CONCLUSIONS AND FUTURE SCOPE OF WORK

8.1. Conclusions

The present work deals with studies on the effects of different parboiling procedures and conditions on Assamese rice varieties widely differing in apparent amylose content. Two traditional rice products, namely komal chaul and bhoja chaul were also characterized after processing by laboratory-scale parboiling techniques. Kola chokua, a pigmented low amylose rice variety was processed by the developed technique followed by necessary milling operations to produce komal chaul. The different milling fractions were collected and analysed for their phytochemical content and antioxidant activities. The experimental works and results of the same are detailed from Chapter 3 to Chapter 7 of this thesis. The major conclusions drawn from the present work are enumerated below.

8.1.1. Chapter 3

This chapter included a study on the effect of mild, moderate and severe steam parboiling at open and under steam pressures on four rice varieties, namely Ranjit, Kola chokua, Aghoni bora and Bhogali bora with 27.2%, 12.6%, 1.1% and 1.1% apparent amylose content, respectively.

1. Degree of gelatinization in all the four varieties was higher on pressure parboiling than open steam parboiling.
2. Marked increase in water uptake properties indicated altered cooking properties attained by the low amylose and waxy rices after parboiling.
3. Pressure parboiled waxy samples showed extensive drop in gelatinization temperature and increased hydration at lower temperatures as revealed by RVA.
Formation of short amylopectin fine structures in these samples was indicated by sediment volume test and viscosity patterns.

4. Development of retrograded crystallinity in the samples was found to be related to stretching vibration patterns of C-H bonds as revealed from FTIR analysis. Crystallinity, measured by XRD, however could not be related to that measured by FTIR. XRD can, therefore, be considered as a more suitable tool than FTIR for crystallinity study.

5. XRD of raw samples showed peaks at 2θ values near 20 which indicated ‘in situ’ points for amorphous amylose complex formation. A, B and V-type polymorphs were seen in pressure parboiled samples and only A and V-type polymorphs were observed in open steamed samples.

6. The existence of V-type crystalline pattern was noted even in waxy parboiled rice.

7. Loss in crystallinity with simultaneous increase in water uptake can be attributed to the amorphous fractions in parboiled rice. Waxy varieties are more susceptible to loss of crystallinity than the high amylose variety. Higher crystallinity observed in the most severely parboiled samples than the moderately parboiled samples may be related to higher retrogradation.

8. Low amylose parboiled rice samples of both processing conditions showed higher content of resistant starch and can be commercially exploited.

8.1.2. Chapter 4

This chapter presented a study on the effect of dry heat parboiling at two different temperatures and three different time periods at each temperature (11, 13 15 min at 140°C and 3, 4, 5 min at 200°C) on physical and physicochemical properties of Ranjit, Kola chokua and Aghoni bora varieties of Assam rice.

1. Dry heat parboiling at 140°C resulted in notable improvement in head rice yield. All the samples showed almost 100% head rice yield which could be attributed to the increase in kernel hardness. The laboratory dry heat parboiling can hence be further studied as a replacement of commercially used steam parboiling process.

2. The lower hardness and head rice yield of the high temperature treated samples was attributed to the development of a cavity in the center of the rice kernels. This
cavity was formed as a result of rapid dislocation of the gelatinized starch of the endosperm towards the outer surface of the paddy and simultaneous dehydration as a result of high conduction heating. This also explained the reason for the reported splitting of dry heat parboiled rice on alkali spreading test.

3. The dry heat parboiled kernels of *Kola chokua* and *Aghoni bora* became bolder in shape than raw rice kernels. Length to breadth ratio of *Ranjit* rice however remained almost unaltered indicating varietal differences in the arrangement of kernel material after parboiling.

4. The kernels and flours of dry heat parboiled samples were highly hygroscopic.

5. In low amylose and waxy varieties, milder parboiling caused increased peak viscosity on cooking whereas severe parboiling caused drop in viscosity. The high amylose variety exhibited gradual fall in viscosity parameters with process severity.

6. XRD and DSC curves suggested formation of additional B-type retrograded starch in the high amylose HR variety. Although peaks for amylose-lipid complex formation were feeble in the curves of HR, peaks for melting of starch-lipid complex in processed LK and WA samples were clearly evident from DSC curves.

7. Dry heat parboiled samples were highly digestible as compared to raw rice. The extensive gelatinization and molecular breakdown led to the development of peculiar physicochemical characteristics.

### 8.1.3. Chapter 5

This chapter deals with processing and characterization of *komal chaul*, a ready-to-eat whole rice product processed from low amylose *Kola chokua* paddy and which requires no cooking. The product was processed by a developed laboratory-scale method and was characterized for different physical and physicochemical parameters.

1. The pressure steaming of *chokua* paddy after hot soaking treatment gave *komal chaul* similar in texture to cooked rice. The textural properties of such pressure steamed rice gives soft textured rice kernels on soaking in water for 20 min at 50°C.
2. Soaking in boiling water results in increased water uptake and altered properties indicating partial gelatinization of the starch. Surface gelatinization of the endosperm prohibits pigment migration on steaming.

3. While the kernel lengths remained almost unchanged on open steaming, pressure steaming caused marked increase. This was accompanied by simultaneous decrease in the breadths, indicating elastic stress development in the kernels during steaming and subsequent drying.

4. Increase in water absorption and thereby lowering of cooking time with severity of steaming was prominent.

5. Severe processing caused thermal degradation of starch polymer structure as revealed by the other physicochemical properties. Increase in the final slurry viscosity, hence may be attributed to leaching of the degraded simpler chains causing rise in slurry densities. The almost continuous rise in the slurry viscosity throughout the RVA cycle with minor breakdown indicated the thickening property of the pressure steamed samples, suggesting its suitability for specific uses.

6. The changes in properties can be attributed to the effect of gelatinisation and thermal degradation of starch which may explain the high rate of starch digestibility of the pressure parboiled samples. On the other hand, komal chaul processed by open steaming of hot soaked paddy gave enzyme resistant starch.

7. The laboratory scale method can be further used for analytical studies on komal chaul and can further be modified into a larger-scale method.

**8.1.4. Chapter 6**

This chapter includes a study on characterization of Bhoja chaul, another traditional ready-to-eat rice product of Assam. The product was processed by an improvised laboratory-scale dry heat parboiling method using Kola chokua and Aghoni bora varieties. The paddy soaked in boiling water for 1 and 3 min followed by hydration in the cook water for 18 h was roasted at 140°C for 13, 14 and 15 min.

1. High head rice yield was obtained by the laboratory-scale process. Decreased porosity indicated better packing properties of the product than the raw rice.
2. No endothermic peak for retrogradation was observed in DSC meaning that the product did not retrograde after gelatinization due to absence of necessary moisture for retrogradation to occur.

3. However, peak for amyllose-lipid complex melting was evident in the severely processed samples. Longer chains of amylopectin may be able to bind lipid molecules.

4. Dry heat parboiling led to significant loss in crystallinity with minor reformation of each type of starch crystalline polymorphs during cooling and storage. Progressive increase in inter-planar spaces of the lamellae could be observed from the shift in the crystalline region of the diffractograms.

5. The product was highly digestible with very high amount of rapidly digestible starch and almost no resistant starch in the severely processed samples.

6. A general observation was that roasting of the low amylose Kola chokua variety for 13 and 15 min at 140°C gave RTE product with better texture on soaking in water at room temperature than cooked rice or processed Aghoni bora samples.

**8.1.5. Chapter 7**

This chapter included a study on the phytochemical content and antioxidant activity of milling fractions of pigmented Kola chokua rice before and after processing into komal chaul by the developed laboratory-scale method involving pressure steaming.

1. Migration of pigments and bioactive compounds occur during parboiling, thereby altering the native compositional structures of the milling fractions of rice.

2. Pressure parboiling caused destruction of natural bioactive compounds with formation of Maillard browning compounds which showed developed DPPH scavenging and metal chelating properties and colour development in milling fractions of komal chaul.

3. While ferric reducing antioxidant potentials of the milling fractions were related to phenoloics and flavonoid compounds, DPPH scavenging activity and metal chelation factors were interrelated.
8.2. Future scopes

From the observations and findings from the present work, the following scopes for future research were enumerated.

1. Ratio of FTIR bands used for measuring crystallinity was found to be related to ratio of FTIR bands responsible for symmetric and asymmetric vibration of H-C-H. Retrogradation may be further analysed with a perspective of involvement of molecular energy.

2. Milder parboiling resulted in development of peak viscosity in the low amylose and waxy samples. Change in molecular structures or nature leading to increased hydration and swelling capacities in these samples may be further analyzed using tools like gel permeation chromatography or high performance size exclusion chromatography.

3. Amylopectin-lipid complexes probably occurred after parboiling. Dry heat parboiling can be further studied as a process for newer starch polymorph formation.

4. The laboratory parboiling techniques used for processing komal chaul and bhoja chaul may be further developed into industrial processes. Dry heat parboiling with high head rice yield created scope for replacing steam parboiling technique.

5. Based on viscosity and starch digestibility patterns, targeted use of the parboiled rice products to consumer groups with special dietetic needs can be explored.

6. The preliminary investigation on bioactive potential of the bran layers of Kola chokua paddy created future scope for a detailed study involving identification and chromatographic isolation of specific bioactive compounds in it and other pigmented rice varieties.