Chapter 1

Introduction

1.1. Background

One of the most abundantly consumed domesticated grains in Asian countries is rice *(Oryza sativa* L.). Asia produces about 90% of total global rice output, which is undeniably the staple crop across many countries [17]. India stands in the second position for production and consumption of rice worldwide with a global production share of 22.3% [19]. Rice production covers over 40% or more than that out of the total food grains production in the country. The number of indigenous rice varieties in India is huge in general and Assam state in the North-eastern region in particular due to the favorable agro-climatic conditions. In Assam, rice varieties of low to intermediate amylose types are widely grown and consumed in polished form as staple food in the form of cooked rice. The waxy and very low amylose rice are usually processed by hydrothermal treatment, and the product so obtained can be consumed simply by soaking in water (without cooking) [13]. Waxy rice is also used to make ethnic or traditional rice-based products like till pitha, tekeli pitha, sunga pitha, etc. However, very few studies have been conducted till now on the properties of these rice varieties and their by-products.

Rice milling involves two processes, dehusking (separation of husk) and polishing (removal of bran). It is primarily done to obtain the head rice (endosperm) when the paddy moisture content is about 13-14 g/100 g. After polishing, rice is sorted into different grades based on size. Brokens, a by-product of rice milling process are characterized by their small size, i.e., less than three-fourth of a whole grain length [5]. Around 10-15% broken rice is produced in medium to large rice mills, while it is higher in smaller mills (aprox. 25%), which constitute a huge economic loss. Broken rice is locally used as an animal feed and in the brewing process [18]. It is considered as a food for the poor due to its low cost [33] as their commercial value is only one-fifth of the price of whole grain [28]. Therefore, broken rice is not only a potent but also a cheaper substitute for rice-based food processing. However, it is underutilized and needs to be explored for product diversification. Use of broken rice as an alternate to head rice can effectively reduce the raw material cost without compromising the product quality. In Assam, regional rice species with a wide range of amylose content and the brokens generated during their milling process have not been explored much for their usage in rice-based convenient food products.

To accomplish the professional goals and adapt to present day's way of living (long working hours and less time for cooking), people often prefer healthy and wholesome but easy and quick cooking options that paved the way for more research on convenience foods. Noodles are made to be used easily by the consumers in their ever-dwindling cooking time schedules and therefore, has gained popularity as a global food although it is a traditional food. Different types of noodles like fresh, dried and frozen are available. Their manufacturing process may vary depending on the place of origin. Noodles are commonly prepared with wheat flour as the major ingredient. However, wheat contains gluten, a protein that triggers immune response in the small intestine of persons with celiac disease-causing malabsorption and also reported to be associated with gynecological issues such as endometriosis, ovarian cyst and infertility [6, 21, 24] in women. Such people should avoid gluten and rely on only gluten free diet for lifetime. It is worth mentioning that rice contains no gluten, which makes it an excellent ingredient for making gluten free noodles. To obtain similar organoleptic and nutritional characteristics as wheat noodles is a challenge though. Rice noodles may be a good substitute for cooked rice since they are made from moderate to high amylose (>22%) rice cultivars [16]. While having a certain elasticity and viscosity [26], rice noodles have a soft, smooth, and delicate taste and are the second most common rice product consumed in Asia after cooked rice [37].

During rice noodle preparation, rice flour is heated with water to gelatinize the starch partially followed by kneading into dough, extrusion, steaming, and drying. Steaming during rice noodle making process promotes gelatinization of rice starches to some extent that helps to compensate a little to the role of gluten in rice noodles. Physicochemical properties like swelling power, paste viscosity and gel texture (hardness) correlates well with the textural and cooking quality of noodles [4, 41]. Fresh rice flour has soft gel quality and practically not suitable for rice noodle preparation [20], so aging of rice is usually done in industries which improve starch granule swelling and starch paste properties, thereby better gel quality is obtained [42]. However, the aging process is time taking process. To overcome this age-old time- consuming aging process, researchers are continuously experimenting with different techniques.

Starch performs an essential function in the quality of rice noodle. Rice starch granules are the smallest of all cereal grains, the size varies from 2 – 7 μm [39]. It has bland taste, good spreadability, smooth texture, white color, high freeze–thaw stability, greater acid resistant. Rice starch is hypoallergenic and differ widely in amylose: amylopectin ratio [25]. These unique properties of rice starch have increased its utilization in food processing. Nonetheless, native rice starch has limited application in food industries, as they provide limited functionality than required. Researchers have been able to improve the structure and performance of starch using suitable modification methods [3]. Starches produced by chemical modifications are obtainable but recently chemically unaltered starch is seen to have more in demand [11] for the industries and consumers.

Physical modification of starches can be a promising alternative to improve the starch characteristics without changing their D-glucopyranosyl units and produce clean label starches. Physical modification brings changes in the packing array of starch components in the granules that ultimately imparts significant changes in the starch functionalities. During physical modification, changes in composition and characteristics of starch take place due to irregular breakage of glycosidic bonds that results in de-polymerization or trans-polymerization. Substituting modified starch partially for rice flour or starch can be a cost-effective approach to improve the quality of rice noodle. The treatment processes of physical modification of starch can be thermal and nonthermal [2].

Heat moisture treatment (HMT) is a hydrothermal treatment of starch by physical means where the starch is exposed to restricted moisture content (10-30%) at elevated temperature (90-120 ^{o}C) [10, 30]. Starch or flour modified by HMT has been used to enhance the overall characteristics of rice noodles in many studies reported in literature [7, 20, 29]. Although HMT starches have shown many improved properties but their large-scale production is limited due to nonhomogeneous distribution of heat [27], and condensation of steam during the procedure leads to gelatinized and treated starch mixture [31]. Nonetheless, osmotic pressure treatment (OPT) is another thermal physical modification method of starch that has been reported to show similar changes in the starch functionalities as those modified by HMT [35]. This method employs heating of native starch (above gelatinization temperature) by suspending it in saturated salt solution of sodium sulphate. Salt solution exerts osmotic pressure on the solute (starch) that was suggested to be the principle behind this method and the modifying factor of starch. Saturated salt solution raises the osmotic pressure and possess limited amount of free water due to which the starch gelatinization is restricted during OPT [22, 36], ultimately preventing the water permeation into the granule. OPT has been used to modify starches like corn starch, potato starch, sago starch, taro starch, and amaranthus starch so far [15, 23, 35]. Nevertheless, effect of OPT on rice starch is yet to be explored. HMT and OPT have been reported to produce amylose-lipid complex which is a resistant starch (RS) type 5. But the confirmatory investigation in OPT starch by *in vitro* starch digestibility is scanty. RS has a beneficial effect on bowel movements, desirable in people suffering from constipation. The presence of RS lowers the glycemic index (GI) of rice [38]. RS formation in OPT rice starch has not been investigated yet and application of rice starch modified by OPT in making rice noodles and their *in vitro* starch digestibility have not yet been explored.

The functionalities of the single modified starches can be further improved by dual modification technique that can be either homo- or hetero-dual modification [1]. Starch is modified by two similar methods in the former and by two different methods in the later technique. There are ample reports on the dual modification of HMT with other physical methods in different starches [8-9, 12, 14, 32, 34, 40]. However, there is limited study on the dual modification of any starch with HMT and OPT.

1.2. Objectives of the Thesis

Based on the above background, surveyed literature and rigorous discussion, the following objectives were set and addressed in the present thesis,

1. To determine the optimal process conditions for osmotic pressure treatment (OPT) and heat-moisture treatment (HMT) of rice starch.
2. To study the effect of single modification by OPT and HMT, and dual modification by HMT-OPT/OPT-HMT on thermal, rheological, morphological, crystalline, and digestibility properties of the rice starches.
3. To evaluate the quality of rice noodles developed using modified starch and rice flour.

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