Abstract

The thesis explores the utilization of broken rice as an alternative to head rice to produce single and dual modified starches, their characterization, and application in rice noodle making. Broken rice, which is less than three-quarters the size of a whole kernel, is typically regarded as a by-product of rice milling process and it is utilized locally as animal feed and brewing component. The use of broken rice instead of head rice can cut down raw material costs while maintaining the quality value-added products. Because of good agro-climatic conditions, India has a large number of rice germplasm in general, and Assam state in the North-eastern region in particular. In Assam, low to intermediate varieties are consumed as cooked rice, and waxy and very low amylose rice are used in traditional food products during various occasions. The rice varieties cultivated in Assam have not been explored much in the manufacturing of rice-based convenience food items. Limited studies have been conducted till now on the properties of rice varieties of Assam and their by-products. Convenience foods such as noodles consumption has been increasing over the years with increased population of working people and the fast pace of modern living. Noodles containing gluten are not fit for celiac patients and people (women) with other health issues such as endometriosis, ovarian cyst and infertility. As a result, non-wheat sources such as rice, corn, etc. have become the only alternative to deal with it. Therefore, it was felt necessary to utilize the broken rice as a base material for the production of a convenience food i.e., rice noodle as a gluten free dietary alternative.

Based on the perceived research gap from the review of literature the present study was conducted with three main objectives, which are discussed in separate chapters in the thesis. The first objective was discussed in **Chapter 3** under three-sub chapters (Chapter 3A, 3B and 3C). The sub-chapter **Chapter 3A** deals with the studies for the selection of broken rice fraction for utilization in rice noodle development. Sieve analysis was conducted using three laboratory sieves of standard ASTM no. 10 (2 mm), 12 (1.7 mm) and 20 (0.85 mm). The broken rice was classified as medium brokens (MBs) with brokens size in the range of 1.7-2 mm, and small brokens (SBs) with size between 0.85 mm and 1.7 mm. Classified fractions of broken rice were compared to the head rice (HR) with respect to chemical composition, functional properties, pasting properties, RVA gel texture and morphology. There were no significant differences in the characteristics of MBs and HR that were investigated. As a result, medium broken fractions were chosen for further investigation. In **Chapter 3B,** MBs rice flour was

sieved through 150 μm, 180 μm and 212 μm size sieves and evaluated for the functional and pasting properties, and gel hardness. Rice noodles were prepared by using 150 μm, 180 μm, and 212 μm size rice flour and cooking quality, sensory, and textural properties were compared with commercial proprietary rice noodle. MBs rice flour with 150 μm showed better functional properties and gel hardness and the corresponding noodle was comparatively better than noodles made from 180 and 212 μm sized MBs flour. However, all the prepared noodles tend to yield high cooking loss and broken strands during cooking which are undesirable. **Chapter 3C** reported the isolation of rice starch from MBs by alkaline steeping method and its modification by heat moisture treatment (HMT) and osmotic pressure treatment (OPT). RSM (FCCD) was used to optimize the process conditions (Time: 15-45 min, Temperature: 100-120 ^{o}C, and Moisture content: 20-30%) with three levels of temperature and time for OPT and three levels of temperature, moisture content of starch, and time for HMT. Optimum experimental condition of OPT was obtained at temperature of 117 ^{o}C and heating time of 35 min. Temperature of 111 °C, moisture content of 29%, and heating duration of 45 min were found to be the optimum process conditions for HMT.

In **Chapter 4** a brief methodology and findings of work related to Objective 2 were described. Single modified rice starches of HMT and OPT were produced at the optimal process conditions (as reported in Chapter 3C). By modifying rice starch at optimal conditions of OPT followed by HMT and vice versa, two dual modified rice starches (HMT-OPTS and OPT-HMTS) were developed. A comprehensive study on chemical composition, pasting, crystalline, thermal, morphology, *in-vitro* starch digestibility, and viscoelastic properties of native and modified starches was conducted. The amylose content and gel hardness increased whereas the swelling power and solubility decreased in all the modified starches. Dual modified starches improved paste stability greatly, as seen by significantly consistent hot paste viscosity and decreased breakdown. OPTS showed high PV and BD than HMT and dual modified starch indicating relatively less paste stability as compared to other modified starches. Weaker birefringence was observed, and dual modified starches in particular displayed poorer birefringence with less well-defined quadrants and voids in the middle of the granule. The modified starches showed the normal A-type pattern and a decrease in relative crystallinity. However, OPT caused less reduction in relative crystallinity than HMT. Both single and dual modification resulted in higher peak intensity at Bragg's angle ($2\theta = 20^{o}$) that is attributed to the formation of amylose-lipid complex. DSC thermograms revealed that gelatinization was delayed in modified starches. The elasticity of HMT-OPTS and OPT-HMTS were improved to higher extent than HMTS and OPTS as evident by the higher storage moduli. Significant increase in RS after modifications was noted by in vitro digestibility study where HMT, HMT-OPTS and OPT-HMTS showed comparatively higher RS than OPTS. Partial gelatinization and amylose-lipid complex contributed to RS formation in modified starches.

Chapter 5 reports the methodologies and findings of Objective 3. Composite rice noodles were prepared using blends of MBs flour and native or modified starches at 10, 20, and 30% substitution levels and then evaluated the physical properties of dry noodles, and cooking, sensorial, and textural qualities, and *in-vitro* digestibility of cooked noodles. Increasing the quantity of native starch had no discernible influence on the quality of the noodles. The cooking properties of composite rice noodles were considerably improved by single modified HMT and dual modified starches, in particular. Usage of 30% HMTS in the blend for noodle significantly reduced cooking loss and the value is comparable to MRN. However, substitution of OPTS up to 30% could not bring the cooking loss percentage down to the level of MRN. Cooking loss of HOSN20, HOSN30, OSHN10, OSHN20 and OSHN30 were significantly low and comparable with the MRN. OSN10 showed higher rehydration than MRN. 30% HMTS and OPTS resulted in significant reduction in swelling index than 10 and 20% substitution. Noodles containing 20-30% dual modified starches showed even lower swelling index than the noodles containing 30% single modified starches. Surprisingly, no broken rate was generated by the noodles containing modified starches except in OSN10 and HOSN10, whereas the test control (RFN) and noodles containing native starch showed high broken rate. Single modified starches up to 30% and dual modified starches below 20% yielded in noodles with comparable hardness to the MRN. Noodles made from blends containing 20-30% single and 10-20% dual modified starches scored higher for overall acceptability ($p > 0.05$). Overall acceptability score of noodles containing 30% dual modified starches was low possibly due to its much higher firmness or hardness. Rice noodles prepared using modified starches showed reduced digestibility as evident by reduced RDS and higher SDS and RS. When noodles were prepared by blending 30% HMT and 30 % OPT the amount of RS formed in both noodles were significantly different. The amount of RS formed at 30% level of substitution with single modified starch is comparable to the noodle containing 20% dual modified starch.

Addition of dual modified starch at 30% level of substitution in the noodle blends caused highest increase in RS content ($p < 0.05$).

The salient findings from this research work makes significant contribution to the area of rice research, particularly in the knowledge of physicochemical properties of *Ranjit* variety (head rice and brokens rice). Noodles prepared from MBs flour with 150 μm size showed relatively better quality. But there was significant difference in quality parameters when compared with market control as evident by higher cooking loss, broken strands during cooking, and lower tensile strength and hardness. Dual modified starches showed overall improvement in paste stability to a greater extent than OPT and HMT single modified starches. Rheological and *in-vitro* starch digestibility properties of modified starches were enhanced after modification. Composite rice noodles prepared from blend containing modified starches improved the textural, cooking, and digestibility properties. Therefore, using medium broken rice flour in rice noodle production can be a cost-effective means to promote development of gluten-free convenience foods, and their overall eating quality can be improved by the incorporation of HMT and OPT single and dual modified rice starches.

Keywords: Broken rice, rice starch, heat moisture treatment, osmotic pressure treatment, rice noodle