ACTA SCIENTIFIC MICROBIOLOGY (ISSN: 2581-3226)

Volume 2 Issue 12 December 2019

Review Article

Factors Influencing Postharvest Quality of Tamarind Fruit Pulp

Satya SS Narina[1]*, Coretta C Davis[2], Michelle M Corley[2], Anwar A Hamama[2], Chyer Kim[2], Li H[2], Grizzard C[2], Umesh K Reddy[1], Kameswari P L[6], Pessarakli Mohammad[3], Bhavani Prasad V Sripathi[4], Christian D'Orgeix[5], Brian L Sayre[5], Glenn Harris[5], Harbans L Bhardwaj[2], Padma Nimmakayala[1] and Yixiang Xu[2]

[1]*Department of Biology, West Virginia State University, Institute, Charleston, WV, USA.*

[2]*Agricultural Research Station, VSU, Petersburg, VA23806, USA*

[3]*School of Plant Sciences, Forbes Building, Room 303, The University of Arizona, Tucson, Arizona 85721, USA.*

[4]*Andhra Pradesh Agricultural University, Rajahmundry, East Godavari District, Andhra Pradesh, India*

[5]*Department of Biology, VSU, Petersburg, VA 23806, USA*

[6]*Krishi Vigyam Kendra, Pandirimamidi, Dr. YSR Horticultural University, East Godavari District, Andhra Pradesh, India*

***Corresponding Author:** Satya SS Narina, Department of Biology, West Virginia State University, Institute, Charleston, WV, USA.

E-mail: snarina@hotmail.com

Received: October 03, 2019; **Published:** November 04, 2019

DOI: 10.31080/ASMI.2019.02.0422

Abstract

Tamarind pulp has potential value in nutrition and health and is useful in variety of ways in the preparations of both food, and medicines. There are several cultivars identified for industrial use, sweet and sour pulp types for table fruit purposes. Fruit is consumed as fresh fruit snack, or its pulp made into puree or sauce to mix with rice and other cereals, vegetables, fruits, and to make candies, high energy bars, ready to use fresh fruit concentrates, sweet juice beverages or flavoring agent for locally consumed drinks, pickles, as a preservative to store several foods. The presence of antimicrobial properties and essential phytochemicals in tamarind pulp or pulp products made them safe for human and animal consumption and free of microbial load. There are reports on an insect pest or larvae carried over from field to storage, enhanced losses of fruit quality and encouraging secondary pathogenic bacteria or fungal contamination. The climatic factors like temperature, relative humidity, ventilation, pH, amino acid to sugar ratio, and moisture content of fruit or dried pulp blocks and their packing materials are some of the factors controlling the pulp quality. However, care during selection of raw material, source location, processing methodology will eliminate cross contamination due to fungi or bacteria from food or food products prepared using tamarind pulp. The wild resources, 2000 genotypes and potential cultivars identified for pulp production would be an excellent source for seedless tamarind table fruit cultivar development. Postharvest studies on improved storage quality by using insect resistant cultivars and inclusion of ready to serve fresh foods with tamarind in United States grocery stores would be beneficial.

Keywords: Genotypes; Pulp Products; Industry; Antimycotic; Antibacterial; Storage

Abbreviation

USDA (United States Department of Agriculture); % (percent); g(grams); mg(milligrams); µg (micrograms); > (greater than); < (less than); IU (International Units); β-D (Beta - Dextro); α, β, γ (alpha, beta, gamma); ml (millilitre); oC(Degrees Celsius); oF(Degrees fahrenheit); BHA (Butylated hydroxy anisole); TSS (Total soluble solids); ± (Plus or minus); HDPE (high density polyethylene); LDPE (Low density polyethylene);LLDPE (Linear low density polyethylene); MDPE(Medium density polyethylene); NAPA (National Action Plan for Agriculture); US-FDA (United States –Food and Drug Administration);

Introduction

The most useful part of tamarind tree (*Tamarindus indica* L.) is the fruit, as it contains a sweetish, acidic pulp, which is widely used for souring curries, sauces, chutneys and certain beverages [1]. Rao and Srivastava in 1974 reported that fruit pulp is soft and thick, brown or reddish brown in color, and 55 per cent of the fruit is filled with fruit pulp while the remaining 34 per cent and 11 per cent are contributed by seed and shell respectively [2]. India is the largest producer (300,000 tons) and exporter of tamarind pulp fol-

lowed by Thailand (140,000 tons) and 45% of tamarind trees are planted only for fruit pulp of food and medicinal value [3,4].

On an average 2000 genotypic collections were from all over the world and widely distributed in tropical and subtropical regions including Europe and Americas. Among these the sweetest and most cultivated tamarind cultivars with high pulp content are Makham Waa, Manila sweet, Urigam, PKM 1 (Peryakulam 1), Tumkur, Yogeswari, No: 86-13-008, No: 87-2-01-035, Prathisthan, T3, T1B, red and brown pulp type, sweet and sour type fruit cultivars for their industrial use traits. Tamarind tree can be cultivated as a main orchard or as an intercrop in vegetable crops like cassava, potato and other annuals or cereals like wheat [4-7].

Evaluation of Tamarind varieties were conducted from various locations of south India (Tamil Nadu - 14 genotypes, Karnataka - 11 genotypes, Andhra Pradesh - 10 genotypes) including famous varieties like Urigum, PKM-1 (Tamil Nadu) and NT1-19 (Karnataka) and selections. Correlation coefficient studies indicated that pulp weight per pod expressed highest positive genotypic and phenotypic association with pod weight, vein weight, shell weight, pod width and pod length. Path coefficient analysis revealed that, pod weight, pulp per cent, seed per cent and shell per cent exhibited a positive direct effect on pulp weight [1].

The potential of this tropical fruit cultivation in temperate and subtropical regions benefits not only farmers, but also industrialists to encourage massive adaptation of tamarind tree planting by taking measures to cultivate for good quality tamarind pulp production in non-traditional areas like United States of America (USA) and for educating young generation of scientists, academic researchers, research scientists about the germplasm resources we have for generations [4].

Tamarind pulp in unripe condition (green pod) shows polyphenol oxidase activity up to 105 days of maturity of the fruit or until it ripens. Thereafter due to ripening there is a marked increase of reducing sugars and available lysine leading to Maillard reaction. This inhibits enzymatic browning in the ripe pulp during subsequent storage. The factors affecting Maillard reaction are high temperature, amino acid to sugar ratio, water content, pH, and organic acids [8].

Very limited literature available with respect to microbial contamination or factors influencing postharvest quality of fruit, pulp and pulp-based food products. Nutritional and preservative roles of fruit pulp and its value in human health made us to find any unknown postharvest storage losses due to microbial contamination and the major factors controlling the quality of pulp after harvest.

Role of tamarind pulp in nutrition and health

Various plant parts of tamarind including seed and leaves are highly nutritious, though fruit pulp is the prime part of this review. The biochemical components of medicinal value, and phytochemicals of a preservative role were controlling various human or animal infections or diseases are summarized below [6].

Fruit pulp used as snack, preservative, and to prepare several culinary dishes, chutney, tamarind juice concentrate, pulp powder, pectin, jams, syrups, candy, and for making souring porridge, tartaric acid, alcohol, summer refreshing drink, seasoning, and flavoring [4]. The fresh raw fruit of 100g weight provides 239 kcal energy. The proximate composition of fruit pulp (Table 1) though varies with sample to sample, revealed that the ripe fruit pulp provides 30-40% invert sugars containing 70 per cent glucose and 30 per cent fructose, more folates (59.35µg), tartaric acid (18.52g/100 g), soluble solids (44oBrix) and vitamin E (108.78µg/g), but less dietary fiber (4.13g/100 g), vitamin C (4.79mg/100g) and carbohydrates (50.07g/100g) compared to raw fruit [4,6, https://fdc.nal.usda.gov/].

The fruit pulp has most of the essential amino acids (β-alanine, proline, phenylalanine, leucine, serine) except tryptophan; carbohydrates – arabinose, galactose, glucose, xylose, cinnamates, citric and uronic acid, dietary fiber, invert sugar, nicotinic acid, 1-malic acid, pectin, pipecolic acid, volatile oils (geraniol, limonene), potassium, lipids, proteins, polyphenols and flavonoids, vitamins B3, C and E (α, β, γ – tocopherols), and folates. Secondary metabolites like polyphenols were identified from mucilaginous tissue of fruit include flavan-3-ols (catechin, epicatechin), flavonoids (vitexin, iso-vitexin), procyanidin and triterpenes [orientin (8-c- β-D-glucopyranosyl-3 ',4', 5,7-tetrahydroxyflavone), and iso-orientin (6-substituted luteolin analog)] while aqueous pulp extract was observed with saponins (2.2%), alkaloids (4.32%) and glycosides (1.59%) [6].

A raw or partially ripe fruit is used as an anti-scorbutic, heal inflammations, to treat asthma, cough, sore throat by hydrolysis of phospholipids, due to the presence of polyphenols and flavonoids [9,10].

Tamarind fruit is anthelminthic (expels worms), antimicrobial, antiseptic, antiviral, sunscreen and astringent and to promote wound healing in the following conditions: asthma, bacterial skin infections, boils, chest pain, cholesterol metabolism disorders, colds, colic, conjunctivitis, constipation (chronic or acute), diabetes, diarrhea, dry eyes, dysentery, eye inflammation, fever, gallbladder disorders, gastrointestinal disorders, gingivitis, hemorrhoids, indi-

Constituent	Dry pulp (range in %)	Raw fruit (%)
Energy (from 100g)	115-216 calories	239 kcal
Moisture	15-30	-
Proteins	2 to 9.10	2.8
Fats/oil/lipids, crude	0.5 to 3.10	0.6
Carbohydrates, total	56.7 to 82.6	62.5
Invert sugar	-	30-41
Fibre, crude	2.2 to 18.3	5.1
Cholesterol	0	0
Tartaric acid, total	56.7 to 82.6	8-23.8
Reducing sugars	25-45	-
Total ash	2.10-3.3	-
Pectin	2-4	> 4
Cellulosic residue	19.40	-
Albuminoids	3-4	-
Total available carbohydrates	41.77	-
Alcohol insoluble sugars	22.7	-
Water insoluble sugars	20.50	-
Non-reducing sugars	16.52	-
Total sugars	41.20 to 58.7	-
Starch	5.7	> 6
Tannin (mg)	600	-
Ascorbic acid (mg)	3 to 9	0.7 to 3.5
Vitamin A (IU)	15	30,000
Beta carotene equivalent (µg)	10-60	18
Thiamine (mg)	0.18 to 0.22	0.43
Riboflavin (mg)	0.07-0.09	-
Vitamin E (mg)		0.1
Vitamin K (µg)		2.8
Niacin (mg)	0.6 to 0.7	1.94
Folates (µg)	-	14
Pantothenic acid (mg)	-	0.14
Pyridoxine (mg)	-	0.07
Sodium (mg)	24	28
Potassium (mg)	116 to 375	628
Calcium (mg)	35 to 170	74
Copper (mg)	21.8	0.86
Iron (mg)	1.3 to 10.9	2.8
Magnesium (mg)	72	92
Phosphorous (mg)	54 to 160	113
Selinium (µg)		1.3
Zinc(mg)	1.1	0.10

Table 1: Proximate composition of dried pulp of tamarind fruit per 100g dry weight and 100g raw fruit.

Source: Average data taken from USDA nutrient database at https://fdc.nal.usda.gov/, [2,4-6].

gestion, jaundice, keratitis, leprosy, liver disorders, iron deficiency, nausea and vomiting (pregnancy related- generally eat raw unripe sour fruits), saliva production, skin disinfection/sterilization, sore throat, sores, sprains, swelling (joints) and urinary stones [11].

Fruit pulp is used as cooling agent during fever, as pain reliver, to protect skin damage from Sun's ultraviolet rays, muscle relaxation via calcium channel blockage, decreases plasma fluoride concentration and reduces fluoride induced liver and kidney damages, regulatory effect on neutrophils due to presence of polyphenols to treat bile disorders and constipation. Tamarind fruit extract is an effective drinking water cleaning agent for fluorine, nickel, and lead toxicities. Fruit pulp is laxative and carminative, and its extract is antimicrobial in action for many secondary bacterial infections of human. The purified xyloglucan from tamarind were in use for eye surgery and fruit extracts enhancing bioavailability of ibuprofen was a promising achievement in medical history [2,5,6].

Antibacterial activity was observed against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Salmonella paratyphi, Salmonella typhi, Bacillus subtilis, Burkholderia pseudomallei, Klebsiella pneumoniae* due to presence of lupeol content. Potential antifungal activity was observed against *Aspergillus niger, Candida albicans* [9,10]. The fungicidal activity observed was mainly due to the brown odorless liquid bitter principle 'tamarindienal', identified as 5-hydroxy 2-oxo-hexa3,5-dienal identified in the tamarind pulp [5].

Extracts from tamarind fruit pulp showing antimalerial and molluscicidal activity against *Bulinus trancatus* snails due to the activity of saponins was reported [2,5]. A research study conducted on rats using tamarind water extract showed anti-obesity effects with no significant change in body weight, hematologic, and clinical biochemistry profiles of the tested group after six months [12].

Products of tamarind fruit and pulp

Unripe or ripened fruits are harvested by young men or children, manually or by using a ladder to avoid contamination from soil. Harvested fruits are processed by removing seed coat, fiber and seeds, usually done by women manually or by using mechanical seed expeller (35kg/hr) in India. The processed fruits will be transported to local regions to make following major pulp products. The tamarind fruit with its shells still intact was sold for the equivalent of half a United States dollar for smaller heaps (≤1kg) and up to one dollar for a basinful (3–8kg) [13].

- **Dried fruit block:** The de-seeded and dehulled dried fruits are pressure compressed to fruit blocks for commercial use by marketing by distant transport and has export value. These blocks are rich in all the nutrients available from a single dry fruit (Table 1).

- **High energy fruit bars and candies:** Tamarind pulp is used to make candies, lollipops, jellies of sweet and sour taste. Tamarind pulp bars are made and mixed with dried or dehydrated fruits like banana, mango, breadfruit, jackfruit or dehydrated dried sweet vegetables like kale, peas, potato, cauliflower, and broccoli to make ready to eat energy fruit bars or fruit and veggie snacks.

- **Puree or Paste:** It is made after removing seeds and fibrous material using little amount of sterilized water with little heating in a pot. This paste is used for making tamarind rice, dahls or sambar with pulses and other vegetables, chutneys with spices and in making other vegetable or fruit pickles and tamarind serves as a preservative for long term storage of food items of different kind. Pulp concentrate added to sauces such as meat to enhance taste, keeps it fresh for a longer period.

- **Sauce and Jams:** In African countries, during dry season, tamarind sauce is eaten with millet bread due to the scarcity of vegetables. Pulp of ripe fruit, boiled with dried potato chips "amukeke", adds flavor and preserves consistency. In other countries, tamarind sauce is used to spice the snacks like chips, and an important ingredient of barbecue sauce (USA) or samosa (India). Sweet tamarind pulp is used to make jams [2,13].

- **Sweet fruits:** Sweet ripened fruits of sweet cultivars of Thailand are consumed as a snack by removing shell and seed [5]. Immature green pods are eaten fresh or boiled with porridge to give it a sour taste. Unripe fruit dipped in salt or wood ash is eaten as a snack. The tender, immature, very sour pods are cooked as seasoning with rice, fish and meats in India [2,13].

- **Sweet fruit pulp balls:** Pulp is extracted, dried or dehydrated to make fine powder. This is mixed with finely ground sugar to make balls. In some areas, the thick concentrated pulp is made into balls and rolled in fine sugar as a coating. The preparation depends on the sweetness of the pulp. If the pulp is highly sweet and it needs less sugar [6].

- **Tamarind pulp powder:** Tamarind puree is dehydrated and dried to get fine powder for use as chief acidulent of many food products. It is the richest natural resource of tartaric acid of 8-18 per cent, starch, minerals like calcium and potassium [14].

- **Tamarind rice:** Squeezed fruit extract of fresh tamarind pulp is boiled with spices, pulses, essential condiments after tampering with sesame oil, red chilli, mustard seeds, ginger and curry leaves. This mixture is added to freshly cooked rice and set aside to cool it down to room temperature, after making sure the rice is completely coated with the juicy mix of spiced tamarind pulp extract. This is good for a period of week at room temperature and will stay for more than three months in refrigerated storage. In grocery stores, readymade tamarind rice mix is also available in both wet and dry powder forms [6].

- **Tamarind Pickle:** Matured ripe fruit without shells and seed are used for making pickle by mixing with spices and salt. This pickle is good for one year without loss in quality and taste. In some regions of Andhra Pradesh in India, tamarind fruit pulp or fruit blocks are used to make vegetable (brinjal, moringa) pickles where tamarind serves as a preservative. All these pickles are good to eat with plain rice during lunch or with any breakfast items like idli, vada or dosa [4,6].

A recipe for tamarind pickle was reported from fresh mature tamarind fruits which are selected and soaked in clean water for 12 hours and the pulp is separated. For each kilogram of tamarind, one kilogram of sugar is added and boiled, stirring the mixture continuously. Then mixtures of spices are added. Spice mixture for one kilogram of tamarind should include the following: 40g coriander, 50g cumin seed, 30g black cumin, 3-4cloves, 3-4 pieces of cardamom, 3-4pieces of cinnamon, 10-12chillies, 30g salt, 250ml mustard oil and 30g black pepper. These are ground into a paste and added to the boiling tamarind and mixed thoroughly. The product is then packed into pre-sterilized glass jars or plastic bags and allowed to cool at room temperature. The pickle can be stored in cool dry place in small polythene bags or in clean jars and sealed [5].

Though recipe varies with region and consumer choice, the tamarind pickle or pickle made with tamarind as an ingredient is ready to serve food at room temperature throughout the year without loss in quality or nutritional value.

Tamarind chutney

This is eaten with rice or any rice product (idli, dosa, punugulu) in India. Green mature or immature fruits are used for making chutney in general to restore its values of nutrition and provide antioxidants to human's internal system. In some regions entire fruit

is ground with shell and green seed inside along with fried pulses, spices and condiments. In some areas, only mature pulp is used to make chutney my mixing pulses and spices. In both cases, oil and salt are used as preservative, black gram and mustard seeds, curry leaf, zeera for tampering and coriander for flavor and taste.

Tamarind rasam

It is a famous south Indian side dish for both rich and poor. It is eaten with rice and any deep-fried vegetable or chips or during the scarcity periods for vegetables in Andhra, Rayalaseema and Telangana regions. The recipe is simple and easy includes boiling of watery extract of dried ripe or matured fruit with preferred vegetables or with onion alone followed by tampering with black gram dahl, fenugreek, mustard seeds, curry leaf, coriander and red chilli. In some regions, this rasam is made without tampering, while in other regions it is made with black pepper. This rasam is treated as a good liquid medicine for children or adult suffering from cold, sore throat and fever and a light food for children or adult after recovery from fever for easy digestion and provide required nutrition and energy.

Tamarind drinks

Several kinds of drinks, either blended with soursop (Annona muricata) or carbonized, are made out of tamarind pulp. These drinks are consumed locally and internationally (South and Central America, Asia, Thailand, Indonesia, many countries of Africa, Mexico and Guatemala) during hot summer weather as effective coolant. Some local drinks are flavored with tamarind pulp extracts. Consumption of tamarind drinks is reported high in journals of Africa, might be because it is a zone of high temperature located near equator. These drinks generally contain 9-12 per cent pulp and 21.5o Brix, vary with the kind of drink. Some of the most commonly consumed drinks are described below.

- **Fruit juice concentrate:** made by squeezing the ripe fruit after soaking in water and removing fibrous material. It is used for flavoring porridge, millet bread and potatoes. fruit concentrate was used as a preservative of millet breads served during the times of war in Africa. Sometimes sugar or honey is added to enhance taste [13].

- **Tamarind juice:** Commerical product produced by small industries from concentrated extract by utilizing variation in tastes like sour, sweet and bitterness of fruit pulp from cultivars of Africa, Asian countries like India, Thailand, Pakistan [15]. Tamarind pulp is diluted with water and jaggery or sugar, or ginger or some spice of choice will be added to make ready to serve tamarind juice during summer. It is not pasteurized and will stay good for one day at room temperature.

- **Tamarind Beverage:** It is a diluted fruit concentrate and most commonly consumed drink by all ages in Africa. Tamarind pulp was manually separated from shells, seeds, and other foreign materials. About 1 g of tamarind pulp was mixed with 750 ml of water. Spices (ginger 0.6 g, clove 0.4 g) and sugar (27.5 g) were added. The mixture was sieved with fourfold layer muslin cloth. The beverage was packaged in sterilized glass bottles, corked, and pasteurized at 95°C for 8 min, cooled and stored to serve. This method was improved with greater storability up to 14 weeks without hampering nutritional quality (carotenoids, beta carotene, lycopene) with good color, ascorbic acid content (less sour) and sweetness over the traditionally used method of preparation where concentrated pulp was extracted, sieved, filtered, diluted(1:100) and heated in open pot at 40oC with high sugar content (275g), cooled and packed [16].

- **Tamarindade:** The liquid extract used for kids as a refreshing juice. It is obtained after shaking a sealed bottled containing tamarind fruit and water without any additives like sugar or salt or spices.

- Over all, tamarind fruit is as good as a mother in providing energy, nutrients in balance, fighting against malnutrition and keeping humans healthy.

Factors influencing post-harvest quality of fruit pulp and pulp products

The postharvest handling practices like harvesting, drying, dehulling, deseeding, packaging and storage played an important role in maintaining quality and extending shelf life pulp and products made from this pulp also fetch higher prices. The most common problems that were reported as quality hazards during postharvest tamarind ripe fruit or pulp storage are inappropriate environmental conditions and longer duration of the storage, insect pests, proper fruit processing method and packaging.

Environmental conditions leading to loss of ripe fruit or pulp quality

Reaction of sugars with amino acids through Maillard reaction is responsible for the non-enzymatic browning causing food quality losses, undesirable changes due to the formation of chemically stable and nutritionally unavailable derivatives known as melanoidins in food and agricultural products [8].

The browning, moisture, total soluble solid, acidity, reducing sugar, amino acids and anthocyanin content increases with the storage time. However, the pH, starch, total sugar, non-reducing sugar, total carbohydrate and phenols content decreases in all packaging

materials with increase in storage period [17]. During long term storage under poor storage conditions of temperature and humidity, the pulp loses its color to brownish yellow or black while at high moisture humid weather conditions it becomes soft and sticky due to moisture absorption and pectolytic degradation [18].

During transport, tamarinds are stored for 3- 4 weeks at a temperature of 7°C (45oF), 90-95 per cent relative humidity. Tamarind are highly sensitive to ethylene and chilling and hence stored at 10°C (50°F), 85-90 per cent relative humidity with proper ventilation upon receipt of the produce. Chilling injury was observed in mature fruits due to improper refrigeration, rarely caused losses due to physiological disorders and reduced the fresh and matured fruit quality. There were no observed losses from dried ripe fruits or fruit blocks [19, 20].

Microbial contamination

The high phenolic content in the peel makes the fruit highly resistant to attacks from pathogens. Pulp separated from peel has good keeping quality but is subjected to various molds in refrigerated storage. Majority of foodborne pathogens in tamarind fruit pulp and its products were eliminated by phytochemicals like alkaloids, saponins and glycosides present in the pulp. Antibacterial activity against *Staphylococcus aureus* >*Escherichia coli*> *Pseudomonas aeruginosa* was observed in decreasing order with an increase in pulp concentration up to 180 mg/ml [21].

The tamarind fruit blocks were observed with mold, sand, and larval excreta with eggs when purchased in an international isle of local grocery store in USA [22]. This might be due to negligence of the food inspectors or trusted commodity providers. The home-made products from the pulp extract were prone to contamination by bread mold if prepared the food product with moist hands, or any raw material of ingredients used in the food contains a microbial pathogen observed enhancing the spoilage during storage even under refrigerated conditions (Table 2).

The extraction and processing techniques of the pulp for the preparation of canned tamarind syrup, clarified tamarind juice and other soft drinks vary with the region. However, pasteurization of products or tamarind drinks to 185-190o F help in quality storage up to one year. The unpasteurized fruit pulp pastes or juices or drinks will stay for a day to one week at room temperature and for two weeks in refrigerated storage.

During storage of tamarind beverage, there might be microbial spoilage by bacteria and can be identified by changes in color of liquid (browning), pH, cloudiness and increased acidity. The reasons for spoilage might be due to hygiene during preparation from contaminated utensils, raw materials and the environment [16].

Paste and squash prepared from tamarind pulp when stored, total soluble solids (TSS), titratable acidity and sugar content increased, whereas, the amount of ascorbic acid decreased. Better quality of paste was prepared from 100g paste + 20g salt with 10ml oil + 20mg BHA (Butylated hydroxy anisole), followed by 100g paste + 15g salt with 10ml oil + 20mg BHA. Squash with 30% juice, 50% TSS, 1% acidity and 0.5% salt were superior to the other recipes. Both paste and squash made from tamarind pulp retained their characteristic color, aroma, taste and were microbiologically safe up to 3 months of storage at room temperature. In tamarind paste, the salt and acid showing an inhibitory effect on bacterial, fungal and yeast populations while in squash, sugar (55-70°Brix) was observed to show an inhibitory effect on pathogen growth [23].

Pulp or name of the food product containing tamarind pulp	Microbial contaminants observed	Possible reasons for observed contamination of food product
Kunu (gruel): Non-alcoholic beverage made out of millets. A few processing steps of kunu involve the use of tamarind solution.	**Bacteria:** *Bacillus sp., Escherichia Coli, Lactobacillus, Pseudomonas aeruginosa*. **Fungi:** *Aspergillus niger, Aspergillus fumigatus and Mucor circinelloides.*	Methods of processing of the raw materials, source of raw materials and locations.
Fruit Blocks	Beetles and larvae	During the packing or in storage
Tamarind drinks	Cloudiness due to fungi	Extended storage time
Fresh fully ripe or dehulled and deseeded ripe fruits	green mold	Humid moist climate immediately after harvest, Improper care in handling dried material during Sun drying in the open air.
Dried dehulled, fully ripe seeded fruits	Many larvae, eggs, sand, dried leaf and debris	Carry over from field, neglected processing practices and high labor cost to hire people at small scale, home based businesses.
Traditional foods made out of pulp (either bread porridge or tamarind rice or chutney) except rasam	Common foodborne pathogens like fungi and bacteria	Unpasteurized, Preparation errors including using wet and moist hands or from vessels used for storage.

Table 2: Possible contaminants observed in fruit pulp or pulp products. Source: [22,24].

Insect pests damage

Harvesting of fully ripe fruits with a moisture content of 22.5 per cent is good for pulp extraction or making dried fruit blocks. For this purpose, the fruits are left on tree until they are fully ripe, to allow complete drying of the shell and ease in harvesting. But the harvesting method depends on the purpose of post-harvest processing of tamarind fruit.

Fruit borers such as larvae of the cigarette beetle, *Lasioderma serricorne*, also of *Virachola isocrates, Dichocrocis punctiferalis, Tribolium castaneum, Phycita orthoclina, Cryptophlebia (Argyroploca) illepide, Oecadarchis sp., Holocera pulverea, Assara albicostalis, Araecerus suturalis* and *Aephitobius laevigiatus*, the fruit borer *Aphomia gularis*, the tamarind beetle *Pachymerus (Coryoborus) gonogra* and the tamarind seed borer *Calandra (Sitophilus) linearis* attack ripening pods before and after harvest. The rice weevil *Sitophilus oryzae,* rice moth *Corcyra cepholonica*, and the fig moth *Ephestia cautella* infest the fruits during storage. The borer *Rhyzopertha dominica* infests tamarind seeds during storage. Larvae of the groundnut bruchid beetle (*Caryedon serratus*) are serious pests that attack the fruit and seed in India [2].

In humid climates, fruit are readily attacked by bruchid beetle, *Pachymerus (Coryoborus) gonogra* (Coleoptera: Bruchidae) in India and Pakistan and fungi, and should therefore be harvested before they are fully ripe. The eggs of this insect are laid on the pods or on seeds whose contents are eaten by the larvae. The infestation frequently continues in storage. Storage pests like beetles, Indian meal moth (*Plodia cautella*), and fruit borers were observed in fruit blocks during storage causing uncontrollable damage and spread of young larvae hatched from eggs carried through fruits and larval excreta [5].

Processing method

In India, sun dried pulp is mixed with salt (10% salt or 10g salt per kg pulp) and packed in leaf mats, polyethylene, jute bags, in bamboo or wooden boxes and stored in cool dried places for more than 35 years [18]. In East India, the pulp is covered with salt, rolled into balls, exposed to the dew and stored in earthenware jars, whereas in Java, the salted pulp is rolled into balls, steamed and sun-dried, then exposed to the dew for a week before packing in stone jars. In Sri Lanka, the dried pulp is mixed with salt, packed in clay pots and kept in a dry place; seedless pulp is stored in plastic bags in retail shops [2,25].

The processing methodologies reported by both El Siddig [5] and Yahia and Salih [2] are a point of quality concern with regards to "exposure to the dew before packing" which is not generally advisable and adopted because of scientific reasons. Dew is having moist air might be absorbed by dried pulp and enhance contamination by unknown microbial load inside post-harvest packed containers.

Enhanced storability of improved tamarind beverages, upon addition of sodium benzoate (100mg/ml) as a chemical preservative, from 3-5 weeks to 6-14 weeks was observed both at room (29 ± 2°C) and refrigerated (4-10°C) conditions [16].

Packing material

Tamarind blocks can be stored for six months when packed with high density polyethylene (HDPE) at 10oC temperature and darkening was reduced when stored in 800 guage bags [14,26]. Tamarind when packed in 520 gauge high density polyethylene (HDPE), the extent of change (increase or decrease) in chemical constituents of tamarind pulp briquettes was found less and received high consumer acceptability followed by 250 gauge medium density polyethylene (MDPE), 150 gauge low density polyethylene (LDPE) and 75 gauge linear low density polyethylene (LLDPE) as compared to control without packaging tamarind briquettes stored in mud pots [17]. Large plastic containers (crates) close to 600 mm x 400 mm x 300 mm were used in Myanmar for the handling and transportation of fresh tamarind fruit [27].

Therefore, possible care should be taken from harvesting, during transport and storage of ripe fruits or pulp by maintaining favorable content of moisture and organic acids, temperature, pH, amino acid to sugar ratio for quality, better price and marketability (Table 3).

Possible health hazards in an animal or human population due to tamarind consumption or incidence of microbial contamination in tamarind products

No hazardous effects on human health were reported from consumption of any tamarind-based food products or tamarind drinks. Appearance of coliforms in improved tamarind beverage with an overall acceptability score of 5.9 was used as deterioration index for better quality beverage and its storage [16]. This article forms the basis to convey that processing industries eliminate the possible hazards of microbial contaminations during processing of raw material by following strict quality control measures.

Aqueous and ethanolic extracts of the fruit pulp is a potential source of antimycotic agent to combat the challenge of the emergence of drug-resistance in *Candida albicans*, a human pathogen and the need to produce more effective antimicrobial agents like this to control life threatening human fungal pathogens. Presence

of alkaloids, tannins and reducing sugars in the ethanol extract and glycosides, saponins and reducing sugars in aqueous extract might be the reasons for this antimycotic activity [28].

Post-harvest stage of matured and ripened tamarind fruit	Critical quality control check points during the processing of tamarind fruit pulp
Fully mature fruits before harvest	Thorough evaluation of the selected trees for an insect pest or pathogen population. Selection of fruit pulp quality, shape and size from randomly selected fruits and trees in the orchard.
Fully ripe fruits during the period of harvest	Checking the density of the fruit, moisture content of pulp in the dried fruit, per cent separation of shell from the pulp. If the required standards are not met, better leave the fruits on tree and delay the harvest for eliminating processing difficulties and associated contamination. Both mechanical and manual methods can be adopted depending on the soil and climate compatibility.
Fully ripe and dried fruits with shell after harvest	Immediately after harvest, dry the fruits in clean open place under Sun. Manually check for any contaminants and visually. This is the critical step for downstream processing.
Dehulling and Deseeding	Mechanical and manual methods can be adopted after thorough examination of men and material. Before proceeding to the next step, check for visible contaminants of fibrous debris, pathogen or soft and soggy fruits to eliminate.
Drying of processed fruits after removal veins, seeds and shells	The cleaned fruits should be dried by turning upside down at frequent intervals during sun drying or by using mechanical dryers.
Packing of dried cleaned fruits	Making fruit blocks by using mechanized compressors, or Packing with 520gauge HDPE material or sterile plastic or wooden bags or locally available material with or without additives like salt depending on the marketer requirement. If the material is intended for pulp or paste or puree or pulp powder, maintain the quality standards as recommended

Table 3: Critical steps for transport and long-term storage of tamarind fruit pulp and pulp products.

Source: [22,26,27].

Food contamination outbreaks or recalls listed by US-FDA (www.fda.gov)

Mexican style soft and hard candies, contain tamarind pulp as an ingredient, were recalled with unacceptable lead levels. The possible elevated lead (0.014ppm) contamination was attributed to leached lead from chili or from lead glazed bowls and was observed in Mexico [29]. In 2001, the food and drug administration (FDA) warned consumers to avoid purchasing or consuming tamarind candy lollipops labeled "Dulmex" brand "Bolirindo" because of high levels of lead that may be associated with the product - especially its wrapper. It is soft dark brown tamarind fruit candy lollipop on a white or orange stick mostly distributed in south western states of USA like in California. Children and people who eat high levels of lead or effected by lead toxicity exhibit symptoms of stomach aches, colic, nausea, vomiting, abnormal irritability, and insomnia, and might lead to neurological disorders. Similarly, FDA on August 17, 2001, Villarreal Distributors of San Antonio, Texas, recalled over 20,000 candy containing clay pots of "JARRITOS" brand Tamarindo candy. The reasons for contamination here was leaching of lead as high as 4.60ppm from clay pots [30]. These reports confirmed that tamarind pulp is pure from any kind of toxicities, and there might be other reasons for leaching of lead from serving containers.

Tamarind being a product with many acids and biochemicals, it is not a bad idea to research various types of metal and plastic containers and study the level of leaching or interaction of biochemicals in tamarind containing food and chemicals present in the containers. Because, tamarind is used in India to clean copper containing brass and bronze (copper and tin) vessels from corrosion (green color) developed due to oxidation over a period of time in storage. Therefore, use of these vessels for tamarind storage or serving such food items is not recommended.

Consumers might assume dark color pulp developed due to long time storage with an unknown microbial contamination. The microbial contamination was reported only in the products prepared from tamarind pulp and these reports were very scarce conveying the contamination is a human error but not tamarind pulp and quality attributes.

Conclusion

There are four other kinds of tamarind locally available in India and Africa, with a different and genus and species. The wild, single seeded, velvet tamarind, *Dialium guineense* [8], and other wild types [4,6] and the cultivated 2000 genotypes [5,7] of tamarind are

a good resource brought forth to the scientific table to develop industrial use seedless tamarind cultivars. Lot of literature on insect pest damage of tamarind fruits before and after harvest, development of efficient genetic and biological control methods would be beneficial.

Acknowledgement

Authors like to thank Mr. Pradeep Kumar Sripathi, IT (Information Technology) professional for providing a computer and high-speed internet facility to search available literature and successfully complete this review article on time. Authors also like to thank one of our coauthors Dr. Pessarakli Mohammad and Dr. Umesh K Reddy for providing us ample opportunity and encouragement to write peer review articles of this kind for handbooks and journals.

Bibliography

1. Divakara BN. "Variation and character association for various pod traits in *Tamarindus indica L"*. *Indian Forester* (2008): 687-696.

2. Yahia EM and Salih NK-E. "Chapter 22: Tamarind (Tamarindus indica): Post-harvest biology and technology of tropical and subtropical fruits". *Woodhead publishing limited* (2011): 442-457.

3. John AP and Tamarind. A review report from centre for the energy and environmental research, university of Puerto Rico, Rio Piedras, Puerto Rico, in collaboration with USDA-Forest Service 5.1 (1990): 1-3.

4. Narina SS and Catanzaro CJ. "Tamarind (Tamarindus indica L.): An underutilized fruit crop with potential nutritional value for cultivation in the United States of America". *Asian Food Science Journal* 5(2018): 1-15.

5. El-Siddig K., *et al.* "Book on Tropical fruit trees "Tamarind (Tamarindus indica L.)" Edited by Williams JT., Smith RW., Haq N., and Dunsiger. Published in 2000 by the International centre for underutilized crops, University of Southhampton, Southhampton, SO17 1 BJ, (2006):1-198.

6. Satya SS Narina., *et al.* "Book Chapter 44: Moringa and Tamarind-Potential drought tolerant perennial crops with nutritional values. In: Pessarakli, M (ed) Handbook of Plant Crops and Stress. CRC Press, Taylor and Francis Group, Boca Raton, Florida, USA, (2019a): 817-835.

7. Catanzaro., *et al.* "A mini review on Tamarind (Tamrindus indica L.) for Induction of Ornamental Phenotype and Seedlessness in fruits". *Actascientific Nutritional Health* (2019b):1-9.

8. Obulesu M and Bhattacharya S. "Color Changes of Tamarind (Tamarindus indica L.) Pulp During Fruit Development, Ripening, and Storage" *International Journal of Food Properties* 14 (2011): 538-549.

9. Santosh SB., *et al.* "Tamarindus indica L: the extent of explored potential". *Pharmacolognosy Reviews* 5(2011):73-81.

10. Kuru P. "Tamarindus indica L. and its health-related effects". *Asian Pacific Journal of Tropical Biomedicine* 4(2014):676-681.

11. Rao YS and Mathew KM. "Book chapter26: Tamarind. Spices Board of India, India". Woodhead Publishing Limited (2012): 512-534.

12. Iskandar I., *et al.* "Six-Month Chronic Toxicity Study of Tamarind Pulp (Tamarindus indica L.) Water Extract". *Scientia pharmaceutica* 85(2017):10.

13. Edifa-Othieno E., *et al.* "Knowledge, attitudes and practices in tamarind (Tamarindus indica L.) use and conservation in Eastern Uganda". *Journal Ethnobiology and Ethnomedicine* 13 (2017): 5.

14. Shankaracharya NB. "Tamarind chemistry, technology and uses - A critical appraisal". *Journal of Food Technology* 35 (1998): 193208.

15. Diallo BO., *et al.* "Breeding system and pollination biology of the semidomesticated fruit tree, Tamarindus indica L. (Leguminosae: Caesalpinioideae): Implications for fruit production, selective breeding, and conservation of genetic resources". *African Journal of Biotechnology* 7 (2008): 4068-4075.

16. Adeola AA and Aworh OC. "Effects of sodium benzoate on storage stability of a previously improved beverage from tamarind (Tamarindus indica L.,)". *Food Science and Nutrition* 2(2014): 17-27.

17. Bhagawat Kumar, Studies on storage stability of tamarind (Tamarindus indica L.) Briquettes packed on different flexible packaging material. M.Tech. (Agril. Engg.) Thesis. Submitted to The Department of Agricultural processing and food engineering, Swami Vivekanand College of Agril. Engg. and Technology and Research Station faculty of Agril. Engg., Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chattisgarh (2015): 292.

18. Bhagwat Kumar., *et al.* "A Review on Post harvest handling practices of tamarind (Tamarindus indica L.) fruits". *Trends in Biosciences* 11 (2018): 565-567.

19. Kitinoja L and Gomy JR. "Post-harvest horticulture series Postharvest Technology for Small-Scale Produce Marketers: Economic Opportunities, Quality and Food Safety. The department of Pomology, University of California, Davis Postharvest Technology Research and Information Center, A publication of the UC Postharvest Technology Research and Information Center In association with the USAID/Agricultural Commercialization and Enterprise Project (ACE· India), (1999): 386.

20. Kitinoja L and Kader AA. "Post-harvest horticulture series No.8E. Small Scale Postharvest Handling Practices: A Manual for Horticultural Crops (5th edition). Published by the University of California, Davis Postharvest Technology Research and Information Center (2015): 283.

21. Abukakar MG., *et al.* "Phytochemical screening and antibacterial activity of Tamarindus indica pulp extract". *Asian Journal of Biochemistry* 3(2008):134-138.

22. Personal Communication. Consumer standards and quality of postharvest food produce. (Draft in progress, unpublished) (2008).

23. Pattar., *et al.* "Standardization of recipes for tamarind paste and squash". *Journal of Horticultural Science* 8 (2013): 282-287.

24. Awache I., *et al.* "Microbial Quality of Millet-Based Kunu (Gruel) Made with Aqueous Tamarind (Tamarindus indica L.,)". *AASCIT Journal of Biology* 3 (2017): 14-18.

25. Gunasena HPM. "Domestication of agroforestry trees in Sri Lanka". Proceedings of the Regional Workshop on Domestication of Agroforestry Trees in Southeast Asia. A publication of Winrock International in collaboration with ICRAF. Yogyakarta, Indonesia (1997): 49-53.

26. Nagalakshmi S and Chezhiyan N. "Investigation on the postharvest deterioration of tamarind (Tamarindus indica L.) pulp during storage. Unpublished PhD thesis, Tamil Nadu Agricultural University, Coimbatore (2001).

27. NAPA. "National Action Plan for Agriculture. Working Paper 13: Post-Harvest and Agro-industry. Horticulture crops, page 15, Formulation and Operationalization of National Action Plan for Poverty Alleviation and Rural Development through Agriculture, Organized by Government of the Republic of the Union of Myanmar in Yongon (2016): 40.

28. Adedayo MR., *et al.* "Antimycotic and phytochemical screening of the fruit pulp extract of Tamarind (Tamarindus indica) on Candida albicans". *Journal of Microbiology and Antimicrobial Agents* 2 (2016): 16-21.

29. US-FDA. United States Food and Drug Administration. Mexican style candy with tamarind pulp as an ingredient. Guidance for Industry: Lead in Candy Likely to Be Consumed Frequently by Small Children: Recommended Maximum Level and Enforcement Policy (2006).

30. US-FDA. Center for Food Safety and Applied Nutrition (2001).

Volume 2 Issue 12 December 2019