ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

CHEMICAL ENGINEERING DEPARTMENT

Development of fruit leather from indigenous Tamarind (Tamarindus indica L.) fruit

By:

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Declaration

I the undersigned declare that this thesis is my original work, has not been presented for a degree in any other University, and that all sources of materials used for the thesis have been duly acknowledged.

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List of Abbreviations

AAU	Addis Ababa University
AOAC	Association of Official Analytical Chemists
ANOVA	analysis of variance
EHNRI	Ethiopian Health and Nutrition Research Institute
Et-Fruit	A state owned Ethiopian Fruit Marketing Agency
FAO	Food and Agriculture Organization
FDA	Food and Drugs Administration
LSD	List Significance Difference
MC	Moisture Content
OAC	oil absorption capacity
ppm	parts per million
RH	Relative Humidity
TA	Titeratable acidity
TJC	Tamarind Juice Concentrate
TPP	Tamarind Pulp Powder
TSS	Total Soluble Solid
WAC	Water absorption Capacity

Abstract

The objective of this research was to develop fruit leathers from indigenous tamarind fruit tree. Tamarind fruits were collected, sorted, washed, grinded, soaked in water and then pulped. Flavoring ingredient that is: sucrose and grounded ginger and lemon juice as color preservatives were added to the tamarind. Tamarind puree was spread on trays and dried in electric oven drier to get thin sheets of leathers. The products were evaluated for physicochemical properties, proximate element composition, vitamin c content, mineral element (Ca, K and Na) and sensory properties.

Proximate analysis result of the fruit leathers showed that they contained low protein (2.23-3.09%), fat (1.210-2.146%) and ash (3.003-3.536%) content. whereas, it consisted mainly of carbohydrates (69.193-76.406%) and crude fiber (3.05-4.71%). The total moisture content (18.316-14.100%) of fruit leathers were low and its titratable acidity (7.645-7.883% citric acid) and pH (3.253-3.390) were high, suggesting that the products would have acceptable storage characteristics and would be microbiologically safe. The vitamin C content of the fruit leathers were found to be in the range between 21.656 and 17.520mg/100g. The mineral contents of the products were ranged between for: Ca 73.111 and 196.39mg/100g, K 595.100 and 731.667mg/100g and Na 102.178 and 125.949 mg/100g. The result of sensory analysis using customer preference test showed that the fruit leathers were well accepted. The two most liked fruit leathers with an overall acceptability of 8.6 and 8.5 (liked very much) were fruit leather dried at 80^0C and 70^0C for 8hr respectively. The lowest score was achieved by fruit leathers dried at 90^0C. In general, significant difference ($P < 0.05$) has been observed among tamarind leathers in terms of pH, titratable acidity, vitamin C content, proximate element composition, mineral element concentration and sensory attributes. The investigation indicated that, Tamarind leather dried at 80^0C for 8hr showed the best quality performance among the rest.

Chapter one

Introduction

1.1 Background

Tropical fruits, which are at present underutilized, have an important role to play in satisfying the demand for nutritious, delicately flavored and attractive natural foods of high therapeutic value. They are in general accepted as being rich in vitamins, minerals and dietary fiber and therefore are an essential ingredient of a healthy diet. According to Sitske *et al*. (2007), the contribution of wild food plants to combating deficiencies in vitamins and micronutrients is essential in the agriculturally marginal areas. Wild food plants are particularly most important during periods of food scarcity (Aline *et al*., 2008).

The Tamarind, scientifically known as *Tamarindus indica* L., fruit which belongs to the dicotyledonous family Leguminosae, sub-family Caesalpinioideae, is an important wild food plants in the tropics. It is a multipurpose tree of which almost every part finds at least some use (Kumar and Bhattacharya, 2008), either nutritional or medicinal. Various geographical areas have been proposed for the origin of tamarind: India (Morton, 1987), the Far East or Africa (Coates-Palgrave, 1988). Others considered it indigenous to the drier savannahs of tropical Africa, from Sudan, Ethiopia, Kenya and Tanzania, westward through sub-Saharan Africa to Senegal (Irvine, 1961). Now a day, tamarind has been introduced and naturalized worldwide in over 50 countries.

Tamarind is valued highly for its fruits, especially the pulp which is used for a wide variety of domestic and industrial purposes (Gunasena and Hughes, 2000). The pulp has a sweet acidic taste due to a combination of high contents of tartaric acid and reducing sugars. It is a good source of the B vitamins (thiamin, niacin, and riboflavin), vitamin C as well as phosphorus, potassium, and calcium (whose content is reportedly the highest found in any fruit). The dry pulp also consists of about 4 percent protein, and 1 percent fat (National Research Council, 2008). Tamarind pulp is used to prepare juice, jam and syrup. Furthermore, it is also used as a raw material for the manufacture of several industrial products, such as Tamarind Juice Concentrate, Tamarind Pulp Powder, tartaric acid, pectin, tartarates and alcohol (Anon, 1982).

Fresh Tamarind fruits have a limited shelf life and are seasonal crops. As a result, the preservation of a fresh substitute and year round availability is important to meet the demands of consumers. Drying of agricultural products is the oldest and most widely used preservation method. It involves the reduction of as much water as possible from the fresh fruit to arrest enzyme and microbial activities, hence, stopping deterioration (Teshome, 2010). Moisture left in dried foods varies between 2 -30% depending on the food type. The reduction of moisture content to a safe level extends the shelf life of the product and provides microbiological stability and reduces deteriorative chemical reactions (Okos, 1992). The drying process is, therefore, an effective means to extend the shelf life of Tamarind fruit and offers an alternative way for consuming Tamarind all year round.

Fruit leather is one of those products that can be made using a drying process. It is dried sheets of fruit pulp that have a soft, rubbery texture and a sweet taste. They are produced by dehydrating of fruit puree into a leathery sheet (Raab and Oehler, 1999). The edible portion of fruit (one or more types) is pureed, mixed with other ingredients to improve its physicochemical and sensory characteristics, heated, formed (flattened and shaped) and then dried on a flat trays until a cohesive fruit leather is obtained (Moyls, 1981; Phimpharian *et al*., 2011). Fruit leathers can be eaten as snack foods or added to a variety of food preparations.

Fruit leathers can be dried using various drying method including sun, oven, cabinet or dehydrator drying method (Irwandi *et al*., 1998; Raab & Oehler, 1999). The composition of the final fruit product may vary depending on the processing conditions. Sun-dried products can become discolored and the process can be unhygienic and lengthy (Teshome, 2010). Hot air drying is an alternative method that needs less drying time and improves the quality of the dried fruit (Maskan *et al*., 2002; Garau *et al*., 2007). However, it has been shown that hot air drying can promote a decrease in the antioxidant capacity of fruit. Raab *et al*. (1999) and Che Man *et al.* (1997) used oven and cabinet drying method to make jackfruit leather and found that both technique resulted in a product with improved quality and acceptability compared to old traditional sun drying method. This is there for the preferred drying method for manufacturing fruit leathers.

Most studies and research on fruit leathers incorporate not only fruit purees in the development of fruit leathers, but also other ingredients (especially sugars) and additives. For example, Che

Man *et al*. (1992) prepared sapota leathers from sapota puree, sucrose, rice flour, sorbic acid and sodium metabisulphite. The fruit leathers were shelf-stable for three months. Jackfruit leathers with added sucrose and sorbic acid were produced by Che Man and Taufik (1995) and the product remained stable for two months. Irwandi *et al.* (1998) produced 12-week stable durian leathers from a formulation including sucrose and sorbic acid. Vijayanand, *et al.* (2000) produced three month shelf-stable guava leathers with the addition of sucrose and sodium metabisulphite. All the above-mentioned studies reported good consumer acceptance of the fruit leather product.

Therefore, this research will be conducted with the objective of producing value added, nutritionally accepted and shelf stable product called fruit leather from locally grown tamarind fruit in order to minimize and/or avoid post-harvest loss to the fruit and nutrition insecurity of our country Ethiopia

1.2 Statement of the Problem

For many years, the importance of wild edible plants in the subsistence agriculture of developing countries, as a food supplement or a means of survival during drought and famine, has been overlooked. Although many wild food plants are used by the majority of the rural population, they are still not as appreciated or valued as are some cultivated food plants, such as mango, orange, cabbage and banana (Bell, 1995; Guinand and Dechassa, 2000; Ruffo *et al*., 2002; Demel *et al*., 2010).

In Ethiopia, where more than 80% of the population is rural, people have depended on their traditional knowledge for the utilization of plants in their surroundings. Despite the wider role of wild edible plants in rural communities, their pre and post harvest handling, management and utilization are still poor. This is particularly true in Northern and Southwestern Ethiopia.

Ethiopia's wide range of agro-climatic conditions and soil types make it suitable for the production of wild fruits like tamarind. Unlike durable crops such as cereals, pulses and oilseeds, fresh fruits are highly perishable and must either be marketed fresh or processed immediately after harvesting. According to Yadav (1997) it is common experience that 20-25% of fruit is completely damaged and spoiled before it reaches the consumer. Some constraints of post harvest products of fruits are related to the perishable nature of the fruit and their post harvest

handling condition. These factors have made growing and marketing of fresh produce in Ethiopia complicated by post harvest losses both in terms of quantity and quality between harvest and consumption.

Currently a higher percentage of tamarind fruit produced in Ethiopia is geared to domestic markets. During peak harvesting seasons, the loss is high and the fruits are sold at low price because of inadequate preservation techniques. Processing is therefore necessary to contribute toward expansion of nutritional input and market of tamarind in availing it during off-seasons and also increasing its value.

Consequently, for many indigenous tropical crops as tamarind, the lack of competitive market access has become the major obstacle to their contribution to agricultural development. Efforts to improve production and yields often result in excess supplies of basic commodities. Hence, there is the need to find other alternative sources of usage.

Therefore, the development of tamarind fruit leather is highly required in order to: utilize the produce at the time of glut, avoid post harvest loss, make the fruit year round available, fill seasonal food shortages, nutritional insecurity and malnutrition, increase the demand and competitive market access for tamarind fruit. It will also generate enough opportunities of self-employment by starting small scale processing unit or cottage industry that will be remunerative to the growers. Thus the preparations of tamarind pulp with simple technology and its utilization in the form of pulp and leather have a great scope.

1.3 Objective of the Study

1.3.1. General Objectives

The general objective of this research work was to develop fruit leathers from indigenous tamarind fruit.

1.3.2. Specific objectives

The specific objectives of this research work were to:

- Characterize the tamarind fruits:
- Develop Tamarind fruit leather using electric oven drying method
- Conduct sensory analysis on final product; fruit leather, to evaluate its acceptability**.**

Chapter Two

Literature Review

2.1 Wild fruit trees

Ethiopia has not only diverse flora and fauna but also rich indigenous knowledge on both domesticated and wild plants. The use of wild plants in the native diet, traditional medicine and religious ceremonies is widespread. Wild food plants are those plants with edible parts, namely leaves, fruits/seeds, roots and tubers, gums and saps, bark as well as pollen and nectar for honey production (by bees), that are growing naturally without having been purposely cultivated. All of these types of food provide essential elements in the human diet. They also provide a number of important dietary elements that the normal agricultural produce does not adequately provide. In many areas, dietary deficiencies and monotony of normal diets are reduced or avoided, through this "hidden harvest". For most of the plants and, hence, fruit trees/shrubs, the edible parts, e.g. fruits/seeds, are still collected from the wild and consumed directly by the households or taken to the market in Ethiopia.

Wild food plants are relevant to household food security and nutrition in some rural areas, particularly in the dry lands, to supplement the staple food, to fill seasonal food shortages, and as emergency food during famine (Amare, 1974; FAO, 1989; 2003; Guinand and Dechassa, 2000; Teshome and Sebsebe, 2002). They are used to generate income through the sale of fruits and fruit products, medicine, gums and resins (Maghembe and Seyani, 1992). The fruits are also used to compliment or supplement diets because they contain vital nutrients and essential vitamins (Maghembe *et al*., 1998). For example, Tamarind fruits are rich in protein, carbohydrates, fibers, vitamin C and other minerals (Pugalenthi *et al*., 2004; Parvez *et al*., 2003).

2.2 Production and marketing of Tamarind fruits in Ethiopia

Ethiopia's wide range of agro-climatic conditions and soil types make it suitable for the production of wild fruits like tamarind. Even though, it is not available any written document by MOARD that indicates about the annual production of the tamarind fruit in Ethiopia, There are two main agro-ecological region in Ethiopia that potentially produce tamarind fruits, such that:-

- **Northern Ethiopia**: including four word's from North Gondar Zone, namely Maksegnit, Tikle dengay, Chilga and Metema; two woredas from West Gojjam Zone, namely Bahar

Dar and Finoteselam; one woreda from Awi zone, namely Kosober; and two woredas from East Gojjam Zone, namely DebreMarkos and Dejen; and

- **Southwestern Ethiopia**: Wolkitie, Gibie, Jimma, Gambela, Bonga, Mizan, Tepi, Masha, Bedele and Dedessa Valley.

In the country, the tamarind fruit is marketed by poor farmers in local market and also exported to markets in Sudan through local routes as a source of income. Traditionally, in our country the fruits of Tamarinds indica are utilized after soaking in cold water for 12 or more hours to make juice for direct consumption.

2.3 Over view of Tamarind fruit

Tamarind is a multipurpose tropical fruit tree used primarily for its fruits, which are eaten fresh or processed. It is used as a seasoning or spice, or the fruits and seeds are processed for non-food uses. Tamarind belongs to the dicotyledonous family Leguminosae which is the third largest family of flowering plants (Lewis *et al*., 2005).

Tamarind is widely grown as a subsistence crop for meeting local demands. It is also grown commercially. Numerous national programs have recognized tamarind as an underutilized crop with wider potential since demand for products is substantial and the species can be incorporated into agro forestry systems. There are also well established international trade channels. Further exploitation of tamarind can therefore provide added incomes for poor rural people thereby improving their well-being.

2.3.1 Nomenclature

Tamarindus indicus L. Species Plantarum (1753) 34

It is thought that Linnaeus gave the specific epithet *indicus* because the name tamarind itself was derived from Arabic which combined Tamar meaning ‘date’ with Hindi meaning ‘of India’. The full Arabic name was Tamar-u’l- Hind and the word date included because of the brown appearance of tamarind pulp.

Subsequent botanists differentiated between tamarind from the West Indies (*T. occidentalis* Gaertn.) and tamarind from the East Indies (*T. officinalis* Hook.). Jackson (1895) in *Index Kewensis*, found these names to be superfluous and the descriptions insufficient to separate the two species.

2.3.2 Common/vernacular names of tamarind

Country	Language	Name(s)
Africa		
Ethiopia	Amharic	hemor, homor, humar, komar, tommar
	Tigrigna	arabeb
	Oromo	b/roka, racahu, dereho, dindie, ghroma, gianko, omar
Kenya	Swahili	mkwaju
	Turkana	eopduran
	Borana	roka
Malawi	Chewa	ukwaju, bwemba
	Nkande	nkewesu
Somalia	Somali	hamar
South Africa	Afrikaans	tamarinde
Asia		
India	Hindi	ambli, amli, imli
	Sanskrit	amalika
	Bengali	tintiri, tintul, tetul
	Marathi	chinch, chitz, amli

Table 2.1 Common/vernacular names of tamarind

Source: Coronel (1991); Salim et al. (1998)

The local names of tamarind fruit used in various regions and languages are shown in Table 2.1.

2.3.3 Description

Tamarind is a long-lived, large, evergreen or semi-evergreen tree, 20-30m tall with a thick trunk up to 1.5-2 m across and up to 8 m in circumference. The trunk forks at about 1 m above ground and is often multi-stemmed with branches widely spreading, drooping at the ends and often crooked but forming a spreading, rounded crown. The bark is brownish-grey, rough and scaly. Young twigs are slender and puberulent. A dark red gum exudes from the trunk and branches when they are damaged.

Leaves are alternate and even pinnate, in length 5-15cm, shortly petiolated (up to 1.5 cm long) and petiole glabrous or puberulent. Laminae are glabrous or puberulent, glaucous underneath and darker green above. Venation is reticulate and the midrib of each leaflet is conspicuous above and below. Leaflets are in 6-20 pairs per leaf, each narrowly oblong, rounded at the apex and slightly notched and asymmetric with a tuft of yellow hairs; at the base obliquely obtuse or sub

truncate. At the leaf base is a pulvinus and two small stipules 0.5-1.0cm long which are caducous early on; stipules are falcate, acuminate and pubescent. A permanent scar is seen after leaf fall.

The fruits are pods 5-16 cm long x 2 cm broad, oblong, curved or straight, with rounded ends, somewhat compressed and indehiscent although brittle. The pod has an outer epicarp which is light grey or brown and scaly. Within is the firm but soft pulp which is thick and blackish brown. The pulp is traversed by formed seed cavities, which contain the seeds. The outer surface of the pulp has three tough branched fibers from the base to the apex.

Each pod contains 1-12 seeds which are flattened, glossy, and orbicular to rhomboid, each 3-10 x 1.3 cm and the Centre of each flat side of the seed marked with a large central depression. Seeds are hard, red to purple brown, non arillate and exalbuminous. Seed chambers are lined with a parchment like membrane.

Pods ripen about 10 months after flowering and can remain on the tree until the next flowering period, unless harvested (Rana, 1975; Chaturvedi, 1985).

Figure 2.1 Tamarind pods (Photo: A. Latham)

2.3.4 Origin

Various geographical areas have been proposed for the origin of tamarind: India (Morton, 1987) or the Far East or Africa (Coates-Palgrave, 1988) but the consensus is that it is Africa. Troup (1921) placed it in Ethiopia, but others considered it indigenous to the drier savannahs of tropical Africa, from Sudan, Ethiopia, Kenya and Tanzania, westward through sub-Sahelian Africa to Senegal (Brandis, 1921; Ridley, 1922; Dalziel, 1937; Dale and Greenway, 1961; Irvine, 1961; NAS, 1979). Figure 2.2 shows the indigenous distribution. Around homesteads in Africa it is still wild or protected. It is thought to have been introduced to South and Southeast Asia a very long time ago (Brenan, 1967; NAS, 1979) and it naturalized in many areas where it was introduced (Simmonds, 1984; Purseglove, 1987; Coronel, 1991).

Figure 2.2 approximate indigenous range of tamarind in Africa (the shade part)

2.3.5 Properties of the Species

Tamarind is a nutritious fruit with a variety of uses. The properties of this species have been extensively studied, particularly with reference to the components of the fruit. Tamarind has many valuable properties and virtually every part of the tree has been utilized by both rural and urban dwellers.

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2.3.5.1 Pulp

The most valuable and commonly used part of the tamarind tree is the fruit. The pulp constitutes 30-50% of the ripe fruit (Purseglove, 1987; Shankaracharya, 1998), the shell and fiber account for 11-30% and the seed about 25-40% (Chapman, 1984; Shankaracharya, 1998). The large range is associated with heterozygosity since many cultivated forms have been seed propagated (Benero*et al.*, 1974). The pulp contains oil, which is greenish in color and liquid at room temperature. The saponification value of the oil is high but the iodine value is low.

The major volatile constituents of tamarind pulp include furan derivatives (44.4%) and carboxylic acids (38.2%), the components of which are furfural (38.2%), palmitic acid (14.8%), oleic acid (8.1%) and phenyl acetaldehyde (7.5%) (Wong *et al*., 1998). According to Lee et al. (1975), the most abundant volatile constituent of tamarind pulp is 2-acetyl-furan, coupled with traces of furfural and 5-methylfurfural, which form the total aroma of tamarind. The total content of volatile compounds in fruit pulps can be around 3 mg/kg. Apart from the major volatile components listed above there may be up to 81 different volatile substances (Pino *et al*., 2004).

Table 2.2 Mean composition of tamarind fruit

Constituents	Amount (per 100 gm)
Water	17.8-35.8 g
Protein	2-3 g
Fat	0.6 g
Carbohydrates	41.1-61.4 g
Fiber	2.9 g
Ash	2.6-3.9 g
Calcium	34-94 mg
Phosphorous	34-78 mg
Iron	0.2-0.9 mg
Thiamine	0.33 mg
Riboflavin	0.1 mg
Niacin	1.0g
Vitamin C	44 mg

Source: Coronel (1991); Feungchan *et al*., (1996 a).

The fruit contains a variety of pigments. The red colour is due to water soluble red-rose anthocyanin pigment, while in the common types of pulp leuco-cyanidin is present (Lewis and Neelakantan, 1964; Bhattacharyya, 1974).

Lectins have been shown to be present and these could be of medical interest (Coutino-Rodriguez *et al*., 2001). Triterpenoids are also a constituent (Neetu and Bohra, 2003).

The most outstanding characteristic of tamarind is its sweet acidic taste, the acid due mostly to tartaric acid, ranging from 12.2-23.8%, and uncommon in other plant tissues (Ulrich, 1970). It is an unusual plant acid, which is formed from the primary carbohydrate products of photosynthesis, and once formed; it cannot be further used in the plant due to the absence of the necessary enzymes. Although tartaric acid occurs in other sour fruits, such as grapes, grapefruit and raspberries, it is not present in such high proportions as in tamarind. The tartaric acid is synthesised in tamarind leaves in the light and translocated to the flowers and fruits (Lewis *et al*., 1961; Patnaik, 1974). It is high in young leaves and decreases with age and has been reported to show seasonal variations (Bueso, 1980). As reported by Lewis and Neelakantan (1964 b) the tartaric acid content in leaves decreased from 28- 12% suggesting that this is due to its transfer to the fruit during ripening. The content of tartaric acid, however, does not decrease during fruit ripening, indicating that it is not utilized in fruit development; but during this time, reducing sugars increase to 30-40% giving the sour fruit a sweeter taste. As the acidity does not disappear with ripening, but is more or less matched with increasing sugar levels, tamarind is known to be simultaneously the most acidic and sweetest fruit (Lewis and Neelakantan, 1964 a; Coronel, 1991).

In general, the dried tamarind pulp of commerce contains 8-18% tartaric acid and 25-45% reducing sugars of which 70% is glucose and 30% fructose. Lewis and Neelakantan (1964 a) reported that one half of the tartaric acid was present as potassium bitartarate (cream of tartar) and to a lesser extent as calcium tartarate. The tender fruits contain most of the tartaric acid in free form (up to 16%), which can be easily extracted with hot water. Lewis et al. (1961) also reported that tartaric acid is present at all stages of fruit development as an optically active (+) isomer. The most commonly found isomer in fruit is malic acid; about 1.37mg/l existed as the (-) form in tamarind fruits.

The ascorbic acid content in tamarind is very small and varies from 2-20 mg/100g (Lefevre, 1971; Ishola *et al*., 1990). The other organic acids reported in tamarind fruit are oxalic acid, succinic acid, citric acid and quinic acid (Lewis and Neelakantan, 1964 a; Singh, 1973; Anon, 1976). The tamarind pulp does not contain any detectable amounts of phytic acid, but the trypsin activity is higher than in the seed (Ishola *et al*., 1990).

Table 2.3 Proximate composition of dried pulp of tamarind fruit per 100g dry weight

Constituent	**Percentage**
Moisture	15.00-30.00
Proteins	2.00-9.10
Fat/oil/lipid, crude	0.50-3.10
Carbohydrates, total	56.70-82.60
Fiber, crude	2.20-18.30
Tartaric acid, total	8.00-18.00
Reducing sugars	25.00-45.00
Total ash	2.10-3.30
Pectin	2.00-4.00
Cellutosic residue	19.40
Albuminoids	3.00-4.00
Total available carbohydrates	41.77
Alcohol insoluble sugars	22.70
Water insoluble sugars	20.50
Non-reducing sugars	16.52
Total sugars	41.20-58.7
Starch	5.70
Tannin, (mg)	600.00
Ascorbic acid, (mg)	3.00-9.00
β-carotene equivalent (mg)	10.00-60.00
Thiamine (mg)	0.18-0.22
Roboflavin (mg)	0.07-0.09
Niacin (mg)	0.60

Source: Meillon (1974); Anon (1976); Duke (1981); Ishola *et al*. (1990); Parvez *et al*. (2003)

Tamarind pulp is also rich in minerals: high in potassium (62-570 mg/100g); phosphorus (86-190 mg/100 g); and calcium (81-466 mg/100g), and a fair source of iron (1.3-10.9 mg/100g). The content of magnesium (25.6-30.2 mg/100g) is high, as is sodium (23.8-28.9 mg/100g) but low for copper (0.8- 1.2 mg/100g) and zinc (0.8-0.9 mg/100g) according to Parvez *et al*. (2003). It also excels in riboflavin and is a good source of thiamin and niacin, but is poor in vitamin A and vitamin C (Leung and Flores, 1961).

Tamarind fruit contains a biologically important source of mineral elements and with a high antioxidant capacity associated with high phenolic content can be considered beneficial to human health. The phenolics include gallic acid equivalent of 626-664 mg per 100g (Parvez *et al*., 2003; Soong and Barlow, 2004 and Komutarin *et al*., 2004).

2.3.5.2 Seeds

The seed comprises the seed coat or testa (20-30%) and the kernel or endosperm (70-75%) (Coronel, 1991; Shankaracharya, 1998). Tamarind seed is the raw material used in the manufacture of tamarind kernel powder (TKP), polysaccharide, adhesive and tannin. The seeds are also used for other purposes and are presently gaining importance as an alternative source of protein, rich in some essential amino acids. Unlike the pulp the seed is a good source of protein and oil. There has been considerable interest amongst chemists, food technologists and nutritionists in the study of the properties of tamarind seeds e.g. recent work on stabilization of xyloglucans of the tamarind seed polysaccharide (Picout *et al*., 2003) and the gelling behavior of polyose from tamarind kernel powder so that pectin/polyose mixes can be recommended (Marathe *et al*., 2002).

Whole tamarind seed and kernels are rich in protein (13-20%), and the seed coat is rich in fibre (20%) and tannins (20%). Panigrahi *et al*. (1989) reported that whole tamarind seed contains 131.3 g/kg crude protein, 67.1g/kg crude fiber, 48.2 g/kg crude fat, 56.2 g/kg tannins and trypsin inhibitor activity (TIA) of 10.8%, with most of the carbohydrate in the form of sugars. The trypsin inhibitor activity is higher in the pulp than in the seed, but both are heat labile. According to Ishola *et al*. (1990), the seed also contains 47mg/100g of phytic acid, which has minimal effect on its nutritive value. It also contains 14-18% albuminoid tannins located in the testa. According to Purseglove (1987), the seeds contain 63% starch and 4.5-6.5% of semi drying oil.

Both pulp and the seeds are good sources of protein (269.3 g/kg), oil (109.1 g/kg) and calcium (Ishola *et al*., 1990).

2.3.5.3 Leaves and Flowers

The leaves are used as a vegetable by indigenous peoples in producing countries. They contain 4.0-5.8% proteins while the flowers contain only 2- 3%. The leaves are also a fair source of vitamin C and beta-carotene and the mineral content is high, particularly in potassium, phosphorous, calcium and magnesium. Leaves contain tartaric acid and maleic acid; the latter is found in excess and increases with the age of the leaves. Oxalic acid (196 mg/100g) is also present and the tender leaves show a good calcium/ oxalate ratio of 1:1 at pH 4.5. This indicates that the leaves are a good source of calcium; however, the presence of oxalic acid may affect the nutritive value (Anon, 1976).

2.3.6 Uses and Products

Tamarind is a versatile fruit, which can be used for many purposes. The unique sweet/sour flavor of the pulp is popular in cooking and flavoring. Virtually every part of the tree (wood, root, leaves, bark and fruits) has some value in the subsistence of rural people and a number of commercial applications are well known; others have the potential for further development.

2.3.6.1 Agro forestry and land use

Tamarind is used in agro forestry systems in many parts of the tropics due to its multiple uses. In India, many farmers integrate several species, including tamarind, with their agricultural crops and livestock. The increasing integration of tamarind with other trees and crops on farmlands offers a strategy to minimize the risk of crop failure. Tamarind is also an important tree in home gardens in south and Southeast Asia.

2.3.6.2 Socio-cultural aspects

Tamarind fruit and other products are sold on local markets in Africa as well as on international markets. Trade in tamarind products is an important source of income for farmers in Kenya. The fruits are also commonly marketed in Karamoja, West Nile and Northern districts of Uganda, and children sell the fruit in Ethiopian towns and coastal towns in Kenya.

2.3.6.3 Fruit and food products

Pulp

More commonly, the acidic pulp is used as a favorite ingredient in culinary preparations such as curries, chutneys, sauces, ice cream and sherbet in countries where the tree grows naturally (Dalziel, 1937; Eggeling and Dale, 1951; Little and Wadsworth, 1964). In Sri Lanka, tamarind is widely used in cuisine as an alternative to lime and also in pickles and chutneys (Jayaweera, 1981). It is also used in India, to make 'tamarind fish', a sea-food pickle, which is considered a great delicacy. Immature tender pods are used as seasoning for cooked rice, meat and fish and delicious sauces for duck, waterfowl and geese are also prepared. In Eastern African countries, the pulp is cooked and made into a porridge called 'ugali' made from sorghum or maize flour or dissolved to make a sweet drink.

Tamarind pulp is often made into a juice, infusion or brine. In Ghana, a bitter infusion of the pods is used for cooking cereals and is often added to the water in which poisonous yams are soaked to detoxify them. In India the juice is used to preserve fish, which can be preserved for up to six months when mixed with acetic acid. Tamarind is used in this way in Sri Lanka and many other Asian countries (Macmillan 1943). The juice is also an ingredient of Worcestershire and other barbecue sauces, commonly used in European and North American countries (NAS, 1979).

Tamarind drink is popular in many countries around the world, though there are many different recipes. In some African countries the pulp juice is mixed with wood ash to neutralize the sour taste of the tartaric acid, but the common method is to add sugar to make a pleasantly acid drink. In Ghana, the pulp is mixed with sugar and honey to make a sweet drink. 'Jugo' and 'fresco de tamarindo' are favourite tamarind drinks in South America (FAO, 1988), and the fruit finds much use as a flavour for guava jelly. Most of the producing countries manufacture drinks commercially. Sometimes it is fermented into an alcoholic beverage (FAO, 1988).

In Ethiopia, the fruit of Tamarindus indica L. is utilized, by the population of such area only after soaking it in cold water for 12 or more hours to make juice for direct consumption.

In the Philippines, Sri Lanka and Thailand, fibres are removed from the fruit pulp, which is mixed with sugar, wrapped in paper and sold as toffees. Sellers of these are a common sight in front of schools and on urban roadsides. The pulp is also used to make sweet meats mixed with

sugar called ‘tamarind balls’ (Purseglove, 1987); in Senegal, they are called ‘bengal’. Similarly in India, the pulp is eaten raw and sweetened with sugar (Lotschert and Beese, 1994). It is desirable to remove the pulp without using water when the pulp is used in confectionery.

Seeds

Tamarind seed is a by-product of the tamarind pulp industry. The presence of tannins and other dyeing matter in the testa make the whole seed unsuitable for direct consumption (Rao&Srivastava (1974) cited in Kumar & Bhattacharya, 2008). However, the seeds become edible after soaking and boiling in water, which removes the seed coat (El- Siddig et al., 2006). In the past, and even today, seeds have been wasted (El-Siddiget al., 2006) even though they could be ground to make a palatable livestock feed (NAS (1979) cited in El-Siddig et al., 2006). The major industrial product of tamarind seed is the tamarind kernel powder (TKP) which is an important sizing material used in the textile, paper, and jute industries (Kumar & Bhattacharya, 2008).

2.3.6.4 Veterinary use

Atawodi *et al*. (2002) reported on the use of tamarind for treating trypanosomiosis in domestic animals in Kaduna, Nigeria. Indigenous knowledge revealed the use of tamarind and Adamsonia digitata, Terminalia avicennoides, Khaya senegalensis, Steruelia setigerain various combinations.

Chungsamarnyart and Junsawan (2001) have shown that a crude extract of tamarind fruits in water with 10% ethanol, 1:2 and 1:5 weight/volume used for seven days can be used as a dip against the engorged female cattle tick, Boophilus microphus. The active substances are the organic acids, especially oxalic and tartaric.

The pulp is also effective in ridding domestic animals of pests in Colombia, through the application of pulp with butter and other ingredients (Morton, 1987).

2.3.6.5 Industrial uses

Tamarind pulp is used as a raw material for the manufacture of several industrial products, such as Tamarind Juice Concentrate (TJC), tamarind fruit lather, Tamarind Pulp Powder (TPP), tartaric acid, pectin, tartarates and alcohol (Anon, 1982a; 1982 b). Tamarind Kernel Powder produced from seeds is another commercial product and is often reported upon in commercial digests (e.g. Mathur and Mathur, 2001).

2.3.6.6 Medicinal uses

The medicinal value of tamarind is mentioned in traditional Sanskrit literature. The laxative properties of the pulp and the diuretic properties of the leaf sap have been confirmed by modern medical science (Bueso, 1980). Tamarind fruits were well known in Europe for their medicinal properties, having been introduced by Arab traders from India (Rama Rao, 1975). Tamarind products, leaves, fruits and seeds have been extensively used in traditional Indian and African medicine (Jayaweera, 1981; Parrotta, 1990). Several medicinal properties are claimed for preparations containing tamarind pulp, leaves, flowers, bark and roots (Bueso, 1980)**.**

Tamarind fruit is regarded as a digestive, carminative, laxative, expectorant and blood tonic (Komutarinet *et al*., 2004). Other parts of the plant present antioxidant (Martinello *et al*., 2006), anti-hepatoxic (Joyeux *et al*., 1995), anti-inflammatory (Rimbau *et al*., 1999), anti-mutagenic (Martinello *et al*., 2006), and anti-diabetic activities (Maiti *et al*., 2004)

Tamarind preparations are universally recognized as refrigerants for fevers, and as laxatives and carminatives. Alone, or in combination with lime juice, honey, milk, dates, spices or camphor. The pulp is considered to be effective as a digestive as a remedy for biliousness and bile disorders, and as an ant scorbutic (Morton, 1987). The laxative properties of the pulp and the diuretic properties of the leaf sap have been confirmed by modern medical science (Bueso (1980) cited in El-Siddig *et al*., 2006).

2.4 Post Harvest Technology and Value Addition in tropical Fruits

Tropical fruits are now considered as an important item of commerce as they have gained enormous market potential. Post-harvest losses of fruits and vegetables are more serious in developing countries than those in well-developed countries. The total losses from harvest to the consumer point are as high as 30-40%. About 10-15% of fresh fruits and vegetables shrivel and stale, lowering their market value and consumer acceptability. Minimizing these losses can increase their supply.

Tropical fruits, which are at present under-utilized, have an important role to play in satisfying the demand for nutritious, delicately flavored and attractive natural foods of high therapeutic value. They are in general are accepted as being rich in vitamins, minerals and dietary fiber and therefore are an essential ingredient of a healthy diet.

Therefore, Processing of tropical fruit is the best way of utilizing surplus production of fruits during seasonal gluts.

The main advantages of processing are:

- Helps in converting perishable fruits in to durable form there by avoid only seasonal availability of the fruit.
- Fruits, which are very difficult to eat out of hand, can be processed in to a range of highly acceptable fruit product.
- Helps in reducing wastage.
- Value addition.

2.5 Processed products of Tamarind fruit

The commonly available market samples of tamarind pulp usually contain extraneous matter such as seed, dust, fiber, etc., and hence can be unfit for various culinary preparations. Value addition is of immense benefit for traders and consumers. Therefore, processed products from tamarind can meet the requirements of consumers for convenience and ready to use. Tamarind is used for the preparation of various processed products and some examples of value additions are cited below.

2.5.1 Tamarind beverage

Tamarind fruit pulp is used for the preparation of beverages in different regions. Good quality ready to serve beverage, syrup and concentrate can be prepared with a shelf life of six months at ambient storage (Kotecha and Kadam, 2003 a). Tamarind pulp was treated with pectolytic enzymes and the extract obtained was used for the preparation of flavored tamarind beverage. The carbonated tamarind beverage having 12.5% juice, 16°Brix and 0.4% acidity was found to be highly acceptable for up to two months of storage at room temperature (Lakshmi *et al*., 2005).

2.5.2 Tamarind juice concentrate

A process for the preparation of tamarind juice concentrate was developed by Central Food Technological Research Institute, Mysore, India. The process involves extraction of tamarind juice and concentrating the juice in a vacuum evaporator to total soluble solids of 70°Brix. The tamarind concentrate is shelf stable at room temperature and can be diluted and used in various food preparations.

Tamarind juice concentrate exhibited Newtonian flow behavior up to 19°Brix and pseudo plastic nature at higher than 23°Brix obeying the power law relationship. The flow behavior index for concentrate of 23°Brix was 0.747 and 0.625 for concentrate of 28-62° Brix.

2.5.3 Dried tamarind product

Ripe tamarind is dried in the form of pieces, powders and flakes. It can be done in the sun, in an oven or in a food dehydrator by using the right combination of warm temperatures, low humidity and air current. Packaged and stored properly, dried tamarind products are stable and nutritious (Dauthy, 1995). Tamarind fruit powder and tamarind fruit leather is the most common dried product of tamarind fruit.

Drying is one of the oldest preservation processes available to the mankind, one that we can track since prehistoric times. In today food market dried foods play an important role in the food supply chain. As for fruits and vegetables it can be estimated that they constitute about 1% of the total drying in the food industry, by large being the grains the most important. The main feature of this process consists on lowering the water content in order to avoid or slow down food spoilage by microorganism.

Although the primary objective of drying is preservation, quality aspects are more and more taken into account, in fact according to the process carried out one may end up with very different products. As it is well known food nutrient degradation, like any other chemical/biochemical reaction depends on temperature. According to the food composition the material is more or less prone to nutrient degradation, the use of different drying technologies and process conditions for nutrient and in general quality preservation is a must (Chou and Chua, 2001; Achanta and Okos,2000).

2.6 Fruit Leather

Fruit leathers are dried sheets of fruit pulp which have a soft, rubbery texture and a sweet taste. It can be made by drying thin layers of pureed fruit in the oven or dehydrator. Sometimes called fruit rolls or toffies, fruit leathers make delicious, wholesome and nutritious high-energy snacks for backpackers, campers and active children. They are relatively light in weight, easy to prepare and a good way to use left-over canned fruit and slightly over-ripe fresh fruit (Andress and Harrison, 1999).

Fruit leathers can be eaten as it is, or made into a beverage by combining 5 parts water with 1 part leather in a food blender. They also can be used in pie fillings, in cooking and as a dessert topping.

Most fruit or combinations of fruits can be used. Apricots, apples, grapes, berries, bananas, pineapples, oranges, pears, peaches, plums, melons, and most tropical fruits can be blended and dried to make fruit leathers. Grapefruit and lemons are not recommended because they turn bitter when dried.

Drying is one of the least exact ways to preserve foods. The length of drying time will depend on the equipment used and the humidity of the air. In the past, recommendations for preparing fruit leather from both fresh and cooked fruit have been given. However, because of increasing concerns with bacteria such as *Escherichia coli* O157:H7 (*E. coli* O157:H7) being able to survive the drying process if present, it's best to heat the fruit to 160°F before drying. Preheating also stops the maturing action of enzymes in the fruit, helps preserve the fruit's natural color and speeds the drying process (Heikal *et al*., 1972; Mir and Nath, 1995)

The shelf-life of fruit leather depends on their low moisture content (15-25%), the natural acidity of the fruit and the high sugar content. When properly dried and packaged, fruit leathers have a shelf-life of up to 9 months. In some places, sodium – or potassium metabisulphite is added to preserve the color and to extend the shelf-life. The permitted levels for use are 0.005 to 0.2 % concentrations in fruit leathers. If too much sulphite is used, it taints the fruit and gives it a bad taste (FPT, 2009).

2.6.1 Preparation of fruit leather

2.6.1.1 Extraction of pulp from the fruits

Prior to extraction of pulp, firstly ripe fruit pods of uniform maturity have to be selected. Then flesh of pod has to be separated manually from shell, fiber, rags and seeds. Extraction of pulp is the major problem in processing of tamarind because the pulp was tightly associated with the seeds (Koteha , 2002).

- **Cold extraction**

In cold extraction method, flesh was soaked in the water. Ratio of flesh: water was varied to obtain maximum separation of pulp. Ratio was maintained as flesh: water as 1:2 for 6 Hrs. After

soaking the mixture was homogenized and filtered to obtain fine pulp. According to Benero *et al*. (1972), the extraction rate was in 1:2 proportions, which gives highest total soluble solids and total sugars. The yield of pulp was calculated on fruit weight basis.

- **Hot extraction**

In hot extraction method, flesh was soaked in water and heated to a temperature of 70^0C for 10 minutes. The ratio was maintained as flesh: water as 1:2, followed by soaking for 6hrs. After soaking the mixture was homogenized and filtered to obtain fine pulp. The yield of pulp was calculated on fruit weight basis.

2.6.1.2 Pretreatment of the fruit

Pretreatments are recommended techniques used to make quality products. Pretreatments not only prevent darkening and improve quality; they also cause the destruction of pathogens that could cause food borne illness, like *Escherichia coli* O157:H7, Salmonella species, and Listeria monocytogenes. Pretreatments include dipping, blanching, cooking, or candying.

Sulfuring - Sulfuring is an old method of pre-treating fruits. Sublimed sulfur is ignited and burned in an enclosed box with the fruit. The sulfur fumes penetrate the fruit and act as a pretreatment by retarding spoilage and darkening of the fruit. Fruits must be sulfured out-of-doors where there is adequate air circulation.

Sulfite Dip - Sulfite dips can achieve the same long-term anti-darkening effect as sulfuring, but more quickly and easily. Sodium bisulfite, sodium sulfite or sodium meta-bisulfite that is food grade or Reagent grade (pure) can be used.

Ascorbic Acid - Ascorbic acid (vitamin C) mixed with water is a safe way to prevent fruit browning. However, its protection does not last as long as sulfuring or sulfiting. One teaspoon of powdered ascorbic acid is equal to 3000mg of ascorbic acid in tablet form.

In such cases, mix 1 tea spoon of powdered ascorbic acid (or 3000 mg of ascorbic acid tablets, crushed) in 2 cups water. Place the fruit in the solution for 3 to 5 minutes. Remove fruit, drain well and place on dryer trays. After this solution is used twice, add more acid.

Ascorbic Acid Mixtures **-** Ascorbic acid mixtures are a mixture of ascorbic acid and sugar sold for use on fresh fruits and in canning or freezing. It is more expensive than and not as effective as using pure ascorbic acid.

In such case first mix 1 1⁄2 tablespoons of ascorbic acid mixture with one quart of water. Place the fruit in the mixture and soak 3 to 5 minutes. Drain the fruit well and place on dryer trays. After this solution is used twice, add more ascorbic acid mixture

Fruit Juice Dip **-** A fruit juice that is high in vitamin C can also be used as a pretreatment, though it is not as effective as pure ascorbic acid. Juices high in vitamin C include orange, lemon, pineapple, grape and cranberry. Each juice adds its own color and flavor to the fruit.

Steam Blanching **-** Steam blanching also helps retain color and slow oxidation. However, the flavor and texture of the fruit is changed.

2.6.1.3 Drying methods

Drying is one of the oldest methods of food preservation techniques and is the most commonly employed commercial technique in the food processing industry. Two processes take place simultaneously during drying; these processes are heat transfer to the product from the heating source and mass transfer of moisture from the interior of the product to the surface and from the surface to the surrounding air (Perumal, 2007). The basic essence of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain period of time, normally regarded as the 'safe storage period' (Ekechukwu, 1998).

To achieve a high quality product, close monitoring of the drying process is important. Moyls (1981) studied the two main factors that influenced drying time: air temperature and velocity. It is vital to get fresh dry air in contact with the surface of the product and the hotter the air the more effective it was in removing moisture. When drying, care must be taken to maintain a consistent thickness of product, otherwise moisture patches will cause the leather to rip when it is removed from the drying trays.

Common drying methods used for drying fruit leathers are oven-drying (including convection / fan forced), sun-drying, electric cabinet drying and off-the-shelf food dehydrators (Raab & Oehler, 1999). Both cabinet and oven drying are reported to produce higher quality leathers with

cabinet dried leather being more acceptable (Raab & Oehler, 1999; Che Man & Sin, 1997). Moyls (1981) conducted leather drying trials using two types of tray dryers – metal trays and wooden trays. The author found that the metal trays were from 20 - 30% more efficient than wood trays in terms of reducing drying times.

Sun dried fruits and fruit products are the most widely known of all dried foods. Sun drying permits the drying of a product with a rich colour, a translucent appearance and a desirable gummy texture, but this method also has many disadvantages (Maskan *et al*., 2002). Open air sun drying is not well suited to large scale production. The disadvantages of sun drying include the lack of ability to control the drying operation properly, the slowness of the process, weather dependency, high labor costs due to the need for hand labor, insect infections, and the exposure to environmental contamination due to mixing with dust and other foreign material (Maskan *et al*., 2002).

During drying, desirable or undesirable chemical or biochemical reactions may lead to changes in color, texture, odor and nutritional properties of the final product. It was reported that solar and oven dried leathers resulted in a greater loss of color than cabinet dried fruit leather. This is likely because solar and oven dryers have longer drying times (72and 18 hours, respectively) compared to cabinet drying (6 hours) (Okilya *et al*., 2010).Improper drying may also lead to physical changes, such as shrinkage, puffing and crystallization of the product (Maskan *et al*., 2002). Dehydration of food materials containing antioxidants is a difficult food processing operation, mainly because of undesirable changes that occur in the quality of the dehydrated products. To achieve a safe and quality product, a good understanding of the fundamental and nutritional properties of fruit leather is required.

Fruit leathers dried at higher temperatures and for shorter drying times have been found to be darker. Che Man & Sin (1997) found that drying at temperatures greater than 60°C caused a rapid increase in non-enzymatic browning. The author produced jackfruit leather with acceptable aroma using a cabinet dryer at 50°C for 24 hours. The aroma in the fresh fruit is due to volatile substances such as esters, ketones and aldehydes. According to Okilya et al. (2010), drying time can influence the volatile substances and lead to a decrease in aroma detection. They found that the aroma of solar dried leather was generally disliked and had significantly lower acceptability scores compared to cabinet and oven dried leather ($P < 0.05$).The aroma for both cabinet and

oven dried leather was acceptable. The authors suggested that high aroma acceptability scores for cabinet and oven dried leathers could be attributed to the short drying times (6 - 18 hours) used, as opposed to 72 hours for solar drying.

Non-enzymatic browning is considered one of the major causes of quality deterioration in fruit products. Kumar et al. (2010) studied the effect of pulp blends on the physical and microbial quality of papaya fruit leather. Non-enzymatic browning increased with increased of papaya pulp in the finished product. This can be treated enzymatically by adding suitable additives such as sodium metabisulphite or sulphur dioxide (Che Man et al., 1992; Perera, 2005; Vijayanand et al., 2000). Che Man & Sin. (1997) proposed that extended boiling times can destroy the enzyme that causes enzymatic browning. Chan and Calvetto (1978) stated that reducing the sugars involved in the browning process can also be effective in improving the end product.

2.7 Tamarind fruit leather recipes and processing procedures

The following basic recipes are only guidelines since they depend on the composition of fruit and different consumer tastes for sweetness. The recipes needed for tamarind fruit leather preparation are: fully ripe tamarind fruit, Sugar (10-15% the pulp weigh), lemon juice or citric acid (2 spoons per kg pulp), and Sodium of potassium metabisulphite (it is optional, 2g per kg pulp). The general procedure for making Tamarind fruit leather is shown in figure 2.3.

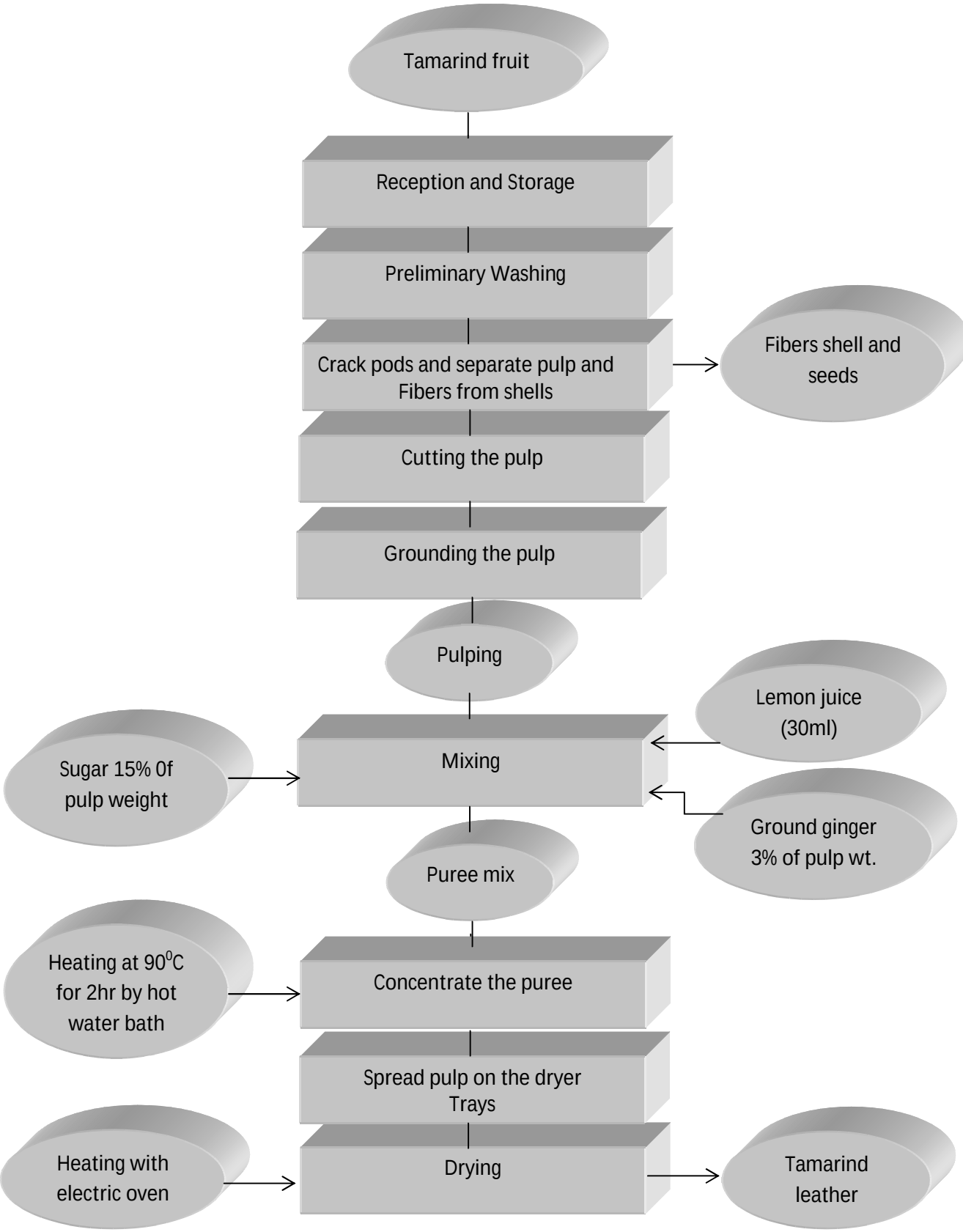

Figure 2.3 Process flowcharts for Tamarind fruit leather development

2.8 Quality control

Quality control begins with the acquisition of high-quality fruit concentrate. Many purees are supplied by well-known fruit processors. Other quality control methods include careful calibration of all additives, particularly of those additives that affect hardening/malleability (malto-dextrin in particular). Also, cooking and drying temperatures are monitored closely to ensure moisture content. Scales are carefully calibrated so that each roll contains just the right amount of extruded product; similarly, the packaging machine is checked and re-checked so that each cardboard package includes the correct number of fruit leathers. Sample testing is performed periodically as well (Nancy, 2009).

One of the most important concerns of the food manufacturer is to produce a final product that consistently has the same overall properties, i.e. appearance, texture, flavor and shelf life. When we purchase a particular food product we expect its properties to be the same (or very similar) to previous times, and not to vary from purchase-to-purchase. Ideally, a food manufacture wants to take the raw ingredients, process them in a certain way and produce a product with specific desirable properties. Unfortunately, the properties of the raw ingredients and the processing conditions vary from time to time which causes the properties of the final product to vary, often in an unpredictable way. How can food manufacturers control these variations? Firstly, they can understand the role that different food ingredients and processing operations play in determining the final properties of foods, so that they can rationally control the manufacturing process to produce a final product with consistent properties. This type of information can be established through research and development work (see later). Secondly, they can monitor the properties of foods during production to ensure that they are meeting the specified requirements, and if a problem is detected during the production process, appropriate actions can be taken to maintain final product quality (McClements, 1999).

Quality control points:

- Use only ripe fruits without bruising or damage. Over-ripe ones can easily become damaged and bruised. Under-ripe fruits will not have the full flavor.
- Use a double boiling pan to avoid burning which can occur if direct heating is used.
- Weigh all ingredients to the correct formulation.

- Do not dry the leather in direct sunlight as there will be loss of color and vitamins A and C.
- Dust the leather lightly with starch before packing to reduce their stickiness.
- Seal the leather packed in the form of a roll interleaved with greaseproof paper to avoid it sticking together.
- Check the correct fill-weight before sealing the bags.
- If available, use 400 gauge polypropylene bags as they provide greater protection against moisture (Nancy, 2009).

Chapter three

Materials and Methods

3.1 Raw materials and equipment

Materials and chemicals to be used for this experimental study were: fresh tamarind fruit, lemon juice, sugar, and the ground ginger. The tamarind fruit was collected from an agricultural area around Gambela region (Emere district Lara wereda). Lemon was bought from Piyasa Atkilt tera, market; in Addis Ababa. It was used as a source of ascorbic acid for preserving the tamarind puree color and as flavoring agent. Sugar and the grounded ginger also obtained from local market, Mercato.

The equipment required for developing tamarind fruit leather were: Bowls, containers(stainless steel), Sharp stainless steel knife, chopping board for size reduction, weighing, sensitive balance, glass jar, beaker, water bath, spoon for stirring, Spoons for measuring, caliper, thermometer, Grease proof paper, glass Trays ,electrical drying oven, Polythene bags, Heat sealer.

3.2 Sample preparation

The ripened and slightly over-ripened but unspoiled tamarind fruits were selected sorted and thoroughly washed using tap water. Remove and discard blemishes or defective part. It was manually peeled with a stainless steel knife; the shell, fiber and seed was removed from the pulp. Accordingly, each composition of the fruit pod was weighed individually to know the approximate yield. The samples were put in air tight polythene bags and kept in a refrigerator at 4^0C prior the analyses.

For the purpose of analysis, triple samples of the tamarind pulp each weigh about 500g were taken to Ethiopian Health and Nutrition Research Institute (EHNRI) to the Food Science and Nutrition Directorate Laboratory. The samples were analyzed for proximate composition, mineral elements composition, vitamin C content and anti-nutritional factors analysis.

Figure 3.1 tamarind fruit pod

Figure 3.2 tamarind fruit shell, fiber and seed

3.3 Development of Tamarind fruit leather

3.3.1 Preparation of fruit pulp

In order for attaining maximum yield during puree preparation, the pulp of tamarind fruit was cut and sliced in to pieces. It was then further reduced and grounded as much as possible using manually operating grinder.

In this study, for each batch of fruit leather development about 500gm of tamarind fruit pod was used. After preliminary treatment 157gm of pulp, 75gm of seed and 50gm of shell and fiber part was achieved.

3.3.2 Preparation of fruit puree and puree mix formulation

The puree was made by soaking the fruit pulp in distilled water through continues stirring in a beaker immediately after the fruits pulp was subjected to preliminary treatment(washing and size reduction) in order to avoid excessive browning. It was pureed in a beaker that operates manually by a method called cold extraction. The optimum conditions for the water extraction of tamarind fruit pulp were 1:5 ratio of pulp to water (w/v), for two day (48hr). The tamarind pulp extract was subsequently filtered through a 1mm filter sieve.

As indicated in Table 3.1, the puree mix was prepared by mixing 1lt of Tamarind puree with 150g sugar and 3.0g of ground ginger and stirred continuously till all ingredients distributed uniformly. The proportion of the ingredients were estimated from literature and decided after the observation of the result from preliminary tests. In order for the puree to be sweetened sugar (15% the weight of the pulp, 150g/kg) was added and its flavor was improved by adding grounded ginger (3% the weight of the pulp, 3gm/kg).

Table 3.1 Percentage composition of tamarind puree mix

Ingredient	Composition by weight (%)
Tamarind puree	100
Sugar	15
Ground ginger	3

3.3.3 Preserving the Tamarind fruit leather color

Since light-color fruit leathers tend to darken during drying, the color of the Tamarind fruit leather was preserved by adding citric acid in the puree. For this study lemon juice was used for preservation of the color. This was done by adding of 30ml of lemon juice per 1lt of tamarind fruit puree.

3.3.4 Heating the puree mix

The tamarind puree was cooked to concentrate the puree mix so as to shorten the drying time and save energy during the process of drying. This was done by heating the puree at 90ºC for 2hr using hot water bath and it was stirred continuously until the mixture become thick. The concentrates were allowed to cool to room temperature by natural convection prior to further processing.

3.3.5 Drying the puree mix

The Tamarind fruit puree was poured and spread evenly as a thin layer (4 mm thickness) onto a glass tray. Thickness was measured and adjusted to 4 mm for each sample. The dryer was preheated to the required drying temperature (70^0, 80^0 or 90^0C) and the trays were placed in the middle compartment of the electric oven dryer for drying. The temperature was then adjusted as required for investigation with appropriate combination of as shown in the below table.

Drying was conducted according to the design that was shown in Table 3.2. In the study two independent variables called drying temperature (80^0, 70^0, and 90^0C) and drying time (6, 8, and10h) was selected; and the thickness of puree sheet/layer was kept constant (4mm) for all samples (Ekechukwu, 1998).

The ranges of the variables were estimated from literature and decided after the observation of the result from preliminary tests.

	Temperature(^{0}c)								
	70			80			90		
Time(hr)	Sample code			Sample code			Sample code		
6	X_1	X_{11}	X_{12}	Y_1	Y_{11}	Y_{12}	Z_1	Z_{11}	Z_{12}
8	X_2	X_{21}	X_{22}	Y_2	Y_{21}	Y_{22}	Z_2	Z_{21}	Z_{32}
10	X_3	X_{31}	X_{32}	Y_3	Y_{31}	Y_{32}	Z_3	Z_{31}	Z_{32}

Table 3.2 Designed sample codes for tamarind fruit leather with its drying time and temperature

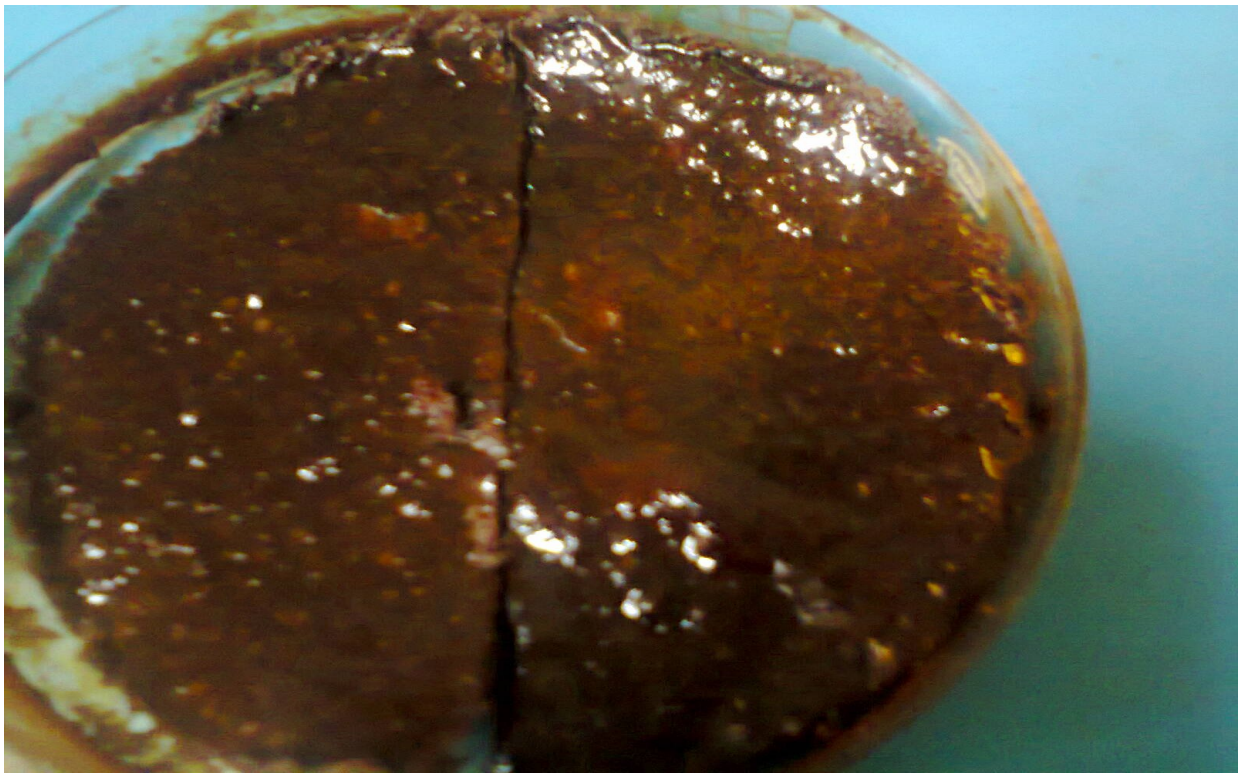

Figure 3.3 Tamarind fruit leather

3.4 Analyzing methods

Tamarind fruit was characterized by analyzing its physicochemical properties, functional properties, proximate composition, mineral element composition, and anti-nutritional factor.

The changes due to processing to develop tamarind fruit leathers were studied by analyzing its physicochemical properties, proximate composition, and sensory evaluation.

3.4.1 Proximate analysis methods for the pulp and leather

The proximate analysis was conducted at the Ethiopian Health and Nutrition Research Institute (EHNRI), and all the moisture content, total ash, crude protein, crude fiber, and crude fat of the sample was determined according to AOAC (2000) using the official methods925.09, 923.03, 979.09 962.09, and 4.5.01, respectively and the total carbohydrates excluding crude fiber were calculated from the difference.

3.4.1.1 Moisture content

Moisture content of Tamarind fruit pulp sample and its fruit leather were estimated according to AOAC (2000) using the official method 925.09. A clean, dried and covered flat aluminum dish

was weighed and about 5gm of the sample was transferred to the dish. The dish then placed in drying oven at 102 ^{0}C for 5hrs and cooled in desiccators and re-weighed. Then, the moisture content was estimated by the formula:-

$$Moisture\ Content(\%) = \frac{[W_2 - W_1] - [W_3 - W_1]}{[W_2 - W_1]} * 100$$

Where, W_1 = empty aluminum dish dried weight

W_2 = aluminum dish and fresh sample weight

W_3 = weight of dish and sample after drying

3.4.1.2 Crude fiber

Crude fiber was determined after digesting a known weight of Tamarind fruit pulp and also its leather sample by refluxing 1.25% boiling sulfuric acid and 28% boiling potassium hydroxide.

Digestion: About 1.5g of fresh sample was placed into a 600ml beaker,200ml of1.25% H_2SO_4 was added, and boiled gently exactly for 30 minutes placing a watch glass over the mouth of the beaker. During boiling, the level of the sample solution was kept constant with hot distilled water. After 30 minute boiling, 20ml of 28% KOH was added and boiled gently for a further 30 minute, with occasional stirring.

Filtration: The bottom of a sintered glass crucible was covered with 10 mm sand layer and wetted with a little distilled water. The solution was poured from beaker into sintered glass crucible and then the vacuum pump was turned on. The wall of the beaker was rinsed with hot distilled water several times; washings were transferred to crucible, and filtered

Washing: The residue in the crucible was washed with hot distilled water and filtered (repeated twice). The residue was washed with 1% H2SO4 and filtered, and then washed with hot distilled Water and filtered; and again washed with 1% NaOH and filtered. The residue was washed with hot distilled water and filtered; and again washed with 1% H_2SO4 and filtered. Finally the residue was washed with water- free acetone.

Drying and combustion: The crucible with its content was dried for 2 hours in an electric drying oven at 130^{0}C and cooled for 30 min in the desiccators (with granular silica gel), and then Weighed. The crucible was transferred to a muffle furnace (Gallenkamp, size 3) and incinerated

for 30 min at 550 ^{0}C. The crucible was cooled in the desiccators and weighed. Then the fiber was calculated as a residue after subtraction of the ash.

$$Crude\ \ Fiber\ \left(\frac{g}{100}\right) = \frac{[(W_1 - W_2)(100 - M)]}{W_3}$$

Where, W_1 *= Crucible weight before drying (g)*

W_2 *= Crucible weight after drying (g)*

W_3 *= Sample dry weigh (g)*

M *= Moisture content of the sample (%)*

3.4.1.3 Crude protein

Protein content was determined according to AOAC (2000) using the official method 979.09. A digestion flask containing about 1g of sample, to which 6 ml of acid mixture (conc. sulphuric acid and conc. orthophosphuric acid) and about 3g of catalyst mixture (K_2SO_4 and Selenium) were added and exposed to about 370^{0}C in order to allow digestion. Then, distillation was took place by adding 25ml of 40% NaOH and using 25 ml of boric acid with 10 drops of indicator solution. Finally, the distillate was titrated with standardized 0.1N sulfuric acid to a reddish color.

$$mg\ nitrogen = (V_2 - V_1) * N * 14$$

$$g\ nitrogen/100\,g\ sample = \frac{mg\ of nitrogen\ * 100}{mg\ sample}$$

$$Total\ \ Nitrogen(\%) = \frac{(V_2 - V_1) * N * 1.4}{W} * 100$$

Crude Protein = total nitrogen (%) * 6.25

Where, V_1*= Volume in ml of the standard sulfuric acid solution used in the titration for the blank*

V_2*= Volume in ml of the standard sulfuric acid solution used in the titration for the test*

N = normality of the acid

14.01 = Molecular weight of nitrogen

W = wt. of the sample

3.4.1.4 Crude Fat content

Crude fat was determined by exhaustively extracting a known weight of sample in diethyl ether (boiling point, 55 °C) in a soxhlet extractor. The ether was evaporated from the extraction flask. The amount of fat was quantified gravimetrically and calculated from the difference in weight of the extraction flask before and after extraction as percentage.

The extraction flasks were cleaned, dried in drying oven (Memmert, Germany) at70^0C for 1hour, cooled in desiccators (with granular silica gel) for 30 minutes, and then weighed. The bottom of the extraction thimble was covered with about 2cm layer of fat free cotton. About 2.00 gram of fresh samples were added into the extraction thimbles, and then covered with about 2cm layer of fat free cotton. The thimbles with the sample content were placed into soxhlet extraction chamber. The cooling water was switched on, and a 50 ml of diethyl ether was added to the extraction flask through the condenser. The extraction was conducted for about 3 hrs. The extraction flasks with their content were removed from the extraction chamber and placed in the drying oven at 700C for about 1hr, cooled to room temperature in the desiccators for about 30 minutes and re-weighed.

$$W = W_2 - W_1$$

Where, W= weight of fat (g)

W_2 *= weight of extraction flask after extraction (g),*

W_1 *= weight of extraction flask before extraction (g)*

$$Crude\,Fat\,content\left(\frac{g}{100g}\right) = \frac{W * (100 - moisture, \%)}{W_D}$$

Where, W_D *= weight of dried sample (g)*

3.4.1.5 Ash content

The ash content of the sample was determined by AOAC (2000) using the official method 923.03. The organic matter is burned off at low temperature and the inorganic materials remaining are cooled and weighed. Heating is carried out in stages, first to derive the water, then to char the product thoroughly and finally to ash at 550^oC in a muffle furnace (AOAC, 1984).

$$Total\ Ash(\%) = \left(\frac{W_2 - W}{W_1 - W}\right) * 100$$

Where w= weight in grams of empty dish

w_1= weight in grams of the dish plus the dried test material

w_2= weight in grams of the dish plus ash

3.4.1.6 Carbohydrates

The total carbohydrate contents of the Tamarind sample by mass including crude fiber can be obtained as follows:

$$Total\ carbohydrate = 100 - [P + F + A + M]$$

Where, P – The mass percent of protein,

F – The mass percent of fat,

A – The mass percent of ash,

M – Moisture content (%)

3.4.1.7 Determination of gross energy

The sample calorific value was estimated (in kcal/g) by multiplying the percentages of crude protein, crude lipid and carbohydrate with the recommended factors (4, 9, and 4 respectively) as proposed by Martin and Coolidge (1978).

3.4.2 Mineral elements analysis

The mineral elements including calcium (Ca), Sodium (Na) and Potassium (K) contents of tamarind fruit pulp and the final leather product were determined using atomic absorption spectrophotometer as describe by the procedure of AOAC (1984). All values were expressed in mg/100g.After removal of organic material by dry ashing; the residue was dissolved in dilute acid. The solution was sprayed into the flame of Atomic Absorption Spectrophotometer and the absorption of the metal to be analyzed was measured at a specific wavelength.

Ashes were obtained from dry ashing. The ash was wetted completely with 5ml of 6N HCl, and dried on a low temperature hot plate. A 7ml of 3N HCl was added to the dried ash and heated on the hot plate until the solution just boils. The ash solution was cooled to room temperature at open air in a hood and filtered through a filter paper into a 50ml graduated flask. A 5ml of 3N HCl was added into each crucible dishes and heated until the solution just boil, cooled, and filtered into the flask. The crucible dishes were again washed three times with de-ionized water; the washings were filtered into the flask.

A 2.5mL of 10% Lanthanum chloride solution was added into each graduated flask. Then the solution was cooled and diluted to the mark (50ml) with de-ionized water. A blank was prepared by taking the same procedure as the sample.

$$Mineral\ content\ (mg/100g) = [a\text{-}b)\ x\ V]/10W$$

Where: W= Weight (g) of samples;

V= Volume (V) of extract;

a = Concentration (µ g/ml) of sample solution;

b = Concentration (µ g/ml) of blank solution.

3.4.3 Physicochemical properties analysis

3.4.3.1 pH value

pH values were determined according to AOAC (1984) using official method 14.022. The pH of the Tamarind fruit and also the final fruit leather were measured immediately on the homogenate at 22^{o}C by potentiometer technique. The pH measurements were taken with a digital model 250 pH meters, USA.

3.4.3.2 Titratable acidity

Titratable Acidity of product is the acidity in terms of the predominant acid present in the juice i.e. citric acid. Titratable acidity was measured according to the method described by (Ranganna, 2001). The % titratable acidity was determined by taking 5ml of sample, adding 4 to 5 drops of 1 % phenolphthalein indicator and titrating with 0.1 N NaOH. The following formula was used to calculate the total acid, % (Ranganna, 2001).

$$Titratable\ acid\ (\%) = \frac{Titre\ X\ Equivalent\ weight\ of\ acid\ X\ 100}{Volume\ of\ sample\ taken\ X\ 1000}$$

3.4.3.3 Total soluble solids

The total soluble solids (TSS) level for both fresh fruits and puree was determined according to AOAC method by using hand refract meter, at room temperature (range from 18 to 23°C).

3.4.3.4Vitamin C

The vitamin C content of the Tamarind fruit pulp and the final leather products were determined using 2, - dichloroindophenol titrimetry as describe by the procedure of AOAC (2000) Method 967.21.

Procedure

5 g of sample was weighed and also 0.6 g of trichloroacetic acid was measured and diluted with 100ml of water. To extract the solution each sample was mixed with trichloacetic acid by blending and transferred in to beaker to settle .Then the solution was filtered by using filter paper in to Erlenmeyer flask. 1 g vitamin C was dissolved with 5% metaphospheric acid. Take from the 100mland dilute with 50ml and then 1ml saturated Bromine was added in 5 test tubes which are used as standard. Then standard solution prepared and in each test tube with required amount of metphosphate.

In one blank test tube 4ml met phosphate was added. And also 1ml bromine was added to extracted samples, 10 ml Thiourea in 6 conical flasks was prepared, 10 ml of filtered sample was added in each conical flask and mixed .Then 4ml was taken from each and added in to empty taste tube. 2% of 1mlDNPH was added in to each prepared and metaphophate mixed taste tube and also 2% concentrated 1ml DNPH added to the conical flask which contains thiourea. Then all placed in water bath at 38^0C about 3 hours. Then it was taken out from water bath and cooled for 5 minutes in cold water .5ml 85% concentrated sulfuric acid was added in all test tubes including the blank. Then1ml 2%2,4DNPH was added in the blank. After 30 minutes exposure of room temperature the sample was filtered .Then the spectrophotometer calibrated.

The calculation to obtain the vitamin C content of the fruit leather was done using the following formula:

$$Mg\ of\ asco\ rbic\ acid/\ 100\,g = \frac{A\ (sample)\ -A\ (blank)\ \times\ 10}{\text{A (10 microgram std)}\ -A(blank)}$$

Where, A (sample) = Absorbance of the sample

A (blank) = Absorbance of the blank

A (10 µgstd) = Absorbance of 10 µg standard

3.4.4 Functional properties

3.4.4.1 Bulk density

Bulk densities were determined by the method of Narayana and Narasinga (1984). An empty tube was weighed, and then tubes filled with a sample to 5 ml by constant tapping until no further change in volume. The weight of the tube and its contents were taken and recorded. The

weights of the sample alone were then determined by difference. Bulk densities were calculated as weight per unit volume of the sample.

3.4.4.2 Water and oil absorption capacity

Water and oil absorption capacity of the raw and processed Tamarind pulp samples were determined using the method of Buchat (1997).

About One gram of the sample was mixed with 10ml of distilled water (density 1 g/cm^3) or oil (density 0.895g/ml) in a centrifuge tube, mixed thoroughly with magnetic stirrer and allowed to stand at room temperature (30 ± 2^0C) for one hour. It was then centrifuged at 200 X G for 30 minute and the supernatant was transferred in a 10 ml graduated cylinder. Water and oil absorption capacity was calculated as ml of water or oil absorbed per gram of the sample.
Water and oil absorption capacity was calculated from the equation:

$$Water\ or\ oil\ absorption\ capacity = 10 - V$$

Where V: volume of water or oil left unabsorbed after centrifugation

3.4.5 Anti-nutritional factor analysis

3.4.5.1 Determination of Phytate Content

Phytate was determined by the method of Latta and Eskin (1980) and later modified by Vantraub and Lapteva (1988). About 0.1000g of fresh samples were extracted with10ml 2.4% HCl in a mechanical shaker (Eberbach) for 1hour at an ambient temperature and centrifuged at 3000rpm for 30 minute. The clear supernatant was used for phytate estimation. A 2ml of Wade reagent (containing 0.03% solution of $FeCl_{13}$.6H2O and 0.3% of sulfosalicilic acid in water) was added to 3ml of the sample solution (supernatant) and the mixture was mixed on a Vortex (Maxi Maxi II) for 5seconds. The absorbance of the sample solutions were measured at 500 nm using UVVI Spectrophotometer (Beckman DU-64- spectrophotometer, USA).

A series of standard solution were prepared containing 0, 5, 10, 20 and 40 µg/ml of phytic acid (analytical grade sodium phytate) in 0.2N HCl. A 3ml of standard was added into 15ml of centrifuge tubes with 3ml of water which were used as a blank. A1ml of the Wade reagent was added to each test tube and the solution was mixed on a Vortex mixer for 5 seconds. The

mixtures were centrifuged for 10 minutes and the absorbance of the solutions (both the sample and standard) was measured at 500nmby using deionized water as a blank. A standard curve was made from absorbance versus concentration and the slope and intercept were used for calculation. Phytate: mineral molar ratios were calculated using the molecular weight of PA=660.

Phytic aci d in mg/ 100 *g = (absor bance-* int *ercept)* 3*/ (slope x density x wt. of Sa mple x* 10 *)*

3.4.5.2 Condensed tannin determination

Tannin content was determined by the method of Burns (1971) as modified by Maxson and Rooney (1972). About 2.0000 gram of chickpea flour was weighed in a screw cap test tube. The chickpea flour was extracted with 10ml of 1% HCl in methanol for 24 hours at room temperature with mechanical shaking. After 24 hours shaking, the solution was centrifuged at 1000rpm for 5 minutes. A 1ml of supernatant was taken and mixed with 5 ml of vanillin-HCl reagent (prepared by combining equal volume of 8% concentrated HCl in methanol and 4% Vanillin in methanol).

D-catechin was used as standard for condensed tannin determination. A 40mg of D-catechin was weighed and dissolved in 1000 ml of 1% HCl in methanol, which was used as stock solution. A 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of stock solution was taken in test tube and the volume of each test tube was adjusted to 1ml with 1% HCl in methanol. A 5ml of vanillin-HCl reagent was added into each test tube. After 20minutes, the absorbance of sample solutions and the standard solution were measured at 500nm by using water to zero the spectrophotometer, and the calibration curve was constructed from the series of standard solution using SPSS-15. A standard curve was made from absorbance versus concentration and the slope and intercept were used for calculation:

Concentration of tannin was read in mg of D-catechin per 100g of sample

Tannin in mg/ 100 *g = (absor bance-* int *ercept)/ (slope x de nsity x we ight of sa mplex* 10 *)*

3.5. Sensory evaluation

Sensory evaluation, using a 9 point hedonic scale (1 – 'extremely disliked' to 9 – 'extremely liked'), was carried out by 10 untrained panelists/consumers selected among Ethiopia commodity exchange staff, from the Department of quality operation. The panel consisted of 10 male, aged 21 to 35 and nonsmokers Panelists. Each sample of tamarind leather were coded with a three-

digit number prior to testing and distributed randomly to the panelist. Water, for rinsing between the samples and scroll sheet (attached in appendix) were provided for each of them. They were asked to give their individual ratings on the characteristics of tamarind leather including color, aroma, taste, flavor and overall acceptability. Each panelist was presented with two types of samples (each for different treatments) at triplicate level for each sample. Their judgments were recorded on scroll sheet and appropriate analysis was carried out to determine the significance of variations of average score and the contribution of individual parameter.

3.6 Experimental design and data analysis

The experiment was conducted in a completely randomized design .Samples were analyzed in triplicate. The results were statistically analyzed by one way analysis of variance (ANOVA) using JMP software package version 7. Least significant differences (LSD) were used for multiple mean comparison tests. Significance were accepted at 0.05 level of probability ($p<0.05$).

Chapter Four

Results and Discussions

4.1 Characterization of Tamarind fruit

The Tamarind fruits were characterized in terms of their physical compositions such as pulp, seed (3-4 seed in one fruit pod), shell and fiber. In the study, the pod shape was observed to range from curved to straight; the colour of pods ranged from light brown to deep brown while pulp colour varied from light to redish brown. As shown in Table 4.1, the average weight of the Tamarind fruit pod was found to be 11.38 $\pm$ 2.75g. The pulp, seed (the total number of seed in a fruit pod), shell and fiber comprised 55, 34, and 11% of the fruit pod weight respectively. Thus, the largest weight of the Tamarind fruit was constituted by its pulp (6.21g) while it's least weight by its peel (1.38g).

Table 4.1: Average Physical Composition of the Tamarind fruit

Samples	Weight (g)	Weight (%)
Fruit pod	11.38$\pm$ 2.75	100
Pulp	6.21$\pm$ 1.52	55
Seed(single seed)	0.80$\pm$0.07	34
Shell and fiber	1.38$\pm$0.46	11

Values are mean of triplicate determinant $\pm$SD

4.2 Physicochemical properties of Tamarind pulp

The physicochemical analysis of the Tamarind pulp was presented in Table 4.2.The selected physicochemical parameters which may have influence on the quality of the final product, Tamarind fruit leather; were: moisture content, TSS, pH, titratable acidity and the vitamin C content.

- **Moisture content**

The research found that, the average moisture content of Tamarind fruit pulp was 31.246$\pm$ 1.020. Such result was in agreement with the reported value (22.6-69.2%) for moisture content of ripe tamarind fruit pulp by Roy and Joshi, (1995). Similar result was also reported by Groller et al., (1998), When Fruit of Tamarind ripe the moisture content of its pulp becomes 38%. Although the high moisture content in a sample is an indication of its freshness (Tressler *et al*., 1980), it

may also be attributed to the protective and hard nature of the pod and seeds to prevent excessive moisture loss (Yusuf and Laisi, 2006).

Table 4.2 Physicochemical properties of Tamarind fruit pulp

Physicochemical properties	Tamarind sample
Moisture (%)	31.24± 1.020
pH	4.16± 0.351
Titratable acidity (%)	6.96±0.821
TSS ^{0}Brix	26.16± 0.440
Vitamin C(mg/100g)	23.36± 1.390

Values are mean of triplicate determinants ± SD

- **pH**

The pH value of tamarind pulp was 4.166 ± 0.351. The value found in this study was in agreement with the value 4.2 to tamarind pulp of Thailand variety given by Joshi et al. (2012). The result was indicated that the pulp was fairly acidic. It might be due to the organic acids such as citric and tartaric acids existing in the tamarind juice (Jittanit *et al*., 2011).

- **Titratable acidity**

Acids present in foods not only improve the palatability of many fruit products but also influence their nutritive value by playing a significant role in the maintenance of acid-base balance in the body. The acids influence the flavor, brightness of color, stability, consistency and keeping quality of the product (Adedeji *et al*., 2006).

The mean titratable acidity of tamarind fruit pulp was 6.963±0.821%. Similar result was also observed by Kotecha et al. (2002) such that, the titratable acidity in fresh tamarind flesh of three different cultivars ranged from 6.98 to11.93%.

- **TSS**

The average TSS of tamarind pulp was found to be 26.166± 0.440 ^{0}Brix. The result was in agreement with the value of TSS content of Tamarindus indica L pulp (26°Brix) report by Takhellambam (2012).

The soluble solids content is one of the most important quality parameters in processing Tamarind fruit. 50 to 65% of soluble solids contents are sugars, glucose and fructose and their amount and proportion influences the organoleptic quality of Tamarind (Adedeji *et al*., 2006).

The remaining soluble solids are mainly citric and malic acids, lipids and other components in low concentrations.

- **Vitamin C content**

The ascorbic acid or vitamin C is important water-soluble vitamin already implicated in most of the life processes but principally functions as an antioxidant. It is present abundantly in fruits and vegetables (Falade *et al.*, 2004).

As shown in Table 4.2, the mean ascorbic acid content of the Tamarind pulp was 23.366± 1.390mg/100g. This value was in agreement with a range, 20.5 to 40 mg/100g given by Eromosele *et al*. (1991) for some wild fruits; Ximenia, Americana wild olive and Sclerocarya birrea Dineygarma.

4.3 Functional properties of Tamarind pulp

The functional properties bulk density (BD), Water absorption Capacity (WAC) and oil absorption capacity (OAC) results of tamarind fruit pulp were shown in Table 4.3.

Table 4.3 Functional properties (g/ml) of Tamarind fruit pulp

Functional properties	Tamarind pulp sample
Bulk density	0.56 ± 0.75
Water absorption Capacity	2.50 ± 0.70
Oil absorption Capacity	1.28 ± 0.71

Values are mean of triplicate determinants ± SD

WAC is an important functional property required in food formulations especially those involving dough handling. Increase in water absorption capacity implies increase in digestibility of the starches (Oselebe *et al*., 2008). The water absorption capacity of tamarind pulp was found to be 2.50 ± 0.70. The result justify that tamarind fruit pulp may find application in baked products and it can be easily digestible.

Fat absorption capacity is also another important functional property in food formulations because fats improve the flavor and mouth feel of foods (Odoemelam, 2005). The tamarind pulp had oil absorption capacity of 1.28 ± 0.71g/ml. The result shows that tamarind may be best for flavour retention.

Bulk density is a measure of heaviness of flour and an important parameter that determines the suitability of flours for the ease of packaging and transportation of particulate foods (Adejuitan *et al*., 2009). The bulk density of tamarind pulp (0.56 ± 0.75g/ml) was in close agreement with that of the Tamarind pulp flour (56.95g/cm3) reported by Isiaku *et al*. (2012).

4.4 Proximate analysis results of the Tamarind pulp

The data on proximate analysis of tamarind fruit pulp was presented in table 4.4.

Table 4.4 proximate composition (%) of tamarind pulp

Proximate composition	Tamarind pulp sample
Protein	4.346 ± .200
Fat	3.213 ± 0.366
Crude fiber	5.927 ± 0.147
Ash	4.463±0.179
Total carbohydrates	50.706± 1.277
Energy value (Kcal)	249.067±3.505

Values are mean of triplicate determinant ± SD

The value recorded for crude protein was 4.346 ± .200%. In the present investigation the values of crude protein contents were on higher side than the values of crude protein of ripe tamarind pulp, 1.4-3.3% reported by Roy and Joshi, (1995). However, the study was indicated that Tamarind was not a very good source of plant protein on its own unless incorporated with other protein sources. In general, low protein content is the common characteristic of plant foods especially fruits (Kuhnlein, 1989 and Ishola *et al*., 1990).

In this study, the value of the crude fat content in Tamarind pulp was fond to be 3.213± 0.366%. Values obtained for crude fat in Tamarind pulp was shown that they had higher fat content compared with the reported value (2.6%) for tamarind fruit pulp by Achoba (1993). But as it was confirmed with present study and other similar study, the edible pulp of tamarind fruit is relatively poor in protein and oil but the seed is a good source of both protein and oil (Ishola *et al*., 1990)

The result in Table 4.4 shown that, the crude fiber content of Tamarind pulp was 5.927 ± 0.147%. This value was in agreement with the reported values on the literature. Emphasis has been placed on the importance of keeping fiber intakes low in the nutrition of infants and pre-school children (Eromosele and Eromosele, 1993). High fiber levels in weaning diet can lead to irritation of the gut mucosa, reduced digestibility, vitamin and mineral availability. Those with high fiber content are desirable in adult diet. Fiber diets promote the wave-like contraction that move food through the intestine, high fiber food expands the inside walls of the colon, easing the passage of waste, thus making it an effective anti-constipation. It also lowers cholesterol level in the blood, reduce the risk of various cancers, bowel diseases and improve general health and well being. Presence of high crude fiber improves glucose tolerance and is beneficial in treating maturity on set diabetics (Eromosele and Eromosele, 1993) thus the incorporation of these fruits into human diets would increase the level of fiber intake and could be of tremendous benefit to the diabetic patients.

The ash content of Tamarind pulp was 4.463±0.179%, which is higher compared with the ash content of Tamarin pulp (1.69%) reported by Isiaku (2012). The ash content value obtained in this study was in a close agreement to a range of 1.63 g/100g to 8.53 g/100g ash content reported by Oluyemi et al. (2006) for commonly consumed fruits. The percentage ash content of the sample gives an idea about the inorganic content of the samples from where the mineral content could be obtained. Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements, which are expected to speed up metabolic processes and improve growth and development.

The average total carbohydrate contents of Tamarindus indica L. pulp was 50.706± 1.277. Roy and Joshi, (1995) were also reported similar results that is, ripe tamarind pulp contain 51.7-71.8 percent of carbohydrates.

4.5 Mineral element analysis of Tamarind pulp

Results of The selected mineral element (calcium, potassium and sodium) composition analysis of the fresh tamarind fruit pulp are shown in Table 4.5. The concentration of Calcium in tamarind pulp was 116.60±1.011 mg/100g. This value was in close agreement with the reported value (117.1-155.8mg/100g) by Jaspher (2010) for tamarind fruit pulp collected from different

agro-ecological zones. Calcium help in regulation of muscle contractions transmit nerve impulses and help in bone formation (Cataldo *et al*., 1999). The recommended dietary allowance (RDA) for calcium is 800 mg/day (FNB, 1974). This shows that these fruit parts could be a better source of calcium than some conventional fruit.

Table 4.5 Mineral element analysis (mg/100 g) of Tamarind pulp

Mineral composition	**Tamarind pulp sample**
Calcium	116.60±1.011
Potassium	215.947±2.345
Sodium	106.416+1.377

Values are mean of triplicate determinant ± SD

The result in Table 4.5 shown that, the amount of potassium in tamarind pulp was 215.947±2.345 mg/100g. The concentration of potassium in this fruit pulp was found to be higher than that of the concentration of 168, 152 and 213 mg/100g potassium reported for grape fruit juice, orange and pineapple pulp, respectively (Olaofe and Akogun, 1990). The concentration of sodium in tamarind fruit was 106.416+1.377gm/100g. The range was similar to 143 and 158 mg/100g sodium reported for grape fruit juice and orange juice respectively (Olaofe and Akogun, 1990). Sodium and potassium are the chief cations in the extracellular fluid and help to maintain osmotic pressure of body fluid, which protects the body from excessive fluid loss. Their deficiency in the body leads to heart fatigue, muscular weakness, drowsiness and mental confusion (Shakuntala and Shadaksharaswamy, 1987).

4.6 Anti-nutritional factor analysis of Tamarind pulp

Table 4.6 shows the result of anti-nutritional factors present in tamarind fruit pulp. The concentration of tannin in tamarind pulp was found to be 0.250±0.020 mg/100g. Tannin in fruits imparts an astringent taste that affects palatability, reduce food intake and consequently body growth. Tannins are known to inhibit the activities of digestive enzymes and nutritional effects of tannin are mainly related to their interaction with protein. Tannin protein complexes are insoluble and the protein digestibility is decreased (Carnovale *et al.,* 1991). The value in tamarind pulp was however low when compared to 13.3, 19.1 and 99.2 g/kg tannin reported for cashew nut, fluted pumpkin and raw breadnut, respectively (Fagbemi *et al*., 2005). Furthermore,

tannins are water-soluble compounds; they can be easily eliminated by soaking, heat treatment, or cooking (Siddhuraju *et al*., 1995).

Table 4.6 Anti-nutritional factors (mg/100 g) of Tamarind pulp

Anti-nutritional factor	**Tamarind pulp sample**
Tannin	0.250±0.020
Phytate	0.280± 0.54

Values are mean of triplicate determinant ± SD

The result shown that, the concentration of phytate in tamarind pulp was 0.280± 0.54 mg/100g. The values reported was very low with respect to the level of phytate in Thailand fruits commonly consumed by diabetic patients; longan, 0.37 mg/g, dragon 0.39 mg/g, durian 0.51 mg/g, guava 0.8 mg/g, mango 0.86 mg/g and pineapple 0.90 mg/g (Suree et al*.,* 2004). The phytate could, however, be substantially eliminated by processing methods such as soaking and autoclaving (Siddhuraju *et al.*, 1995). The problem with phytic acid in foods is that it can bind some essential minerals nutrients in the digestive tract and can result in mineral deficiencies. Phytic acid also binds to phosphorus and converts it to phytate, while other mineral elements like calcium, zinc manganese, iron and magnesium are converted to the phytic complexes, which are indigestible substance, thereby decreasing the bioavailability of these elements for absorption. Phytic acids also have a negative effect on amino acid digestibility, thereby posing problem to non-ruminant animals due to insufficient amount of intrinsic phytase necessary to hydrolyze the phytic acid complex, but the presence is also beneficiary because it may have a positive nutritional role as an anti oxidant and anti cancer agent (Turner *et al*., 2002).

4.5 Tamarind fruit leather

The nutritional value of food products has become an important consideration for consumers in today's marketplace. In order to choose the most suitable method of drying it is necessary to know the rate of loss of nutrients caused by the drying process. Water removal through the drying process may lead to serious loss of the nutritive and sensory properties of food. Because

Table 4.7 designed code of sample at different combination of factor

Factor		**Sample code**		
Temperature (^{0}C)	**Time(hr)**	**Replication** ⟶		
70	6	X_1	X_{11}	X_{12}
	8	X_2	X_{21}	X_{22}
	10	X_3	X_{31}	X_{32}
80	6	Y_1	Y_{11}	Y_{12}
	8	Y_2	Y_{21}	Y_{22}
	10	Y_3	Y_{31}	Y_{32}
90	6	Z_1	Z_{11}	Z_{12}
	8	Z_2	Z_{21}	Z_{32}
	10	Z_3	Z_{31}	Z_{32}

Of the possible beneficial roles of phyto-nutrients present in tamarind, it is critical to monitor their changes during processing to better assess the direction for product development. There for, to analyze the change due to processing two independent factors called drying time and drying temperature were selected and the samples at different treatments were coded and designed as shown in table 4.7. The result of each treatment was reported as mean value of triplicate determination $\pm$ SD. The change of nutritional value and quality parameters of tamarind fruit during processing and the properties of fruit leather developed from it are discussed below.

4.5.1 Physicochemical properties of fruit leather

Table 4.8 physicochemical properties of fruit leather

Drying condition		physicochemical properties of tamarind leather sample				
Temperature (^{0}C)	**Time (hr)**	**Moisture content (%)**	**pH**	**Titeratable acidity (%)**	**TSS (^{0}Brix)**	**Vitamin C (g/100)**
70	6	18.316±0.104^a	3.390±0.010^a	7.883±0.015^a	62.356±1.193^a	21.656±0.486^a
	8	18.233±0.070^a	3.393±0.015^a	7.872±0.008^a	62.843±1.117^a	21.500±0.533^a
	10	18.203±0.065^a	3.383±0.015^a	7.856±0.015^a	63.283±0.614^a	21.106±0.302^a
80	6	15.226±0.050^b	3.383±0.015^a	7.801±0.011^b	63.336±0.714^a	19.346±0.878^b
	8	15.126±0.116^b	3.380±0.010^a	7.786±0.019^b	63.396±0.532^a	18.850±0.055^b
	10	15.026±0.050^b	3.376±0.011^a	7.776±0.015^b	63.730±0.640^a	18.823±0.060^b
90	6	14.183±0.066^c	3.276±0.015^b	7.671±0.024^c	63.613±1.194^a	16.966±0.058^c
	8	14.136±0.032^c	3.266±0.015^b	7.651±0.019^c	63.680±1.143^a	16.933±0.045^c
	10	14.100±0.010^c	3.253±0.015^b	7.645±0.016^c	63.800 ±1.012^a	17.520±1.108^c

Value is mean of the triplicate determination ± SD

$^{A-c}$ Means not sharing a common superscript letter with in a column are significantly different ($P<0.05$).

- **Moisture content**

Table 4.8 shows the moisture content, pH, °Brix, titratable acidity and Vitamin C content of tamarind fruit leather produced at different drying condition. The final moisture content of fruit leathers ranged between 18.316% ± 0.104% and 14.100% ± 0.010%. The result shown that there was a significant difference ($P < 0.05$) between means moisture content of the tamarind fruit leathers produced at different drying temperature. The study justified that the average moisture content of the fruit leather is dependent on drying temperature. As the drying temperature increases from 70^0C to 80^0C and then to 90^0C, the average moisture content decreases significantly, but there were no significant differences ($p< 0.05$) between the moisture content of the fruit leathers produced at constant drying temperature for different drying time (Table 4.8).

When compared to the fresh tamarind pulp, the moisture content of tamarind fruit leather was significantly decreased because of the effect of drying. The moisture content of the tamarind fruit

leather produced at 80^0C and 90^0C agreed with the reported value, 11-17% moisture content for jackfruit leather (Che Man and Taufik., 1995). Harsimrat and Dhawan (1998) reported that 15% final moisture level is optimum for good quality guava fruit bar. Naikare et al (1998) found that 16% moisture level in fruit leather had extended shelf life and retained sensory and physical quality up to six months. It has been spectacular that moisture content at or below 15% (wet base) for most fruit is rather safe indicator that there is no microbial or mould growth and reaction rate of a number of other deteriorative reaction (sugar crystallization, non enzymatic browning, flavor deterioration, lipid oxidation etc…) is considerably reduced (Masker A *et al*., 2002).

- **pH**

In this study, no significant differences ($P<0.5$) were found among the tamarind fruit leather produced at 70^0C and 80^0C, but there observed significant difference of pH value of tamarind fruit leather produced at 90^0C from the others. On average, the pH of the leather ranged between 3.253 ± 0.015 and 3.39 ± 0.010. The value was slightly increased from the reported value (2.78 ± 0.03) of tamarind fruit leather contained 15% sucrose by Abdel **(**2012). But, compared to the pH of the fresh tamarind pulp, it was somewhat lowered after the drying operation.

- **Titratable acidity**

This research found that the tamarind fruit leather had a titratable acidity (TA) between 7.645 ± 0.016 and 7.883 ± 0.015 (% citric acid). In this study, significant differences were found regarding the titratable acidity between tamarinds fruit leather produced at different drying temperature. However no significant different of titratable acidity were observed between fruit leather developed at different drying time for constant drying temperature. The TA value of tamarind fruit leather produced at 80^0C and 90^0C were in agreement with the reported TA value (7.83%) of tamarind leather containing 15% sucrose (Abdel, 2012)

After drying, the titratable acidity of all fruit leathers increased significantly. The increase in TA levels of tamarind fruit leather may be due to the addition of lemon juice (3%) to the fruit leather puree. The drying process also concentrated the natural acidity of the fruit. As a result, the acidity of the fruit leather increased significantly after drying. High acidity in fruit leather prevents the growth of microorganisms and helps maintain the color and flavor of the fruit;

therefore, it is important from a processing or manufacturing point of view to use tamarind cultivars with high acidity.

- **TSS**

The °Brix results showed that there was no significant difference ($p < 0.05$) between TSS of fruit leather produced at all drying time and temperature. The highest TSS value was recorded by tamarind leather produced at 90^0C and 10hr 63.800 $\pm$1.012 and lowest TSS value was recorded by tamarind leather produced at70^0C and 6hr 62.356$\pm$1.193

The TSS values of all the tamarind fruit leathers were found to be higher than that of raw tamarind fruit pulp. In previous studies, °Brix of fruit leathers was also found to be higher than those of raw fruit; this was especially prevalent in sweet fruits. For example, raw pineapple puree had a °Brix that increased to 66.4 – 75.3 °Brix with the addition of other ingredients (such as pectin, glucose syrup, sugar and maltodextrin). After drying the final °Brix of pineapple fruit leather ranged from 82.4 to 86.9. Similarly, kiwifruit °Brix was increased by adding 15% sugar and was found to be higher (68 °Brix) after drying in a cabinet drier at 45 ± 2 °C for 15 hours (Vaidya *et al*., 2007). In this research, sugar was added as a sweetener. The addition of sugar (15%) may lead to an increase in °Brix of the final tamarind fruit leathers. Such phenomenon was also observed by Abdel (2012) study. Such that, He was found the lowest TSS value (5.19%) of Tamarind leather without sucrose dried using cabinet drier than the TSS value (8.30%) of the one that contain 15% sucrose. It was known that products with a high TSS value are a good source of energy. Kumar et al. (2010) proposed that the high °Brix of blended papaya fruit leather could be attributed to the high carbohydrate content and, therefore, could be considered as good source of energy.

- **Vitamin C**

The average vitamin C content of the tamarind fruit leather was significantly affected ($P < 0.05$) by drying temperature. When the drying temperature increased, the average vitamin C content decreased from 21.656$\pm$0.486 to 17.520$\pm$1.108. But, no significant difference ($P < 0.05$) was observed when the drying time increased at constant drying temperature.

When comparing fresh fruit with the corresponding dried fruit leather, it was shown that the drying operation led to reductions in vitamin C content. The loss in vitamin C content during drying involves oxidation and hydrolysis. The ascorbic acid is oxidized to dehydroascorbic acid,

followed by hydrolysis to 2, 3-diketogulonic acid and further oxidation and polymerization to form a wide range of other nutritionally inactive products (Gregory, 2008).

4.5.2 Proximate composition of fruit leather

After the Tamarind fruit puree was dried with the combination of different drying time-temperature combination using electric oven dryer, the sample of fruit leather was subjected to nutritional composition (proximate, vitamin and mineral) analysis in JJ Labo Glass Laboratory. The proximate composition analysis result of tamarind leather was presented in Table 4.9.

- **Protein**

From the analysis result, a significant difference ($P < 0.05$) has been observed on the average protein content of fruit leather at all drying temperature. As indicated in Table 4.9, the average protein content of the fruit leathers were ranged between 3.09%±.010 and 2.23%±.070

When comparing fresh fruit with the corresponding dried fruit leather, it was shown that the drying operation led to reductions in protein content. The loss of protein can be explained by the denaturation or changes in solubility during drying and the release of amino acids from the proteins after denaturation, which could then react with other compounds via the Maillard reaction (Perera, 2005; Scala *et al.,* 2011; Miranda *et al.,* 2010).

Table 4.9 Proximate analysis (%) result for Tamarind fruit leathers

parameter		**Proximate composition of Tamarind fruit leather sample**					
Temperature (^{0}C)	Time (hr)	Protein	Fat	Fiber	Ash	Carbohydrate	Energy(Kcal)
70	6	3.09±.010^a	2.146±.032^a	4.71±.102^a	3.536±.040^a	69.193±.290^a	304.453±.910^a
	8	3.08±.076^a	2.143±.030^a	4.61±.084^a	3.513±.035^a	68.413±.309^a	305.247±.700^a
	10	3.06±.150^a	2.143±.020^a	4.55±.092^a	3.490±.030^a	68.546±.378^a	305.717±.723^a
80	6	2.54±.145^b	1.286±.040^b	3.81±.143^b	3.293±.045^b	73.833±.456^b	317.717±.882^b
	8	2.63±.065^b	1.280±.040^b	3.71±.084^b	3.260±.040^b	73.883±.511^b	317.587±1.43^b
	10	2.48±.081^b	1.276±.025^b	3.62±.084^b	3.236±.030^b	74.130±.252^b	317.930±.457^b
90	6	2.30±.100^c	1.213±.045^c	3.08±.062^c	3.060±.052^c	76.153±.295^c	324.760±.383^c
	8	2.27±.116^c	1.206±.040^c	3.06±.026^c	3.033±.025^c	76.286±.241^c	325.113±.153^c
	10	2.23±.070^c	1.210±.030^c	3.05±.024^c	3.003±.011^c	76.406±.135^c	325.437±.047^c

Values are means of triplicate determinations ± SD

[A-c] Means not sharing a common superscript letter with in a column are significantly different ($P<0.05$).

- **Fat**

The mean fat contents of the fruit leathers were significantly different ($P < 0.05$) due to the effect of drying temperature. The highest value (2.146±.032%) was observed on fruit leather produced at 70^0C and 6hr while the least value (1.210±.030%) was recorded with leather developed at 90^0C and 10hr.

When comparing fresh fruit pulp with the corresponding dried fruit leather, it was shown that the drying operation led to reductions in fat content. The decrease in lipid (fat) content was likely due to either enzymatic hydrolysis during the first drying period or lipid oxidation because of the thermal treatment (Perera, 2005)

- **Crude fiber content**

The mean crude fibers content of the tamarind fruit leathers were also significantly different from each other ($P < 0.05$) as they are affected by drying temperature. However, drying time did not have a significant effect on the fat content of the leather.

Comparing with fresh fruit pulp, crude fiber content of fruit leathers were significantly decreased because of drying operation. The loss of fiber was likely due to thermal degradation resulting in disruption of the polysaccharide network of the cell wall (Miranda *et al.,* 2010; Scala *et al.,* 2011).

- **Carbohydrate**

The analysis showed that drying temperature has a significant effect on the average carbohydrate content between Tamarinds fruit leather ($P < 0.05$) produced at different drying temperature. As indicated in Table 4.8, highest average carbohydrate content (76.406%±0.135%) was observed with fruit leather produced at 90^0C and 6hr, while the lowest value (69.193±0.290%) was observed at 70^0C and 10hr.

Comparing to fresh fruit pulp, the carbohydrate content of tamarind fruit leather was significantly increased. During the drying process fruit loses water and its nutrients and sugars become more concentrated

4.5.3 Mineral element composition of tamarind fruit leather

The mineral contents of the tamarind fruit leathers are shown in Table 4.10. From the mineral element analysis results; it was shown that the tamarind fruit leather contained higher levels of minerals than raw tamarind fruit pulp. The drying process required to make fruit leather resulted in a significant increase in several of the major minerals when compared to fresh fruit.

After drying, the mineral contents of tamarind fruit leathers ranged between: for calcium 196.39 ± 1.490mg/100g and 73.111 ± 0.402mg/100g, for potassium 731.667 ± 1.259 and 595.100 ± 0.986mg/100g and for sodium was 125.949 ± 1.430 and 102.178 ± 0.416mg/100g. Significant difference ($P < 0.05$) has been observed on all average mineral element content of tamarind fruit leather at all drying temperature. During fruit leather preparation, the addition of ingredients such as sugar and lemon juice may have led to an increase in mineral composition found in the fruit leather.

Table 4.10 Mineral element composition (mg/100g) analysis result of Tamarind fruit leather

Drying condition		**Mineral element composition of Tamarind leather**		
Temperature(^{0}C)	Time(hr)	calcium	Potassium	Sodium
70	6	196.390±1.490^a	731.667±1.259^a	125.949±1.430^a
	8	195.433±1.530^a	732.017±0.127^a	125.124±0.839^a
	10	194.960±1.160^a	732.772±0.384^a	124.7±0.410^a
80	6	182.595±0.115^b	624.633±0.577^b	111.422±0.647^b
	8	181.810±0.090^b	623.756±0.546^b	111.073±0.834^b
	10	181.067±0.067^b	623.634±0.656^b	110.286±0.604^b
90	6	176.565±0.878^c	596.262±1.162^c	103.429±0.594^c
	8	175.366±1.185^c	595.660±0.695^c	103.256±0.647^c
	10	173.111±0.402^c	595.100±0.986^c	102.178±0.416^c

Values are means of triplicate determination ± SD

$^{A-c}$ Means not sharing a common superscript letter with in a column are significantly different ($P<0.05$).

4.5.4 Sensory analysis of Tamarind fruit leather

Analysis of sensory attribute scores of liking is given in Table 4.11. As seen from the results there are significant differences ($P < 0.05$) among fruit leather produced at different drying condition. Results of sensory evaluation in terms of sensory attributes such as color, aroma, taste, flavor, and overall acceptability of the tamarind fruit leathers were shown in Table 4.10

Color

From the sensory analysis result, it was observed that the color of the fruit leather was significantly affected ($P < 0.05$) only by drying temperature. On average, acceptability scores for colour of fruit leathers dried at 70^0C, 80^0C and 90^0C were liked very much, liked moderately and liked slightly respectively. The highest mean score (8.6±0.699) was recorded for tamarind leather dried at 70^0C for 6hr, which indicates that the sample was liked very much by the panelists. Whereas leather dried at 90^0C for 10hr had the lowest mean score (6.4±0 .966) which indicates that the sample was liked slightly by the respondents. It is clear from the data that colour acceptability ratings of the leathers decreased with increase in drying temperature.

Table 4.11 Sensory characteristics of tamarind fruit leather

Parameters		**Sensory analysis of tamarind fruit leather sample**				
Temperature(^{0}C)	**Drying Time(hr)**	**Color**	**Aroma**	**Taste**	**Flavor**	**Overall acceptability**
70	6	8.6±0.699^a	7.6±.966^a	8.2±.788^a	7.8±.919^a	8.3±.483^a
	8	8.5±0.707^a	7.5±.971^a	8.2±.632^a	7.7±.948^a	8.5±.527^a
	10	8.4±0.699^a	7.5±.849^a	8.1 ±.737^a	7.5±.849^a	8.4±.516^a
80	6	7.5±0.849^b	7.6±.966^a	8.5±.527^a	7.3±.948^a	8.4±.516^a
	8	7.5±0.707^b	7.6±1.349^a	8.4±.051^a	7.3±.674^a	8.6±.516^a
	10	7.4±0.966^b	7.5±.849^a	8.3±.483^a	7.2±.788^a	8.2±.632^a
90	6	6.6±0.699^c	6.6±.966^b	7.4±.843^b	6.7±.674^b	7.5±.971^b
	8	6.5±0.971^c	6.6±.843^b	7.4±.966^b	6.6±.843^b	7.3±.948^b
	10	6.4±0 .966^c	6.5±.707^b	7.3±.674^b	6.6±.966^b	7.2±.788^b

Values are means of triplicate determination ± SD

$^{A-c}$ Means not sharing a common superscript letter with in a column are significantly different ($P<0.05$).

Aroma

The aroma of products results from volatile substances in the fresh food such as esters, ketones, terpenes, aldehydes and others (Cremer and Eichner, 2000). The loss of these volatiles leads to a decrease in aroma detection. Longer drying temperature may allow for greater loss of volatiles. The addition of ingredients like honey and or sugar can be used to enhance the aroma of fruit leathers (Raab and Oehler, 1999). However, the mean score for flavor rating decrease with increase in sugar content beyond a given optimum amount (Jain and Nema, 2007). It is therefore important to optimize the amount of sugar added for the purpose of enhancing flavor.

In the study, the sensory analysis result was found that the aroma of fruit leathers dried at 90^0C were significantly different ($P< 0.05$) from the others. It had the lowest acceptability scores (score ≤ 6.6) for aroma and was generally liked slightly by the panelists. In contrast, tamarind fruit leather dried at 70^0C and 80^0C had comparable scores (7.5-7.6) and were not significantly different ($P<0.05$).

Taste

On average, the overall preference score for the test of fruit leather were ranged between $8.2\pm.788$ and $7.3\pm.674$. The test of fruit leathers dried at 90^0C was generally liked moderately and had significantly lower acceptability scores compared to fruit leathers dried at 70^0C and 80^0C ($p < 0.05$).both of the fruit leathers dried at 70^0C and 80^0C were Liked very much by the respondents and no significant different ($p < 0.05$) were observed between them. The taste of leather is contributed by the amount of sugars contained in the fresh pulp. Increase in the amount of sugar beyond optimum amounts may, however, reduce the taste ratings thus requiring optimization (Jain and Nema, 2007). Sweetness rating may also depend on the type of the fruit and may also vary during storage (Ashaye et al., 2005). Besides sugar and honey, other ingredients such as leaf oregano, grounded ginger and garlic-salt among others could be used to improve the taste of fruit leather (Raab and Oehler, 1999). It is important to note that taste may also be influenced by and may correlate with aroma (Fennema, 1996). Therefore, enhancing aroma may also improve taste acceptability.

Flavor

The highest acceptability rating for flavor was observed for fruit leathers dried at 70^0C followed by fruit leather dried at 80^0C while fruit leathers dried at 90^0C received the lowest rating (Table 3.10). The acceptability for flavor of the fruit leathers dried at 70^0C and 80^0C were not significantly different ($p<0.05$) and was generally liked moderately. But there observed significant different ($p< 0.05$) of the acceptability for flavor of fruit leathers dried at 90^0C from fruit leather dried at another temperature and were generally liked slightly by the panelists.

Overall acceptability

Sensory analysis results showed that the average overall acceptability of the leathers were highest for both fruit leathers dried at 70^0C (8.3$\pm$.483 to 8.5$\pm$.527) and 80^0C (8.2$\pm$.632 to 8.6$\pm$.516) and lowest for fruit leathers dried at 90^0C (7.2$\pm$.788 to 7.5$\pm$.971). The overall acceptability of fruit leather that was dried at 70^0C and 80^0C were not significantly different ($p<0.05$) although both of them were significantly different ($p< 0.05$) from fruit leathers dried at 90^0C. It has been also observed that the overall acceptability of the fruit leather dried at 70^0C and 80^0C for all drying time was liked very much by the respondents, whereas the fruit leather dried at 90^0C for all drying time was like moderately. Therefore, according to the panelists' preference, the tamarind fruit leather dried at 70^0C and 80^0C is considered to be the best leather in terms of overall acceptability.

Chapter 5

Conclusions and Recommendations

5.1 Conclusions

Fruit leather was successfully developed from indigenous tamarind fruit using three additional ingredients: sugar, lemon juice and grounded ginger. The main purpose of this processed food product was to keep or improve the nutritional value and sensory quality of tamarind fruit and develop higher quality, less expensive, and a convenient consumer product. The final product needed to have an extended shelf life so that it will be a commercially viable product.

The fruit leathers made from tamarind fruit had moisture content in the range between 18.316 and 14.100%. But the moisture content (15.126%) of fruit leather dried at 80^0C for 8hr was unique from other tamarind leather developed in this study with that it could be microbially safe, and at the same time it had acceptable sensory quality. The addition of lemon juice as a preservative increased the acidity level of the fruit leather from 6.963 to a range between 7.883 and 7.645% (citric acid). This was expected for a dried product, especially if it contained an acidic juice with a pH of 2.7 and acidity of 5.3%. The texture analysis showed that tamarind fruit leather had a soft texture. The thicknesses of the product were found to be in the range between 2 and 3mm.

The proximate analysis for all tamarind fruit leather indicated that processing affected the nutritional composition of the fruit leather. Because of the high sugar content it contained a high energy value. The leather had low fat, protein and ash contents and consisted of acceptable fiber and carbohydrates contents. The vitamin C content was found to be dependent on drying temperature and decreased significantly due to the effect of processing. It was also found that the mineral content of fruit leathers was significantly increased.

Results of the sensory analysis for sensory attributes of the tamarind fruit leather reviled that there were no significant differences ($p < 0.05$) for test, aroma flavor and overall acceptability between leather dried at 70^0C and 80^0C However, they were significantly different in licking score for color. All the sensory attributes of Tamarind leather dried at 90^0C was significant differences ($p < 0.05$) from the other fruit leathers developed in this study. That is, the panelists showed preferences ($p < 0.05$) to the color, aroma, taste, flavor, and over all acceptability of

tamarind fruit leather that was dried at 70^0C and 80^0C than the fruit leather dried at 90^0C. This variability could be arising from drying temperature used since all the other processing conditions were similar. The study then concluded that the selection of appropriate process parameters (drying temperature and time) were important to produce higher quality and acceptable sensory quality product of tamarind fruit leather. Furthermore, sensory attribute of the fruit leather were the most influential characteristics for its acceptability.

The tamarind fruit leathers developed were generally judged to be acceptable by the sensory panelists. Fruit leather development was a relatively new concept for preserving fruit that can be easily implemented and its advantage is that it may utilize fruit not suitable for canning, freezing or other storage methods. Tamarind fruit can be preserved by the production of tamarind fruit leather without addition of any artificial / chemical preservatives. The additions of sugar, lemon and grounded ginger in this research was very small and so that this can be considered as natural product. This met consumer demands for healthy food products. This product has strong appeal and sales potential. Manufacturing of fruit leather required simple processing technology and was cost effective. However, the product needed further improvement for better market acceptability. This study will benefit growers, tamarind fruit marketers and product developers who were interested in diversifying into tamarind products.

5.2 Recommendations

Even though, the development of such nutritional products will not only reduce the postharvest losses but also impart value to less appreciated fruits, Investigation of the shelf life of tamarind fruit leathers is still required. Studying shelf life will help to understand the stability of the product and identify optimal suitable packaging and storage conditions. Unless the fruit leather will be packed with suitable packing material and stored in a proper storage condition, it would not meet the long time shelf stability for the fruit.

Only one variety of tamarind fruit (grown around Gambela region, from Emere district in Lara wereda) was studied in this research. Further research on tamarind cultivars (cultivars available in other than Gambela region that is from metema, humera or other region in Ethiopia) are required to gain a better understanding of the different types of tamarind cultivars. Preparation of

fruit leather by mixing different types of cultivars could help to balance the nutritional properties and physical characteristics of blueberry fruit leather.

To improve the colour of the fruit leather, different proportions of various types of fruit could be mixed to develop nutritionally enriched fruit leather and to increase customer demand. Adding a variety of ingredients, preservatives or protein rich nuts could create an interesting fruit leather product and deserved further evaluation.

Due to the fact that fruit leathers are excellent in taste, rich in nutritional quality, retained original fruit flavor and safe for consumption, its popularity is increasing in day by day throughout the world. Fruit leather comes under the category of healthy snacks because of their high nutrition value along with a chewy structure. In order to gain such ample benefit of fruit leather, further study and investments will be needed in Ethiopia along this processing area that add value to tamarind fruit.

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Annexe A

A.1 Instruction for panelists

Panelist Instructions

You will be evaluating 6 fruit leather sample

Please evaluate the sample in the order presented. Be sure to answer the question on the Questioner/scroll sheet that accompanies the fruit leather sample.

Evaluation Techniques:

Hold the sample:

- Observe the color and overall appearance
- Record your answer on the sheet

Test the sample:

- Record your answers for aroma, taste, flavor and overall acceptability on scroll sheet.

Before tasting each sample please take a sip of water to cleanse your pallet. Retest the product as needed and tick the box for your response.

Please take one minute break between each sample.

Raise your hand if you have any question or need more water.

A.2 sensory evaluation scroll sheet

Name:				**Product:**		
Panelist No.:				**Date:**		
Instructions: Taste the given samples, then place an x mark on the point in the scale which best describes your feelings.						
Score *	**Sample code**					
	Attribute					
	Color	**Aroma**	**Taste**	**Flavor**	**Toughness**	**Overall Acceptability**
Like extremely (9)						
Like very much (8)						
Like moderately (7)						
Like slightly (6)						
Neither Like nor dislike (5)						
Dislike slightly (4)						
Dislike moderately (3)						
Dislike very much (2)						
Dislike extremely (1)						
Comments:						