CHAPTER 1
INTRODUCTION
1.1 Background

Fruits and vegetables have historically been considered as an important requirement of human diet and are widely recommended for their health-promoting properties. Fruits and vegetables form an indispensable part of healthy diet. Apart from fulfilling quantitative needs with delicious taste and flavor, they are also rich sources of some essential dietary micronutrients and dietary fibers; vitamins, especially vitamins C and A; minerals, especially electrolytes which improve the quality of the diet and maintain health. A well-balanced diet is incomplete without fruits and vegetables. They are also an important source of a wide array of phytochemicals and it has been reported that these phytoconstituents play a vital role in reducing risk of many diseases (Li et al., 2006; Alesiani et al., 2010; Slavin and Lloyd, 2012). Fruits and vegetables are generally consumed for their nutritive value and bioactive compounds (Banerjee et al., 2005). It is, therefore necessary to make them available for consumption throughout the year in fresh or processed/preserved form.

Several reports have revealed that adequate quantity of fruits and vegetables in regular diet helps in preventing the risk factor for chronic diseases like coronary heart disease, stroke, several forms of cancer and cataract formation (Van Duyn and Pivonka, 2000; Daucher et al., 2005). It also has been indicated that the intake of fruits and vegetables have a strong protective effect against various types of cancer (oropharynx, oesophagus, stomach, colon and rectum) and that people with a higher intake may have less risk than people with low or very low fruit and vegetable intake (Block et al., 1992; Van’t Veer et al., 2000). Scientific evidence indicates that fruits and vegetables contain a variety of antioxidant compounds (phenolics and carotenoids) which are essential to cope up with oxidative stress induced by free radicals and to reduce the risk of developing chronic diseases (Vinson et al., 2001; Adom et al., 2003). Though antioxidant capacity varies
greatly among fruits and vegetables, it is better to consume a variety of them rather than limiting consumption to a few with the highest antioxidant capacity.

Fruit and vegetable intake in proper amount is also beneficial in weight management and obesity prevention (Tohill et al., 2004). Vitamin C and carotenoid rich diet also proven preventive for cataract disease (Brown et al., 1999; Christen et al., 2005). Generally, it is assumed that consumers of fruits and vegetables smoke less, exercise more and are better educated than non-consumers (Joshipura et al., 1999).

1.2 Fruit and vegetable production scenario in India

India is an agriculture based country. India’s diverse physiogeographical conditions and climate is comprised of several agro-ecological regions which ensure plenty of opportunities to grow a variety of horticultural crops. This includes a wide range of agricultural produce in the country containing fruits, vegetables, flowers, tuber crops, medicinal and aromatic plants, spices, condiments and mushrooms.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fruits</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-09</td>
<td>32.0</td>
<td>60.1</td>
</tr>
<tr>
<td>2009-10</td>
<td>32.2</td>
<td>60.0</td>
</tr>
<tr>
<td>2010-11</td>
<td>31.1</td>
<td>61.0</td>
</tr>
<tr>
<td>2011-12</td>
<td>29.7</td>
<td>60.8</td>
</tr>
<tr>
<td>2012-13</td>
<td>30.2</td>
<td>60.3</td>
</tr>
</tbody>
</table>

Due to the wide range of fruits and vegetable cultivation, India has emerged as one of the major producer of fruits and vegetables in the world. India is the second largest country after china (figure 1.1), in the production of fruits (81.282 million metric tons) and vegetables (162.19 Million metric tons) in the world (FAO, 2009; Indian Horticulture
Database, 2011). Data from last few years prove that fruits and vegetables have an important share in India’s all horticultural products. Fruits contain almost 30% and vegetables share 60% in total horticulture shown in table 1.1.

The trend in figure 1.2 shows remarkable enhancement in cultivation area and production of fruits and vegetables over two decades. In India, the area under fruit cultivation is estimated to be increased from 2874 ha (in 1990-92) to 6982 ha (in 2012-13). This leads to increased production from 28.632 (in 1990-92) to 81.285 (in 2012-13) million metric tons. In vegetables cultivation area increased to 9205 ha (in 2012-13) from 5593 ha (in 1990-92). Vegetable production is also increased to 16.2187 (in 2012-13) from 58.532 (in 1990-92) million metric tons.
1.3 Fruit and Vegetable processing industries in India present scenario
The primary objective of food processing is the preservation of perishable foods in a stable form that can be stored and shipped to distant markets during all months of the year. Processing also can change foods into new or more usable forms and make foods more convenient to prepare.

The canning of fruits and vegetables is a growing, competitive industry, especially the international export portion. The industry is made up of establishments primarily engaged in canning fruits, vegetables, fruit and vegetable juices; processing ketchup and other tomato sauces; and producing natural and imitation preserves, jams, and jellies (http://www.epa.gov/ttnchie1/ap42/ch09/final/c9s08-1.pdf, 6-8-15).

In food processing sector fruits and vegetables are one of the most important and fast growing sub-sectors. In India 2.2% part of total production of fruits and vegetables are being processed to value added products. Various products, such as tomato puree, canned fruit, frozen fruit, frozen vegetables and ginger-garlic pastes, gained popularity among Indian consumers. Frozen and canned/preserved food products are proving to be better alternatives to fresh foods due to the convenience of storage and usage they offer. Demand for fresh, chilled and processed fruits and vegetables is also increasing in modern retail. Some small retailers have started keeping refrigerators to stock frozen peas or corn. This trend is likely to continue over the forecast period and will help drive sales and penetration of processed fruits and vegetables in India. (http://foodprocessingindia.co.in/fruits-and-vegetables.html, 29-7-15).

Various methods of fruit and vegetable preservation, helps to enhance their shelf life as well prevent the wastage. Sometimes, during harvesting season farmers are forced to sell
their produce at very less price due to market superfluity. Therefore, such food processing industries can also help farmers to get valid income for their produce and also avoid market surplus (https://www.nabard.org/pdf/MediumFruitandVegetableProcessingUnit260814.pdf; 6-8-15).

Processing is several step procedure which includes cleaning (general cleaning and dirt removal), trimming, peeling (removal of skin and seeds) followed by cooking, canning or freezing (packaging). The processing results in high amounts cleanup wastewater and solid wastes which are the primary area of pollution within the fruit and vegetable food-processing industry. Solid waste includes materials such as peels, seeds, stones, and oilseed meals (Kameswari et al., 2007; Djilas et al., 2009).

1.4 Fruit and vegetable waste
The waste produced in the fruit and vegetable processing industries comprises both solids and liquids. In processing, there is a step called trimming and peeling (skin removal) which deals with solid waste. This processing step aims at removing the parts of fruit and vegetables which are either not edible or difficult to digest especially the skin. (http://www.fao.org/docrep/V5030e/V5030E0i.htm, 6-8-15; 12:15). This results into lot of solid waste (by-products) from fruits and vegetables. Proper management of the waste is both a regulatory requirement as well as an economic necessity. The fruit and vegetable industries generate 10%-60% of the raw materials as solid waste. The composition of these wastes suggests enormous potential for producing value added products (Eipeson and Ramteke, 1997).

1.5 Selected fruit and vegetable by-products for the study

18 different fruit and vegetable by-products were selected for the study are as follows.
1.5 (a) **Onion Peel** (OP)
Scientific name: *Allium cepa* L.
Local name: Onion (English), Pyaz (Hindi), Dungari (Gujarati)
Nature of waste: Peel

1.5 (b) **Garlic Peel** (GP)
Scientific name: *Allium sativum* L.
Local name: Garlic (English), Lehsun (Hindi), Lasan (Gujarati)
Nature of waste: Peel

1.5 (c) **Potato peel** (PTP)
Scientific name: *Solanum tuberosum* L.
Local name: Potato (English), Aaloo (Hindi), Batata (Gujarati)
Nature of waste: Peel
Peel is the main by-product of potato processing which contains up to 3% - 5% part of potato tuber (Habeebullah *et al.*, 2010).

1.5 (d) **Mango peel** (MNP) and **Mango seed kernel** (MNS)
Scientific name: *Mangifera indica* L.
Local name: Mango (English), Aam (Hindi)
Nature of waste: peel, stone (kernel)
Mango is an important fruit crop which is cultivated in over 90 countries (mainly tropical and subtropical regions) worldwide (Joseph and Abolaji, 1997). Fresh mango fruit contains 33-85% edible pulp, while the seed shares 20-60% of whole fruit weight and peel covers 7-24% (Wu *et al.*, 1993).
1.5 (e) Pigeon pea pod shell (TP)
Scientific name: *Cajanus cajan* millsp.
Local name: Pigeon Pea, Red gram (English), Tur (Hindi), Tuver (Gujarati)
Nature of waste: Pod shell

1.5 (f) Pea pod shell (PSP)
Scientific name: *Pisum sativum* L.
Local name: Pea (English); Vatana (Gujarati)
Nature of waste: Pod shell

1.5 (g) Black plum seeds (JS)
Scientific name: *Eugenia jambolana* Lam.
Local name: Black plum (English), Jamun (Hindi), Jambu (Gujarati)
Nature of waste: Seeds
Its fruit contain 25% waste i.e. seeds.

1.5 (h) Custard apple seeds (SS)
Scientific name: *Annona squamosa* L.
Family: Annonaceae
Local name: Custard apple (English), Sitaphal (Hindi and Gujarati)
Nature of waste: Seed
*Annona squamosa* is a native of the west indies and it is widely grown throughout the tropics of India. The plant is deciduous and small; reaching a maximum of 6 m in height with many lateral branches. It is known for its delicious fruits and seeds are the main byproduct of the fruits which comprise 30% of its fruit’s weight and is inedible (Pinto et
al., 2005; Intaranongpai et al., 2006).

1.5 (i) **Orange peel** (ORP)
Scientific name: *Citrus sinensis* (L.) Osbeck
Local name: Orange (English), Santara (Hindi), Narangi (Gujarati)
Nature of waste: fruit peel
A Pulp and their seed contribute to bulk of the fruit weight comprising about 46% and 44% while peel constitutes about 10%. The orange fruit is highly nutritious and rich in minerals, proteins, carbohydrates, and fat (Prasad et al., 2010).

1.5 (j) **Sweet lime peel** (SLP)
Scientific name: *Citrus limetta* Risso.
Local name: Sweet lime (English), Mosambi (Gujarati)
Nature of waste: Peel

1.5 (k) **Watermelon peel** (WMP)
Scientific name: *Citrullus lanatus* (Thunb.) Matsum. and Nakai
Local name: Watermelon (English), Tarbooz (Hindi and Gujarati)
Nature of waste: Peel
Watermelon biomass can be categorized as three main components which are the flesh, seed, and rind. Watermelon constitutes approximately 68% flesh, seeds 2%, the rind 35%, of the total weight and 15% peel goes to waste (Kumar, 1985; USDA, 2004).
1.5 (l) **Peanut pod shell** (GNP)
Scientific name: *Arachis hypogaea* L.
Local name: Peanuts (English), Moong Phalli (Hindi)
Nature of waste: Pod shell

1.5 (m) **Pomegranate peel** (PG)
Scientific name: *Punica granatum* L.
Local name: Anar (Hindi), Dadama (Gujarati)
Nature of waste: Fruit Peel

1.5 (n) **Split green gram peel** (MDP)
Scientific name: *Vigna radiata* (L.) R. Wilczek
Local name: Green gram (English), Moong daal (Hindi), Mug dal (Gujarati),
Mug dal (Gujarati),
Nature of waste: Seep peel
Structurally, mungbean may consist of 12.1% seed coat, 2.3% embryo and 85.6% cotyledons (Singh, 1988; Kanatt et al., 2011).

1.5 (o) **Chilli Pedicel** (CA)
Scientific name: *Capsicum annuum* L.
Local name: Chilli (English), Mirch (Hindi), Marcha (Gujarati)
Nature of waste: Pedicel
1.5 (p) **Jackfruit peel** (JFP)

Scientific name: *Artocarpus heterophyllus* Lam.
Local name: jackfruit (english) and Kathal (hindi)
Nature of waste: Peel

1.5 (q) **Cucumber peel** (CC)

Scientific name: *Cucumis sativus* L.
Local name: Cucumber (English), Khira (Hindi), Kakadi (Gujarati)
Nature of waste: Fruit peel

1.6 **Statement of the problem**

During processing of fruits and vegetables, a large amount of by-products are produced as waste. These wastes are disposed along with municipal solid wastes in the landfills or dumpsites. Decaying of these waste become a place for vectors, pest breeding, odour nuisance and Green House Gas (GHG) emission into the atmosphere. Thus, exert harmful impact on environment. Therefore, such waste need to be managed or some alternative ways should be investigated for their utilization (Kameswari *et al.*, 2007; Duda-Chodak and Tarko, 2007).

Fruits and vegetables wastes and by-products, which are formed in great amounts during industrial processing, represent a serious problem, as they exert an influence on environment and need to be managed and/or utilized. Fruit and vegetable by-products are prone to microbial spoilage. So, drying is essential before further exploitation. Generally, it increases cost and efforts when it comes to drying, storage and transport of waste and it becomes an economical limitation for waste utilization. Therefore, agro industrial waste is often utilized as feed or fertilizer. These by-products contain good amount of secondary metabolites and are highly nutritious. So, further exploitation of these waste
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materials for a different use like food additives or supplements with high nutritional values can be more striking (Djilas et al., 2009; Chanda et al., 2010).

1.7 Significance of the study

Solid waste in the form of peels and seeds are generated in large quantity by fruit and vegetable processing industries, and these wastes can cause serious environmental problems such as water pollution, unpleasant odors, explosions and combustion, asphyxiation, and greenhouse gas emissions if not disposed properly (Kumar et al., 2011; Ayala Zavala et al., 2011). It is very essential to manage such waste properly or to find out some alternative use of it.

The term by-product will be more suitable for fruit and vegetable peels and seeds rather than waste as nature does not produce any waste. These by-products are an important source of minerals, organic acids, dietary fibers and bioactive compounds such as phenols, glycosides, alkaloids, terpenoids and flavonoids etc. These have potential applications as antioxidant, antimicrobial, flavoring, colorant, texturizer and have a wide range of actions (Nijveldt et al., 2001; Dewick, 2002).

The hazardous effects of synthetic antioxidants and the appearance of antibiotic resistant strains turn the face of research towards exploring natural resources for finding a substitute to synthetic substances. Synthetic molecules are suspected to cause or promote harmful health effects and such researches will help consumers to become sure about the safety of products. Several studies on fruit and vegetable by-products indicate that the present phytochemicals are the major bioactive compounds with human health benefits and they also have remarkable potential to serve as a source of newer, efficient, safer and improved antioxidant and antimicrobial agents. Concerning these wastes as by-products and further exploitation on the production of food additives or supplements with high nutritional value is gaining tremendous interest as innovative aspect (Djilas et al., 2009; Parashar et al., 2014). The exploration of functional compounds from fruit and vegetable by-products processing and their application in various fields is a promising field and
requires interdisciplinary research of food technologists, food chemists, nutritionists and toxicologists (Djilas et al., 2009).

By-products of food processing is an inexpensive, affordable, and valuable starting material for the extraction of value added products such as dietary fiber, natural antioxidants, biopolymers, and natural food additives (Di Mauro et al., 2004; Bildstein et al., 2009). However, the central dogma is still the stability, and economic feasibility of the processing development (Chiu and Chan, 1992; Bhushan et al., 2008).

1.8 Objectives of the study

1.8.1 Overall objective: a statement of whole work

Fruit and vegetable processing results into a large amount of waste (by-products). These by-products are very rich in bioactive compounds. Exploring such material to utilise them in different way can help in managing and reducing the waste. So, present study aims to exploring potential of selected fruit and vegetable waste through phytochemical studies, antioxidant and antimicrobial assays. These so called wastes can also be turned to value added products. The work will also focus on the various aspects by which these by-products can be utilized into products.

1.8.2 Specific objectives

The current study was carried out to

- Collect and prepare powder from selected plant waste material.
- Estimate the extractive values by using different solvents according to polarity.
- Quantifying ash values (Total ash, Water soluble ash and Acid insoluble ash).
- Preliminary phytochemical screening for primary and secondary metabolites.
- Quantitative analysis for selected primary and secondary metabolites
- Developing the HPTLC profiles of the extracts
- Determination of antioxidant activity
- Analyzing Antimicrobial potential
- Exploring the possibilities for product development on the basis of results
1.9 Organisation of the thesis

This thesis is composed of discrete chapters. The general introduction and literature review are presented in chapters 1 and 2 respectively. Chapter 3 comprises of phytochemical aspect of selected fruit and vegetable by-products. It includes the extractive values, ash analysis, qualitative and quantitative analysis. The TLC and HPTLC analysis also covered in this chapter. Chapter 4 represents the antioxidant capacity of selected plant materials. Antimicrobial studies are presented in chapter 5. Each chapter (objective) contains a discussion part with reference to product development in relevance to the results. The general discussion, conclusions and recommendations emanating from the entire study are presented in chapter 6. Chapter 7 include references.