repeatedly. As a result, there is severe abrasion at the edges of the grain along with grain breakage. An improvement of this process is the installation of another idle roll in the edge runner which increases the yield to 66%–67%. Roasting of the soaked paddy grains in this method is done in a continuous roaster. The roasted paddy grains are successively dehusked in a centrifugal dehusker and polished in a polisher. An aspirator removes all the husk and bran particles. The modified dehusker gives 100% dehusked roasted rice. The polished rice is then roller flaked. This process gives undamaged flaked rice. Ali and Bhattacharya (1976a, b) reported certain additional changes occurring in flaked rice which were not perfectly described then.
roasting. Lower starch content in the products than the raw rice is attributed to the adhering bran layers and formation of resistant starch in them. The products were hence suggested to be used in preparation of diabetic foods. Domestic pan roasting and using microwave were found to significantly reduce the rancidity development in rice bran (Ahmed et al, 2007). These hence have scope of application for rice products as development of rancidity in parboiled rice during storage is considered as a serious problem.

**Parboiled rice products of Assam**

In Assam, the high and intermediate amylose rice varieties are consumed as staple foods, and the low amylose and waxy varieties are processed to make specialty products. Steam parboiled rice is consumed by a significant mass of the Assamese population in their staple diet. A recent study was carried out on the effect of open and pressure parboiling on four rice varieties that are native to Assam and belong to high amylose, low amylose and waxy categories (Dutta and Mahanta, 2012). Differences in parboiling severity result in distinctly different product characteristics. Pressure parboiled glutinous samples show simultaneous loss in crystallinity and increased hydration at low temperatures. Unique taste and texture are attained when common dry-heat parboiled rice products like moori (puffed rice) and chira (flaked/beaten rice) are prepared using the glutinous varieties which are commonly eaten in Assam whereas moori and chira made from non-glutinous rice are popular throughout the Indian subcontinent. Further, there are certain specialty rice products, namely Hurum, Komal chaul, Bhoja chaul, Korai and Sandahguri (Fig. 2), which despite of having possible ethno-economic importance have not been extensively researched. Special parboiling treatments develop peculiar hygroscopic and sensory characteristics in these products. A few such products and their present status in the scientific scenario are detailed below.

**Hurum**

Hurum is an expanded rice product made from waxy Bora rice of Assam (Fig. 2). It is distinctly different from the more popular moori both in the processing method and the product quality. The basic traditional parboiling method (Fig. 3-A) comprises the following steps: full soaking of grains, parboiling, dehusking at high moisture, immediate flaking, rubbing fat to the flaked rice and expansion in sand. This product can therefore be called as ‘expanded flaked’ rice. A previous study identified the essential steps of Hurum making in the laboratory using paddy grains processed by normal, dry-heat and pressure parboiling methods (Mishra et al, 2000). Pressure parboiling was found to give comparatively higher expansion to the product. However, varietal differences were observed. Based on the findings, a process was further optimized for cottage scale production of Hurum (Mahanta and Goswami, 2002). The traditional practice of dry-heat parboiling is chosen over pressure parboiling as the later is not feasible for cottage scale processing in rural Assam of that time. The optimized process is given in Fig. 3-B. Instead of a longer soaking period and intermediate simmering in water, paddy grains are soaked overnight in freshly boiled water and allowed for self-cooling to room temperature to allow optimum moisture absorption. It is directly followed by vigorous roasting in sand on the Bhatti to bring the moisture content down to 21%–23%. The paddy grains are then simultaneously flaked and dehusked in an edge runner in a flaked rice mill. The flaked and dehusked grains are rubbed with an optimum amount of hydrogenated oil. The oiled and flaked grains are then roasted on the Bhatti to expand for a short time to obtain Hurum. The product is traditionally relished with milk and sugar or jaggery. The extensive expansion and translucency acquired during processing are the distinctive characteristics of Hurum. The translucency is due to the negligible amylose content in waxy rice. No other scientific literature is available on this product till date.

**Komal chaul**

Quick cooking rice has come to international knowledge in recent times. Komal chaul (soft rice) is a whole grain, ready-to-eat product, which needs no cooking and can be consumed after simply soaking in cold to lukewarm water (Fig. 2). It is a special rice product of Assam. Recently, the Central Rice Research Institute of India reportedly developed Komal chaul varieties by using panicle progeny methods on waxy rice varieties like Aghuni Bora (Yadugiri, 2010). However, in Assam, the name Komal chaul designates the parboiled rice product and not a group of rice varieties. The tradition of preparation and consumption of Komal chaul in Assam is age-old. Low amylose rice varieties, locally termed as Chokua rice varieties, are preferred over the waxy Bora varieties to prepare this product.
The Chokua varieties result in a better, less-sticky Komal chaul than Bora varieties. Komal chaul has already been considered and detailed as a potential geographical indicator (GI) for the region by Samaddar and Samaddar (2010). The authors have taken it up as a bio-cultural product which has yet to attain its GI registration. The traditional parboiling technique is given in Fig. 4-A. Traditionally, Chokua rice grains are soaked in water at room temperature for 3–4 d to attain an acceptable moisture level. The excess water is drained, and the grains are put in fresh water and cooked over wood fire till the husks start splitting. The water is again drained and the grains dried under the sun on the same day. Dried grains are milled in a dheki, the traditional foot pounding machine to get the Komal chaul product. Drying of the boiled grains is done on the same day so that there is negligible retrogradation and the milled product attains soft texture on simple soaking in water at room temperature. Das et al (2005) analyzed the nutrient profiles of a few Assamese dishes. Komal chaul is generally relished with curd and jaggery. The dish is high in carbohydrate and minerals, especially iron. A recent work from our laboratory was on developing a laboratory scale method (Fig. 4-B) for processing of the product using low amylose Kola Chokua rice grains (Dutta and Mahanta, 2014). Briefly, the grains are cooked in boiling water for 1–3 min, and the boiling vessel is then covered with a gunny bag to retain the temperature for a longer time. Optimum moisture level (37%, wet basis) can be obtained after a soaking period of 18 h. Excess water is drained, and...
the grains are steamed in an autoclave using steam. Both open (100 °C/0 psig) and pressure steaming (121 °C/15 psig) for 10 to 20 min are employed followed by shade drying for 48 h and subsequent milling to obtain Komal chaul with acceptable quality. When the product is soaked in water at 50 °C for 20 min, a texture similar to normal cooked rice is obtained. The flour of the raw untreated rice is highly resistant to \( \alpha \)-amylolysis. However, steaming pressure, whether open or under pressure, and the severity of steaming have an effect on the extent of amylolysis. While in open steamed Komal chaul, steaming severity decreases the starch hydrolysis rate, indicating the formation of enzyme-resistant fractions, and pressure steamed Komal chaul shows higher digestibility with treatment severity.

Works on process optimization for different instant rice products have been carried out by various researchers (Amornsin, 1994; Prasert and Suwannaporn, 2009), wherein raw milled rice was processed to get instant rice. None of the processes however fall under ‘parboiling techniques’ as used for Komal chaul. This is because milled raw rice was used instead of brown rice as a raw material and parboiling strictly involves cooking the grain inside the husk followed by drying. Rewthong et al (2011) used hot-air dryer and freeze dryer to make quick-cooking rice, which makes the processing quicker but costlier. Prapluettrakul et al (2012) developed a process for preparing instant rice for young children. The product is prepared by boiling jasmine rice followed by freezing for 24 h at -20 °C, drying at 70 °C, and allowing for rehydration by boiling for 3 min. These conditions are most suitable for development of desired texture. Sripinyowanich and Noomhorm (2012) compared various modern drying techniques and found that product quality of unfrozen cooked rice that was subjected to vibro-fluidized bed drying at 160 °C is superior to the other techniques that involved freezing prior to drying. Recently, Boluda-Aguilar et al (2013) developed a similar product using jasmine rice wherein the rice was cooked with microwave rather than simple soaking in water as in the case of Komal chaul. A positive attribute of these works over the developed method for Komal chaul lies in the much shorter soaking times employed.

**Bhoja chaul**

Bhoja chaul in simple terms is a dry-heat parboiled rice product (Fig. 2). Unlike the common puffed rice,
Bhoja chaul grains do not undergo excessive structural and morphological disorganization during the process. The conventional technique for processing Bhoja chaul is given in Fig. 5-A. Waxy rice grains are soaked for 3–4 d at room temperature after the water is drained out. The moistened grains are roasted in an iron vessel over wood fire with constant stirring. Roasting is stopped when the grains sufficiently dry up. The roasted grains are spread over mud floor to cool for about 30 min before milling in a dheki (a hand and foot operated pounding and milling device) to get Bhoja chaul. However, many variations can be seen in the time and temperature of soaking and roasting in different rural households. Soaking in hot water overnight or boiling the grains till very fine split in a few husks occur are also practiced by some. The roasting temperature is controlled by the intensity of the wood fire. The prepared Bhoja chaul is soaked in water at room temperature prior to consumption to let it hydrates sufficiently to an optimum level. The excess water is squeezed out with hand during which the sticky grains cling to one another forming an oval and flat shaped lump. These lumps are eaten with milk, cream, curd and jaggery. According to the rural household processors, the desirable characteristics of Bhoja chaul are the roasted aroma and colour, a sticky and chewy texture and appearance of the rice grains clinging together to form the lump.

In a laboratory scale process developed, a motor operated, electrically heated, drum type roaster was used for roasting. Out of many aged waxy grain samples soaked at 98 °C overnight and roasted between 145 °C–175 °C for 6–11 min, a few samples gave high hydration capacity (35%–41%). However, none had the desirable sensory characteristics. The raw starch taste was indicative of insufficient hydrothermal treatment. To increase the severity of the process, paddy grains were added to boiling water, cooked for 1 min and left overnight to hydrate, which increased the moisture content of the grains upto 37%. These grains were then processed into Bhoja chaul after roasting at temperatures between 145 °C–165 °C for 9–13 min. Based on the developed colour and water uptake, a roasting temperature of 145 °C and roasting time of 12 to 13 min at 39 r/min speed of roaster was found to be appropriate. It brings down the kernel moisture to 11%–12%, which is found to be suitable for higher head rice yield and longer storage of the product. It is also found that the colour of the product intensifies with roasting time. The developed

![Fig. 5. Traditional method (A), developed laboratory-scale method using aged waxy grains (B) and developed laboratory-scale method using new waxy grains (C) of Bhoja chaul making.](image-url)
method is given in Fig. 5-B.

Newly harvested waxy rice exhibits acceptable texture after roasting at 145 °C for 10.5 min. This necessitated trial for different combinations of roasting time and temperature for new waxy rice. A roasting temperature of 130 °C and processing times of 12.5, 13.5 and 14.5 min were hence tried. A higher roasting time is required for a product with higher hydration capacity, aroma and colour which is only possible when the soaked grains have higher initial moisture content to be evaporated during roasting process. Boiling step is hence further increased to 3 min, which markedly increases the moisture absorption by the grains. The process for new waxy rice is developed (Fig. 5-C). Even though the use of waxy rice grains results in excellent textural properties, the higher level of resultant moisture (11.98%–12.69%) is found to cause early spoilage due to mould growth, colour change and rancid odour. Any further roasting to reduce moisture can result in grain breakage due to moisture gradient within the grains. Therefore, a two-stage roasting of the soaked grains with a tempering period in between the two stages is carried out to equilibrate the grain moisture. Amongst the different combinations tried, the grains that are roasted for 10 min at 130 °C, tempered for 30 min and roasted again for 4.5 min at the same temperature give higher head rice yield and the optimum moisture level in the grains.

**Sandahguri**

Unlike Hurum, Komal chaul and Bhoja chaul, Sandahguri is obtained as a coarsely ground powder of parboiled rice (Fig. 2) involving a longer process. Although no specific type or rice variety is used for this product, Chokua rice variety is known to be the traditional method of this product, Chokua rice variety is known to be preferred over others. The traditional method using aged Chokua rice is developed (Fig. 6-A). Instead of soaking for long duration, a double parboiling method is traditionally employed. The grains are cooked in water for 15–20 min until a few bubbles appear indicating boiling. The vessel is then removed from fire and kept overnight to hydrate, after which the grains are again boiled afresh till a few husks split. The water is drained out and the grains are allowed to sun-dry. The dried grains are stored and further processed into Sandahguri whenever needed. For that, the grains are milled in a dheki and roasted in an iron pan without sand. The roasting is done either directly or after moisture treatment. Moisture treatment may be simple washing and draining or longer soaking for 15–20 min and draining. Roasting results in very slight puffing of the rice, now called Korai. This may be consumed as such or further powdered to obtain Sandahguri. The moisture content before roasting influences the extent of puffing of Korai, which in turn determines the product quality of Sandahguri. High moisture gives lower puffing and therefore is roasted at lower flame for a longer time which gradually reduces the moisture and develops desirable flavour and aroma in the Korai. Lower moisture results in undesirably excessive puffing. The puffing should not be extensive as that gives an unsuitable end product quality. Roasting may be carried out for 2–20 min depending on the rice used, followed by pounding using a dheki to get lumpy or dry powdery textured Sandahguri. Traditionally, the powder is mixed with hot milk and stirred to a thick, slightly sticky, cohesive, porridge like consistency and consumed along with jaggery or sugar. A strong roasted aroma from the slightly particulate mixture is a desirable characteristic. Certain notable variations in the traditional process are also available. Instead of double boiling, many households use a standard dry-heat parboiling technique with grains soaked for 4–6 d. A practice of rubbing salt solution to the parboiled rice and sun drying for 20–25 min prior to roasting is also practiced by some for better puffing quality of Korai.

Many variations in conditions of soaking, cooking, moistening and roasting were tried to develop a basic laboratory scale method for processing Sandahguri. Based on sensory acceptance of five panellists, a method using aged Chokua rice is developed (Fig. 6-B). Soaking for 1 min in boiling water and keeping overnight are enough for the necessary moisture uptake. The developed method used single stage pressure cooking (0.5 kg/cm²) for 10 min instead of the traditional, time consuming open cooking technique carried out twice. The milled parboiled rice is moistened by soaking in water for 40 min prior to roasting in an electrically operated roaster used as for Bhoja chaul. Optimum roasting condition is 50 g rice grains at 160 °C for 7.5 min at 39 r/min. The roasting operation gives the Korai which is coarsely pulverized to obtain Sandahguri.

**Research possibilities on the products**

Even though there is a tremendous scope for studying the traditional parboiled rice products of Assam, research has been scanty. The uniqueness of the products
has seldom been reported. Komal chaul has every scope to be popularized as a convenience food for defence personnel, for people in adventure quests or in any places where there is a scarcity of fuel for cooking. The quick cooking product has been used during historical wars fought by the soldiers in Assam owing to the ease in their carriage and consumption. The product can hence also be further analyzed for fuel and cost efficiency. Sandahguri and flours of Hurum, Komal chaul and Bhoja chaul also have tremendous possibility to be used as green ingredients in food systems due to their high hygroscopic and pasting properties. The peculiarity in the products’ hygroscopic behaviour is attributed to the status of starch in them (Bhattacharya, 1985). Starch undergoes definite breakdown and probable reconstruction after the severe hydrothermal treatments applied during processing. Characterization of molecular weight distribution of starch in the products can be considered as one of the important parameters (Zhu et al., 2011) that have never been studied. Application of hot soaking instead of prolonged soaking at room temperature for longer duration has markedly reduced the time consumption of the parboiling process. The physicochemical phenomenon behind this has not been understood well till now, which creates scope for possible research.

Fig. 6. Traditional method (A) and developed laboratory-scale method (B) of Korai and Sandahguri making.
Again, certain rice varieties used for the Komal chaul preparation are coloured and hence may be studied for antioxidant and phytochemical status. Drying has been considered as an important step for producing instant rice. Further research trials on soaking and drying stages of Komal chaul processing are hence necessitated. The intermediate tempering stage in case of Bhoja chaul as practiced by certain household processors is interesting. Further systematic studies on the process involving this step is required for a superior standardization of the process. A standardized method using new Chokua paddy rice grains for making Sandahguri is still awaited. Engineering aspects of the standardized processes may further be studied after developing industrially feasible processes. A scientific approach has to be made to understand the peculiar characteristics of the products. Molecular characterizations primarily relating to the end product characteristics have to be carried out. Study of the thermal behaviour is important as the products are hydrothermally treated and further processed involving temperature gradients. Besides further development in processing methods, proper packaging may increase their potential commercialization. The products have been brought to the market as packaged commodity by only a few local companies but value addition in terms of uniform product quality and extended shelf life is at a suboptimal level. Assam’s waxy rice varieties are markedly high in lipid content. The hydrothermal treatment employed results in quick development of rancidity in the product, which is a negative attribute. Measures or studies on controlling rancidity in the products have however not been reported in the available literatures. Again, the hygroscopic nature of the products make them prone to become unfavourably moist and the high starch content makes them suitable media for fermentative mould and bacteria. A great part of the modern research in food science involves digestibility study of the products. A study on the products’ glycaemic status is hence important for its commercialization and targeted use. Furthermore, there is a great need of preserving the ethnic identity of the products, and an anthropological approach seems to be the most important need of the time. There is also need for proper identification of waxy and low amylose rice varieties that are traditionally grown and used by the village processors. Our general observation suggested that many such unidentified varieties are gradually getting endangered due to the lack of scientific preservation of their germplasms.

**Prospective**

Parboiling is a traditional hydrothermal technique used for value addition of rice. It brings about significant changes in the rice grain properties. Different parboiling techniques have been used to make speciality rice products, the qualities of which are highly dependent on amylose and proximate compositions. Assam produces a wide range of rice varieties from which different products are made. The products are special due to the high hygroscopic behaviour acquired during their processing. Hurum is a unique expanded flaked rice product made from waxy rice with high moisture absorption capacity. Komal chaul and Bhoja chaul are other products that require simple soaking and no cooking to attain cooked rice texture. Sandahguri is another product relished for its texture, colour and roasted aroma as well as for its convenience. Although peculiar in behaviour, the products have been studied only up to limited levels. The thoroughly described traditional techniques and newer processes developed in our laboratory aims to popularize them for further in depth analytical studies and commercialization. The inherent characteristics of the products make them eligible for GI registration by the state of Assam, India.

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