CHAPTER – 1

Introduction

The rapidly growing market of health foods has emerged in response to changing trends in demographics, health and disease, innovation in food and health related research, and globalization. Due to consistently increasing ageing population and prevalence of lifestyle related diseases in developed countries, many people consume health foods to maintain optimal health. In developing countries, similar demographic and public health trends are evolving among higher socio-economic groups, and health foods have penetrated these markets.

1.1. Health Food Industry

Health food industry is witnessing robust growth in the world and will be worth US$13.5 billion by 2010 (Ismail, 2006). The health food industry in India is expected to grow by 68% in five years from 2005 to 2010 (Kotilainen et al., 2006). India’s population is large and predominantly young and two-third of its 1.1 billion population is under 35 (The Mint, 2008). As the younger generation moves toward middle age and disposable income increases, the need to maintain and/or establish a healthy diet will increase health enhancing food consumption.

The growing consciousness in the urban middle-class to different types of health risks can be linked to three critical factors: high calorie diet, sedentary-, and high stress-lifestyles (Popkin, 1993). Incidence of obesity is as high as 25-30% while lifestyle related diseases account for 40% of the deaths in urban India. India has been identified by the World Health Organization (WHO) as the diabetes capital of the world with its 30 million diabetic population (King et al., 1998; Ramachandran et al., 2002). With changing lifestyle, especially in the cities, more and more consumers are opting for low-calorie foods.

The term health food has been used in the U.S.A. to refer to specific foods claimed to be especially beneficial to health for a long time. Low calorie foods are one type of health foods. They mimic in appearance, taste, and texture of processed foods with the difference that the food energy provided per serving is substantially less (Altschul, 1993; Khan, 1993). Low calorie foods can be divided into low sugar or low fat products prepared with additives like alternative sweetener or fat replacers and...
bulking agents (Khan, 1993; Sandrou and Arvanitoyannis, 2000). Due to increasing consumer awareness and demand, the market of low calorie foods is growing worldwide. The market of low calorie food products in India is about Rs. 800 million and growing at a rate of 20% annually (http://www.agricultureinformation.com). The use of low calorie sugar-free products has tripled in the last two decades of the 20th century in the world (Nabors, 2001). In the U.S.A. alone, more than 180 million people use these products regularly (ADA, 2004). Internationally, sugar substitute based low calorie products like diet soft drinks, jam, jelly, confectionery, ice creams, and frozen desserts and foods rather than direct use of sweeteners have propelled growth in the low calorie dietetic market. There is hardly any processed food category that does not have its subgroup of low calorie foods (Altschul, 1993). In India, it has however been the opposite with direct consumption of alternative sweeteners (table top sweeteners) accounting for over 90% of the low calorie market (http://www.agricultureinformation.com).

The dietary awareness of consumers has led to reduction of sucrose content of food products and full or partial replacement of sugar using alternative sweeteners. Low calorie food products of good quality can be made by taking advantage of the combinations of non-caloric and carbohydrate sweeteners (Hyvönen and Törmä, 1983). Low calorie products were originally developed for diabetics and people with specific health problems but were considerably expensive. The food industry has been confronted with a new challenge in order to satisfy consumers by development of low calorie products with acceptable sensory characteristics, competitive price, and conforming to prevailing legislation (Sandrou and Arvanitoyannis, 2000).

From 1990s, Food and Drug Administration (F.D.A.) approved use of acesulfame potassium (acesulfame-K) in soft drinks and aspartame and sucralose as general purpose sweeteners in the U.S.A. Further, the recognition by Codex Alimentarius Commission (CAC) that polyols (sorbitol, mannitol, maltitol, erythritol, etc.) have reduced caloric values compared to sucrose have resulted in enormous growth of sugar free or low sugar based food products throughout the world (Nabors, 2001). There are several alternative sweeteners available in the market. Some of these do not provide any calorie (acesulfame-K, alitame, cyclamate, neotame, saccharin, sucralose, stevioside, etc.), or provide very less calorie (aspartame, neohesperidine dihydrochalcone), while others are mainly sugar alcohols which are reduced calorie
sweeteners (sorbitol, mannitol, maltitol, erythritol, etc). Ideally, alternative or artificial sweeteners should have the following characteristics (Nabors, 2001):

(i) provide and expand food and beverage choices to control caloric, carbohydrate, or specific sugar intake;
(ii) assist in weight management or reduction;
(iii) aid in management of diabetes or hypoglycemia;
(iv) assist in control of dental caries;
(v) water soluble and stable in both acidic and basic conditions over a range of temperatures;
(vi) colorless, odorless, and non-carcinogenic; and,
(vii) impart clean and pleasant taste.

The food product incorporating alternative sweetener should taste similar to the traditional product. The sweetener must therefore be compatible with wide range of food ingredients because sweetness is only one component of complex flavor systems. Several products like low fat mayonnaise, cheese, milk, yoghurt, ice cream, meat patties, sausage, cookies, muffin, and low calorie beverages are being manufactured using sugar or fat substitutes. The low calorie fruit beverage and soft drinks prepared with aspartame and acesulfame-K have become popular worldwide due to their desirable sweetness and mouthfeel (Sandrou and Arvanitoyannis, 2000). Low calorie jam products are also gaining popularity in Japan, China, U.S.A., U.K. etc.

Less than 2% of all fruits and vegetables produced in India are processed. The main processed fruit and vegetable products are fruit juice, squash, jam, ketchup, pickle, sauce, preserve, etc. The fruit and vegetable processing industry is divided into organized and unorganized sectors. The market of jam is about Rs.1350 million (Rs. 900 million in organized sector and Rs. 450 million in unorganized sector) (GAIN Report, 2005). The major players in the organized sector are Hindustan Unilever Limited (HUL), Cremica, Druk, Mapro, etc. In jam industry, innovative low calorie products are few and mainly produced in unorganized sectors.
1.2. Jam

Jam is an intermediate moisture food containing fruit pulp, sugar, pectin, and acid. Jam is prepared by boiling the fruit pulp with sugar (sucrose), pectin, acid, and other ingredients (preservative, coloring, and flavoring material) to a reasonably thick consistency, firm enough to hold the fruit tissues in position (Lai et al., 1998; Baker et al., 2005). According to Bureau of Indian Standards (BIS) and Prevention of Food Adulteration (PFA) specifications, jam should contain more than 68% total soluble solids (TSS) and at least 45% fruit (A 16.07, 287; PFA, 2004). Whereas, the Codex Alimentarius Commission (standard 79, 1981) specify that the finished jam should contain more than 65% TSS. Pectin, sugar, acid, and water must be present approximately in the following proportions: 1% pectin, 60-65% sugar, 1% fruit acid, and 33-38% water (Lai et al., 1998). If the fruit do not contain sufficient pectin, commercial pectin is added to develop the desired consistency of the final product.

1.3. Role of Various Ingredients in Jam Manufacture

1.3.1. Fruit Pulp

Jam is made from fruits or fruit pulps like apple, cherry, mango, orange, papaya, pineapple, strawberry, etc. Mixed fruit jam, a blend of different fruits is also a popular product. Amount of sugar, acid, and pectin added for jam manufacturing depends on composition of the pulp. In some cases, extra fruit flavor is added to enhance the flavor of the jam (Lal et al., 1998). Mango jam is highly popular in India. Mango pulp was therefore used to prepare jam in the present work.

1.3.2. Sugar (Sucrose)

Sugar constitutes more than 40% of total weight and 80% of total solids in jam (Lal et al., 1998). In addition to its sweetening effect, sugar contributes to soluble solids, an effect that is essential for the physical, chemical, and microbiological stability; provides body and mouthfeel; improves appearance (color and shine); and makes gelation of pectin possible (Hyvönen and Törnä, 1983). The added sugar acts as a dehydrating agent for the pectin molecules, permitting closer contact between the chain molecules (Suutarinen, 2002). Sucrose in jam exerts osmotic pressure leading to reduction in water activity. Principal spoilage organisms in jam are yeasts and moulds, which do not survive when the water activity is below 0.8. It is therefore necessary to incorporate 40-75% sucrose in
jam to prevent microbial spoilage. Addition of preservatives, such as sodium benzoate, potassium sorbate, potassium metabisulfite, citric acid, etc. facilitate reduction of sucrose content without adversely affecting shelf-life.

1.3.3. Pectin

Pectin is a polymer chain of galactosyluronic acid, and is present in fruits naturally. It consists of complex anionic polysaccharides composed of a linear backbone of randomly connected $\alpha-(1\rightarrow4)$ linked D-galactosyluronic acid residues partially esterified with methanol, and interrupted by $\alpha-(1\rightarrow2)$ linked D-rhamnopyranosyl residues (Thakur et al., 1997). Neutral sugars are also present as side chains, in different amounts depending mainly on pectin source and the extraction method used. When sugar is added to the pectin solution, it destabilizes the pectin-water equilibrium and the pectin conglomerates forming a network of fibrils through the jam. The network of the fibrils holds the sugar solution in the intrafibrillar space. The strength of the network depends on the structure of the fibrils, their continuity and rigidity, and is dependent on: (i) concentration and nature of sugar; (ii) concentration and chemical nature of pectin; (iii) acidity; and, (iv) calcium ion concentration. The gelation mechanism of pectins is mainly governed by their degree of esterification (DE). For the low methoxyl pectin (LM pectin, DE<50%), gelation results from specific non-covalent ionic interaction between blocks of the pectin backbone and divalent cation such as calcium (Cardoso et al., 2003). High methoxyl pectin (HM pectin, DE>50%) is widely used in high sugar jams as gelling agents, mainly due to its characteristic gelation at low pH and high content of soluble solids, and to their natural sources (Lopes da Silva et al., 1992). Commercial pectins are generally produced either from citrus peels (containing 25% pectin) or from apple pomace (containing 15-18% pectin) (Pilgrim et al., 1991).

1.3.4. pH or Acidity

Acidity of the fruit pulp plays an important role in jam manufacture. Low pH leads to satisfactory gelation process and improves the fruit flavor. Citric, malic, or ascorbic acid are generally used to adjust the pH of the fruit pulp. The optimum pH for jam containing 1% pectin varies between 3 and 3.4 (Lal et al., 1998).
1.4. Problem Statement

The alternative sweeteners like acesulfame-K, aspartame, sorbitol, stevioside, sucralose, etc. can be used to fully or partially replace sucrose in jam manufacture. However, systematic studies on the development of jam using alternative sweeteners are limited (Damasio et al., 1997; Gajar and Badrie, 2001; Acosta et al., 2008). There is lack of published information on effects of various ingredients on rheological, textural, and sensory properties of jam produced using alternative sweeteners. Product development or formulation is an immensely important activity for the industry, as it is governed by consumer choices. Product quality is the major determinant of consumer choice. The ingredients affect the jam quality in terms of both subjective (sensory) and objective (textural and rheological) attributes.

For a product like fruit jam, it is important to understand the relationships between the perception of food gel texture and structure. Variation in ingredients or their concentration levels usually lead to changes in food structure that are often perceived by consumers through texture or mouth feel. A new product like a low calorie jam in which the sugar content is low has to be manufactured by controlling the sensory and textural perception of the product. The prerequisite to accomplish this is to well understand the relationship between food structure and its sensory properties (Renard et al., 2006).

Rheology, the science of deformation and flow of matter, has been extensively applied to food products to understand the relationship between structure, texture, and physical changes during processing. Rheology provides guidelines in defining set of parameters (yield stress, consistency index, flow behavior index, elastic modulus, and viscous modulus), which can be used to correlate with quality attribute(s) (Toledo, 1991). Rheological properties are useful in determining ingredient functionality in the product development, quality control, and correlation of food texture to sensory attributes (Saravacos, 1970; Kokini and Plutchok, 1987; Dervisi et al., 2001). Flow behavior of various food products, particularly fruit jams, jellies, spreads, and pulps, which contain high or moderate levels of sugars and small amount of gelling agent, have been widely studied (Carbonell et al., 1991a,b; Gabriele et al., 2001; Alvarez et al., 2006). It has been established that the rheological properties of jam are mainly affected by the amount and type of sugar added, proportion and kind of gelling agent.
used, fruit pulp content, and process temperature (Glicksman and Farkas, 1966; Saravacos, 1970).

Texture is one of the major criteria that consumers use to judge the quality and freshness of foods. Texture is included with flavor, appearance, and nutrition as a principal quality factor of foods (Bourne, 2002). Texture influences the mouthfeel of a product. Mouthfeel is the sensory experience derived from the sensation in the mouth or on the tongue after ingestion of a food material. The consumer judges the quality (fresh, stale, tender, ripe) when the food produces a physical sensation (hard, soft, crisp, moist, dry) in the mouth (Szczesniak, 1963 a,b; Kokini and Cussler, 1987). Understanding the factors that influence the texture of processed food items are essential to food scientists. Sensory analysis in combination with mechanical measurements (textural and rheological) could represent the jam quality more precisely. In physical terms, jam is a viscoelastic food product and all textural characteristics are a combination of measurable rheological and fracture (mechanical) properties. A material, such as jam, is considered viscoelastic if during (and after) deformation under stress, part of the mechanical energy supplied to it is stored in the material (elastic part) and part is dissipated (viscous part). The ratio of dissipated to stored energy depends on time of deformation. Jam has to provide a balance between desired mechanical stability (for storage and handling) and desired instability (to elicit a specific texture attribute during spreading over a piece of bread or during mastication). This implies that both the structural properties as well as the changes in these properties during mastication are important determinants of the perceived quality and texture of semi-solid foods like fruit jam. Proper selection of ingredients and their concentration levels, and optimized manufacturing process conditions are therefore essential to improve textural and rheological characteristics of jam.

Low calorie jam has immense commercial viability. Systematic studies on development of jam using alternative sweeteners like sorbitol, stevioside, sucralose, etc. are however lacking. Considerable work has been done on rheology of pectin-sucrose gel using different types of pectin with different degrees of esterification (Costell et al., 1993; Evageliou et al., 2000 a,b; Fu and Rao, 2001; Norziah et al., 2001; Bulone et al., 2002; Lootens et al., 2003; Tsoga et al., 2004 a,b). However, little information is available on the optimization of parameters (pulp, sugar, pectin, pH) based on rheological, textural, and sensory properties for development of jam using
sucrose (Skrede, 1980; Skrede, 1982; Rosenfeld and Nes, 2000). Further, systematic studies have not been carried out on the rheology of pectin-artificial sweetener gel, or textural and sensory attributes of artificially sweetened jam (Gerdes et al., 1987; Ozdemir and Sadikoglu, 1998; Fu and Rao, 1999; Sato et al., 2004).

1.5. Objectives

In the present work, it was proposed to optimize the process parameters like pulp content, pH of pulp, sugar and pectin concentration for development of good quality mango jam based on rheological, textural, and sensory attributes. From the optimized condition, development of alternatively sweetened mango jam using sorbitol, stevioside, and sucralose were carried out. The quality attributes were judged based on rheological, textural, and sensory properties of alternatively sweetened mango jam. Molecular bonding pattern and microstructure formation in jam with variation in composition was evaluated using Fourier Transform Infra Red (FTIR) spectroscopy and Scanning Electron Microscopy (SEM) techniques. The specific objectives of this work were:

1. To study the effects of pulp to sugar ratio, pectin concentration, and pH on the rheological, textural, and sensorial properties of mango jam and to optimize the process for best quality jam production.

2. To study the gelation mechanism of mango jam prepared with selected sweeteners (sucrose, sorbitol, stevioside, and sucralose) at different soluble solid levels based on textural, rheological, and spectral characteristics.

3. To study the effect of replacement of sugar by selected alternative sweeteners (sorbitol, stevioside, sucralose) on the rheological, textural, and sensorial properties and microstructure of jam.