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Utilizing tamarind seed flour as a sustainable nutritional source in bakery formulations

Ashwini H N[1], Sushma B V[2], Shweatha H E[2*]
[1] Department of Nutrition & Dietetics, JSS Academy of Higher Education & Research, Mysuru, Karnataka, India
[2] Assistant Professor, Department of Nutrition & Dietetics, JSS Academy of Higher Education & Research, Mysuru, Karnataka, India

Abstract

Background: Fruits and vegetables, as prominent horticultural crops, are consumed in various forms: raw, processed, or as ingredients in culinary preparations. They serve as valuable sources of essential nutrients, including polysaccharides, vitamins, minerals, and bioactive phytochemicals such as phytosterols, carotenoids, polyphenols, and dietary fiber. In addition to providing energy, these nutrients offer antioxidant, anti-cancer, anti-inflammatory properties, and contribute to maintaining gut health. The fruit processing industry produces substantial waste, including skins, rinds, seeds, and pomace, which can be transformed into value-added products, contributing to the advancement of sustainable food security efforts. There is still a significant opportunity to explore these resources further, aiming to create value-added products and fully utilize their nutritional and bioactive advantages.

Objective: Hence, the present study was structured to capitalize on the potential of tamarind seeds in crafting commercially viable value-added products.

Methods: Three bakery products *viz*., cookies, muffins and buns were made by incorporating 25, 50 and 75% of Tamarind seed flour (TSF). The developed products were subjected to descriptive sensory, proximate (AOAC) namely moisture, ash, fat, and protein and mineral *viz*., iron (Wong's method) and phosphorus (Phosphomolybdate based method) analysis.

Results: The products incorporated with 25% showed the maximum acceptability and contained higher amounts of the analytes analysed. This underscores the importance of further investigating TSF as a potential nutrient source for enhancing the nutritional profile of existing products or innovating new ones.

Keywords: Tamarind seeds, bakery products, sensory evaluation, proximate, iron, phosphorus

Introduction

Fruits and vegetables are among the most widely consumed horticulture crops that are eaten raw, processed, or used as ingredients in various dishes. They are rich source of essential nutrients like polysaccharides, vitamins, minerals, bioactive phytochemicals like phytosterols, carotenoids, polyphenols, and dietary fibre. These apart from providing energy have antioxidant, anti-cancerous, anti-inflammatory functions and promote gut health.

Fruits being perishable due to their high moisture content, there's a necessity to process them to prolong their storage or shelf life significantly. Fruits undergo various processing techniques such as canning, drying, and freezing and made into a range of products including ketchup, jam, juices, pickles, preserves, candies, and chips etc. The fruit processing sector generates significant waste such as skins, rinds, seeds, and pomace, which can be made into value-added products, thus playing a role in promoting sustainable food security.

One such by product is tamarind seed, which despite being deemed as waste initially have been repurposed for various uses. Tamarind *(Tamarindus indica L.)* is an economically important tree, widely cultivated in Asia, Africa, and South American countries. In India it is widely grown in Madhya Pradesh, Bihar, Andhra Pradesh, Karnataka, Tamil Nadu, and West Bengal [1]. Primarily tamarind is valued for its fruits, which can be consumed fresh, processed, or used as a seasoning or spice. The pod pulp, which constitutes around 40% of the fruit, is particularly notable for its high vitamin C content and contains tartaric, malic, and citric acids, as well as sugars. Known for its sweet-sour taste, the pulp is commonly used in various beverages, confections, savoury dishes like curries, and condiments like chutneys [2].

However, the seeds remaining after the use of fruit pulp, are flat, shiny, and either circular or rhomboid in shape, measuring between 3 to 10 cm in length and 1.3 cm in width. They are dicotyledonous and hard, ranging in color from red to purple, brown. The seed comprises approximately 20-30% seed coat (testa) and 70-75% kernel (endosperm), with the seed portion accounting for about 40% of the total weight of the tamarind fruit.

These seeds are notably rich in protein, boasting significant quantities of essential amino acids such as isoleucine, leucine, lysine, methionine, phenylalanine, and valine. Additionally, they serve as a valuable source of essential fatty acids and minerals, with notably high levels of calcium, phosphorus, and potassium compared to other legumes [3]. They also serve as sizing materials in industries like textiles, paper, and jute [4].

Nevertheless, there remains ample opportunity for further exploration of this resource to create value-added products and fully leverage its nutritional and bioactive benefits. Therefore, the current work was designed to harness the potential of tamarind seeds to develop commercially viable value-added products.

Material and methods

1. Material

Tamarind seeds were sourced from local market in Mysore and milled into fine flour. Three products each were developed by incorporating tamarind seed flour *viz*., cookies, muffins, buns. All the ingredients for product development were also locally sourced.

2. Tamarind seed flour products

Cookies, cupcakes, and buns were made by incorporating tamarind seed flour (TSF) at different levels (25%, 50%,75%) creating three variations each of the product. The popular bakery products were made using standard recipes as given below.

Cookies: Butter and powdered sugar were beaten until creamy, then combined with milk. Wheat flour, baking soda, and a pinch of salt were added and mixed into a dough. The dough was shaped into balls, rolled, and cut into cookie shape and baked at 170°C for 25 minutes. After baking, the cookies were cooled before storing in an airtight container.

Cupcakes: Ripe smashed banana was mixed with sugar and warm water, then blended thoroughly. Melted butter and lemon juice were added and mixed in. Wheat flour, baking soda, baking powder, and a pinch of salt were sifted into the mixture. The batter was poured into muffin cups and baked at 170°C for 25 minutes.

Buns: Wheat flour, sugar, butter, salt, and dry yeast were made into a dough. The dough was fermented for 2.5hrs and made into shape of buns were baked at 170°C for 30 minutes.

3. Sensory analysis

Sensory analysis was done using the descriptive method which is a systematic approach to evaluate and quantify sensory attributes of food products. In this method, trained panelists assess various sensory characteristics, such as appearance, aroma, flavor, texture, and overall quality, using standardized terminology and scales [5].

4. Proximate and mineral analysis

The developed products were subjected to proximate analysis *viz*., moisture, ash, protein, and fat using AOAC methods [6]. Iron and phosphorus were also determined using Wong's and a variation of the Phosphomolybdate method respectively [7, 8].

Moisture: The method for moisture estimation entails first weighing a sample, subjecting it to 16 hours of drying in an oven, followed by a subsequent weighing, cooling it within a desiccator, and then conducting a final weighing. Moisture content is quantified as a percentage, derived by subtracting the initial weight from the final weight, dividing the difference by the sample weight, and then multiplying by 100.

Ash: The procedure for ash determination includes charring 5 grams of the sample on a hot plate until the cessation of smoke indicates removal of organic matter. The charred residue is then subjected to a muffle furnace at 550 degrees Celsius for 5 to 6 hours. Upon cooling, the weight change represents the estimated ash content.

Fat: Fat estimation was conducted using the Soxhlet method. The sample was placed in a Soxhlet extractor, where it was repeatedly extracted with an organic solvent, typically hexane, to remove the fat content. After multiple extraction cycles, the solvent containing the extracted fat was evaporated, leaving behind the fat residue. The residue was then weighed, and the fat content was determined based on the weight difference before and after extraction.

Protein: Protein estimation was carried out using the Kjeldahl method. The sample was digested in concentrated sulfuric acid with the addition of a catalyst, typically a mixture of copper sulphate and potassium sulphate. After digestion, the nitrogen content in the sample was determined by distillation with sodium hydroxide solution, followed by titration with standardized acid. Protein content was calculated based on the nitrogen content, using a conversion factor.

Iron estimation by Wong's method

This method provides a reliable means to determine iron content based on the intensity of the red color developed upon reaction between ferric ions with potassium thiocyanate, offering a quantitative assessment of iron content in the sample and is modified accordingly for food samples.

A series of steps were undertaken to quantify the iron content in the sample. Initially, 1ml to 5ml aliquots of a standard solution containing $FeCl3.6H2O$ were pipetted into multiple test tubes. Subsequently, the volume in each test tube was adjusted to 5ml by adding distilled water. Following this, 30% sulfuric acid was introduced into all test tubes, bringing the total volume to 6ml. Then, 1ml of potassium persulfate solution was added to initiate the reaction. In the final step, 1.5ml of potassium thiocyanate solution was uniformly added to each test tube, and the mixture was allowed to incubate for 20 minutes at room temperature. The intensity of the resulting red coloration, indicative of the iron concentration, was measured spectrophotometrically at 540nm against a blank [7].

Phosphorus estimation

A variation of the Phosphomolybdate Method, was used to estimate phosphorus from the samples [8].

A phosphorus working standard (Potassium dihydrogen phosphate in water plus 10N sulphuric acid) solution is treated with ammonium molybdate reagent, hydroquinone, and sodium sulphate. First, 1 mL of ammonium molybdate reagent, containing ammonium molybdate and sulfuric acid, is added to an aliquot of the standard solution. Following this, 1 mL of hydroquinone solution, serving as a reducing agent, and 1 mL of sodium sulphate solution are introduced. The mixture is thoroughly mixed and then allowed to incubate for 30 minutes. During this incubation, phosphorus reacts with the ammonium molybdate reagent, forming a yellow phosphomolybdate complex. After incubation, the optical density of the solution is measured at 660 nm using a spectrophotometer. The intensity of the blue color produced is directly proportional to the phosphorus concentration, allowing for its quantification by comparison with a standard curve.

5. Statistical Method: Statistical methods, including percentage and standard deviation, were used to analyse the data comprehensively. Percentages allowed for comparing relative proportions across various categories, providing a clear view of the variable distribution within the sample population. Standard deviation measured the variability or dispersion of data points around the mean. Calculating the standard deviation provided insights into data consistency, showing how much individual observations differed from the average.

Result and Discussion

1. Sensory acceptability of the tamarind seed flour (TSF) incorporated products.

Three bakery treats, specifically cookies, muffins, and buns, were created by integrating TSF into conventional recipes at levels of 25%, 50%, and 75%. Bakery items enjoy widespread popularity across diverse demographics, presenting an excellent opportunity to introduce innovative nutritional compositions. Improving the nutritional value of these familiar products enhances their acceptance and enjoyment among consumers. With an increasing preference for healthier food choices, there is a rising demand from consumers. Manufacturers can leverage this trend by revamping bakery goods to offer enhanced nutrition, effectively catering to the needs of health-conscious individuals.

The products prepared were subjected to sensory evaluation by 50 panel members and radar charts were used to illustrate the sensory attributes of the developed food product, with each axis representing a specific characteristic such as taste, texture, aroma, appearance, and overall acceptability.

Figure 1 represents the sensory scores of cookies; CV1, CV2 and CV3 incorporated with TSP at various levels, *viz*., 25, 50 and 75 % compared to CV, the cookies made without TSP which served as standard or control. CV2 variant of the cookies made with 50% TSP were found to match favourably with the standard cookies in terms of taste, flavour, and overall acceptability.

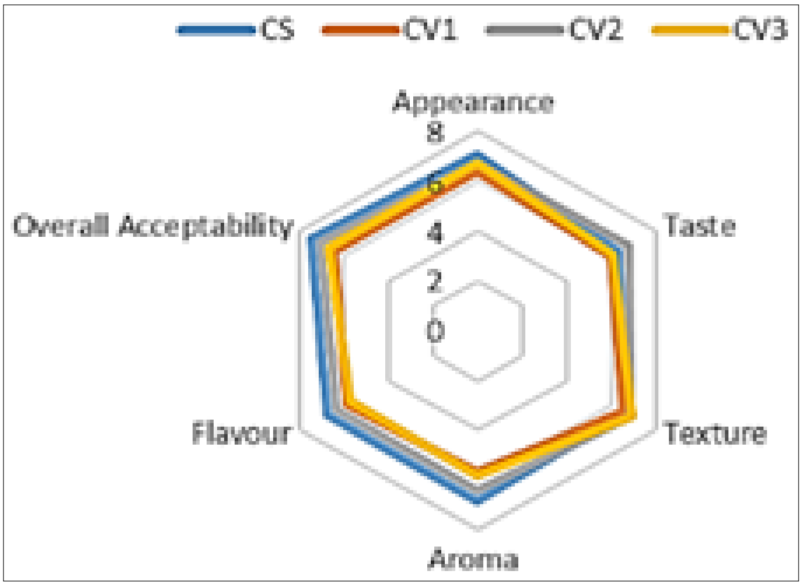

Fig 1: Sensory scores of cookies incorporated with TSF at various levels

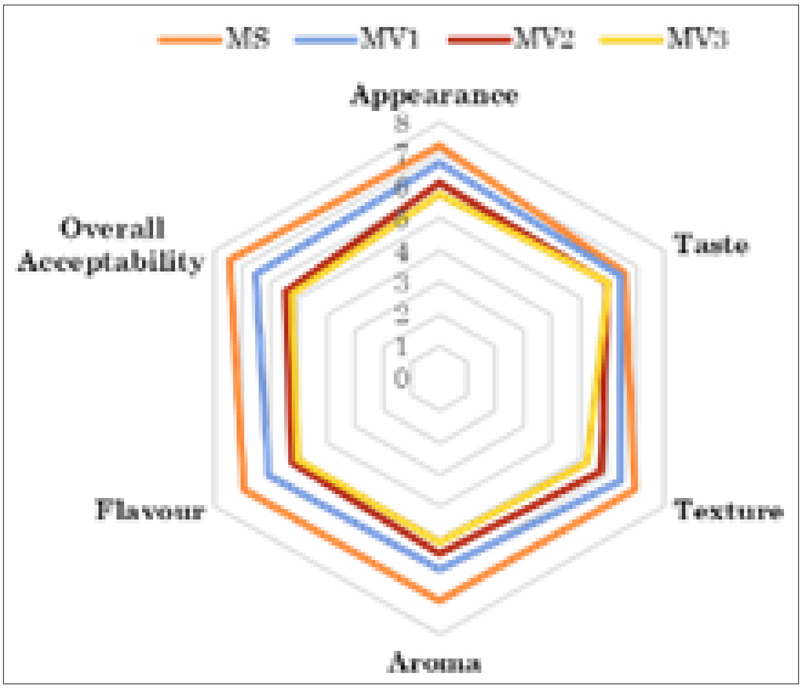

Fig 2: Sensory scores of muffins incorporated with TSF at various levels

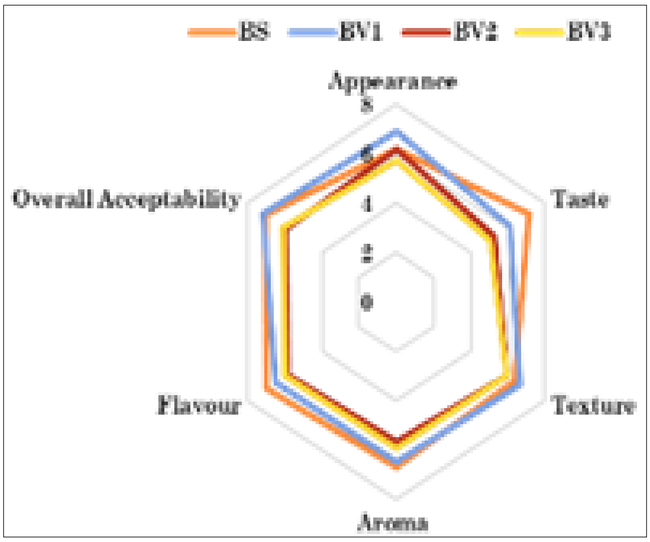

Fig 3: Sensory scores of buns incorporated with TSF at various levels

Muffins with higher concentration of tamarind powered scored less on overall. The muffins made with 25% TSP i.e., MV1, fared better than the higher concentration of TSF, Fig 2. Like wise buns made with 25s% TSP i.e., BV1, Fig 3 scored well on all the sensory parameters studied. Remarkably, both buns and muffins crafted with 25% tamarind powder achieved comparable scores to the standard products. Additionally, cookies featuring a higher percentage (50%) of tamarind powder received higher ratings. TSF's nutty flavour added on to the organoleptic experience of the products developed. A similar investigation was conducted, utilizing Tamarind Kernel Powder (TKP) in the formulation of baked goods like biscuits, bread, and cakes, with subsequent assessment of their physicochemical characteristics. Biscuits were subjected to analysis for width, thickness, and spread factor, revealing significant changes upon incorporating TKP. Bread samples were assessed for weight, volume, specific volume index, and width-to-height ratio, while cake batter underwent testing for pH and specific gravity. The protein content varied among the products, ranging from 13-14g per 100g in biscuits, 15-16g per 100g in bread, and approximately 9.2% to 9.8% in cake. Antioxidant studies demonstrated improved properties in the products. Overall, both analytical and sensory evaluations concluded with satisfactory findings [9]. This demonstrates the potential for integrating tamarind seed flour into existing recipes to enhance their nutritional value.

Another study aimed at producing cookies enriched with tamarind seeds found that the protein content in the enriched cookies ranged from 15.52% to 17.25%, surpassing the protein content of whole wheat cookies at 14.28%. This indicates the potential of utilizing tamarind seeds for enriching cookies. The study also revealed that processed tamarind flours (including pressure-cooked, oven-roasted, and microwave-roasted) exhibited higher total phenolic contents, ranging from 1.72 to 2.71 mg GAE/g, in comparison to whole wheat flour, which measured at 1.26 mg GAE/g [10].

2. Nutrient profile of the developed products

Proximate analysis is an indispensable tool in food product development, providing essential information for nutritional labelling, quality assurance, regulatory compliance, and product optimization. Understanding the nutritional composition allows developers to create products that meet specific dietary requirements or target certain consumer preferences, such as low-fat or high-protein options. The most acceptable products i.e., buns and muffins crafted with 25% TSF and cookies made with 50% of TSF were subjected to moisture, ash, fat, and protein estimation. Two dietary minerals were also analysed namely iron and phosphorus. Fig4, represents the proximate values of TSF and the products developed thereof. Products produced using TSF exhibited higher levels of ash, fat, and protein content when compared to standard products. For example, CV2 had 4.37% ash, 34.95% fat, and 13.98% protein, whereas CV had 3% ash, 30.35% fat, and 5.8% protein. Similarly, MV1 exhibited 2.8% ash, 12.18% fat, and 13.5% protein, while the standard product showed 2% ash, 9.7% fat, and 2.5% protein. Buns incorporating 25% TSF had 2.31% ash, 32.35% fat, and 12.5% protein, compared to the standard bun with 1.28% ash, 29.98% fat, and 5.74% protein, respectively.

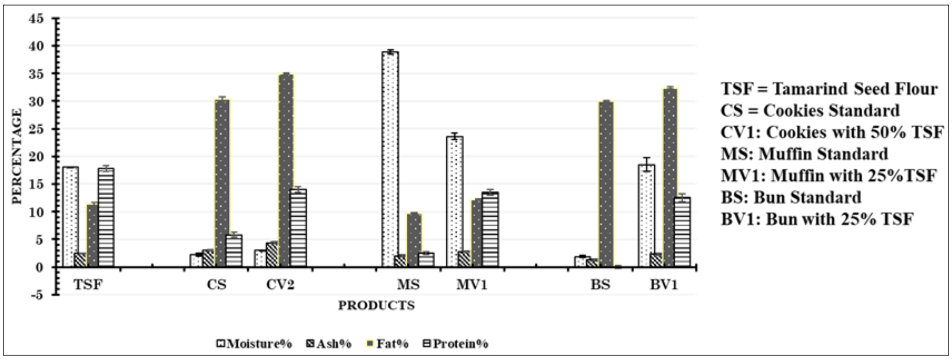

Fig 4: Proximate composition of the developed products

A study examined the composition of *Tamarindus indica* seed nuts after processing through roasting at 100°C for 15 minutes and soaking for 14 days to remove the seed coats. Proximate analysis of the roasted and soaked samples revealed varying levels of crude protein, moisture, crude fat, crude fiber, ash, and carbohydrates [11].

Whole tamarind seed and seed kernel are rich sources of protein. Tamarind seeds exhibit strong protein content and meet WHO standards for three out of the eight essential amino acids. Specifically, the levels of isoleucine, leucine, lysine, methionine, phenylalanine, and valine in the seeds are notably high [12, 13].

The seeds are rich in fatty acids and typically contain between 1 and 2 mg/g of linoleic acid on a dry weight basis. It was found that tamarind seeds consisted of a higher proportion of unsaturated fatty acids (55.6%) compared to saturated fatty acids (44.4%) [3, 14,15].

The current study focused on two minerals, iron and phosphorus, and found significant amounts in the developed products (Fig 5). For instance, the standard cookies contained 4.29 mg/100g of iron and 180 mg/100g of phosphorus, whereas cookies incorporating 50% TSF had higher levels of 6.4 mg/100g of iron and 212 mg/100g of phosphorus. Similarly, MS exhibited 4.3 mg/100g of iron and 199 mg/100g of phosphorus, whereas MV1, containing 25% TSF, showed 5.3 mg/100g of iron and 206 mg/100g of phosphorus. Likewise, BS had 4.6 mg/100g of iron and 100.8 mg/100g of phosphorus, while BV1, with 25% TSF, had 5.6 mg/100g of iron and 216 mg/100g of phosphorus.

A study conducted in Nigeria aimed to determine the proximate, mineral, and anti-nutrient composition of processed tamarind (Tamarindus indica) seed nuts, which were soaked and roasted. Both roasted and soaked samples contained minerals such as potassium (K), magnesium (Mg), phosphorus (P), sodium (Na), and iron (Fe), while calcium was undetected in either form. The research group suggested that incorporating tamarind seed nuts into food processing could lessen reliance on traditional legumes for protein, particularly in developing nations like Nigeria [11].

Tamarind seeds apart from being source of nutrients are also good source of phytochemicals that have health benefits. Analysis of *T. indica* seeds uncovered numerous bioactive compounds, including phenolic compounds, cardiac glycosides, L-(−)-malic acid, tartaric acid, mucilage, pectin, arabinose, xylose, galactose, glucose, and uronic acid. These constituents exhibit diverse biological properties such as antioxidant, anticancer, anti-inflammatory, antivenom, and antidiabetic activities [16, 17, 18].

A research investigation focusing on the extraction of phytochemicals from *Tamarindus indica Linn*. seeds through petroleum ether and ethyl acetate solvent methods discovered distinct compounds in each fraction. Steroids were identified in the petroleum ether fraction, while flavonoids and tannins were detected in the ethyl acetate fraction. Additionally, the study evaluated the anti-inflammatory effects through carrageenan-induced paw oedema and cotton pellet-induced granuloma models in rats, while analgesic effects were assessed using tail immersion and hot plate models in mice. The presence of active components such as flavonoids and tannins in *T. indica* seeds might contribute to their anti-inflammatory and analgesic properties [19]. Tamarind seeds possess not only industrial applications but also potential food-related uses that warrant further exploration.

Conclusion

The fruit industry produces a substantial volume of waste, including peels, seeds, and other leftover materials, which frequently find their way into landfills, posing environmental challenges. Nevertheless, there's a growing awareness of the untapped potential in repurposing this waste to craft nutritionally dense products. Through innovative techniques, fruit waste can be metamorphosed into high-value items like dietary supplements, functional foods, and natural flavourings or incorporated into existing popular snack products thus increasing their nutritional value. Bakery goods present a promising avenue for incorporating this waste, as they are commonly consumed as convenient snacks. Enhancing these products with essential nutrients can boost their nutritional density, rendering them significantly more beneficial compared to existing nutrient-deficient products. Moreover, by repurposing waste into valuable commodities, the fruit industry can minimize its environmental footprint, promote circular economy principles, and contribute to building a more sustainable food system. Embracing waste utilization in creating value-based, nutritionally rich products represents a promising pathway towards addressing nutritional challenges while simultaneously achieving sustainability goals.

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