Chapter 1

Introduction

Fruits and vegetables are important for human life as they provide, apart from calories, the much needed vitamins and micronutrients in the diet. India endowed with diverse agro-climatic conditions, produces a wide variety of fruits and vegetables and enjoys an enviable position in the horticultural map of the world. India is the 2nd largest producers of fruits and vegetables in the world with annual production of 63.5 million tons of fruits and 125.9 million tons of vegetables during 2007-08 (http://nhb.gov.in/database2008.pdf accessed on 15th December 2009). During the production season, there is always a glut of fruits and vegetables which substantially reduces their market prices. Lack of handling, storage, transportation and processing facilities result heavy losses of the commodity. The loss value of the commodities was estimated to be Rs 20 – 24 thousand crores per annum (Rai and Chauhan, 2008). In order to prevent the losses it becomes necessary to process the commodities into various value added products.

India is a home of wide array of minor fruits which are found grown in different climatic conditions. Many of the under exploited fruits grown in India have very good nutritional, therapeutic and medicinal values and hold a lot of potential to become an important and valuable fruit crop.

Bael fruit (*Aegle marmelos* L.) is a tropical fruit native to India and belongs to the Rutaceae family. The history of this tree has been traced to Vedic period (800 BC - 200 BC). References of Bael fruit are available has been made in *Yajur Veda*. It is also grown throughout the Southeast Asian countries like Sri Lanka, Pakistan, Bangladesh, Burma, Thailand etc. (Singh and Roy, 1984). Bael fruit was introduced into Europe from India in 1959 (John & Stevenson, 1979). The peel of the fruit, very hard shell is green to brown in color depending on stage of ripening. The edible pulp is yellow or orange in colour having pleasant flavour. The seeds of the fruits are surrounded by slimy transparent mucilage. The bael fruit pulp contains many functional and bioactive compounds such as carotenoids, phenolics, alkaloids, coumarins, flavonoids, terpenoids, and other antioxidants (Maity *et al*., 2009). In addition, it also contains many vitamins and minerals including vitamin C, vitamin A, thiamine, riboflavin, niacin, calcium, and phosphorus (Roy and Khurdiya, 1995). This fruit is also used for indigenous traditional medicine (Subhadrabandhu, 2001). Its medicinal properties have been described in the ancient medical treatise in Sanskrit, *Charaka Samhita.* The unripened or half ripe fruit is astringent, digestive stomachic which improves appetite and helps to fight scurvy caused due to vitamin C deficiency. Psoralen present in the pulp is employed in the treatment of leucoderma as it increases tolerance of sunlight and aids in maintaining normal skin colour. Marmelosin derived from the pulp is used as a diuretic and laxative.

One of the problems aggravating food shortages in developing countries is a lack of adequate inexpensive preservation methods for local foods to ensure their supply throughout the year. Many methods of food preservation rely on removal of water in order to decrease water activity below a level that retards growth of spoilage microorganisms. Decreased water content also influences unwanted chemical reactions affecting not only the nutritive value of food but also its sensory properties. Furthermore, dried products reduce the cost of transportation, packaging and storage apart from enhancing shelf-life. Dehydrated food saves 86 per cent of costs incurred in transportation, 77 per cent in storage space and 82 per cent in handling cost (Patel, 1996).

Drying has been practiced for centuries as a method of preservation of food materials. Dehydrated foods are unique in that they have specific quality attributes which are crucial for the acceptability factor which includes retention of nutritional content, flavor and aroma substances, colour, bulk density and stability during storage. But drying of sugar rich foods such as fruit pulp and juices to powder is difficult, mainly due to low molecular weight sugars, such as fructose, glucose, sucrose and acids such as citric acid present in ripe fruits (Jaya and Das, 2003a). These low molecular weight materials have low glass transition temperature, T_g (Roos and Karel, 1991a,b; Roos, 1995) and their molecular mobility is high at temperature just above the glass transition temperature. They are very hygroscopic in their amorphous state and loose free flowing nature at high moisture content. The temperature at which amorphous substances exhibit stickiness is about 20 to 50 $^{\circ}$C higher than the glass transition temperature (Roos, 1995). While drying at high temperature, they tend to stick to the walls of the dryer and finally give a paste like product instead of powder (Bhandari *et al*., 1993).

The existing standard methods for drying of the liquid foods are spray drying, vacuum drying, freeze drying and drum drying. Conventional spray dryers are not suitable for dehydration of bael fruit pulp as they induce thermoplasticity in the dried product owing to its high sugar content which does not allow the powder to flow easily out of the drying chamber. Also, the spray dried powder forms sticky, tenacious lumps upon wetting (Bhandari *et al*., 1997). Despite quality advantages, economic considerations of high production cost and large capital investment have deterred commercial exploitation of freeze drying technology for the manufacture of fruit and vegetable juice powders. Vacuum drying is time consuming batch process. It takes several hours for completion of drying a batch of concentrated juice. Standard drum dryers are unsuitable for drying food stuff having high sugar content, due to sticking of the dried product on to the doctor blade. More ever, drum drying yields product which reconstitute with difficulty.

Foam mat drying is a promising technology in the field of drying aqueous foods. This method offers a wide scope for application in vegetables and fruits juice/pulp processing industry and in such other materials which are sticky and heat sensitive, and hence difficult to dry. In this drying method, surface area of the product which is to be dried is increased by incorporating air/gases (foaming) and thus drying time is markedly reduced. The developed foam structure offers advantages in drying and removal of dried material; also it improves the texture and rehydration properties. But while maintaining thickness of foamed layer for drying, escaping of air or rupture of bubble is a great problem. Actually foams provide unique texture and the nature of the foam and its physical properties are important for foam-mat drying (Foegeding *et al.*, 2006). A layer of foam dries more rapidly than the same amount of unfoamed liquid under the same external conditions because vapour moves more easily through a dry foam structure than through a dense layer of the same material. This is due to capillary action along dry interstices and evaporation into bubble spaces followed by gaseous movement through the thin outer dry walls. The foam structure decreases drying time to about 1/3 of what it would be for liquids under the same conditions (Sankat and Francois, 2004). Other advantage of foam-mat drying includes faster drying and better quality of final product as the drying temperature is less than the conventional drying methods. Water vapour produced below the already dry outermost portions diffuses through the thin, warm walls of foam's outer parts and not through the thick, dense layer which would result from shrinkage of an unfoamed mat (Thuwapanichayanan *et al*., 2008). The same structure ensures rapid rehydration of the dry product. The water travels along the web of solid material, like ink into blotting paper. Formation of gummy capsule is avoided by the small gas inclusions which do not escape until the solids outside are dissolved or dispersed. Sufficiently stable foams yield uniform dried product retaining foam structure. Dried product obtained from sufficiently small foam bubble subdivided finely without losing the advantages of foam structure. From the rehydration point of view, foam structure provides the advantages of natural porosity.

To acquire high efficiency and product quality, the liquid must not only be foamed, but the foam must also persist throughout drying to a great extent. Prior to the drying process, suitable chemicals are used in a pretreatment step to enhance the foaming ability and improve the foam stability of the product. Concentration of the material prior to conversion into stable foam may or may not be essential requirement and will depend on its surface tension and consistency. A thick mass of fluid may be difficult to be converted into good stable foam but can be achieved by the use of certain additives. Foams are inherently unstable systems and among the mechanism which contributes to foam rapture are drainage of the continuous phase from the thin films between the bubbles and mass transfer across the foam lamellae (Heller and Kuntamukkula, 1987). This process is accompanied by the growth of large bubbles at the expense of smaller ones, which is known as Ostwald ripening. For formulating foams, the technological aim should, therefore, be to control the processes which influence its instability.

Foam mat drying is a process in which the transformation of products from liquid to stable foam follows air drying at relatively low temperature to form a thin porous sheet or mat. The dried mat is then cooled, conditioned and disintegrated to yield free flowing powder. The advantages of foam mat drying process are that the material can be dried in a relatively short period of time and dried powder reconstitutes readily. The process is of potential interest for developing countries for its simplicity and economics.

Dehydrated fruits are used either as food products or as industrial ingredients in the processing of various foods. Powdered dehydrated products for longer storage life require protection against ingress of moisture, oxygen and the loss of volatile flavours and colour. During storage and distribution, foods are exposed to a wide range of environmental conditions such as temperature, humidity, oxygen, and light that can trigger several biochemical and other reactions leading to their spoilage or quality degradation. As a consequence, foods may be altered to such an extent that they are either rejected by the consumer or they may become harmful to the person consuming them. Shelf life testing is carried out by holding representative samples of the final product under conditions likely to mimic those that the product will encounter from manufacturing stage to consumption (Brown and Williams, 2003). It is a complex concept that is dependent on the nature of food product under consideration, the preservation technologies applied, and the environmental conditions to which the food product is exposed. Potter (1978) reported that accelerated storage involving high humidity (90% or more) and high temperature 40 ºC can be used for developing moisture ingress and storage time relationships quickly.

Published literature is rather limited on foam mat drying of fruit pulps and not many reports could be found on bael fruit pulp. For process upgrading and quality improvement, intensive engineering and technological support is necessary. The present project was undertaken to study the foam–mat drying of bael fruit pulp for preparation of bael powder. Not only the quality of such powder should be satisfactory but it should also have good stability during storage and should have good reconstitution properties so as to make its efficient utilization in various foods and drink mixes. A storage study makes it possible to assess the shelf life of the prepared dehydrated bael fruit powder. The specific objectives of the study were as follows:

1. To study the relevant physico-chemical characteristics, bioactive composition and sorption behavior of bael pulp.
2. To study the effect of additives on foaming characteristics of bael pulp for maximum expansion and stability.

3. To study drying characteristics of foamed bael pulp and optimize drying process parameters for maximum retention of ascorbic acid.
4. To evaluate quality and shelf life of the prepared bael powder.
5. To prepare beverage from bael powder and analyze its sensory attributes using fuzzy logic.
6. To develop rapid method for the determination of moisture in bael pulp using Fourier Transform Near Infrared (FTNIR) spectroscopy.