https://doi.org/10.48047/AFJBS.6.12.2024.2616-2643

AFJBS African Journal of Biological Sciences
Journal homepage: http://www.afjbs.com

Research Paper Open Access

PROCESSING OF TAMARIND (*Tamarindus indica L.*) SEED POWDER AND ITS IMPACTS ON PHYSICAL, CHEMICAL, FUNCTIONAL, PASTING AND ANTI-NUTRITIONAL CHARACTERISTICS

Hemalatha.C[1] and Parameshwari.S[2*]

[1]Ph.D Scholar, Department of Nutrition and Dietetics, Periyar University, Salem, Tamil Nadu, India. Mail id: hemalathac144@gmail.com

[2*]Professor and Head, Department of Nutrition and Dietetics, Periyar University, Salem, Tamil Nadu, India. Mail id: parameshwari@periyaruniversity.ac.in

Orcid id:

Hemalatha.C:https://orcid.org/0009-0003-9791-596X

Parameshwari.S: https://orcid.org/0000-0002-8053-9780

***Corresponding Author Email: parameshwari@periyaruniversity.ac.in

Corresponding Author Address: Professor and Head, Department of Nutrition and Dietetics, Periyar University, Salem, Tamil Nadu, India.

Article History
Volume 6, Issue 12, 2024
Received :25 Apr 2024
Accepted :25 June 2024
doi: 10.48047/AFJBS.6.12.2024.2616-2643

ABSTRACT

The tamarind pulp industry produces tamarind seeds, which are a by-product and are a rich source of protein, crude fiber, carbohydrate, and mineral components, including potassium and magnesium. It is crucial to understand that despite the seeds' many nutritional advantages, they are nevertheless used as ingredients in meals. The study's objectives are to develop tamarind seed powder using various processing methods and to investigate the powder's physical, chemical, functional, pasting, and anti-nutritional characteristics. The chosen tamarind seeds were subjected to different processing methods like drying, autoclaving, boiling, and roasting, and these processed seeds were powdered. The whole tamarind seed was powdered and treated as control. Using a conventional approach, the seeds that had been processed were ground into powder, and the physical (color), chemical, functional, pasting, and anti-nutritional properties of the powders were analysed. The physical characteristics of roasted tamarind powder revealed a noteworthy difference ($p<0.05$) between the L^*, a^*, and b^* values. The findings showed that each processing method differed significantly ($p<0.05$), and roasted powder had high titratable acidity, carbohydrate, protein, and fiber levels and low pH and moisture content levels. As a result of the functional characteristics of tamarind seed powders, roasted powder had superior functional values than powder made using other processing techniques. Among the processing, roasting had the lowest pasting temperature and the highest peak viscosity of all the processing methods. Tannin, trypsin inhibitor, and hydrogen cyanide levels in roasted powder were significantly inferior than those in other processing methods. It was determined from this experimentation that; some anti-nutrients were comparatively lowered by the roasting method more efficiently than other methods. However, among the others, the powder made from roasted seeds had the most nutritional and functional benefits. According to the overall findings, roasted seed powders may be helpful in the creation of the extrusion of foods like pasta and noodles, as well as the bread industry.

Keywords: Anti-nutrients, Autoclaving, Boiling, Chemical, Functional, Physical, Roasting

INTRODUCTION

Tamarindus indica L., a species of the genera *Leguminosae*, is a fruit that is frequently grown in Thailand and India as well as other countries in South and Southeast Asia[1]. The sizeable evergreen tamarind tree, sometimes known as the "Indian date," belongs to the *Fabaceae* family. It is a long-lived, bushy tree with a medium growth rate that thrives in soils with acidity, clay, loam, and sand. It is also particularly scarce and vaporizer salt (wind-borne salt that is common in littoral locations) resistant. It also thrives in direct sunlight. This phenomenon is commonly observed in dry tracks throughout Southeast Asian countries, as well as in states located in Central and South India[2].

The de-hulled tamarind seeds are soaked in water overnight by rural dwellers and some ethnic groups, mainly Malayali and Dravidian tribes in India. The seeds are systematically stripped of their seed coverings, then they are roasted before being consumed. The tamarind's blossom and leaves are consumed as vegetables, and the gum from the seed is used to make tamarind gum, which can be commonly utilized in Japan to thicken a variety of meals [3,4]. Furthermore, inexpensive tamarind kernel powder may be a more cost-effective alternative to expensive pectin for creating jelly[5].

Tamarind seeds are an exceptional source of protein that can help alleviate the severe protein scarcity that exists across several Asian and African nations. According to Ajayi et al. (2006)[6], they are good providers of crude fiber, carbohydrates, and mineral concentrations, especially potassium. The entire seed should not be consumed since it contains phytohemagglutinin, phytic acid, hydrogen cyanide, trypsin inhibitor, and tannin. The only way to remove the testa is to roast it or soak it in water, as suggested by El-Siddig et al. (2006)[7]. During this operation, bowel movements, anxiousness, and digestive issues could occur.

The seed of the tamarind fruit is often overlooked and discarded in the pulp industry, but it can be repurposed in various ways. Tamarind kernel powder, a small portion of the seed, is commonly used as a sizing material in the textile, paper, and jute industries. Additionally, tamarind powder can serve as a raw ingredient in baking bread and pastries. Nowadays, people have found alternative uses for tamarind powder, such as coagulating fruit juice, treating ulcers, and maintaining fabrics without the use of starch. The decorticated seed powder has remarkable gelling and sticking qualities, making it suitable for various purposes in the food, cosmetic, and pharmaceutical industries[5].

The nutritional value of food can be influenced by how it is prepared, cooked, and stored. However, various food processing methods, such as soaking, boiling, roasting, blanching, autoclaving, and fermenting, can enhance the quality of processed foods by eliminating antinutrients and improving their flavor and appearance[8]. Previous studies[7,8] have shown that tamarind nuts can be transformed into detoxified powders through soaking, boiling, roasting, sprouting, and fermentation.

According to Suresh and Samsher (2013)[9], Kaur and Singh (2006)[10], and Siddiq et al. (2009)[11], functional attributes are essential physicochemical features of foods. These attributes represent the complex interactions between the structures, atomic configuration, compositions, and physicochemical qualities of food components with their surroundings. They are measured and connected under specific conditions. Demonstrating functional qualities is necessary to determine whether novel proteins, fats, carbohydrates (starch and sugars), and fibers can be used in addition to or instead of more conventional sources. These properties can predict and accurately evaluate the behavior of these novel components in certain food systems.

Tannins are phenolic chemicals with a molecular weight greater than 500 Da. One of their characteristics is the ability to precipitate proteins. Plants produce tannins in their leaves, fruits, and bark as secondary chemicals[12]. Researchers Lampart-Szczapa et al. (2003)[13] and Raes et al. (2014)[14] discovered that tannins frequently result in a loss of essential amino acids and a decrease in protein digestibility by creating transient and irreversible tannin-protein compounds through the hydroxyl group of tannins and the carbonyl group of proteins. Proteinases, a class of enzymes, perform various roles in enhancing the nutritive and functional qualities of different protein molecules[15]. There is limited information available on the utilization of tamarind seed processing and its incorporation into food formulations. To address this, a study was conducted to investigate the impact of various processing methods on the physical, chemical, functional, and anti-nutritional characteristics of tamarind seed powders.

MATERIALS AND METHODS

Tamarind seeds were purchased at an adjacent shop in the Salem District of Tamil Nadu, India. The purchased tamarind seeds were scrubbed and dried before being kept for later processing. Scientists from the Agricultural Department in Salem, Tamil Nadu checked, identified, and verified the selected tamarind seeds. The experiments were carried out at the Department of Nutrition and Dietetics laboratory at Periyar University in Salem, Tamil Nadu, India.

Processing Methods

The process of creating processing powders from tamarind fruit seeds involved manual removal of stones and impurities, followed by division into five portions. The first portion was sun-dried for four days during peak sunlight hours (9 a.m. to 5 p.m.) until it reached a consistent moisture level of 8.0%, then milled without further processing. The separated second portion was shadow-dried for three days at room temperature until it reached a constant moisture content of 8.5%. The remaining portions underwent distinct processing methods such as drying, roasting, boiling, autoclaving, and whole seed (with hull) powder.

Whole tamarind seed (Control)

The first control sample was created by sorting, milling, sieving, and packaging one kilogram of sun-dried seeds in a sealed container.

Drying

By shattering one kilogram (kg) of the exposed sun seeds with a mortar and pestle, isolating them from their outer coat, grinding, sifting, and putting them in a tightly sealed container, the second control sample was developed.

Autoclaving

To prepare the grains, they were heated in an autoclave at 250°F for 50 minutes, then cooled. To remove the seed coat, a combination of manual harvesting, friction, and a mill and pestle were used. The seeds were steeped in one kilogram of purified water for two hours before being roasted at 60°C for 8 hours to maintain a constant moisture content of 8.30%. After roasting, the dried seeds were processed into powder and passed through a 1.7 mm mesh-size strainer. Finally, the resulting powder was stored in an airtight container.

Boiling

One kilogram of seeds had been boiled in water for forty-five minutes at 110^0 C. Sun-dried seeds were stripped of their coats and processed into powder by Akajiaku et al. (2014)[16]. The resulting powder was put through a sieve with a 1.7 mm particle size, put in a tightly sealed container, and left in the research laboratory at the ambient temperature.

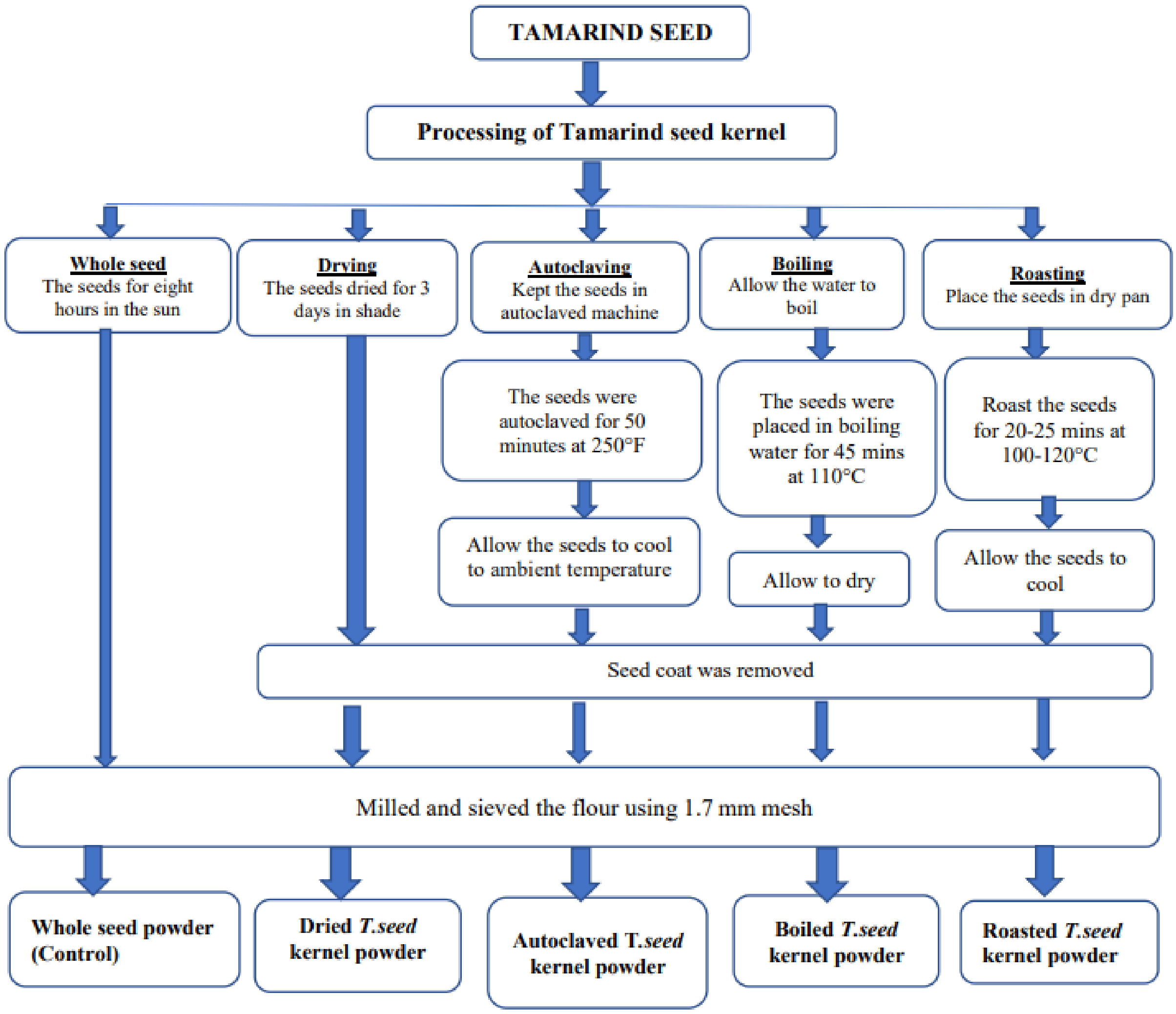

Figure -1: Flow chart for preparation of processed tamarind seed kernel powder

Roasting

As a result of initial investigations, 1 kilogram of tamarind seeds were roasted in an open pan on an electric stove for 20 to 25 minutes at a temperature between 100 and 120 degrees Celsius. The seed coatings had been eliminated by rubbing (rubbing between palms) and winnowing after the cotyledons were split utilizing the attrition mill and the roasted seeds subsequently de-hulled. The cotyledons were sun-dried, pounded into powder using an attrition mill, and processed using a 1.7 mm mesh size screen before being placed in an airtight container made of plastic and kept at ambient temperature in the laboratory.

Analysis of physical (Colour) properties of tamarind seed powder

The color of different specimens of powder was assessed using a Konica Minolta Spectrophotometer (CR-410, Japan), as pointed out by Makinde and Ayodele (2022)[17]. The powder (30g) was put into the sample holder, and the surface color was checked at three different sites. The color measurements were displayed as L*, a*, and b* values, where L (100 = white; 0 = black) symbolizes lightness; a*, measuring chromaticity, suggests redness using positive values; b*, which also determines chromaticity, reveals yellow with positive values; and b*, which implies green with negative values. "Eab" is the designation for the distinction among two colors indicated as two points in the Lab color. Once the parameters for the respective L, a, and b characteristics of two colors have been set, simple geometry can then be employed to calculate the distance between their positions in the Lab color. The following algorithm is used to calculate Eab:

$$\Delta Eab = \sqrt{(L^1-L^2)^2 + (a^1-a^2)^2 + (b^1-b^2)^2}$$

Analysis of chemical properties of tamarind seed powder

The AOAC (2010)[18] method was used to determine the proximate constituents, which included ash, moisture, carbohydrates, protein, crude fat, and crude fiber. The titratable acidity of tamarind powders was ascertained using the procedure outlined by Goncalves (2009). With a sample-to-water ratio of 1:9, the pH values were determined using a penetration electrode and a digital pH meter (Hanna Instruments, Woonsocket, USA). Each assessment was conducted more than once, and the results' percentages were presented.

Analysis of functional properties of tamarind seed powder

Water absorption capacity

The method Phillips et al. (1988)[19] used to calculate water absorption capacity was slightly modified. One gram of the material was centrifuged at 4500 rpm for 20 minutes after being dissolved in 10 ml of purified water and vortexed intermittently for 10 minutes. The aqueous supernatant from the centrifugation procedure was collected, and the test tubes were inverted and left to drain on a towel for five minutes. The water absorption capacity, which is expressed as a percentage of water gained per gram of material, could be determined by weighing the remainder.

Oil absorption capacity

To calculate oil absorption capacity, Eke and Akobundu's approach from 1993[20] was used. Each powder sample was blended for 30 seconds with approximately 0.50 g and 5 ml of oil. The samples were centrifuged for 30 minutes at 5000 rpm after 30 minutes of standing at room temperature (30.02°C). The test tubes were flipped over and left to drain on a towel for 15 minutes after the supernatant, which was mostly oil, had been decanted. The oil absorption capacity, which is expressed as grams of oil absorbed per gram of material, could be calculated by weighing the residue.

Emulsion Capacity

Onwuka and Onwuka's (2005)[21] approach was used to ascertain emulsification capability. 25 cc of distilled water and two grams of powder sample were mixed at 1600 rpm for a period of thirty seconds. Following thorough mixing, 25ml of vegetable oil was incorporated and the combination was stirred for a further thirty seconds. The mixture was put into a centrifuge tube and agitated for five minutes at 1,600 rpm. Direct measurements were taken from the tube of oil that had separated from the sample during centrifugation.

Bulk Density

The bulk density was calculated using Onwuka's (2018)[22] approach. A graduated measuring cylinder with a 10-ml capacity was weighed. Once the sample had been gently poured into the cylinder to the 10-ml mark, it was pounded on the bottom until the level of the sample wouldn't go any lower. The bulk density was determined as follows:

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of the sample}}{\text{The volume of the sample}}$$

Swelling Properties

To prevent sedimentation, the powdery substance was produced in falcon tubes and heated at 60, 70, 80, or 90 °C for 30 min. Then, Sorvall centrifugation was performed at 1,000 x g for 15 min. at 20 °C. Santacruz et al. (2003)[23] assessed the fragmented fraction and reported its mass in relation to the total quantity of dry starch as swelling power (w/w).

Water Activity

Employing a device referred to as the water activity meter (Pawkit, Decagon Devices Inc., Pullman, Washington, USA), the water activity was directly determined at a temperature of 25°C. Approximately 2 grams of pulverized powders were used for each of the tests.

Pasting Properties

To examine the pasting properties of tamarind powder after heating and chilling, a Rapid Visco-Analyzer (RVA) from Newport Scientific in Warri Wood, Australia was used. The RVA General Pasting Method (STD1) was utilized, with Thermocline Software recording viscosity data every 4 seconds during a 13-minute operation. The temperature was augmented since 50°C to 95°C and then decreased back to 50°C. The rotation speed was 960 rpm for the first 10 seconds and 160 rpm for the following 10 seconds. To conduct the test, 25ml of distilled water and 3g of powder were mixed in a canister, and a paddle was shaken throughout the sample. The canister was then placed into the RVA from Newport Scientific in 1998[24].

Analysis of anti-nutritional content in tamarind seed powders

Tannin content

Singh and colleagues (2012)[25] utilized the Folin-Denis spectrophotometric method to determine the amount of tannin present. To create the extract, one gram of each sample was mixed with 10 ml of distilled water, stirred, and left to settle for 30 minutes at 28°C. 2.5 ml of the resulting extract was evenly dispersed in a 50 ml volumetric flask. In a separate 50 ml flask, a 2.5 ml concentration of a typical tannic acid solution was added. About 1ml of Folin-Denis's reagent and 2.5 milli liters of saturated Na_2CO_3 solution were added to each flask. The mixture was then diluted to the required concentration (50 ml) and allowed to sit for 90 minutes at 28°C. Using a spectrophotometer, the absorbance at 250 nm was measured and readings were taken with the reagent set to zero. The tannin content was calculated using the following formula.

% Tannin = $An\ As \times C \times 100\ W \times Vf\ Va$

The absorbance of the test sample is represented by As, while the absorbance of the standard solution is represented by As. C represents the concentration of the standard solution, W represents the weight of the sample, Vf represents the total volume of the extract, and Va represents the volume of the extract.

Hydrogen Cyanide

The alkaline picrate technique was explained in detail by Onwuka (2018)[26]. A conical flask with a stopper was used to dissolve five grams (5g) of each powder type in fifty milliliters (50 ml) of distilled water. The cyanide extraction was left in place overnight before being filtered. A mixture of 1 ml of the filtrate and 4 ml of alkaline picrate was incubated in a water bath. At 490 nm, the absorbance was assessed after the development of colors. The absorbance of the blank was calculated using just 1 ml of pure water and 4 ml of alkaline picrate solution. The cyanide concentration in the solution was determined by calculating the slope of an extrapolated standard curve obtained from KCN solutions containing 5-50 g of cyanide in a 500 ml conical flask.

Trypsin Inhibitor

The trypsin inhibitor activity can be measured using a spectrophotometric technique, according to Onwuka (2018)[26]. The sample extract was created by mixing 1 g of the test sample with 50 cc of a 0.5 M NaCl solution. Before centrifuging, the liquid was agitated for 30 minutes at room temperature. The supernatants were filtered through watchman No. 41 filter paper to obtain the filtrate, which was then used for the test. To create standard trypsin, the filtrate/extract was combined with BAPA (N-Benzoyl-DL-Arginine-P-nitroanilide) reagents.

In a test tube containing 10 ml of the sample extract, 2 ml of the standard trypsin solution was added. Additionally, 10 ml of substrate were made as a blank, although these were empty of the extract. The test tube materials were let to stand for 10 minutes while measurements were being made using a Spectronic 401 spectrophotometer at a wavelength of 410 nm. The formula below was used to determine the trypsin inhibitor activity as a quantity of trypsin units blocked per unit weight of the sample:

$$TIU\ mg = Absorbance\ of\ sanple \times \mathbf{0.01}F\ Absorbance\ of\ standard\ TIU/mg = b - a \times F\ \mathbf{0.01}$$

The equation used to calculate the experimental factor, F, is F = 1/(w x Vf/Va x D). Here, w represents the weight of the sample, Vf is the total volume of the extract, Va is the volume of the extract used in the assay, and D is the dilution factor.

Data analysis

The standard deviation around the mean has been employed to report the inaccuracies after the findings were triple-checked. The Analysis of Variance test (ANOVA one way) with Duncan's post hoc was employed by the International Business Machines Corporation (IBM) application for Windows, version 25.0, Armonk, New York, to identify the least significant differences. The significance criterion for excluding the null hypothesis was set at 5% prevalence.

Results and Discussion

Physical properties (color) of processed tamarind seed kernel powders

Table -1

Physical properties (color) of processed tamarind seed kernel powders

Colour profile	Whole tamarind seed (Control)	Drying	Autoclaving	Boiling	Roasting
L*	65.25±0.69	66.39±0.65	62.33±0.71	63.12±0.76	64.85±0.68
a*	8.46±0.21	7.9±0.24	7.98±0.26	8.18±0.36	8.39±0.26
b*	24.14±0.34	14.33±0.31	12.3±0.35	13.02±0.30	13.33±0.21

Values expressed are mean ± standard deviation of triplicates.

The data in Table 1 and Figure 2 show that the processed tamarind seed powder's color values differ significantly from those of dried and whole tamarind seed powder. Dried tamarind powder (66.39) had the highest L^* value among the powder samples according to tests made with the Chroma Meter equipment (CIE Lab). The observation suggests that unprocessed and dried powder is whiter than other powder samples. In comparison to the unprocessed sample, the color of the tamarind seed powder darkened after soaking, autoclaving, or roasting. According to Mahmoud and Abdel-Halim (1994)[27], the oxidative degradation of the tamarind powder's naturally occurring pigments during roasting and autoclaving as well as the relationship among air oxygen and endogenous enzymes may be to blame for the color loss that occurs during these processes. Although the roasted powder was lighter (having a greater L^* value) than the autoclaved and boiled powder, a similar pattern was seen there as well. Yellowness (b^*) values ranged from 12.3 to 24.14, and redness (a^*) values were between 7.9 and 8.46. When tamarind powders were formed from the autoclaved, boiled, and roasted, the color characteristics differed greatly. Buyers' perceptions of the finished items will be impacted by the coloration of such a component because it will be evident in them. This makes the powder color important for use in the food chain. Customers essentially select food ingredients based on color; thus, it is sensible to consider how the darker color of processed tamarind seed powder may alter food formulations.

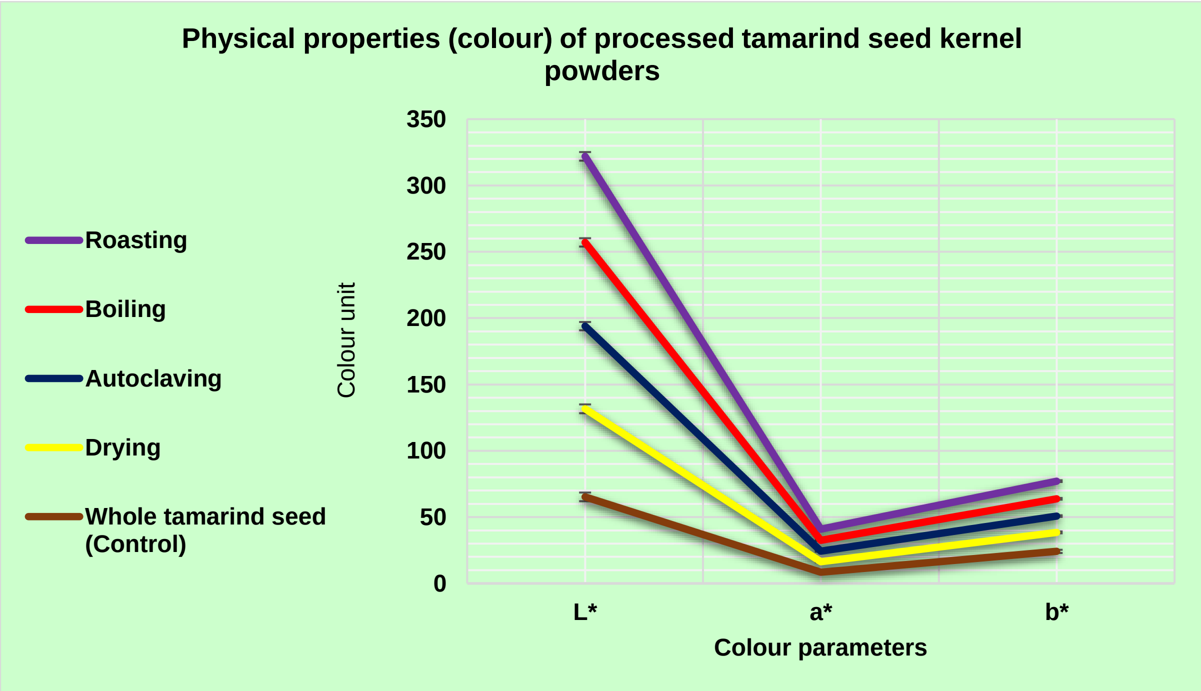

Figure -2: Physical properties (colour) of processed tamarind seed kernel powders

Chemical analysis of processed tamarind seed kernel powders

Table –2

Chemical analysis of processed tamarind seed kernel powders

Chemical analysis	Whole Tamarind Seed (Control)	Drying	Autoclaving	Boiling	Roasting	F value
pH (%)	5.59±2.15[b]	5.32±2.63[a]	4.85±1.36[ac]	4.68±1.68[c]	4.46±1.60[b]	2.67[*]
Ash (%)	1.43±1.65[ac]	1.56±0.85[b]	2.01±0.01[a]	1.85±0.58[ab]	2.33±0.36[c]	2.54[*]
Titratable acidity (g/lit)	17.19±3.19[ac]	12.22±3.45[b]	14.51±3.14[c]	11.27±3.20[a]	19.19±3.63[ab]	2.79[**]
Moisture (%)	6.43±2.36[ab]	9.42±3.21[a]	10.39±2.54[b]	8.86±2.64[ac]	8.90±2.68[b]	1.38[**]
Carbohydrate (%)	63.88±4.61[c]	61.23±2.65[ac]	58.84±2.42[a]	62.26±2.45[b]	60.61±2.47[ab]	3.49[**]
Protein (%)	23.13±2.68[b]	22.79±2.30[ab]	23.68±2.45[c]	22.09±2.36[ac]	24.13±2.63[a]	1.78[**]
Crude Fat (%)	4.11±1.54[c]	4.98±1.36[b]	5.05±1.36[a]	4.91±1.63[ab]	5.01±1.65[ac]	1.54[NS]
Crude Fibre (%)	4.67±1.68[a]	4.18±2.68[b]	4.28±1.68[b]	3.90±1.65[ab]	4.25±1.68[ac]	2.78[*]

Values expressed are mean ± standard deviation of triplicates. There is no statistically significant difference (P<0.05) between means in the column with the same superscript.

*- significant at 5% level; ** -significant at 1% level and NS- Not significant.

Table- 2 displays the results of a chemical analysis of processed tamarind seed powders. Whole tamarind seed, dried, autoclaved, boiled, and roasted processed tamarind powder had titratable acidities of 17.19%, 12.22%, 14.51%, 11.27%, and 19.19%, respectively. Roasted powder exhibited the highest titratable acidity, followed by autoclaved and boiled powder, which implied that fermentation flavors would be more potent the greater the titratable acidity. Additionally, very acidic dough or preferment (with high titratable acidity) would have a tangy or sour flavor. This study found that roasted powder had a high titratable acidity and a low pH value, which is compatible with the definition of high titratable as having a high acid concentration and a low pH.

Tamarind powder that has been treated had a pH that varied from 4.46 to 5.59%. Compared to whole tamarind seed powder (control), dried, autoclaved, and boiled powder, roasted powder showed a lower pH value (4.46%). When contrasted with those obtained by Abd Alhameed (2007)[28], who reported a value of 2.8, the current study's result was determined to be more significant. Reduced pH lengthens the shelf life of foods like juice, vinegar, and pickles by preventing the growth of food-spoiling microorganisms.

The processed powder had a varying ash content of 1.56% to 2.33%, as estimated by Mlakar *et al*., (2009)[29] for the crude ash percentage of raw tamarind powder at 1.66 percent. Boiling significantly reduces the amount of ash as both soluble macro and micro components are released into the processing media. On the other hand, autoclaved and roasted tamarind powder contained more ash than raw powder.

The moisture concentration of the other powders varied between 6.43% to 10.39%, with un-hulled powder having the lowest moisture value (6.43%). The highest moisture percentage (10.39%) was found in the autoclaving powder, which was substantially different from the other processing techniques ($p<0.05$). A study conducted by Singh et al. (2010)[30] has revealed that our processed tamarind seed powder is ideal for long-term preservation as the moisture content of the powder formulations is within the permissible range of 10% or less. This designates that the powder can stay on the shelf for a longer period without any physical, chemical, or biological changes. Furthermore, the moisture content and water activity play a significant role in food preservation and shelf life, as reported by Eke-Ejiofor and Owuno (2012)[31]. This is beneficial because a decrease in moisture content can prevent the growth of microorganisms that cause spoilage, particularly mold, thereby extending the shelf life of the product.

There was a statistically significant difference ($p<0.05$) in the carbohydrate content of the processed powder, ranging from 58.84% to 63.88%. Additionally, tamarind seeds contained 61.70% carbohydrate, according to Siddhuraja *et al*, (1995)[32], although Gunasena and Huges (2000)[33] observed a range of 65.10 to 72.20%. The research as reported in the aforementioned literature was consistent with the tamarind seed powder we prepared. However, all of the carbohydrate contents of the powder sample were substantially different from one another at $p<0.05$. The boiled tamarind powder (62.26%) had the most carbs, followed by the roasted powder (60.61%) and the autoclaved powder (58.84%). The processed tamarind seeds have a higher carbohydrate count than the control due to a decrease in fat and protein levels in the samples. The study suggests that tamarind seed powders have the potential for use in creating starch and industrial powder based on their carbohydrate content. According to Oluseyi and Temitayo (2015)[34], the observed differences may be attributed to variations in cultivars and genetic diversity across different geographic regions.

The protein composition of the powders varied from 22.09% to 24.13%. The maximum value was found in roasted powder (24.13%), while the lowest value was found in boiled powder (22.09%). However, Caluw et al. (2010)[35] revealed that the protein content of raw tamarind seed powder fell between 18.4 and 26.9%. According to research by Costa et al. (2015)[36], tamarind seeds function as nutrient reserve organs and are superior sources of protein when compared to other fruit sections. Tamarind seeds undergo a significant loss of protein after being autoclaved and boiled, which may be caused by the leaching of soluble nitrogen into the processing media. Accordingly, denaturation may be the cause of the roasted seed's apparent decrease in protein content. The powder could be utilized as a component in baking powders because of the high protein content it has, especially for the best dough formation[37]. Despite having substantial protein levels, the raw dried and whole tamarind seed powder samples could not be used in any food compositions without further processing because their powders could also include other pollutants in considerable quantities in addition to their highly dark color.

According to Siddhuraju *et al.,* (1995)[32], the fat percentage of the powder varied between 4.11% and 5.05%, and there were statistically significant differences ($p<0.05$) between them. The fat composition aligns with the nutritional and anti-nutritional qualities of underutilized legume species. The lipid content was significantly reduced ($p<0.05$) when the seeds were boiled during processing, which may be linked to the heating technique used. The dried (4.98%) and Whole Tamarind seed (4.11%) tamarind seed powders exhibited lower fat content than the processed powders.

In a research study conducted by Oluseyi and Temitayo (2015)[34], it was found that the fiber content in tamarind varieties ranged from 6.0 to 7.0%, which is higher than the range of 3.90 to 4.67% found in our processed powders. Boiled powder had the lowest fiber value of 3.90%. According to Plaami (1997)[38], incorporating fiber into one's diet can help lower bad cholesterol (LDL) levels and decrease the risk of coronary heart disease, colon cancer, and breast cancer. The importance of crude fiber was explored in the study by Islam *et al*., (2007)[39], who discovered that while soluble fibers help lower total blood cholesterol, insoluble fibers are effective in preventing constipation and reducing the risk of colon cancer. Adult men and women require that they ingest 38 and 25 g of dietary fiber regularly correspondingly, by Neha and Ramesh (2012)[40].

Functional properties of processed tamarind seed powders

Table 3 presents the results concerning several useful properties of processed tamarind seed powder. In the current investigation, the water absorption capacity ranged from 87.28 to

98.16 ml/g. Roasted powder (98.16 ml/g) has a substantially higher capacity to absorb water than other processing methods. Autoclaved powder showed a lower degree of water absorption capacity (87.28ml/g) than dried and whole tamarind seed powders. Water absorption capacity (WAC) is a measure of the capacity of any powder to interact with water in a specific environment when water is scarce. It is primarily dependent on proteins at ambient temperature and to some extent on starch and cellulose[41]. This agrees with the findings of our investigation. Plenty of hydrophilic substances in food, such as carbohydrates (especially polysaccharides), proteins, particularly polar residues of amino acids, and other hydrophilic elements, can be assigned to high water absorption capacity values.

Table -3: Functional properties of processed tamarind seed kernel powders

Functional properties	Water absorption capacity	Oil absorption capacity	Emulsion Capacity (%)	Bulk Density (g/ml)	Swelling Properties	Water Activity (a_w)
Whole Tamarind seed (Control)	90.87±10.47	85.11±8.46	33.62±2.36	0.44±0.01	10.78±2.54	0.30±0.02
Drying	96.36±10.43	74.37±8.31	45.17±2.56	0.46±0.02	10.46±2.68	0.45±0.01
Autoclaving	87.28±10.62	85.89±8.56	34.32±2.46	0.46±0.01	9.81±3.26	0.46±0.01
Boiling	94.11±10.89	88.07±7.56	39.91±2.34	0.44±0.02	11.12±1.24	0.41±0.2
Roasting	98.16±10.56	88.60±8.12	41.43±2.49	0.48±0.01	11.34±1.65	0.47±0.01
F value	3.45^{**}	6.45^{**}	3.15^{NS}	1.65^{NS}	4.16^{*}	1.68^{NS}

Values are expressed as mean ± standard deviation of triplicates. There is no statistically significant difference (P<0.05) between means in the column with the same superscript.

*- significant at 5% level; ** -significant at 1% level and NS- Not significant.

Powders may be employed to make several foods, including dough, sausage, processed cheese, and baked goods, owing to their great propensity to absorb water. Being able to soak up water is extremely important for food products, especially those that involve making dough[42]. The starch granules in these products have a weak connection between amylopectin and amylose, which means the granular structure is not very stable and may affect the product's ability to absorb water. Having a good water absorption capacity is crucial for baking, making sure the product is consistent, and adding bulk[42].

According to the findings, roasted powder (88.60) had the highest capacity for absorbing oil, followed by autoclaved powder (88.07), while boiled powder had the lowest capacity (88.07%). The capacity of wheat flour to absorb oil yielded findings of 146%, 124%, and 168%. They also found that wheat flour, rice flour, and gram flour powder formulations produced comparable outcomes. According to Akinyede and Amoo (2009)[43], the ability of dietary protein to bind with water and oil is determined by its amino acid composition, protein structure, and surface polarity or hydrophobicity. This trait is essential for enhancing tongue feel and maintaining the flavor of food products, as noted by Iwe et al. (2016)[42]. Foods with high protein content tend to absorb oil quickly. The structure, amino acid composition, and surface polarity or hydrophobicity of a protein influence its ability to bind with water and oil in food[9].

The emulsion capacity of the powder according to the investigation ranged from 33.62 to 45.17%. The roasted powder had a larger emulsion capacity (41.43%) than the boiled and autoclaved powders. The emulsion capacity of the processed powder gradually increased with each processing step and showed a significant difference ($p<0.05$) across the powders. According to Huang and Zayas (1991)[44], who studied the emulsion capacity in maize, maize germ proteins have been shown to enhance not only emulsifying capacity but also emulsion stability, which in turn can improve texture and result in the development of stable gels. The significantly better emulsion properties of roasted tamarind powder, according to Lawton and Wilson (2003)[45], can be attributed to the substance's high soluble protein content, which creates a barrier of defense around fat droplets to prevent them from coalescing. The high emulsion capacity roasted powder has the possibility of being used as a stabilizing agent in colloidal foods as well as a component in bread and processed foodstuffs.

The bulk density readings for the powder ranged from 0.44 to 0.48g/ml. The powder values did not vary substantially ($p> 0.05$). The diversity in food bulk density may be due to the starch content of the various foods. Iwe et al. (2016)[42] found that the higher the starch concentration, the more likely it is that the bulk density will grow. Recent research suggests that the initial moisture content of powders may affect their bulk density. The partially roasted powder's high bulk density (0.48g/ml) supported Suresh and Samsher (2013)[9] assertion that powders with high bulk densities are more likely to be suitable for use in culinary applications. On the other hand, low bulk density would be advantageous when producing complementing foods. Starch is the main ingredient and the bulk of numerous foods, including biscuits, bread, cakes, and pastries.

The swelling capacities of the four treated powders ranged from 9.81 to 11.34%, and there was no significant difference between them ($p>0.05$). According to Adebowale et al. (2008)[48], the swelling power of powders is affected by association binding inside the starch granules and the strength and composition of the micelle network in proportion to the amount of amylose in the powder. Therefore, the ability of powders to absorb water strongly correlates with their swelling power. The swelling qualities of some food products, such as bread goods, are used as an indication of quality. It is also a factor that determines the ratios of -amylose and -amylopectin and indicates that non-covalent linkages are present in the molecules of starch granules[42]. Particle size, taxonomic variety, processing method, or unit activities can influence the swelling properties of powders[9].

The water activity in the processed tamarind powder ranged from 0.30 to 0.47%. In comparison to other processed powders and dried and whole tamarind seed powder, the water activity value of roasted powder was higher (0.47%). According to the maximum water activity, roasted powder and processed powder both have comparatively elevated vapor pressure ranges. According to the FDA (2014)[47], the majority of foods have a water activity above 0.95, which is an appropriate amount of moisture for the growth of bacteria, yeasts, and mold. It was determined from the previously mentioned research that processed tamarind powder had a reduced water activity and could potentially be easily included in food formulations, extending the shelf life of the finished items.

Pasting properties of processed tamarind seed kernel powders

Table –4

Pasting properties of processed tamarind seed kernel powders

Treatments	Peak Viscosity	Trough Viscosity	Breakdown Viscosity	Final Viscosity	Set back Viscosity	Peak Time (Min)	Pasting Temperature (°C)
Whole tamarind seed (Control)	138.79	95.64	98.72	132.10	37.65	5.80	95.80
Drying	138.21	95.23	129.54	131.25	37.20	5.78	95.75
Autoclaving	210.56	96.42	102.56	165.45	72.15	5.35	82.31
Boiling	200.58	99.87	38.49	143.25	71.56	5.20	83.65
Roasting	235.88	108.52	38.47	186.54	68.30	5.80	72.35

The study presents the outcomes of tamarind seed powder's pasting properties, as shown in Table 4 and Figure 3. When evaluating the pasting abilities of powders from three distinct processing processes, dried and Whole Tamarind seed powder was employed as the raw material. Peak viscosity readings for the research ranged from 138.21 to 235.88. The peak viscosity readings for roasted tamarind seed powder (235.88cP) were higher than those for other processing techniques like autoclaving, boiling, and raw powder. The lowest peak viscosity was recorded for boiled powder (200.58cP), an autoclave powder (200.58cP), and both dried (138.21cP) and whole tamarind seed (138.79cP) powders. Peak viscosity is the level of thickness reached by a product during or immediately after being heated. It is a good indicator of the rate at which carbohydrates swell before breaking down physically[48]. Rosenthal et al., (1974)[49] claimed that high peak viscosity enhances paste texture, which is mostly dependent on high viscosity and relatively high gel strength. These qualities are compatible with the way we roast the tamarind powder. Since most of the types have high peak viscosities, the powder can be beneficial for items that need substantial gel strength and flexibility. As per the noted pasting properties of starch, its granules experience considerable swelling at the gelatinization humidity, leading to quick paste disintegration and high peak viscosity[50]. Peak viscosity is a key factor in determining the quality of the final product since it predicts the viscous load that will likely be experienced during mixing. Powders with a high peak viscosity show how the starch molecules interact with one another comparatively weakly. The molecules may enter the starch granules much more easily, which causes the granules to greatly expand. As a result, the associated pressures weaken, increasing the likelihood of granule fragmentation and the formation of weak gels[51].

Investigations of trough viscosity (TV) revealed a range of 95.23 to 108.52cP. Each of the dried and whole tamarind seed powders had low trough viscosity, with the autoclaved powder having the lowest value (69.42cP) and the roasted tamarind seed powder having the greatest value (108.52cP). Hot paste viscosity, according to Harmdok and Noomhorm (2006)[52], is the viscosity after the holding period at 95°C. According to Jimoh et al. (2009)[53], it measures the starch's ability to undergo processing without suffering harm whenever exposed to high temperatures over a lengthy period. Roasted powder had the highest trough viscosity (108.52cP), autoclaved (96.42cP), boiled, and last dried and whole tamarind seed powder. The trough viscosity of each processing method exhibited a range of readings as it increased. According to Singh et al. (2006)[54], who hypothesized that the degree of starch leaching may be to blame for the significant variation in trough viscosity among cultivars, viscosity may vary significantly. It has been demonstrated that starches with an amylose percentage that readily dissolve into the aqueous phase undergo re-association, leading to increased trough viscosities. The higher holding capacity of roasted tamarind powder may be attributed to the strong association forces among starch granules[53].

The range of breakdown viscosity (BD) values was 38.78cP to 129.54cP. It measures how brittle starches are. The breakdown viscosities of the powders vary by 5%, with the roasted powder having the lowest breakdown viscosity (38.47cP) and the dried powder having the highest breakdown viscosity (129.54cP). According to Tsakama et al. (2010)[55], breakdown viscosity measures the level of stability in granules or pastes. Powder samples with minimal paste stability or disintegration have very little cross-linkage within their granules as stated by Oduro et al. (2000)[56]. The aforementioned literature indicates that our roasted tamarind powder had a low breakdown viscosity or paste stability. According to Olufunmilola et.al., (2009)[57], a low breakdown value indicates a higher level of stability in hot temperatures. This indicates that the roasted tamarind powder granulates, which had the lowest disintegration value among the powder samples, have more robust cross-linking.

The final viscosity (Table 4) ranged from 131.25 cP to 186.54 cP. Control (whole tamarind seed powder) and treated powder had significantly different final viscosities ($p<0.05$). The difference in viscosity at the end of the process could be explained by the varying levels of amylose in the powders. Additionally, the cooling process and the way starch molecules associate in the samples can also affect viscosity[58]. The final viscosity measurements showed that roasted powder had the highest viscosity at 186.54cP, followed by autoclaved powder (165.45cP), boiled powder (143.25cP), dried powder (131.25cP), and whole tamarind seed powder (132.10cP). According to Shimelis et al. (2006)[59], the final viscosity of starch indicates its ability to form pastes or gels after cooling. A high rate of breakdown typically leads to reduced stability of the starch paste. The ultimate viscosity is the most commonly used factor to describe the quality of a sample. It shows the material's capacity to form a viscous paste or gel after cooking and cooling, as well as its resistance to shear force during stirring. The final viscosity is the variation in viscosity after the retention of cooked starch at 50°C, which demonstrates the stability of the cooked starch. This shows that starch can form a gel or paste when cooled, and that cooked starch paste is durable for real-world use[59].

The setback viscosity ranged from 37.20cP to 68.30cP. The setback viscosity among the powders varied substantially ($p<0.05$). Low setback viscosity suggests increased resilience to retrogradation, according to Sanni et al. (2004)[60]. These results (Table -4) show that both dried and whole tamarind seed powder had the lowest setback viscosity, indicating a better resilience to retrogradation. Roasted powder (68.30cP) has low setback values compared to autoclaved (72.15cP) and boiled powder (71.56cP). It is worth noting that various processing techniques can decrease the setback viscosities of tamarind powder, which may indicate an increased ability to resist retrogradation. This is particularly advantageous for household items like fufu, which require high viscosity and paste stability even at sub-zero temperatures[61]. Previous research by Kim et al. (1995)[62] has shown that cohesive paste and elevated setback values go hand in hand. Setback viscosity, which refers to the retrogradation index, can be measured by the viscosity of the cooked paste after being chilled to 50°C. This indicates that the starch molecules are undergoing rearrangement or retrogradation. Many products' textures and setback values are interrelated. Maziya-Dixon et al. (2005)[63] discovered that high setback values were linked to syneresis, or crying, during freeze/thaw cycles. The roasted powder's lowest setback value indicates that it has a lower tendency to retrograde. This is beneficial in food items such as soup and sauce, which suffer from viscosity loss and precipitation due to retrogradation. The powder may thus be ideal for product formulations owing to its smaller tendency to retrograde[64].

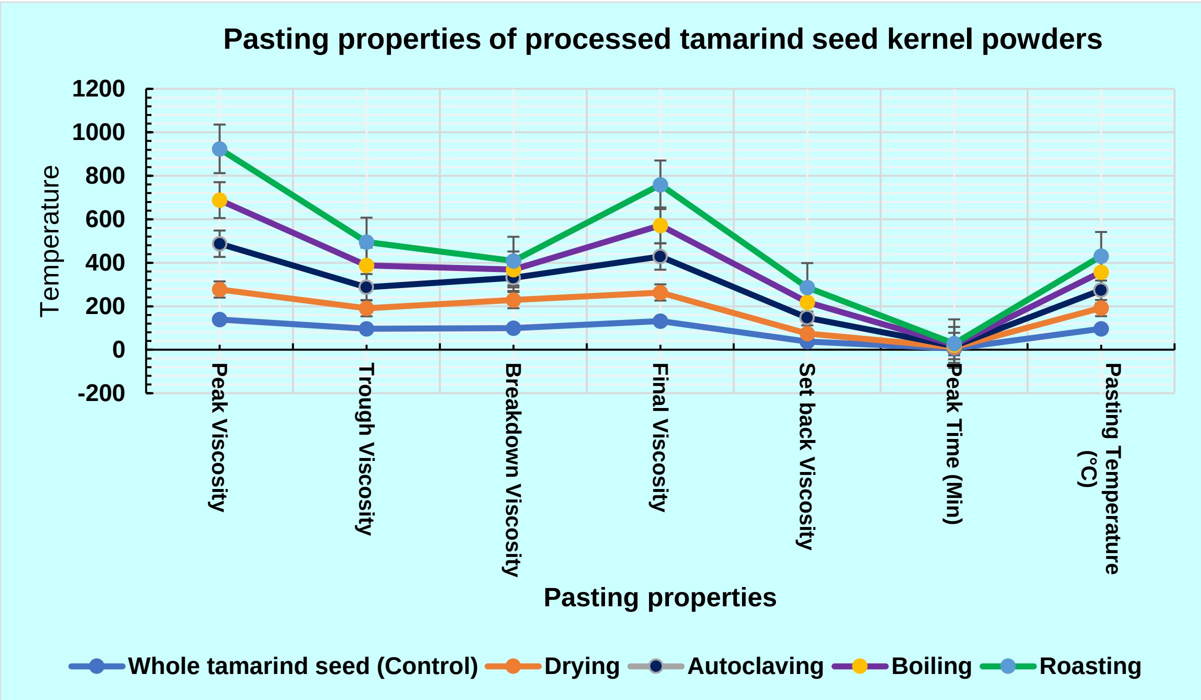

Figure -3: Pasting properties of processed tamarind seed kernel powders

During peak usage, a time interval of 5.78 to 5.10 minutes was observed. Additionally, the product's preparation is straightforward. A longer peak time for paste may suggest that the granules expand more slowly, making them less prone to mechanical damage[65]. Powders with shorter paste peak durations have lower swelling resistance, which means they are more likely to expand quickly and be vulnerable to concurrent shear-induced disintegration[66]. According to Etudaiye et al. (2015)[67], the timings for viscosity and cooking time were quite similar.

Table 4 shows the temperature range for pasting, which is between 72.35°C and 95.75°C. These figures are somewhat close to the temperatures that Aprianita et al. (2009)[68] measured for powdered yam and sweet potato, which were 72.7°C and 80.9°C, respectively. According to Sandhu and Singh (2007)[69], a high pasting temperature is related to a higher swelling resistance. Due to their ease in forming pastes and low pasting temperatures, the various powder samples were better suited for the majority of commercial food and non-food operations because they required less energy to manufacture. The pasting temperature is the minimum temperature needed to cook a specific type of food. According to Eliasson et.al., (2006)[70], differences in amylose levels, crystallinity, and whether or not amylose-lipid interaction is present affect how different starches behave in terms of their pasting ability.

Anti-nutritional content of processed tamarind seed kernel powders

Table –5

Anti-nutritional content of processed tamarind seed kernel powders

Anti-nutritional content	Tannin (mg/100g)	Trypsin inhibitor (TIU/mg)	Hydrogen cyanide (mg/kg)
Whole Tamarind seed (Control)	4.91 ± 0.03^{ab}	24.95 ± 1.54^{a}	5.28 ± 1.11^{b}
Dried	4.51 ± 0.04^{a}	22.33 ± 1.30^{b}	2.65 ± 1.14^{ac}
Autoclaving	3.18 ± 0.12^{b}	18.87 ± 1.24^{c}	5.41 ± 1.56^{a}
Boiling	3.56 ± 0.01^{c}	12.34 ± 1.65^{ab}	2.64 ± 1.30^{b}
Roasting	3.58 ± 0.16^{ac}	10.32 ± 1.34^{ac}	3.04 ± 1.25^{a}
F value	2.68^{**}	1.68^{**}	1.74^{*}

Values are expressed as mean ± standard deviation of triplicates. There is no statistically significant difference (P<0.05) between means in the column with the same superscript.

*- significant at 5% level; ** -significant at 1% level and NS- Not significant.

Table 5 displays the anti-nutritional components present in tamarind seed powders. Tannin content ranged from 3.18 to 4.91 mg per 100 grams. Autoclaving powder (3.18mg/100g) had lower tannin concentrations than boiling (3.56mg/100g) and roasting powder (3.58mg/100g). According to Uzogara et al. (1990)[71] analysis, the lower tannin content in processed powder may be due to some tannin's solubility in water during soaking and heating. Tannin levels were lower in the powders steamed without dehulling compared to those that were soaked, sprouted, and roasted with dehulling. This implies that steaming affects tannin reduction more so than roasting. Nakitto et al. (2015)[72] discovered that roasting and steaming were more effective than boiling at reducing tannins.

Trypsin inhibitor concentration in processed powders ranged from 12.34 to 24.95 TIU/mg. Processed powders (autoclaving, boiling, and roasting) showed lower trypsin inhibitor levels than dried and Whole Tamarind seed tamarind powder (18.87TIU/mg, 12.34TIU/mg, and 20.32TIU/mg, respectively). Protease inhibitors are proteins that inhibit the biological function of trypsin. They control the activation and catalytic processes of other proteins and compete with other proteins to bind to trypsin. This prevents trypsin from binding to other proteins and digesting them. Previous studies[73] have shown that by eliminating anti-nutritional elements like tannins and trypsin inhibitors, heating or boiling foods can significantly enhance their nutrient value. Roasting soybean meal also reduces trypsin inhibitor activity, making it an ideal ingredient for our processed tamarind seed powder[74]. Additionally, Torres et al. (2016)[75] found that boiling, soaking, and autoclaving beans significantly decrease the level of various anti-nutritional constituents.

The powders showed varying levels of hydrogen cyanide, ranging from 2.6 to 4.28 milligrams per 100 grams. Boiling the powder resulted in lower levels of hydrogen cyanide compared to autoclaving and roasting. This decrease in cyanogen content can be attributed to the heat involved in processing, which has been proven to significantly reduce cyanogen levels[76]. However, the seeds can become edible by soaking and boiling them in water to remove the seed coat[7]. It's important to note that the entire seed is not fit for consumption due to the presence of tannin, phytic acid, hydrogen cyanide, trypsin inhibitor activity, and phyto haemaglutin activity throughout the seed testa[16].

CONCLUSION

The results of the study showed that the different methods of processing have significantly impacted the physical and chemical properties, functionality, pasting, and anti-nutritional components of tamarind seed powders. The physical characteristic (color) of this study showed that roasted powder had high L*, a*, and b* values, which distinguished it from the tamarind powders. This indicates that roasting improves the color of powders. In terms of chemical analysis, roasted powder had higher levels of titratable acidity, ash, carbohydrate, protein, and crude fiber than other processing methods. However, it had lower levels of pH, moisture, and fat (within 10% level). Roasting also resulted in the highest functional properties compared to other methods, including the highest water absorption (98.16%), oil absorption, emulsion capacity, bulk density, swelling properties, and water activity. This study found that roasted tamarind powder has excellent pasting properties, with a high peak viscosity of 235.88°C and a low pasting temperature of 72.35°C. Compared to other processing techniques, roasted powder showed lower levels of tannin (3.58 mg), trypsin inhibitor (10.32 TIU/mg), and hydrogen cyanide (3.04 mg/kg), which are known to have anti-nutritional properties. The study concluded that roasting improves the physiochemical and functional properties of seed powder while minimizing the negative effects of anti-nutritional aspects. Furthermore, the study suggests that novel roasting processes can produce safe and high-quality foods by using various operating settings on different types of items.

Conflict of interest:

There are no conflicts of interest stated by the authors.

Funding:

The author is grateful to Periyar University in Salem, Tamil Nadu, for supporting her research efforts financially by awarding her a University Research Fellowship (URF).

Acknowledgement:

Both investigators received extensive support from the Department of Nutrition and Dietetics at Periyar University in Salem, Tamil Nadu, India, wherever the experiments were carried out. The investigators acknowledge the assistance of the Departments of Microbiology, and Food Science and Nutrition at Periyar University in Salem, Tamil Nadu, India.

REFERENCES

1. Sudjaroen Y., Haubner R., Würtele G., Isolation and structure elucidation of phenolic antioxidants from Tamarind (*Tamarindus indica L.)* seeds and pericarp, *Food Chem. Toxicol.* 2005; 43(11):1673–1682.
2. Christman S. Tamarindus indica. Floridata.com. Tallahassee, Florida USA. Available from: http://www.floridata.com/ref/t/ tama_ind.cfm. [Last cited in 2004 Feb 2].
3. Linda O. A., Justina N. N., Ngozika C. O., Njideka E. N. Egbeneke, C.O. Proximate, Mineral, and Anti Nutrient Composition of Processed (Soaked and Roasted) Tamarind (*Tamarindus indica)* Seed nut. *Curr. Res. Nutr. Food Sci.* 2014; 2(3): 136-145.
4. Khairunnuur F.A., Zulkhairi A., Azrina A., Moklas M.A.M., Khairullizam S., Zamree M.S. Nutritional composition, in vitro antioxidant activity, and Artemia salina L. lethality of pulp and seed of *Tamarindus indica L*. Extracts. *Malays J Nutr*. 2009; 15 (1): 65–75.
5. Pugalenthi M., Vadivel V. L- Dopa (l-3,4 Dihydrooxyphenylalanine): a non – protein toxic amino acid in mucana pruriens seeds. *Food*. 2007; 13: 22-27.
6. Ajayi I.A., Oderinde R.A., Kajogbola D.O., Uponi J.I. Oil content and fatty acid composition

7. El-Siddig K., Gunasen H.P.M., Prasa B.A., Pushpakumara D.K.N., Ramana K.V.R., Vijayanand P., Williams J.T. Tamarind (Tamarindus indica L.) fruits for the future1. Southampton Centre for Underutilized Crops, Southampton, UK, 2006; 188.
8. Oluseyi E.O., Temitayo O.U. Chemical and functional properties of fermented, roasted, and germinated tamarind (Tamarindus indica) seed powders. *J Nutri and Food Sci*. 2015; 45 (1), 97-111.
9. Suresh C., Samsher S. Assessment of functional properties of different powders. African *J Agri Res*. 2013; 8(38): 4849-4852. DOI:10.5897/AJAR2013.6905. ISSN 1991-637X ©2013.
10. Kaur M., Singh N. Relationships between the selected properties of seeds, powders, & and starches from different chickpea cultivars. *Int. J. Food Prop*. 2006; 9: 597-608.
11. Siddiq M., Nasir M., R Ravi., Dolan D.K., Butt S.M. The effect of defatted maize germ addition on functional and textural properties of wheat powder. *Int J. Food Prop*. 2009; 12: 860- 870.
12. Timotheo C.A., Lauer C.M. (2018). Toxicity of vegetable tannin extract from *Acacia mearnsii* in *Saccharomyces cerevisiae*. *Int J Environ Sci and Technol*. 2018; *15*(3): 659–664.
13. Lampart-Szczapa E., Siger A., Trojanowska K., Nogala-Kalucka M., Malecka M., Pacholek B. Chemical composition and antibacterial activities of lupin seeds extract. *Food/Nahrung*, 2003*; 47*(5), 286–290.
14. Raes K., Knockaert D., Struijs K., Van Camp, J. Role of processing on bio-accessibility of minerals: Influence of localization of minerals and anti-nutritional factors in the plant. *Tren in Food Sci & Technol*, 2014; *37*(1): 32–41.
15. Salas C. E., Dittz D., Torres M. J. (2018). Plant proteolytic enzymes: Their role as natural pharmacophores. In *Biotechnological applications of plant proteolytic enzymes*. 2018; 107–127.
16. Akajiaku L.O., Nwosu J.N., Onuegbu N.C., Njoku N.S., Egbeneke C.O. Proximate, mineral, and anti-nutrient composition of processed (soaked and roasted) tamarind (Tamarindus indica) seed nut. *Curr Res Nutr Food Sci.* 2014; 2(3):136-145.
17. Makinde., Ayodele. Impact of Processing on Physical, Chemical and Pasting Properties of Tamarind (T. indica) Seed Powder, *J Appl Sci Environ Manage*. 2022; 26 (6): 1039-1047.
18. AOAC., Official Methods of Analysis of Association of Official Analytical Chemists. 18th Edition, Washington, DC. 2010.
19. Phillips R. D., Chinnan M. S., Branch A. L., Miller J., McWatters K. H. Effects of pretreatment on functional and nutritional properties of cowpea meal. *J Food Sci.* 1988; *53*(3), 805-809.
20. Eke O. S., Akobundu E. N. T. Functional properties of African yam bean (*Sphenostylis stenocarpa*) seed powder as affected by processing. *Food Chem.* 1993; *48*(4): 337-340.

21. Onwuka G. I., Onwuka N. D. The effects of ripening on the functional properties of plantain and plantain-based cake. *Int J Food Prop.* 2005; *8*(2), 347-353.
22. Onwuka J. C., Agbaji E. B., Ajibola V. O., Okibe F. G. Treatment of crude oil-contaminated water with chemically modified natural fiber. *Applied Water Science,* 2018*; 8:* 1-10.
23. Santacruz S., Rualesa J., Eliasson A.C. Three under-utilized sources of starch from the Andean region in Ecuador. Part II. Rheological characterization. *Carbohydr Polym.* 2003; 51:85–92. doi: 10.1016/S0144-8617(02)00140-6.
24. Newport-Scientific (1998). Operational Manual for the Series 4 Rapid Visco Analyzer. Newport Scientific Pty, Ltd, Sydney.
25. Singh S., Gupta A. K., Kaur N. Influence of drought and sowing time on protein composition, antinutrients, and mineral contents of wheat. *The Sci World J.* 2012.
26. Onwuka G.I. Food Analysis and Instrumentation (Theory and Practice)-Second edition. Naphtali Printers, Nigeria, 2018; 299-314.
27. Mahmoud H., Abdel-Halim M. Monitoring the quality of wheat and dairy products manufacturer part I. Alneshracharkh Holding Rackets and Almills. 1994; 253.
28. Abdul-Hamid A., Luan S.Y. Functional properties of dietary fibre prepared from defatted rice bran. *Food Chem*. 2000; 68:15–19.
29. Mlakar S. G., Turinek M., Jakop M., Bavec M., Bavec F. Nutrition value and use of grain amaranth: potential future application in bread making. *Agricultura*. 2009; 6(4): 43-53.
30. Singh K. P., Mishra H. N., Saha S. Moisture-dependent properties of barnyard millet grain and kernel. *J Food Eng.* 2010; 96(4): 598-606.
31. Eke-Ejiofor J., Owuno F. Functional and pasting properties of wheat/three-leaved yam (*Dioscorea dementor*) composite powder blend. *Global Rese J Agri and Biolo Sci.* 2012; 3: 330–335.
32. Siddhuraja P., Vijayakumari K., Janardhanan K. Nutritional and anti-nutritional properties of the underexploited legumes Cassia laevigata Willd and *Tamarindus Indica L. J Food Compost Anal.* 1995; 8(4):351-362.
33. Gunasena H.P.M., Hughes A. Tamarind (*Tamarindus indica L.*). Eds. Hughes A., Haq N; Smith, R.W. International Centre for Underutilized Crops, Southampton, UK. 2000; 56-68.
34. Oluseyi E.O., Temitayo O.U. Chemical and functional properties of fermented, roasted and germinated tamarind (*Tamarindus indica*) seed powders. *J Nutri and Food Sci.* 2015; 45 (1): 97-111.
35. Caluw E.D., Halamov K., Damme P.V. Tamarindus indica L.: A review of traditional uses, phytochemistry and pharmacology. *Afrika Focus*. 2010; 23(1): 53-83.

36. Costa WD., Loiola L.C.O., Nonato C.F.A., Andrade C.C., Martins da Costa J.D., Rodrigues F.F.G. Analise fisco-quimica, bromatologica e antibacteriana dos frutos de Tamarindus indica LINN. *Cadernos de Ciencia e Cultura*. 2015; 14(1): 86- 95.
37. Onwurafor E. U., Umego E. C., Uzodinma E. O., Samuel E.D. (2017). Chemical, functional, pasting, and sensory properties of sorghum-maize-mungbean malt complementary food. *Pak J Nutri*. 2017; *16*(11): 826-834.
38. Plaami S.P. Content of dietary fiber in foods and its physiological effects. *Food Rev Int.* 1997; 13 (1): 29-76.
39. Islam T., Chowdhury A., Islam M., Islam S. Standardization of Bread Preparation from Soy Powder. *Int J Sustain Crop Prod*. 2007; 2(6): 15-20.
40. Neha M., Chandra R. Development of functional biscuits from soy powder and rice bran. *Int J Agric Food Sci*. 2012; 2:14–20.
41. Otegbayo B.O., Samuel F.O., Alalade T. Functional properties of soy enriched tapioca. *Afri J Biotech.* 2013;12(22): 3583-3589.
42. Iwe M.O., Onyeukwu U., Agiriga A.N. Proximate, functional & and pasting properties of FARO 44 rice, African yam bean, and brown cowpea seeds composite powder. *Cogent Food & Agri*. 2016; 2: 1142409. http://dx.doi.org/ 10.1080/ 23311932.2016.1142409.
43. Akinyede A. I., Amoo I. A. Chemical and functional properties of full fat and defatted Cassia fistula seed powders. *Pak J Nutr.* 2009; 8(6): 765-769.
44. Huang C.J., Zayas J. F. Aroma quality of corn germ protein powders determined by sensory and gas chromatographic profiles. *J. Food Quality*. 1991; 14: 377–390.
45. Lawton W.J., Wilson C.M. Proteins of the kernel. In Corn: Chemistry and Technology, 2nd ed.; White, P.J.; Johnson, L.A., Eds. Amer. Assoc. Cereal Chemists: St. Paul, MN, 2003; 314–354.
46. Adebowale A.A., Sanni L.O. and Onitilo M.OChemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods. *Afri J Food Sci.* 2008; 2, 077-082.
47. FDA Drug Safety Communication: FDA reporting mental health drug ziprasidone (Geodon) associated with rare but potentially fatal skin reactions 12/11/2014.
48. Sanni L. O., Kosoko S. B., Adebowale A. A., Adeoye R. J. The influence of palm oil and chemical modification on the pasting and sensory properties of fufu flour. *Int J Food Prop*. 2004; *7*(2): 229-237.
49. Rosenthal J., Angel A., Farkas J. (1974). Metabolic fate of leucine: a significant sterol precursor in adipose tissue and muscle. *Ameri J Physiol-Legacy Cont*. 1974; 226(2): 411-418.

50. Rickard E. C., Strohl M. M., Nielsen R. G. (1991). Correlation of electrophoretic mobilities from capillary electrophoresis with physicochemical properties of proteins and peptides. *Analytical biochemistry*, 1991; 197(1): 197-207.
51. Etudaiye H. A., Nwabueze T. U., Sanni L. O. (2009). Pasting and functional properties of processed cassava from mosaic disease-resistant varieties cultivated in a high rainfall zone. *Nig Food J*, 2009; 27(2):185-193.
52. Hormdork R., Noomhorm A. Hydrothermal treatments of rice starch for improvement of rice noodle quality. *LWT - Food Sci Technol.* 2006; 40: 1723 - 1731
53. Jimoh K. O., Olurin T. O., Aina J. O. (2009). Effect of drying methods on the rheological characteristics and colour of yam flours. *Afri J Biotech*. 2009; *8*(10).
54. Singh S. P., Grange T. Measuring pathways to care in first-episode psychosis: a systematic review. *Schizophrenia research*, 2006; *81*(1): 75-82.
55. Tsakama M., Mwangwela A. M., Manani T. A., Mahungu N. M. Physicochemical and pasting properties of starch extracted from eleven sweet potato varieties. *Afri J Food Sci and Technol.* 2010; *1*(4): 090-098.
56. Oduro I., Ellis W. O., Dziedzoave N. T., Nimako-Yeboah K. Quality of gari from selected processing zones in Ghana. *Food Control*, 2000; *11*(4), 297-303.
57. Oladunmoye O. O., Aworh O. C., Maziya-Dixon B., Erukainure O. L., Elemo G. N. Chemical and functional properties of cassava starch, durum wheat semolina flour, and their blends. *Food science & nutrition*, 2014; 2(2), 132-138.
58. Ikegwu O. J., Nwobasi V. N., Odoh M. O., Oledinma N. U. Evaluation of the pasting and some functional properties of starch isolated from some improved cassava varieties in Nigeria. *Afri J Biotechnol.* 2009; 8(10).
59. Shimelis E. A., Meaza M., Rakshit S. Physico-chemical properties, pasting behavior and functional characteristics of flours and starches from improved bean (*Phaseolus vulgaris L.*) varieties grown in East Africa. 2006.
60. Sanni L. O., Kosoko S. B., Adebowale A. A., Adeoye R. J. The influence of palm oil and chemical modification on the pasting and sensory properties of fufu flour. *Int J Food Prop.* 2004; *7*(2): 229-237.
61. Oduro I., Ellis W. O., Aryeetey S. K., Ahenkora K., Otoo J. A. (2000). Pasting characteristics of starch from new varieties of sweet potato. *Tropical science*, 2000; 40(1), 25-28.
62. Kim J. M., Marshall M. R., Cornell J. A., III J. P., Wei C. I. Antibacterial activity of carvacrol, citral, and geraniol against Salmonella typhimurium in culture medium and on fish cubes. *Journal of food science*, 1995; 60(6): 1364-1368.

63. Maziya-Dixon B., Adebowale A. A., Onabanjo O. O., Dixon A. G. O. Effect of variety and drying methods on physico-chemical properties of high-quality cassava flour from yellow cassava roots. In *African crop science conference proceedings*. Kampala, Uganda: African Crop Science Society. 2005; 7(2 – 3): 635-641.
64. Adebowale K. O., Lawal O. S. Foaming, gelation and electrophoretic characteristics of mucuna bean (*Mucuna pruriens*) protein concentrates. *Food chemistry*, 2003; *83*(2): 237-246.
65. Wiesenborn D. P., Orr P. H., Casper H. H., Tacke B. K. Potato starch paste behavior as related to some physical/chemical properties. *Journal of Food Science*, 1994; *59*(3), 644-648.
66. Tsakama M., Mwangwela A. M., Manani T. A., Mahungu N. M. Physicochemical and pasting properties of starch extracted from eleven sweet potato varieties. *African Journal of Food Science and Technology*, 2010; *1*(4): 090-098.
67. Etudaiye H. A., Oti E., Aniedu C., Omodamiro M. R. Utilization of sweet potato starches and flours as composites with wheat flours in the preparation of confectioneries. *African journal of Biotechnology*, 2015; 14(1): 17-22.
68. Aprianita A., Purwandari U., Watson B., Vasiljevic T. Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. *International Food Research Journal*, 2009; *16*(4): 507-520.
69. Sandhu K. S., Singh N. Some properties of corn starches II: Physicochemical, gelatinization, retrogradation, pasting and gel textural properties. *Food Chemistry*, 2007; *101*(4), 1499-1507.
70. Eliasson J., Larsen G., Tumi Gudmundsson M., Sigmundsson F. (2006). Probabilistic model for eruptions and associated flood events in the Katla caldera, Iceland. *Computa Geosci*. 2006; *10*, 179-200.
71. Uzogara S.G., Agu L.N., Uzogara E.O. A review of traditional fermented foods, condiments and beverages in Nigeria: their benefits and possible problems. *Ecology of Food Nutri*. 1990; 24 (4): 267-288.
72. Nakitto A.M., Muyonga J.H., Nakimbugwe D. Effects of combined traditional processing methods on the nutritional quality of beans. *Food Sci Nutr*. 2015; 3(3): 233-241.
73. Patterson C. A., Curran J., Der T. Effect of processing on antinutrient compounds in pulses. *Cereal Chemistry, 2017;* 94(1): 2–10.
74. Vagadia B. H., Vanga S. K., Raghavan V. Inactivation methods of soybean trypsin inhibitor– A review. *Trends in Food Sci & Technol.* 2017; *64,* 115–125.
75. Torres J., Rutherfurd S. M., Muñoz L. S., Peters M., Montoya C. A. The impact of heating and soaking on the in vitro enzymatic hydrolysis of protein varies in different species of tropical legumes. *Food Chemistry,* 2016; 194: 377–382.

76. Siddhuraju P., Vijayakumari K., Janardhanan K. Nutritional and antinutritional properties of the underexploited legumes cassia laevigata wild and *Tamarindus Indica L. J Food Composi and Anal*, 1995; 8, 351-362.