Chapter I

Introduction

Chapter-I

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Rice is the most widely consumed staple food of the world population among which Asian countries are the major consumers of rice and rice products. Rice belongs to the *Gramineae* family and has two cultivated species, *Oryza sativa* L. (Asian cultivated species) and *Oryza glaberrima* (species found in Western Africa). Between them Oryza sativa is widely cultivated and consumed worldwide. Based on the amylose content rice can be classified as waxy (0-2% amylose), very low (5-12% amylose), low (12-20% amylose), intermediate/normal (20-25% amylose) and high amylose (25-30% amylose) rice [8]. Rice is commonly consumed after boiling in water. Several products including ethnic foods are also prepared using rice flour as the main ingredient though other raw materials like pulses and vegetables are commonly incorporated [4]. The worth mentioning advantages of rice is that it does not contain gluten and is the least allergenic grain [13]. These advantages make rice-based formulations a reasonable choice for preparing gluten-free products for people suffering from celiac disease which is a digestive tract disorder for a human, who must avoid gluten-containing foods throughout their lifespan [7]. Thus, a need exists to develop gluten-free products which can match the product characteristics of popular wheat-based products. Moreover, rice, although reported to be rich in carbohydrates, vitamins and minerals but contains less protein and dietary fiber compared to other cereals such as wheat and maize [15]. Rice is mainly consumed after the process of milling which involves dehusking and polishing. However, some varieties of rice have the poor milling properties which result in a high extent of broken kernels leading to indigent market value.

Malting is a traditional and economic process which can be employed to improve the nutritional composition of rice [12]. Malting mainly involves the process of germination of the cereal grains during which the seed absorbs the water and the embryo develops and leads to the production of phytohormones especially gibberellic acid (GA) which diffuses to the aleurone layer via the scutellum. Eventually, the aleurone layer cells are induced to produce and secrete hydrolytic enzymes (α and β amylase) which otherwise remains dormant into the endosperm before malting. The endosperm consisting of starch degrades to simple sugars (maltose, glucose and dextrin) and protein to peptides and amino acids [3].

The hydrolytic enzymes mainly act on the reserve compounds of grain i.e. starch. Starch comprises of two major constituents viz. amylose and amylopectin. Amylose is a linear molecule, formed by D-glucose residues linked by α (1→4) bonds in a helicoidal structure, and the helix contains hydrogen atoms which characterize amylose as a hydrophobic species [2]. The hydrophobic nature allows the amylose to be strongly associated with non-polar compounds such as free fatty acids, alcohol and iodine. Amylopectin differs with amylose in α (1→4) glycosidic linkages which are extensively branched through α (1→6) linkage to form a ramified structure. The α-amylase (molecular weight of 20–55 kDa) is an endo-amylase which acts on α (1→4) glycosidic linkages in a random manner; it can produce a complex mixture of sugars i.e. glucose, maltose and dextrins. However, its action ceases near to α (1→6) branches. On the other hand, β-amylase is an exo-enzyme which hydrolyzes α (1→4) glycosidic linkage to produce β maltose successively from the non-reducing ends of the starch polymer. This enzyme does not hydrolyze α (1→6) linkages or α (1→4) linkages which are immediately linked to them. Therefore, it completely degrades amylose whereas amylopectin is degraded to maltose and *β*-limit dextrins [5]. The malt is later dried at a lower temperature to reduce the moisture content and during this process, some enzymes may be inactivated. Several cereals, millets and legumes are subjected to germination process and the malted flour is incorporated to prepare health-benefitting foods. Malting of paddy is although reported from different parts of the world but it was performed without considering the role of amylose and amylopectin fractions of starch in rice.

The process of germination brings about various physico-chemical changes due to hydrolysis of starch. The modification of starch by the process of germination to modifies the pasting property and thermal behaviour which play important roles during processing. The characterization of cereal biopolymers by thermal analysis is important in apprehending the functionality of starch on the structural and molecular levels [1]. Germination also improves the nutritional properties. Some of the bio-functional compounds which increases during germination are GABA, inositols, ferulic acid, tocotrienols and gamma-oryzanol. These compounds aid in accelerating metabolism in the brain, prevent colon cancer, protect cardiovascular disease etc. [11]. GABA is a four-carbon non-protein amino acid, which is an inhibitory neurotransmitter that lowers the blood pressure, reduces anxiety and boost the immune system. The germinated brown rice also contains a high amount of dietary fibers which help maintain the colon health by expanding fecal volume, assisting bowl movements, and removing toxic metabolites [6]. The hydrolysis of starch and protein by various enzymes also lead to the formation of sugars, oligosaccharides and amino acids. Moreover, the formation of sugars also increases the organoleptic properties of malted rice.

Malting apart from the generation of bio-functional components also improves the organoleptic properties due to the release of flavoring compounds and softening of texture [16]. Thereby malted rice flour can also be potentially used in various novel functional food products such as gluten-free beer, tortillas, beverages, puddings, salad dressings, gluten-free confectionaries. Germinated brown rice has also been used in the preparation of other products such as rice-balls, soup, bread, doughnuts, cookies, rice burger, Italian risotto, Spanish paella, Brazilian feijoada, and Indian curry [11]. The malted rice due to low bulk density can be employed for the preparation of weaning formula.

Malnutrition is a major problem among the weaned infants and preschool children in developing countries due to poverty and illness. Surveys have shown that due to lack of properly balanced diet around 1-3% of the children in the age group 1-5 years suffer from protein-calorie malnutrition which eventually leads to diseases like Kwashiorkor, Marasmus, vitamin A deficiency and may even cause mortality [10]. To prevent malnutrition several countries including India have developed various weaning or supplementary food for preschool children Most of them consists of blends of cereals like wheat, rice, corn, pea, lentils, chickpea, soy, peanut, milk etc which are nutritionally balanced. However, these products due to their high processing cost are very expensive and thereby beyond the reach of common. So, they feed their children with food such as porridges prepared from locally available cereals and tubers. These porridges are rich in starch which increases the dietary bulk since the starch swells and gelatinizes to become thick and voluminous when cooked with water [9]. So, more water is added for easy feeding which eventually lowers the energy and nutrient contents. Moreover, the stomach capacity of the infants is limited and therefore only a certain amount of feed can be given [14]. Therefore, use of malted cereals in weaning formulation can be a solution to this problem which reduces the dietary bulk and increases the calorie intake.

In the light of the above backgrounds, the present study was performed to investigate the following:

- Effect of germination conditions on malting potential of two paddies with different amylose content and change in enzyme activity and physiochemical properties of malted grain was estimated.

- The modeling of the enzyme kinetics during the process of germination was investigated. The enzymatic starch hydrolysis mechanism during malting of paddy under different germination conditions based on the structural change was predicted from the spectra of vibrational spectroscopy.
- The malted rice obtained was employed for the preparation of the weaning formula and the physico-chemical and rheological behaviour of the formula was investigated. In-vitro starch digestibility and cytotoxicity of weaning formulation was also studied. Further, the moisture sorption isotherm of the weaning formula at different storage temperature was also investigated.

The objectives of the present investigation:

1. To evaluate the malting characteristics and mechanism of paddy at different germination time and temperature.
   1.1. To measure the Phyisco-chemical properties of the malted rice flour
   1.2. To model enzyme reaction rate and germination process using ANN approach
   1.3. To predict the starch hydrolysis mechanism during germination based on structural changes
   1.4. To evaluate starch hydrolysis process based on pasting properties and thermal behaviour

2. To formulate an instant weaning food using malted rice flour and other ingredients.
   2.1. To optimize the weaning formulation based on its physico-chemical and nutritional properties
   2.2. To study the starch digestibility and rheological behavior of weaning formulation in simulated human digestive system
   2.3. To test the cytotoxicity of the developed weaning formula

3. To study the storage study of the developed weaning formula
   3.1. To model moisture sorption isotherm and its thermodynamic properties for weaning formula
   3.2. To evaluate the sensory attributes and quality evaluation of the weaning formula

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