CHAPTER I

INTRODUCTION

Rice is one of the most important food items in the world. Millions of people eat rice as their staple food. An attempt to parboil the rice and dry it to safe moisture for storing and milling will improve the quality of rice. Rice is semi aquatic annual grass plant. Because of long history of cultivation and selection under diverse environments remarkable diversity exists in the rice. Parboiled rice is mostly consumed in South Asian nations (FAO web site, 2002). However, it has gained popularity as a part of cereal diet in recent years in the western countries including the USA due to its non-sticky plum cooking as well as nutritional qualities. The parboiling process is applied to rice with a preliminary objective of hardening the kernel in order to maximize head rice yield in milling. Besides milling yield, it was also the realization of the nutritional and health benefits of parboiled rice compared to raw milled rice that created the awareness and importance of parboiling among consumers and processors. For safe storage and processing of parboiled rice it is necessary to bring down the water activity of rice for inhibiting mould growth, preventing production of mycotoxins and resultant deterioration. The moisture content of about 12-13 % w.b. is considered to be adequate for safe storage, milling and further storage as milled rice (Hall, 1957). Drying of parboiled paddy is a very energy-intensive operation. The milling quality of paddy depends on an adequate control of drying parameters. The flow rate, temperature and relative humidity of drying air and flow rate, temperature and moisture content of grains play major role in drying. Factors such as type, variety and temperature of grain, moisture content, physical properties of grain and type of drying method affect the drying rate and energy use. A complete mechanical system that parboils rice utilizes almost 80% of the total energy for drying alone.

Sun drying was the most common method of drying cereal crops but it has many drawbacks. It depends entirely upon the weather conditions. Even in fair weather, drying is non-uniform, considerable losses are there due to birds and spillage, and contamination occurs with dirt, dust and surrounding foreign materials.

The efficient use and management of energy is an important concern in developing of a drying system. Large amount of mechanical / electrical energy is used in pumping hot air into the grain during drying operation which perhaps may not be necessary if the grain is dried by natural convection of air at optimum relative humidity and temperature of drying air. Saving in electrical energy by adding a vibratory mechanism is expected to reduce overall energy consumption in a drying system. Considering the energy consumption during commercial drying process, mechanical drying would be energy efficient if energy used for pumping hot air through the grains is minimized.

Dryer design is an increasingly challenging problem which aims to select proper type of equipment, its associated grain flow and air flow arrangement and operating conditions. Some significant developments are identified as multistage drying (Bal *et al.* 1976), a combination of high and low temperature drying (Adithap *et al*. 1999; Agrawal and Singh, 1977), thin layer drying (Raje, 1970), drying with intermittent rest periods (Chakraverty, 1976; Steffe and Singh, 1980), recirculation of the exhaust air (Soponronnarit *et al.* 2001) and stirring while drying (Shah and Goyal, 1980). Replacing the fossil fuel energy by solar or biomass energy has also been widely investigated. More recently, computer controls have been incorporated in grain dryers, which allow careful monitoring and control of process parameters and optimization procedures. The efficiency of drying with respect to both energy and time is an important economic consideration. Low thermal conductivity and case hardening of the material are the main factors responsible for slowing the hot air drying process.

Drying involves simultaneous heat and moisture transfer operations. As drying proceeds, moisture and thermal gradients are setup in different thickness of grain bed as well as at different layers of grain. This may lead to moisture and thermal stresses with in the grain. The rice kernel is fragile and is sensitive to thermal and moisture stresses which ultimately leads to formation of stress cracks called fissures. Cracked and fissured grains form brokens during milling. Properly dried parboiled paddy is mostly free from stress cracks and fissures hence quite resistant to mechanical breakage during milling. If drying is not properly accomplished, the economic advantage of higher yield and higher value of the product by parboiling process can not be enjoyed.

Fluidization is a unit operation (Leva, 1959) in which bed of particulate solids supported over a fluid-distributing plate is made to behave like a liquid by passing the fluid at flow rate above a certain critical value. Fluid bed provides an excellent environment for the process of drying of granular solids. Often it is difficult or even impossible to bring certain materials into a stable fluidized state because of their physical properties, e.g. large particle size, adhesiveness, poly-dispersity.

Fluidization difficulties arise from the fact that inter-particle forces are greater than the forces that the fluid can exert on the particles. Inter-particle forces may be due to Van der Waals, electrostatic, capillary, liquid blinder, wet and sticky particle surface, interactions. Fluidization irregularities can be reduced by introducing mechanical energy into the layer of material by using a stirrer or by vibration of particulate bulk with impulses produced by vibrating the whole dryer or parts thereof.

Vibrating grain trough can also be used to transport the granular solids. Combining fluidization and vibration regulates the flow of grains at a regular rate in heat and mass transfer zone of the dryer. The vibratory mechanism provides the vibration energy input to the trough and grain. The bed can be dried using contact heater, infrared radiation or convectively by blowing hot gases over the bed or through the bed. A vibrated system consists of exciting mechanism which provides the vibration energy input. The vibration energy is transformed mainly into kinetic energy and partly dissipated as heat, electric charge etc. due to friction and impact. The main problem in the effective use of vibration is the occurrence of energy dissipation (Erdez *et al.*, 1989). The physical properties like particle size distribution, characteristics of friction and elasticity play an important role in dissipation of kinetic energy. The energy dissipation could not be reduced because all external vibrations acting upon weakly jointed particles that lose most of their kinetic energy as a result of friction and impact during displacement. In aerated vibrated beds resonance might be the cause of reduction in energy dissipation.

The drying time depends on the physical properties of the material, thermal parameters of the bed and operational parameters. The residence time depends on the mechanical properties of the particles, intensity of transport and the geometrical parameters of the equipment. The overall drying process depends on the intensity of vibration, synchronization of the drying time with residence time, optimization of the process and design of the equipment by the control of operational parameters (Szalay *et al* .1995). The effect of vibration parameters viz. intensity, amplitude, frequency on physical characteristics of material should be studied for selection and design of the dryer. Quicker drying with high air temperature is preferable in terms of time and money but it is very likely to cause breakage of grains during milling. An increase in grain temperature during drying process causes an increase in its vapour pressure (Sarkar *et al.*, 1994). The drying characteristics of high moisture (45-50% db) parboiled paddy are different from that of raw paddy.

If vibration acceleration applied to the bed of particles is strong enough, it may evoke a state like fluidization without using forced convection. Fluidized bed drying uses an air velocity high enough so that the grains are suspended and totally surrounded and sometimes transported by dryer air. This requires very large amount of air to be pumped into the grain to achieve these conditions resulting in very high consumption of electrical energy. This renders such a system uneconomical. Fluidization and transport of grain achieved by vibration is more effective and less energy intensive. For successful design and operation of an industrial vibration assisted drying system, knowledge of the drying characteristics of the material to be dried under a range of condition of frequency, stroke length, air flow rate and temperature of hot air are of vital importance. The present study aims at determining the feasibility of vibration assisted drying of parboiled paddy with the following specific objectives:

1. To study the drying characteristics of parboiled paddy at different temperatures and bed depths under natural convection.
2. To study the drying characteristics of parboiled paddy at different temperatures using Infra red radiation.
3. To study the effect of vibration of bed depths on drying rate of parboiled paddy and optimization of grain temperature, frequency and amplitude of vibration for drying parboiled paddy under natural and forced air convection.
4. Determination of the effect of drying conditions and vibration parameters on the drying time, milling and cooking qualities of the dried product.