Chapter 1

INTRODUCTION

Rice ranks first in terms of global production (603 million tonnes) and used as a staple food for approximately 400 million people in the developing countries (FAO, 1998). India produced about 144 million tonnes of paddy in 2007 (Anonymous, 2009a), which is about one-fifth of total world production and second-largest next to China. More than 200 commercial rice varieties of *indica* sub-species are grown in India (Chattopadhyay, 2004). India exports 5% of the produced rice to the international market and compete with Thailand, Vietnam, and Pakistan (Anonymous, 2009b).

Though rice is mainly consumed as whole cooked grains either in the form of raw or modified rice (parboiled, cured, canned, cooked, quick cooking, flavoured, coloured), a variety of products are also prepared as breakfast foods, snacks and fermented products. It is reported that about 10% of the production of paddy is converted to three rice products, namely, puffed rice, popped rice and flaked rice (Chattopadhyay, 2004; Narayanswamy, 1956; Ghose et.al., 1960).

Among the rice based breakfast cereals, puffed rice is largely demanded product for centuries in India because of its lightness and crispness. Its production mainly confined to rural areas. However, puffed rice made using gun-puffing technique was first commercially introduced by Quaker in 1904 World's Fair in St. Louis. Puffed rice is popular across the world under different brand names, but in India, its production process remained confined to unorganized sector. Very recently, mechanized production system is being adopted to meet increasing domestic and export demands.

Puffing of rice is done by different methods, such as puffing at normal atmospheric pressure and using pressure differential. Under atmospheric puffing, it is conduction puffing on hot sand bed, convection heating in hot air and convection and conduction heating in hot air or oil, while explosion puffing employs pressure differential (Chinnaswamy and Bhattacharya, 1983a and 1983b; Villareal and Juliano, 1987; Chandrasekhar and Chattopadhyay, 1988). The puffing method traditionally followed in most part of India is sand-roasting, in which hydro-thermally treated pre-conditioned rice (cured rice ready to puff) at 9 to 10% moisture content (wb) is roasted on hot sand at 250-260^{0}C for 10-15 seconds (Jaya Smita, 2008).

Pre-puffing conditioning (pre-conditioning) of rice is the most critical factor for achieving the good quality expanded product. It is basically uniform and slow heating of high moisture (water soaked) parboiled grains in a large bowl coupled with turning or agitation system that facilitates proper structural changes like, surface modifications and hardness, and hence, highly expanded smooth-surface puffed rice (Chinnaswamy and Bhattacharya, 1983b; Chandrasekhar and Chattopadhyay, 1991). Non-uniform heating of grain severely impairs the quality of product with less expansion ratio in addition to rough and blistered surface. This tedious and laborious but cheap process of pre-conditioning necessitates replacement with a developed mechanical system to increase production, decrease cost and improve product quality through uniform heat and mass transfer in the grain. State of distribution or movements of grain particles in the mass with duration of agitation (turning) could be an index of uniformity in heat transfer to the grains during its residence time. Thus, performance of any developed system for pre-conditioning of rice could be best ascertained by estimating the mixing characteristics of the grain bed using tracer technique.

Contamination of sand particles and unhygienic condition are the limitations with this cheapest puffing process for widespread acceptance and export of the prepared products. Additionally, high cost is involved in packaging, transport and storage of bulk puffed rice, which is very prone to become soggy and loose crispiness. Bulk preparation of pre-conditioned rice, its appropriate retail-size packaging and convenient puffing (using common kitchen gadgets) of that packed rice by the consumer as and when required could be a best way to tackle the above aspects, similar to in-vogue commercial popcorn product (Singh and Singh, 1999; Lin and Anantheswaran, 1988).

Puffing of pre-packed freshly prepared pre-conditioned rice using domestic microwave oven have been reported to give as high as 95 - 100% puffing and hygienic product (Jaya Smita, 2008). Further, puffing efficiency for rice grain depends on several factors including nature and concentration of salts diffused into the kernel (Chinnaswamy and Bhattacharya, 1983b). No open literature is available on microwave puffing of rice. Thus, this knowledge gap could be bridged with generation of standard protocol on the process and optimization of parameters involved in raw materials as well as microwave heating to maximize puffing of rice with high expansion ratio. This could be very useful for commercialization of this technique.

Interestingly, extended study carried out by Jaya Smita (2008) showed deterioration of puffing quality (82 - 89 %) of the packed pre-conditioned rice grains when its period of storage was increased. There was change in moisture content of the grains from its optimum value of 10 – 10.5% (wb), due to adsorption of moisture during storage. Knowledge of moisture sorption isotherms of such pre-conditioned rice could be helpful to understand this shift in equilibrium moisture content, and best-fitted sorption models could be applied for designing of suitable packaging system to control moisture migration and preserve puffing quality.

Beside varietal differences, amylose and amylopectin content, storage of rice, extent of parboiling etc., addition of salt and heat curing (pre-conditioning) of rice considerably affect the expansion, vis-à-vis puffing quality (Mahanta and Bhattacharya, 2010; Chinnaswamy and Bhattacharya, 1983b; Chandrasekhar and Chattopadhyay, 1991). The pre-conditioning operation involves salt and moisture diffusion during heat treatment for extended period which brings about many gradual or sudden structural changes in its surface and inner core. This structural modification ultimately leads to generation of porous and expanded products. Microstructure of parboiled rice revealed formation of thin peripheral layer of fused endosperm with closely packed swollen starch granules embedded in protein matrix, and during progress of puffing, expansion of cell initiates along the outer endosperm, adjacent to this peripheral thin layer, creating large void spaces (vacuoles) at the centre of the grain (Chandrasekhar and Chattopadhyay, 1990). Microstructure changes in surface and core of the rice kernel in pre-conditioning process as well as at the onset of puffing in microwave heating may be interesting and helpful to evaluate the role of salt and mode of heating on the quality of the puffed rice.

Puffing takes few milliseconds to puff once the grain attains temperature sufficient for puffing. Heat transfer characteristics and mode of heating are very important in puffing of grains. Several studies have been reported in this direction viz. conduction and convection heating of the grain for puffing (Das and Srivastava, 1993; Chandrasekhar and Chattopadhyay, 1988; Venkatesh Murthy et al., 2009). Report on heat transfer characteristics in volumetric heating of food in microwave oven have been reported by several workers (Ressings et al., 2007, Gedipalli et al., 2007; Rakesh et al., 2009; Vadivambal and Jayas, 2010). Modeling for microwave heating of rice kernel and prediction of its time-temperature profile would be very useful to understand puffing characteristics of the kernel.

Considering all these aspects and identifying the existing knowledge gap, the present study has been undertaken with the following specific objectives.

1. To develop a proto-type mechanized system for batch production of pre-conditioned rice.
2. To evaluate performance of the pre-conditioner for uniform heat transfer followed by preparation of pre-conditioned rice with this system and testing for its puffing quality.
3. To study the effect of power levels, puffing time and salt levels in the pre-conditioned rice on its puffing characteristics followed by optimization of the operating parameters of the microwave puffing system.
4. To study the effect of storage period on puffing quality of pre-conditioned rice heated with microwave energy.
5. To study the moisture sorption behavior of pre-conditioned rice with and without salt at different temperatures.
6. To study the effect of various treatments on changes in microstructure of raw, parboiled, pre-conditioned rice (0 – 10% w/w salt) and rice at the onset of puffing.
7. Heat transfer modeling for single rice kernel during puffing inside a microwave oven