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Physicochemical, antioxidant, antinutritional and sensory properties of tamarind (Tamarindus indica)

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Abstract

The sweet, acidic pulp of the tropical fruit known as the tamarind (Tamarindus indica, Fabaceae), which is found throughout Africa and Asia, is highly prized. Ethiopia's Dire Dawa is home to a large tamarind consumption. This study aimed to investigate the physicochemical, antioxidant, antibacterial, antinutritional, and sensory properties of tamarind indica pulp under different processing conditions (roasted and soaking). As a remedy, tamarind pulp that had been raw, steeped, and roasted was utilized. These treatments were examined for their antinutritional capabilities using the disc diffusion method, their proximate composition using gravimetric analysis, their antioxidant and antinutritional components using UV spectrophotometry, and their sugar profile using HPLC. All but crude fat showed a significant ($p<0.05$) difference in proximate composition between the soaked, roasted, and control samples. The mineral profile revealed the presence of calcium, magnesium, manganese, sodium, and potassium, and a significant difference ($p < 0.05$) was found between the treatments. The antinutritional analysis showed that both soaked and roasted tamarind had a significant reduction in tannin, phytate, and oxalate. Tamarind fruit extract had 76.12 µg/mL, 79.86 µg/mL, and 105.51 µg/mL antioxidant activity in the DPPH assay for control, soaked, and roasted treatments, respectively. In comparison to the control treatment, the results showed that soaking and roasting enhanced the nutritional profile, antioxidant and sensory qualities, and decreased the antinutritional aspects. This could be helpful input for making the most of and promoting the traditional uses of tamarind in the community.

1. Introduction

Tamarind, scientifically known as Tamarindus indica L., whose fruit belongs to the dicotyledonous family Leguminosae, sub-family Caesalpinioideae, is an important underutilized food plant in the tropics [1]. Every part of the Tamarindus indica (T. indica) plant (root, body, fruit, and leaves) not only has rich nutritional value but also has broad usage in medicine and industry [2]. There are different varieties of Tamarindus indica, which are mostly divided into acidic and sweet varieties. Acidic varieties are commonly found in most countries and therefore easily develop in warm and sunny locations. The varieties of sweet type are not readily available [3]. Tamarindus indica fruits provide two important products, namely pulp and seed. In Dire Dawa, Ethiopia, the pulp is mostly eaten directly or used for making local food and drinks and sold for domestic income, whereas the seeds are obtained after depulping the pod. The seeds, which are rich in protein [4], are usually thrown away in Dire Dawa [4].

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 [5]. 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 [5, 6]. Though the nutritional composition of tamarind fruit pulp varies with geographical conditions [3], the nutritional composition, antioxidants, and antinutritional factors of tamarind fruit grown in Dire Dawa were not investigated. There are many plant-based traditional fermented beverages in Ethiopia. In everyday life, people consume beverages, particularly when having guests on holidays [7]. Dire Dawa is an administration region found east of Addis Ababa, at a distance of 520 km. According to the Central Statistical Agency (2008) [8], Dire Dawa has 341,834 inhabitants of different ethnic groups. In Dire Dawa, tamarind fruit was widely used in raw and processed forms. Tamarind juice is widely used in Dire Dawa for household consumption in the form of juice locally called Roka juice. Roka juice is made from ripened

tamarind pulp after removing the seed coat. Usually, 1kg of tamarind pulp is soaked in 2 liters of water for 6 hours and then separated using a sieve (Figure 1). The filtrate is mostly used for stomach aches and to avoid thirstiness due to the hot environment. According to Shlini & Murthy [9], geographical conditions, processing conditions, types, and parts of tamarind have a higher effect on nutritional value, anti-nutritional factors, and antioxidant factors. In this study, different processing methods (soaking and roasting) were applied to tamarind pulp, and the products were characterized for nutritional composition, antioxidant, antimicrobial, antinutritional, and sensory characteristics.

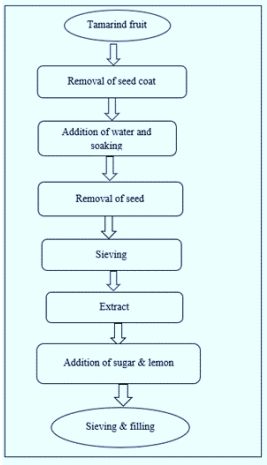

Fig. 1. Juice making adapted from traditional knowledge of the community.

2. Materials and methods

2.1. Materials

Tamarind indica fruit was collected from a local Dire Dawa, Kefira market trader. The fruits were taken to the Addis Ababa Science and Technology Food Science and Applied Nutrition Laboratory for further analysis. Tamarind indica were sorted to remove dirt and bad fruits. After removing the dirt, the tamarind fruit was washed and the raw tamarind fruit was soaked and roasted for analysis.

2.1.1. Soaking

Soaking is a simple technological treatment that helps prolong the obligatory washing of the seeds and can also have advantages, such as facilitating the dehulling or swelling of the seeds [10]. Accordingly, 500g of tamarind fruit was soaked for ½ days in 500 mL of water to facilitate easy removal of the seed coats. The sun-dried seed kernel for 24 hours and milled into flour using a Laboratory mini grinder (FW 100). The milled flour was sifted through a 1mm mesh sieve and packaged in an airtight container.

2.1.2. Roasting

Roasting of tamarind pulp was done using Huang et al. [11]. Accordingly, 500g of tamarind fruit was roasted in a microwave oven (MW 73AD, 2013) at a temperature of 1000 °C for 10 minutes, and the seed was dulled after roasting. The roasted fruit pulp was milled into flour using a Laboratory mini grinder (FW 100). The sample was sieved with a 1mm mesh sieve to obtain fine flour and packaged in an airtight container for further analysis.

2.2. Physicochemical analysis

2.2.1. pH and acidity

The pH of the tamarind samples was measured based on AOAC (2000) [12] official method number 943.02 using a pH meter (AD 8000 pH/MV/EC/TDS & T0 Bench Meter, Romania). Buffer solutions of pH 4.0 and 7.0 were used for periodic calibration of the pH meter. Three readings were performed for each replicate. The total titratable acidity of the tamarin was determined according to ES ISO 1842 by titration, using 0.1N sodium hydroxide with phenolphthalein. The results are expressed as % tartaric acid, using the weight of the molar mass of tartaric acid as the equivalent weight of acid [13].

2.2.2. Moisture

The moisture content of the samples was determined by AOAC (2000) [12] method number 925.10. Moisture content was expressed as the percentage weight (%) and was calculated by the following equation:

$$WC\ (\%) = \frac{W_1 - W_2}{W_2} x100 \quad (1)$$

Where, MC= moisture content, W_1 = Weight of the wet sample, W_2 = weight of the dry sample.

2.2.3. Ash

The ash content was determined by using AOAC (2000) [12] method number 941.12. Total ash content was expressed as the percentage weight (%) and was calculated by the following equation:

$$AC\ (\%) = \frac{m_1 - m_2}{m_3} x100 \quad (2)$$

Where, Ac = Ash content, m_3 = weight of Tamarind fruit, m_1 = weight of crucibles and ash, m_2 = weight of crucibles.

2.2.4. Protein content

Protein content was determined according to AOAC (2000) [12] using the official method number 979.09. Protein was determined by estimating the amount of nitrogen (Model 3) in the sample and subsequently multiplied by a factor of 6.25.

$$\%N = \frac{B_{H2SO4} \text{xN H2SO4 (0.1)x14.00}}{\text{W}} x100 \quad (3)$$

Where, V= volume of H_2SO_4 in mL consumed to the end point of titration, N= the normality of H_2SO_4, W= sample weight on dry matter basis.

%Protein = % N×6.25.

2.2.5. Crude fat

Five (5) g of Tamarind sample was taken, and it was determined by using AOAC, (2000) [12] method number 4.5.01 using Soxhlet apparatus (BUCHI E- 812) plus hexane as extraction solvent. Fat % can be calculated using the following formula.

$$F\ (\%) = \frac{\text{FW} - \text{BW}}{SW} x100 \quad (4)$$

Where, F% = % crude fat, FW= Final weight, BW= Beaker weight, SW= sample weight.

2.2.6. Crude fiber

One (1) g of Tamarind sample was taken for the analysis. The crude fiber content of the Tamarind sample was quantified by using ISO 6865, Official Method (2000) [12] with a concentration of 0.15M H_2SO_4 and 0.23 M of KOH. Followed by half filtration using a sintered crucible. % crude fiber was calculated by

$$CF\ (\%) = \frac{\text{W}_2 - \text{W}_3}{W_1} x100 \quad (5)$$

Where, W_1= weight of the sample, W_2 = weight of crucible and residue after drying, and W_3= weight of crucible and residue after incineration.

2.2.7. Determination of total carbohydrates

The total percentage of carbohydrates was determined by the difference. This involves, adding crude protein, crude fat, crude fiber, and moisture and ash constituents to the sample and subtracting them from 100 [14]. The percentage of carbohydrate was calculated using the following relation:

Total CHO = 100 - (% crude protein + % crude fat + % crude fiber + % moisture + % ash). (6)

2.2.8. Sugar content

Five (5) g of tamarind sample was taken, and the extracted sugar was determined using a high-performance liquid chromatograph (Agilent 1260 infinity, G7111B) equipped with a differential refractive index (DRI) detector (AOAC, 2000, method no. 977.20) [12] with some modifications. The mobile phase was acetonitrile and water (80:20 v/v) with a flow rate of 2 mL/min. The final injection volume was 25 µL. The result was calculated as follows:

$$S.C = \frac{S \times C}{S} x100 \quad (7)$$

Where, S.C = sugar concentration, S = sample taken, and C = concentration from the standard curve.

2.2.9. Mineral profile

Five (5) g of the tamarind sample was taken, followed by dry ashing. 5mL 6M HCl was added to each sample. The residue of the sample dissolved in 30 mL of 0.1M HNO3 and kept for 1 hour. The mineral profile of tamarind fruit pulp was measured based on AOAC (2000) [12] 999.11 Official Method using ICP-OES (inductively coupled plasma optical emission spectrometry). Mineral content was calculated using the following formula:

$$M.c = \frac{[(a-b)*v]}{f*w} \quad (8)$$

Where; M.c = mineral content, W = weight of samples (g); V= volume of extract (mL); a = concentration of sample solution (µg/mL); b = concentration of blank solution (µg/mL), and f= dilution factor.

2.3. Antioxidant determination

Sample extraction was done based on Samar et al. [15] with some modifications. 5 g of the tamarind sample was extracted by 50 mL of methanol in a shaker for 24 hours, and the extract was filtered with Whatman filter paper (grade 1, diameter of 150 mm, 11µm pore size). 50 mL of methanol was again added for recovery, shaken for 2 hours, and then filtered. The filtered extract was transferred to a round bottom flask and put in a rotary evaporator (RE-2000A, Germany) until the methanol evaporated. Then, methanol was added to the sample, and it was stored in the refrigerator at 4 °C.

2.3.1. Total phenolic content

Phenolic compound determination was performed using the Folin-Ciocalteu method by UV Vis mass spectrophotometry (Lambda 950 UV-Vis, Agilent Technologies) [16] with slight modifications. The reaction mixture consists of 1 mL of extract and 9 mL of distilled water, which was taken in a volumetric flask (25 mL). One milliliter of Folin-Ciocalteu phenol reagent was added to the mixture by shaking well. 5 minutes later, 10 mL of 7% sodium carbonate (Na_2CO_3) solution was added to the mixture, and the total volume of the mixture was made up to 25 mL by deionized water. A set of standard solutions of gallic acid (20, 40, 60, 80, and 100 µg/mL) were prepared in the same fashion as described earlier and incubated for 90 min at room temperature. The absorbance for test and standard solutions was determined against the reagent blank at 550 nm (Lambda 950 UV-Vis, Agilent Technologies, Germany).

DPPH free radical-scavenging activity

2.3.2. Flavonoid content

Flavonoid content was determined using the method of Muanda et al. [17]. In brief, 0.5 mL of catechin standard solution was mixed with 2 mL of deionized water and 0.15 mL of sodium nitrite (5% w/v). After 5 minutes, 0.15 mL of 10% aluminum chloride was added, followed by the addition of 1 mL of molar sodium hydroxide after another 6 minutes. Finally, distilled water was used to adjust the total volume to 5 mL, and absorbance was read at 510 nm (Lambda 950 UV-Vis, Agilent Technologies, Germany). A standard calibration curve was plotted using different concentrations of catechin (0.002 to 0.125 mg/mL). Total flavonoid content values were expressed in milligram catechin equivalents per 100 mL of juice (mg CE/100 mL).

2.3.3. DPPH free radical-scavenging activity

The determination of antioxidant activity was done using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method. The antioxidant activity of different concentrations (0.78–100 mg/mL) of tamarind extracts was dissolved in methanol and measured in terms of hydrogen donating or radical scavenging ability, using the stable radical DPPH. The results were expressed in % inhibition as the mean of three replicates [18].

$$I\ (\%) = \frac{(Ac-As)}{Ac} * 100 \quad (9)$$

where, I (%) = percentage of inhibition, As = Absorbance of sample and Ac =Absorbance of control.

2.3.4. Ferric reducing antioxidant power

The FRAP (Ferric reducing/antioxidant power) assay was performed as previously described by Lee et al. [19] with slight modification using a spectrophotometer with the function of an auto-rate assay. The FRAP reagent was prepared by mixing 2.5 mL of TPTZ (10 mM in 40 mM HCL), 2.5 mL of acetate buffer, and 2.5 mL of FeCl3.6H20 with distilled water. The solution was incubated at 370 °C for 15 minutes. The concentration of the standard (200, 500, and 800 µl/mL) was taken, and tamarind sample extract and methanol were added to make 1000 µL/mL. Then, 3 mL of FRAP reagent was added to each sample and incubated for 30 min. The standard used was ascorbic acid, and it was also prepared at concentrations of 200, 500, and 800 µl/mL. Then 3 mL of prepared fresh FRAP was added to the standard and incubated for 30 min, and the absorbance was measured at 593nm.

2.4. Antinutritional property

2.4.1. Tannin content

Tannin content was determined based on Akajiaku et al. [20]. About 0.2 g of the dried fruit pulp was weighed and extracted with tannin for 5 hours. Standard solutions of tannic acid were prepared ranging from 10 to 50 ppm, and their absorbance was read at 500 nm on a spectrophotometer (Genesys 10-UV spectrophotometer, Thermo Electron Corporation). The absorbance of the filtrate was also measured at this wavelength, and the percentage tannin was calculated as follows:

$$Tannin\ (\%) = \frac{Absorb.(sample) \times slope\ average\ gradient \times dilution}{10{,}000} \quad (10)$$

2.4.2. Phytate

Phytate content was determined using the method of AOAC (2000) [12], method number 986.11. Accordingly, a 0.1 g Tamarind dried sample was extracted with 10 mL of 2.4 % HCl for 1 hour at ambient temperature and centrifuged (Eppendorf 5425) at 3000 rpm for 30 min. Absorbance was measured at 500 nm using a UV spectrophotometer. The concentration of phytate was calculated using the phytic acid standard curve, and the results were expressed as phytic acids in mg per 100 g fresh weight.

2.4.3. Oxalate

Oxalate was determined using the titration method based on Ijarotimi & Keshinro [21]. One gram of tamarind fruit sample was weighed and added to a 100-mL conical flask. A 25-mL extract was collected from a filtered sample and titrated against a hot 0.1 N $KMnO_4$ solution to the point where a faint pink colour occurred that persisted for at least 30 sec. The total concentration of oxalate in the samples was obtained from the calculation:

1 mL 0.1 permanganate = 0.006303 g oxalate (11)

2.5. Antimicrobial Activity

Tamarinds' antibacterial activity was tested against bacterial strains of E. coli and S. aureus using the disk diffusion method. Tamarind pulp extracts of soaked, roasted, and control treatments were administered to each strain, and the zone of inhibition was measured using a Verniercaliper (Mitutoyo, 530-119, Japan). The diameter of zones, including the diameter of the well, was recorded [22].

2.6. Sensory properties of tamarind juice

Tamarind juices were evaluated by the effective method of sensory analysis in the Addis Ababa Science and Technology University sensory laboratory. Accordingly, 70 consumer panelists (35 female and 35 male) were used to assess the acceptability of tamarind juice using a 7-point hedonic scale (7 like very much to 1 dislike very much) for the attributes of taste, colour, aroma, sweetness, and overall acceptability of the tamarind juices. The panellists were presented with 50 mL of each juice sample at room temperature under normal lighting conditions. The flowchart for tamarind juice making was done based on Adeola & Aworh, [23], with some modifications

2.7. Statistical analysis

All the analyses were carried out in triplicate, and the means and standard deviation (SD) were determined for each treatment. Treatment means comparisons for ANOVA and significance difference ($p< 0.05$) were determined using SPSS version 20.

3. Results and discussion

3.1. Moisture content

The mean±sd value for moisture content of tamarind fruit for soaked, roasted, and control was stated in Table 1. The highest value of moisture was 17.67±0.58 (control), and the lowest value was 10.00±0.00 (Roasted). There was a significant difference ($p<0.05$) between the treatments (soaked, roasted, and control). The result of this study was in agreement with the report of Rana & Sharma (16.82±0.2) [24]. The significant difference between the treatments could be due to the variation in processing temperature used for soaking and roasting [20].

3.2. Ash content

The mean±sd value of the ash content of the tamarind sample is stated in Table 1. The highest value of ash was 3.90±0.10 (roasted), and the lowest value was 3.17±0.15 (control). There was a significant difference ($p < 0.05$) between among the three samples. This was in agreement with the result of Akajiaku et al. [20]. The result found from this study was lower (6.24%) than the study of Ishaku et al. [25]. The roasted tamarind sample had the highest value of all the samples. According to Olanipekun et al. [26], the low value of ash in the raw sample could be a result of the binding effect of antinutrients on the mineral contents of the food sample, and they reported that antinutrients could interfere with the bioavailability of minerals.

3.3. Protein content

The mean±sd value for protein content of tamarind fruit is described in Table 1. The highest value of protein was 6.91 ± 0.19 (roasted), and the lowest value was 6.13 ± 0.25 (soaked). There was a significant difference ($p < 0.05$) between the roasted and soaked samples. A significant difference ($p < 0.05$) was also observed between the control and soaked sample. However, there was no significant difference between the control and roasted samples. The result of this study was in agreement with Agume et al. [27], who reported that the total proteins were significantly ($p < 0.05$) affected by soaking, with a decrease in total protein content. The protein content of tamarind fruit from different varieties was between 3.5 to 7.4 [28]. Olanipekun et al. [26], reported that the value of protein in the processed kidney bean seeds increased due to the breakdown of crude protein into amino acids during processing. According to Mbah et al. (2012) [29], when roasting is subjected to food, the activity of proteolytic enzymes increases as a result.

3.4. Crude fat

The mean±sd value for fat content of tamarind fruit was 1.96±0.06 (control), 1.92±0.02 (soaked), and 2.03± 0.07 (roasted) (Table 1). The highest value was 2.03± 0.07 (roasted), and the lowest was 1.92±0.02 (Soaked). There was a significant difference ($p < 0.05$) between soaked and roasted tamarind pulp. This was in agreement with the findings of Shlini & Murthy [9] and Akajiaku et al. [20]. Roasting has an effect on degrading different components; nevertheless, soaking affects depleting the fat content [26]. However, as confirmed by the present study and other similar studies by Akajiaku et al. [20] and Shlini & Murthy [9], the edible pulp of tamarind fruit is relatively low in fat content, but the seed is a good source of both protein and oil, which need further investigation.

3.5. Crude fiber

The mean±sd value for fiber content of tamarind fruit is stated in Table 1. The highest value was 6.85± 0.06 (soaked), and the lowest was 5.65±0.02 (roasted). There was a significant ($p < 0.05$) difference between treatments (soaked, roasted, and control). This was in agreement with the result of Akajiaku et al. [20]. 6.15–6.30 g/100g. The roasted tamarin had the least value and showed that roasting can decrease fiber content. However, the soaked tamarin showed an increase in fiber content. This was in line with the report by Shlini & Murthy [9] that soaking decreases the fiber content of tamarind seed.

3.6. Carbohydrate

The mean±sd value of total carbohydrate was stated in Table 1. The highest value of total carbohydrate was 70.97±0.10 (roasted), and the lowest value was 63.79±0.06 (control). There was a significant difference ($p < 0.05$) between the treatments. This was in agreement with the report of Ishaku et

al. [25]. The carbohydrate values obtained were found to be higher than those of some earlier investigation by Rana and Sharma [24] (35.56±0.2). Both soaking and autoclaving can increase the carbohydrate content of tamarind fruit pulp [9].

3.7. pH and titratable acidity

The pH and titrable acidity of tamarind juice are stated in Table 1. The highest pH value of the tamarind was 4.13±0.06 (soaked), and the lowest was 4.03±0.06 (Control). The total titrable acidity of tamarin ranged from 0.13 to 0.14. There was no significant difference ($p > 0.05$) in the titratable acidity of the tamarind juice. This was in agreement with the report of Oluseyi and Temitayo [14]. In this study, the high pH and titrable acidity of tamarind juice were reported to be due to the high sugar content of tamarind. The pH value was similar to the report of Sulieman et al. [30]. It showed that there was no significant ($p > 0.05$) difference between the soaked and control tamarind pulp. According to Natukunda et al. [13], the reduction of total titratable acidity is consistent with the increase in pH.

3.8. Mineral profile

The mean±sd value of the mineral profile is stated in Table 2. The highest value of calcium was 588.56±0.46 mg/g (Roasted), and the lowest value was 459.95±0.74 mg/g (Control) (Table 2). A significant difference ($p < 0.05$) was found between the three treatments. This was in agreement with the report of Bashir et al. [31] that roasting has an effect on the Ca content of tamarind and is known to increase the Ca content compared to raw tamarind. Olagunju et al. [32] also reported that soaking increased the Ca content. The result of Ca in this study was in line with Suleiman et al. [30]. Food processing may produce either beneficial or deleterious effects on nutrient bioavailability. Regarding minerals, processing could increase the content of some minerals, destroy some inhibitors, or form beneficial complexes between minerals and matrix components [33].

The mean±sd of magnesium content of the tamarind fruit sample is stated in Table 2. The highest value of magnesium was 219.60±0.02 mg/g (Roasted), and the lowest was 194.78±0.00 mg/g (Control). There was a significant difference ($p < 0.05$) between treatments. This was in agreement with the reports of Akajiaku et al. [20], Ishaku et al. [25], and Bashir et al. [31]. The high content of magnesium in roasted tamarind is linked to the high level of phytate. According to Kumar et al. [34], phytate in legume grains and oil seeds is bound with calcium and magnesium. The availability of calcium and magnesium in roasted and soaked treatments is a good indication to use tamarind for bone formation [31].

The highest value of phosphorus was 93.25±0.04 mg/g (control), and the lowest value was 66.12 ± 0.00 mg/g (soaked) (Table 2). There was a significant difference ($p < 0.05$) between the three samples. The control tamarin had the highest value compared to the soaked and roasted tamarin. This was different from Akajiaku et al. [20], who reported that the soaked tamarin had a higher value than the roasted.

The mean±sd of tamarind fruit iron was stated in Table 2. The highest value of iron was 8.20±0.00 mg/g (rough), and the lowest was 5.57±0.00 mg/g (control). There was a significant difference ($p < 0.05$) between the three treatments. This was in agreement with the report of Sarkar et al. [35]. The report of Adeola & Aworh [28] was lower than this finding in iron content.

3.9. Sugar content

The sugar profile of the tamarind treatments is stated in Table 1. The mean±sd values of glucose were found in Table 3. The highest value of glucose was 5.76±0.06 g/100g (control), and the lowest value was 1.34±0.03 g/100g (roasted). There was a significant difference ($p < 0.05$) between the treatments (control, soaked, and roasted). The result showed that processing affects glucose levels. This was related to Adeola and Aworh [23]. However, the value of this finding was lower than that of Trila et al. [18] and higher than Niyi [36]. This variation could be the geographical condition of Tamarind Shlini and Murthy [9].

The mean±sd value of fructose is listed in Table 1. The fructose content of tamarind fruit ranged between 1.74±0.08 g/100g (roasted) and 8.00±0.11 g/100g (Control). There was a significant difference ($p < 0.05$) between the treatments. This was in agreement with Adeola and Aworh [22]. Fructose was decreased through soaking and roasting. This reduction of sugars may decrease the sugar content by leaching sugars when soaked. In addition, based on the soaking time, the sugar could ferment and be reduced [36].

The mean±sd values of maltose were stated in Table 1. The maltose content of tamarind fruit ranges from 0.24±0.00 g/100g (soaked) to 0.45±0.014 g/100g (control). Maltose was not detected in the roasted tamarind. There was a significant difference ($p > 0.05$) between the control and the soaked treatments. This result was in agreement with the report of Niyi [36].

Table 1: Mean±sd nutrient composition of soaked, roasted, and control Tamarind fruit pulp.

Physicochemical parameters (g/100g)	Treatment Soaked (%)	Roasted (%)	Control (%)
Moisture	13.33±0.58^{a}	10.00±0.00^{b}	17.67±0.58^{c}
Ash	3.57±0.06^{a}	3.90±0.10^{b}	3.17±0.15^{c}
Protein	6.13±0.25^{a}	6.91 ± 0.19^{b}	6.75±0.17^{c}
Fat	1.92±0.02^{a}	2.03± 0.07^{b}	1.96±0.06^{ab}
Fiber	6.85±0.06^{a}	5.65 ±0.02^{b}	6.50 ±0.10^{c}
Carbohydrate	67.93±0.45^{a}	70.97±0.10^{b}	63.79±0.06^{c}
Glucose	4.67±0.03^{a}	1.34±0.03^{b}	5.76±0.06^{c}
Fructose	5.59±0.06^{a}	1.74±0.08^{b}	8.00±0.11^{c}
Maltose	0.24± 0.00^{a}	*	0.45± 0.014^{b}
Sucrose	*	*	*
Turanose	*	*	*
pH	4.13±0.06^{ab}	4.12±0.06^{b}	4.03±0.06^{a}
Titrable Acidity	0.14 ± 0.02^{a}	0.14 ± 0.01^{a}	0.13 ± 0.01^{a}

Values not sharing common superscript letters across the raw are significantly different ($p < 0.05$) from each other.
* = not detected

3.10. Antioxidant content

3.10.1. Phenol Content

The mean±sd of phenol content was described in Table 3. The highest phenol was 277.68±6.88 mg/g (Roasted), and the lowest was 81.24±20.93 mg/g (Control). There was a significant difference ($p < 0.05$) between the treatments. This result was in agreement with Trila et al. [18]. Phenolic compounds, with their ability to donate hydrogen or electrons beyond their capacity to form stable radical intermediates, are considered major active antioxidant metabolites from plants [37]. According to Vasco, Ruales, and Kamal-Eldin [38], tamarind fruit is classified as having low polyphenol content, and processing helps to improve phenol content. Accordingly, the roasted tamarin had a higher value than the soaked one, and the raw

tamarin's phenol content was lower than both soaking and roasting. According to Lee et al. [19], total phenolic contents increased with irradiation and other processing.

3.10.2. Flavonoid content

The mean±sd of flavonoid for tamarind fruit was stated in Table 3. The highest value of flavonoid content was 114.85±6.75 mg QE/g (control), and the lowest value was 63.39±17.04 mg QE/g (Soaked). There was a significant difference ($p < 0.05$) between the treatments (control, soaked, and roasted). This study showed that flavonoid was decreased in both roasting and soaking. Paz et al. [37] reported a higher flavonoid content (178 ± 32 mg QE/g). The possible reason for lower and higher variation could be the type of tamarind found in different localities. According to Trila et al. [18], the flavonoid content of raw tamarin powder extracted by methanol was 89.60± 2.12 mg QE/g, which was lower than this study. Contrary to this, phenolic and flavonoid contents are correlated with the antioxidant activity of plant extracts. These constituents are important for human health due to their free-radical scavenging activity and protection against oxidative stress [18].

Table 2: Mineral profile of Tamarind fruit.

Treatment	Mineral content(mg/g)											
	Ca	K	Mg	Na	P	S	Fe	Mn	Zn	Bo	Cu	Mo
Soaked Tamarind	564.17 ±0.29 [b]	170.56 ±0.06 [b]	206.60 ±0.03 [b]	128.75 ±0.05 [b]	66.12 ± 0.00 [b]	15.80 ±0.02 [b]	5.84± 0.00 [b]	0.78 ±0.00 [b]	19.12 ±0.08 [b]	3.23 ±0.0[b]	1.70±0. 20	0.03±0.0 0
Roasted Tamarind	588.56 ±0.46 [c]	155.78±0. 01 [c]	219.60 ±0.02 [c]	134.59 ± 0.03 [c]	87.72 ±0.00 [c]	37.96 ±0.00 [c]	8.20±0. 00 [c]	0.98 ±0.00 [c]	18.19 ±0.00 [c]	2.92 ±0.00 [c]	1.58±0. 00	0.10 ±0.13
Control	459.95± 0.74 [a]	149.62 ±0.08 [a]	194.78 ±0.00 [a]	69.00 ±0.00 [a]	93.25 ±0.04 [a]	50.92 ±0.00 [a]	5.57±0. 00 [a]	0.73±0. 00 [a]	7.10±0.0 0 [a]	3.67 ±0.00 [a]	1.12±0. 00	0.08±0.0 6

Values with the different superscripts have a significantly different ($p<0.05$) from each other.

Table 3: Mean±sd value for phytochemicals antioxidant activities and EC_{50}.

Sample	TPC (mg GAE/100 g)	TFC (mgCE/100mL)	FRAP (mM/g)	DPPH(µl/mL)	EC50	Phytate	Tannin	Oxalate
Control	81.24±20.93[a]	114.85±6.75[a]	1.55±0.83 [a]	79.73±0.40 [a]	76.34±0.31[a]	4.04 ± 0.15[c]	6.31±0.07[b]	0.02±0.00 [b]
Soaked	107.28±5.17[b]	63.39±17.04[b]	2.95±1.68 [b]	79.19±0.23 [a]	79.96±0.13[b]	3.04± 0.15 [a]	4.20±0.16[a]	0.01±0.00 [a]
Roasted	277.68±6.88[c]	85.30±3.17[c]	2.21±1.19 [c]	75.76±0.13 [b]	105.28±0.33[c]	2.46± 0.13[b]	4.12 ±0.12[a]	0.00 ±0.00 [a]

Values not sharing common superscript letters across column are significantly different ($p <0.05$) from each other. TPC= Total phenol content, TFC= Total flavonoid content, FRAP=Ferric reducing assay power, DPPH= Diphenyl-2-Picryl Hydroxyl.

3.10.3. Radical scavenging activity

The mean ±SD radical scavenging for the assay of DPPH is stated in Table 3. The highest value was 79.73±0.40 (control), and the lowest was 75.76±0.13 (roasted). There was a significant difference between the three treatments. Figure 2 shows the percentage inhibition. The IC50 values of treatments, in increasing order, were: control< soaked< roasted, with IC50 values of 76.12, 79.86, and 105.51, respectively. According to Trila et al. [18], the methanolic extract of tamarin showed good antioxidant activity in the DPPH assay (92.62% inhibition of radicals). It was also stated that the bioactivity extracted from tamarind pulp, ground tamarind seeds, seed coat, flowers, and leaves is known to scavenge free radicals. Similar results were reported that raw and dry heat-treated methanolic extracts of tamarind seed coat were effective in inhibiting DPPH radicals and therefore exhibited the lowest IC50 values: 39.0 and 38.7 mg/mL [18].

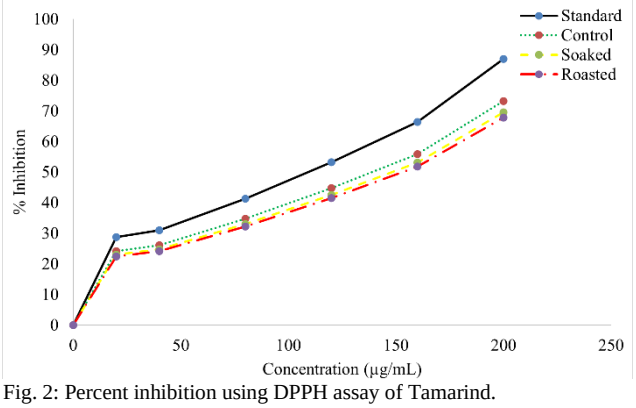

Fig. 2: Percent inhibition using DPPH assay of Tamarind.

3.10.4. Ferric reducing power

The mean±sd value of ferric reducing power was stated in Table 3. The highest value of ferric reducing power was 2.95±1.68 (soaked), and the lowest value was 1.55±0.83 (control). There was a significant difference ($p < 0.05$) between the treatments. This was in agreement with the report of Trila et al. [18]. The highest ability to reduce Fe^{3+} to Fe^{2+} corresponded to tamarin powder extract with methanol at concentrations of 800 and 1000 mg/mL, with values of 2.95 and 2.30 mmol/g, respectively. The soaked tamarin had a high value of ferric-reducing power activity, and the roasted

tamarin had a better value than the control. So, both soaking and roasting affect ferric-reducing power activity.

3.11. Antinutritional factors

3.11.1. Tannin content

Tannins are large polyphenol polymers that are known to bind proteins, limiting their digestibility, but they are also excellent antioxidants. Kaufman et al. [39]. The mean±sd of tannin for tamarind fruit was stated in Table 3. The highest value of tannin content was 6.31±0.07 g/100g (control), and the lowest was 4.12±0.12 g/100g (roasted). There was a significant difference ($p < 0.05$) between the control and soaked tamarind pulp and the control and roasted tamarind pulp. However, there was no significant ($p > 0.05$) difference between the soaked and the roasted. It was shown that both roasting and soaking significantly decreased the tannin content. This was in agreement with Johanis et al. [40]. According to Bashir et al. [31], the tannin content of tamarind fruit during roasting was not changed. It describes that roasting has no significant difference in the tannin content of tamarind fruit. According to Akajiaku et al. [20], the tannin content ranged from 4.84% to 8.34%. It was described that soaking has a higher effect on decreasing the tannin content than roasting because of the water-soluble nature of tannin [20].

3.11.2. Phytate content

Phytate (hexaphosphates of myo-inositol) is common in plant seeds. They can chelate with di- and trivalent mineral ions such as Ca2+, Mg2+, Zn2+, Cu3+, and Fe3+, resulting in these ions becoming unavailable for consumers [41]. The mean±sd value of the phytate content of tamarind is stated in Table 3. The highest value of phytate content was 4.04 ± 0.15, and the lowest was 2.46 ± 0.13. There was a significant difference ($p < 0.05$) between the treatments. This result was in agreement with the report of Akajiaku et al. [20], which described that the phytate content of soaked tamarin was less than that of roasted tamarin. Contrary to this, Bashir et al. [31] reported that roasting does not cause a change in phytate content. Besides, Oluseyi and Temitayo [14] described that roasting has significantly affected the phytate content. It shows that phytate content decreases as roasting time increases. Phytate content was decreasing through processing trends. It shows that both soaking and roasting significantly decreased the phytate content. According to Albarracín et al. [33], soaking treatment could reduce phytates, improving mineral and protein bioavailability.

3.11.3. Oxalate content

Oxalates are ubiquitous metabolic end products in plants and are unwanted in the human diet due to their adverse effects [42]. The mean±sd value of oxalate content was stated in Table 3. The highest value of oxalate content was 0.02±0.00 (control), and the lowest was 0.01±0.00. The control was different ($p < 0.05$) with the roasted and soaked tamarind. This was in agreement with the report of Adeola and Aworh [28]. According to Shi et al. [43], soaking and cooking decrease the oxalate content of pulse. Therefore, both soaking and roasting can decrease the oxalate content of tamarind fruit.

3.12. Antimicrobial analysis

The microbiological analysis was conducted for tamarind fruit by the disc diffusion method, and the application was carried out against E. coli and S. aureus. The results representing the antibacterial activity of tamarind pulp extract are stated in Table 4. The antibacterial activity ranged between 13.30 and 14.07 mm of zone inhibition against E. coli (Table 4). The result showed that there was no significant difference ($p > 0.05$) between the three samples and a significant difference ($p < 0.05$) between the treatments and the positive control. The result for S. aureus ranged from 13.00 to 13.93mm. It also describes that there was no significant ($p > 0.05$) difference between the three samples. However, chloramphenicol was significantly different ($p < 0.05$) from the samples. The result found from this study was similar to the report of Ajiboye et al. [44] (15mm).

Gupta et al. [45] describe that the minimum inhibition zone of E. coli and S. aureus was 13.0 mm and 18.0 mm, respectively, which is in agreement with these findings. According to Gumgumjee et al. (2012) [46], the minimum inhibition zone of E. coli and S. aureus was higher than in this study.

Table 4: Zone of inhibition (mm) of Tamarind (Tamarinds indicia) on selected bacteria.

Types of bacteria	Zone of inhibition (mm)			Positive control
	Control (%)	Soaked (%)	Roasted (%)	chloramphenicol
E. coli	14.07±1.98^{a}	13.85^{a}±2.02^{a}	13.30±0.67^{a}	22.63±0.63^{b}
S. Aureus	13.00±0.29a	13.93a±0.87a	13.99±0.06a	22.42±0.63^{b}

Values not sharing common superscript letters across rows are significantly different ($P < 0.05$) from each other.

3.13. Sensory properties

The mean ± sd for the test attributed was described in Table 5 and the spider distribution in Figure 3. The colour value for tamarind juice was 5.38±1.50 (846), 5.46±1.14 (379), and 5.46±1.12 (512). There was no significant ($p > 0.05$) difference between the three samples. The taste of tamarind juice had a mean score of 5.52±1.22 (512), 5.39±1.50 (379), and 5.06±1.63 (846). There was no significant variation between the three treatments, which had different taste sugars. These might possibly be due to the sweet and sour taste of tamarind coming from tartaric acid [47].

The aroma value of tamarind juice was 4.52±1.72 (846), 4.82±1.31 (379), and 5.20±1.23 (512) (Table 5). Tamarind juice with high sugar (512) was 'liked' by panalists. There were significant differences between the three treatments. The aroma of tamarind fruit comes from the natural content of antioxidants like polyphenol compounds.

The mean±sd of tamarind juice sweetness was stated in Table 5. The highest value was 5.27±1.21 (512), and the lowest was 4.52±1.73 (846) respectively. There was no significant difference between the medium and low and the medium and high as well. However, there was a significant ($p<0.05$) difference between the high-sugar (512) and low-sugar (846) tamarind juices. The variation was due to different levels of sugar.

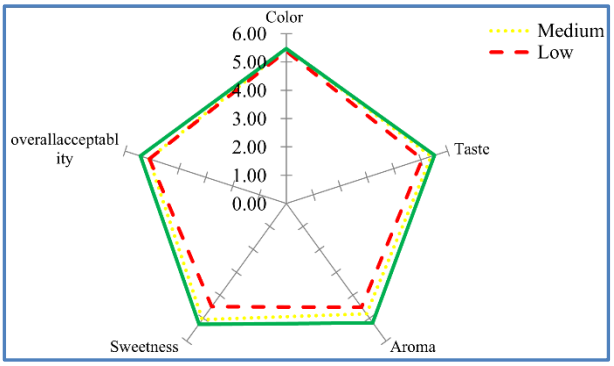

Fig. 3. Spider web describing the sensory acceptability for different attributes.

Sample code	Attributes				
	Colour	Taste	Aroma	Sweetness	Overall acceptability
512	5.46±1.12[a]	5.52±1.22 [a]	5.20±1.23 [a]	5.27±1.21[a]	5.44±1.21[a]
379	5.46± 1.14 [a]	5.39± 1.50 [a]	4.82±1.31[ab]	5.06±1.37[a]	5.11±1.52[a]
846	5.38±1.50 [a]	5.06± 1.63 [a]	4.52±1.72 [ab]	4.82± 1.73[a]	5.10±1.62[a]

Values not sharing common superscript letters are significantly different (P<0.05) from each other. 512: high sugar (0.75g/mL), 379: medium sugar (0.5g/mL) and 846: low sugar (0.25g/mL)

The mean±sd of overall acceptability of tamarind juice with high, medium, and low sugar content were 5.44±1.21 (512), 5.11±1.52 (379), and 5.10±1.62 (846), respectively. There was no significant ($p > 0.05$) difference between the low sugar (846) and medium sugar (379). However, there was a significant ($p<0.05$) difference between high (512) and low sugar (846) as well as the high and medium sugar content of tamarind juice. The overall acceptability of tamarind juice with a high sugar content was liked by panelists. So, according to the respondents, tamarind fruit with a high sugar content was preferred.

4. Conclusions

Tamarind fruit pulp had a highly valuable nutritional composition for human consumption, but it was an underutilized fruit. The outcome showed that the antioxidants, sensory qualities, and nutritional profile were all enhanced by soaking and roasting. The variables that are antinutritional, however, decreased. To reach the entire community in Dire Dawa and throughout Ethiopia, the possible application of tamarind fruit in the food business needs to be considered.

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References

[1] Okello J, Okullo JB, Eilu G, Nyeko P, Obua J. Mineral composition of Tamarindus indica LINN (tamarind) pulp and seeds from different agro - ecological zones of Uganda. Food science & nutrition. (2017); 5(5):959-66.

[2] Kuru P. Tamarindus indica and its health related effects. Asian Pacific Journal of Tropical Biomedicine. (2014); 4(9):676-81.

[3] Reis PM, Dariva C, Vieira GÂ, Hense H. Extraction and evaluation of antioxidant potential of the extracts obtained from tamarind seeds (Tamarindus indica), sweet variety. Journal of Food Engineering. (2016); 1:173:116-23.

[4] Okello J. Morphological and nutritional characteristics of Tamarindus Indica (LINN) fruits in Uganda. Makerere University, Uganda. (2010); 1:4-16.

[5] Van den Bilcke N, Alaerts K, Ghaffaripour S, Simbo DJ, Samson R. Physicochemical properties of tamarind (Tamarindus indica L.) fruits from Mali: selection of elite trees for domestication. Genetic resources and crop evolution. (2014); 61(2):537-53.

[6] Gunasena HP, Hughes A. Tamarind: Tamarindus Indica L. International Centre for Underutilized Crops; (2000).

[7] Lee M, Regu M, Seleshe S. Uniqueness of Ethiopian traditional alcoholic beverage of plant origin, Tella. Journal of Ethnic Foods. (2015); 2(3):110-4.

[8] Central Statistical Agency (CSA). Summery and Statistical Report of the 2007 Population and Housing Census: Population size by Age and Sex. Federal Democratic Republic of Ethiopia, Population Census Commission, Addis Ababa, Ethiopia. 2008.

[9] Shlini P, Murthy SKR. Proximate composition, anti-nutritional factors and protein fractions of Tamarindus indica L. seeds as influenced by processing treatments. International Journal of Food and Nutritional Sciences. (2015); 4(4):91-6.

[10] Lestienne I, Icard-Vernière C, Mouquet C, Picq C, Trèche S. Effects of soaking whole cereal and legume seeds on iron, zinc and phytate contents. Food chemistry. (2005); 89(3):421-5.

[11] Huang Y, Xiao D, Burton-Freeman BM, Edirisinghe I. Chemical changes of bioactive phytochemicals during thermal processing.(2016).

[12] Official methods of analysis. AOAC International Assn of Official Analytical Chemists. Methods 925.09, 923.03, 979.09, 962.09, 4.5.01. (2000); Vol. ii 17th ed.

[13] Natukunda S, Muyonga JH, Mukisa IM. Effect of tamarind (Tamarindus indica L.) seed on antioxidant activity, phytocompounds, physicochemical characteristics, and sensory acceptability of enriched cookies and mango juice. Food science & nutrition. (2016); 4(4):494-507.

[14] Oluseyi EO, Temitayo OM. Chemical and functional properties of fermented, roasted and germinated tamarind (Tamarindus indica) seed flours. Nutrition & Food Science. (2015); 45(1):97-111.

[15] Samar A, Abdeltaif, Khitma, SirElkhatim and Amro B, Hassan. Estimation of Phenolic and Flavonoid Compounds and Antioxidant Activity of Spent Coffee and Black Tea (Processing) Waste for Potential Recovery and Reuse in Sudan. (2018); 3(27), doi: 10.3390.

[16] Peschel W, Sánchez-Rabaneda F, Diekmann W, Plescher A, Gartzía I, Jimenez D, Lamuela-Raventos R, Buxaderas S, Codina C. An industrial approach in the search of natural antioxidants from vegetable and fruit wastes. Food Chemistry. (2006); 97(1):137-50.

[17] Muanda F, Koné D, Dicko A, Soulimani R, Younos C. Phytochemical composition and antioxidant capacity of three malian medicinal plant parts. Evidence-Based Complementary and Alternative Medicine. (2011); 1-8.

[18] Trila U, Fernández-Lópezb J, Álvarezb JN, Viuda-Martosb M. Chemical, physicochemical, technological, and antibacterial and antioxidant properties of rich-fiber powder extract obtained from Tamarind (Tamarindus indica L.).Industrial Crops and Products. (2014); (55): 155–162.

[19] Lee JW, Kim JK, Srinivasan P, Choi JI, Kim JH, Han SB, Kim DJ, Byun MW. Effect of gamma irradiation on microbial analysis, antioxidant activity, sugar content and color of ready-to-use tamarind juice during storage. LWT-Food Science and Technology. (2009); 42(1):101-5.

[20] Akajiaku LO, Nwosu JN, Onuegbu NC, Njoku NE, Egbeneke CO. Proximate, mineral and anti-nutrient composition of processed (soaked and roasted) Tamarind (Tamarindus indica) seed nut. Current Research in Nutrition and Food Science Journal. (2014); 2(3):136-45.

[21] Ijarotimi OS, Keshinro OO. Determination of nutrient composition and protein quality of potential complementary foods formulated from the combination of

fermented popcorn, African locust and bambara groundnut seed flour. Polish journal of food and nutrition sciences. (2013); 63(3):155-66.

[22] Sandra MO, Ana Pascual-Maté, Daniel de la F, Ana de Pablo MA. Fernández Mui˜no MT, Sancho. Comparison of methods to determine antibacterial activity of honeys against Staphylococcus aureus. Department of Biotechnology and Food Science, University of Burgos. (2014); 1:29–3.

[23] Adeola AA, Aworh CO. Development and sensory evaluation of an improved beverage from Nigeria's tamarind (Tamarindus indica L.) fruit. African Journal of Food, Agriculture, Nutrition and Development. (2010); 10(9).

[24] Rana M, Sharma P. Proximate and phytochemical screening of the seed and pulp of Tamarind indica. Journal of Medicinal Plants. (2018); 6(2):111-5.

[25] Ishaku GA, Ardo BP, Abubakar H, Peingurta FA. Nutritional composition of Tamarindus indica fruit pulp. J Chem Sci. (2016); 6(8):695-9.

[26] Olanipekun OT, Omenna EC, Olapade OA, Suleiman P, Omodara OG. Effect of boiling and roasting on the nutrient composition of kidney beans seed flour. Sky J Food Scis. (2015); 4(2):24-9.

[27] Agume A, Njintang N, Mbofung C. Effect of soaking and roasting on the physicochemical and pasting properties of soybean flour. Foods. (2017); 6(2):12.

[28] Adeola AA, Aworh OC. A comparative evaluation of the chemical properties of wild tamarind (Tamarindus indica L.) fruits in Nigeria. Food. (2012); 6(1):49-57.

[29] Mbah BO, Eme PF, Ogbusu OF. Effect of cooking methods (Boiling and Roasting) on Nutrients and Anti-Nutrients contents of Moringaoleiferaseeds. Pak. J. Nutr. (2012); 11(3): 211-215.

[30] Sulieman AM, Alawad SM, Osman MA, Abdelmageed EA. Physicochemical characteristics of local varieties of tamarind (Tamarindus indica L), Sudan. International Journal of Plant Research. (2015); 5(1):13-8.

[31] Bashir AY., Abdullahi SA. and Suleiman B. Effect of roasting on the proximate, mineral and anti-nutrient composition of Tamarindus indica seed nuts. Fuw Trends in Science & Technology Journal. (2016); 1(2), 493 – 496.

[32] Olagunju OF, Ezekiel OO, Ogunshe AO, Oyeyinka SA, Ijabadeniyi OA. Effects of fermentation on proximate composition, mineral profile and antinutrients of tamarind (Tamarindus indica L.) seed in the production of daddawa-type condiment. LWT. (2018); 90:455-9.

[33] Albarracín M., González R.J, Drago S.R. Effect of soaking process on nutrient bio-accessibility and phytic acid content of brown rice cultivar. Food Science and Technology. (2013); 53: 76-80.

[34] Kumar V, Barman D, Kumar K, Kumar V, Mandal SC & Clercq E.D.Anti-nutritional factors in plant feedstuffs used in aquafeeds. World Aquaculture. (2012); 64-68.

[35] Sarkar BR, Awasthi P, & Joshi H. Physical properties and nutritional composition of Tamarind kernel powder and quality evaluation of instant chutney mix prepared incorporating Tamarind kernel powder. Journal of Pharmacognosy and Phytochemistry (2018); 7(6): 1342-1346.

[36] Niyi OH. Sugar, physicochemical properties and fatty acid composition of velvet Tamarind (Dialium guineense) pulp and oil. European Journal of Biotechnology and Bioscience. (2014); 2 (3): 33-37.

[37] Paz M, Gúllon P, Barroso MF, Carvalho AP, Valentina F, Domingues A, Gomes AM, Becker H, Longhinotti E. & Delerue-Matos C. Brazilian fruit pulps as functional foods and additives: Evaluation of bioactive compounds. Food Chemistry. (2015); 172: 462–468.

[38] Vasco CRJ & Kamal-Eldin A. Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. Food Chemistry, (2008); 111,816–823.

[39] Kaufman RC, Herald TJ, Bean SR, Wilsona JD and Tuinstrab MR. Variability in tannin content, chemistry and activity in adverse group of tannin containing sorghum cultivars. JSciFoodAgric. (2013); 93:1233–1241.

[40] Johanis Ly, Irfan HOS, Djunaidi, Suyadi. Effect of processing methods on nutrient and tannin content of Tamarind seeds. Tropical Drylands. (2017); 1(2): 78-82.

[41] George F, Harinder P.S. Makkar B, Klaus B. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture. (2001); 199:197–222.

[42] Nguyen HVH., & Savage GP., Original research article Oxalate content of New Zealand grown and imported fruits, Journal of Food Composition and Analysis (2013),

[43] Shi L, Arntfield SD, & Nickerson M. Changes in levels of phytic acid, lectins and oxalates during soaking and cooking of Canadian pulses. Food research international. (2018); 107:660-668.

[44] Ajiboye AE., Ameen MT., & Adedayo MR. Antimicrobial activity and phytochemical screening of the fruit pulp of Dialium guineense (Velvet Tamarind) on some microbial isolates. Journal of Microbiology and Antimicrobials. (2015); 7(4), 33-41.

[45] Gumgumjee NM., Khedr A., & Hajar AS. Antimicrobial activities and chemical properties of Tamarindus indica L. leaves extract. African Journal of Microbiology Research. (2012); 6(32), 6172-6181.

[46] Gupta C., Prakash D. and Gupta S. Studies on the antimicrobial activity of Tamarind (Tamarindus indica) and its potential as food bio-preservative. International Food Research Journal. (2016); 21(6): 2437-2441.

[47] Rao YS., & Mathew KM. Tamarind, Spices Board of India, India Woodhead Publishing Limited. (2012); 1:512-533.