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RESEARCH ARTICLE

In Vitro Study of the Nutrients, Antioxidant, Glycemic Activities, and Storage Stability of the Instant Tamarind Seed Kernel Powder Soup Mix

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Abstract

This study aimed to develop a soup mix using roasted tamarind (*Tamarindus indica* L.) seed kernel powder and evaluate its physical, chemical, mineral, and sensory characteristics, as well as glycemic response, antioxidant activity, and shelf life. Four different formulations of Tamarind seed kernel powder Soup Mixes (TSM1-10%, TSM2-20%, TSM3-30%, and TSM4-40%) of tamarind seed kernel powder were used to replace corn flour, and a control group (100% corn flour) was also tested. The physicochemical, mineral, sensory characteristics, antioxidant activity, glycemic response, and shelf life of each soup mix were evaluated using standard procedures. TSM4 had the best physical properties, while chemical analysis showed that this formulation had the highest protein content (11.31%) and caloric value (404.99 Kcal/100g). TSM4 also had the highest mineral composition and the greatest levels of TFC (23.12mg/100g), TPC (14.08mg/100g), and DPPH activity (112.41%). All five soup mix formulations had low glycemic indices and low glycemic loads. Sensory analysis indicated that TSM3, which contained 30% tamarind seed kernel powder, was the most acceptable option, with an overall acceptability score of 8.04. Shelf-life evaluation showed that the Total Plate Count (TPC) and fungal growth increased significantly over time, but the soup mixes could be stored for up to 15 days. The study found that the prepared soup mixes were more cost-effective and affordable than commercial soup mixes available in the market. Additionally, the research explored the effect of processing steps on these compounds and innovation trends for developing healthier soups that cater to specific consumer requirements.

Keywords: Antioxidant, Chemical, Glycemic, Physical, Soup Mix, Tamarind Seed Kernel Powder

1. Introduction

Food consumption has been in flux for the past decade and the need for instant formulations has been on the rise. In the present scenario, the convenience food sector is expanding rapidly in India and adapting to the needs of the country. The potential driving the Indian convenience food industry includes the country's changing demographics, convenience, and nutritional advantages[1]. When it comes to meal preparation, convenience foods only need to be slightly heated or warmed, or dried foods may be rehydrated in either hot or cold water[2].

Convenience and health-promoting products are demanded by today's health-conscious consumers. High-grade processed foods that are ready to use, convenient, shelf-stable, and of good quality are in demand. One type of essential dry food is instant soup. Convenient meals like soup powder are made using materials like corn starch, spices, taste enhancers, and salt. Of all the dry items, instant soup mixes have become more popular. They come in a variety of packing options and are rather easy to make. Soups are eaten by patients whose intake of solid foods is limited owing to different physiological problems, as well as for their nutritive value. By including entire grains, pulses, and veggies in soup formulas, nutritional balance may be achieved[3].

Instant soup mixes can meet the energy and nutrient adequacy requirements of the body[4] and

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can be used as a substitute food for mealtime. An excellent soup powder should be prepared quickly because it is a liquid food. According to Abeysinghe and Illeperuma[5], it ought to maintain its nutritional value and have a flavour that is nearly identical to that of freshly prepared food. One benefit of dried soup mixes is that they maintain their flavour for extended periods—up to a year at room temperature and are resistant to oxidative and enzymatic deterioration[6]. They are accessible year-round, light to carry, and don't require refrigeration[7]. The consumer's health can be enhanced by adding useful ingredients to the soup powder.

According to Hafeel *et al.*,[8] ready-to-drink dry soup mixes are easy-to-make meals made with a variety of components, mostly maize starch, spices, salt, flavourings, and enhancers. A "soup" is a dish made by adding items, like vegetables or meat, into boiling or hot water until their flavour comes out, creating a broth. Oftentimes, soup has been utilised to help patients cure diseases particularly if they are only able to digest liquids. In addition, soup can be used as an appetiser at the beginning of a meal to increase appetite and facilitate the passage of digestive fluids through the stomach[9].

This research might provide to explore the tamarind seed's kernel nutritional qualities because of their high nutritional value, and antioxidant and glycemic activity making them a necessary raw material for the food industry. The present study aimed to study the physical, chemical, mineral, and sensory characteristics, glycemic response, and antioxidant activity along with the storage stability of roasted tamarind seed kernel powder incorporated soup mix.

2. Materials and Methods

The tamarind seeds were purchased from a Salem, Tamil Nadu, marketplace. Corn flour and ingredients for the spice powder (coriander, cumin, pepper, chilli, ginger and garlic) were purchased from a nearby grocery store in Salem, Tamil Nadu.

2.1 Roasted Tamarind Seed Kernel Powder Preparation

Tamarind seeds were roasted at a constant temperature (100-120°C for 20-25 mins) then removed the seed coat and ground in a mill. Store the powder in a properly cleaned, airtight container[10] at the right temperature for further processing.

2.2 Spice Mix Powder Preparation

The freshly dried spices such as coriander, cumin, pepper, and chilli were procured from the local market, in Salem, Tamil Nadu. the dry ingredients were placed in a pan to dry roast to enhance the flavour until its colour changed to a slightly golden colour. The roasted ingredients were cooled and powdered using a mixer grinder and stored in an air-tight container. The other freshly purchased ginger and garlic pods were cleaned properly and were washed in water properly. The sliced ginger and garlic cloves were dried out and were oven-dried for 8-10 hours at 60°C[11]. Then the dried ginger and garlic cloves were powdered using a mixer grinder and stored for further processing.

2.3 Preparation of Instant TSM

Following the collection of the dried powders, TSM (Tamarind seed kernel powder Soup Mix) was formulated in various ratios and combined with additional spices and salt. The flow chart (Figure 1) indicates the instant tamarind seed kernel powder incorporated soup mix preparation.

Table1. Ingredient combinations of instant tamarind seed kernel powder soup mix (TSM)

Ingredients	Control	TSM1	TSM2	TSM3	TSM4
Tamarind seed kernel powder (g)	0	10	20	30	40
Corn flour (g)	100	90	80	70	60
Spice powder (g)	20	20	20	20	20
Salt (g)	10	10	10	10	10

TSM -Tamarind seed kernel powder Soup Mix

Five distinct soup mix formulations were made using varying percentages of tamarind seed kernel powder (Control-0%, TSM1-10%, TSM2-20%, TSM3-30%, and TSM4-40%), as indicated in Table 1. Reconstituted the instant soup mix with water to make the soup. All of the final mixes were sealed and preserved as a stock for further analysis.

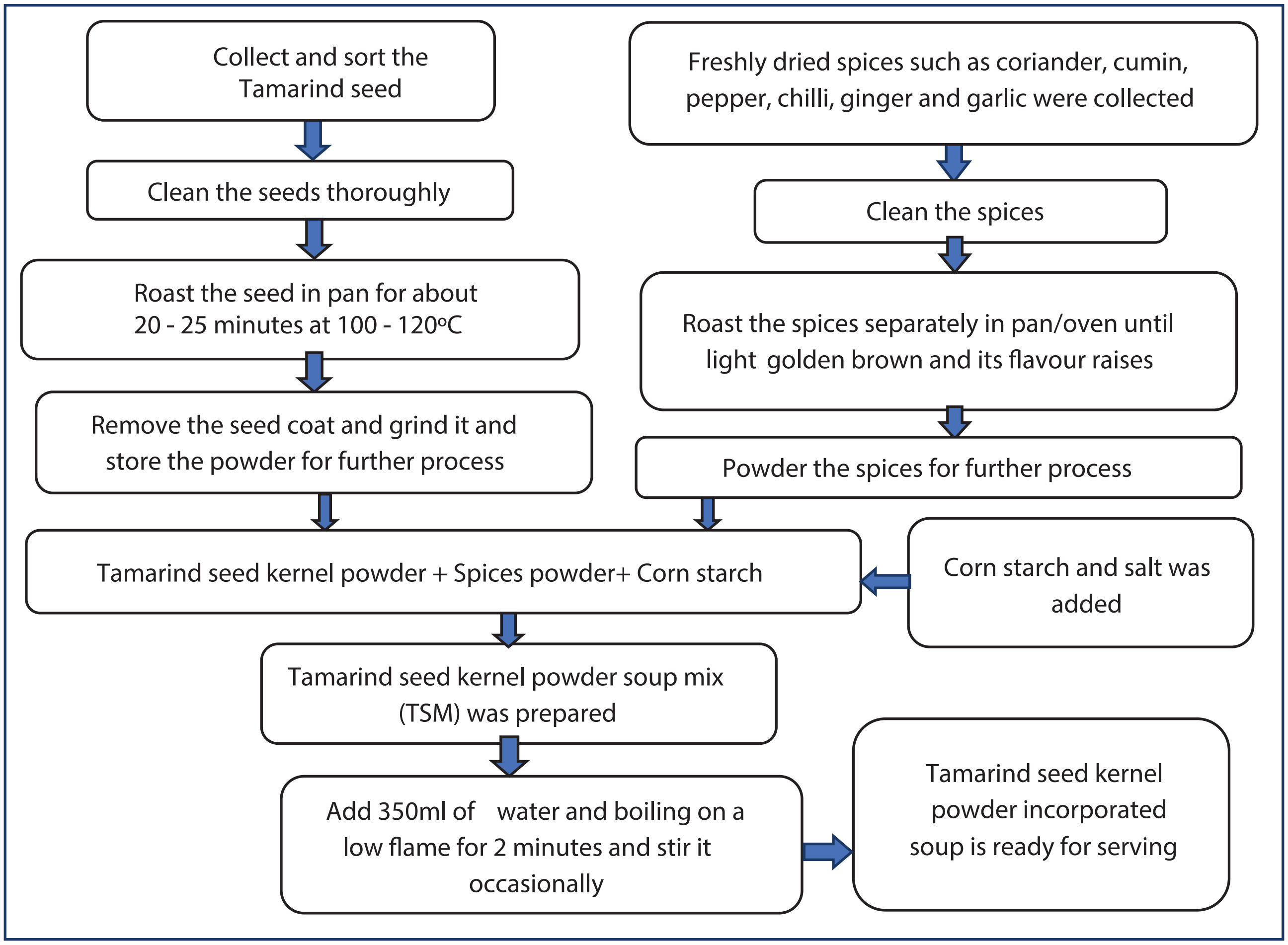

Figure 1. Flow chart: Instant tamarind seed kernel powder incorporated soup mix preparation.

2.4 Physical Properties of Instant TSM

2.4.1 Reconstitution Index (RI)

The reconstitution index of the samples was calculated using the procedure outlined by Onwuka[12]. In cold, potable water (soup mix: water = 1:16), the TSM was reconstituted. To create a soup that was ready to sip, it was stirred and brought to a boil.

2.4.2 Solubility

The traditional approach[13] was followed with minor adjustments to test the solubility of the instant soup mix. The mixture was blended for five mins at a high speed of 13,000 rpm to disperse one gm of it in 100 ml of distilled water. The blended mixture was subsequently centrifuged for five mins at 3000 rpm. A meticulous pipetting process was used to transfer a 25 ml aliquot of the supernatant to an aluminium dish that had been pre-weighed. The dish was then oven-dried for five hours at 105ºC. Every hour, the sample was weighed as it continued to dry for the full two hours. By calculating the weight differential, the mixture's solubility (%) was found. The water solubility (%) of the product was ascertained by using the weight differences.

2.4.3 pH

The AOAC (1995)[14] technique was used for measuring pH. To sum up, a digital pH metre (make: Metrohm, Switzerland; model: 780) was used to record the pH after 10 g of TSM and 50 ml of distilled water were homogenised in a laboratory blender (POLYTRON, PT 300) for one min[15].

2.4.4 Water Absorption Capacity (WAC)

The soup sample's propensity to absorb water was indicated by its mass increase. The volume of water absorbed by one gm of the test sample was determined by the volume difference. According to Onwuka[12], the unit of measurement for absorption capacity is gram of water absorbed per gm of sample.

2.4.5 Bulk Density (BD)

The soup mix sample was carefully poured into a graduated 10 ml cylinder. Next, many light taps on a lab bench were made on the bottom of the cylinder. This keeps happening until there is no longer any noticeable decrease in the test flour in the cylinder following filling to mark[12].

2.4.6 Rehydration Ratio (RR)

As per Krokida and Marinos-Kouris[16], the rehydration ratio can be determined by the weight of the rehydrated samples divided by the sample's dry weight.

2.4.7 Swelling Index (SI)

The swelling index was calculated using the procedure outlined by Ukpabi and Ndimele[17].

2.4.8 Water Activity (a_w)

To fill the specimen ampule to the halfway to three-quarters mark, an instant soup mix was added. According to Sopotenska and Chonova[18], the sample container was stored under the sample chamber, and the water activity was measured using an Aqua Lab water activity metre (Dew point water activity metre 4TE).

2.4.9 Colour Measurement

The CIE technique (1976)[19] was utilised to measure the colour of formulated instant soup mixes using a Hunter colour measuring system. The results were reported in terms of L*, a*, and b*.

2.5 Chemical Properties

Following the standard procedure established by the AOAC (2007)[20], the proximate composition of moisture, crude fat, protein, and ash percentage of the instant TSM and the control soup mix were estimated.

2.5.1 Calorific Value

As per Osborne and Voogt's 1978 study[21], the energy content was calculated by multiplying the percentage values of crude protein, crude fat, and total crude carbohydrate by 4, 9, and 4, respectively, and then adding these results.

2.5.2 Mineral Compositions of Instant TSM

Samples of soup mixes were analysed for mineral content using the AOAC (2015)[22] procedure. Vanadomolybdate technique was used in a colourimeter with an absorbance reading of 430 nm (Jenway 6051, model PFP7) to assess phosphorus levels, while titration with ethylenediaminetetraacetic acid (EDTA) was used to verify the levels of calcium and magnesium.

2.6 Antioxidant Activities of Instant TSM

The DPPH test (0.1 mM) was used to measure the free radical scavenging activity[23]. After two hours of shaking and 20 ml of methanol, two gm of the TSM samples were extracted. There were two extractions carried out. After the extract was combined, it was centrifuged for 15 mins at 10,000 rpm. Up to analysis, the supernatant was kept at 20° C. Test tubes were filled with 100 µl of the extract aliquot and 2.9 ml of DPPH solution. After one minute of vortexing, the mixture was left in the dark for three mins. At 517 nm, the discolouration of DPPH was measured in comparison to a blank. We calculated the DPPH scavenging effect using the following formula: Percent inhibition = AB-AA/AB ×100 Where AB = absorbance of blank; AA = absorbance of the sample.

2.7 Glycemic Index and Glycemic Load

Using tables and standardised calculation processes, the GI and GL of meals and daily intake may be determined based on the GI and GL values of foods[24,25].

2.8 Sensory Analyses of Instant TSM

A panel consisting of thirty semi-trained participants assessed the sensory qualities of TSM samples for several sensory aspects. A nine-point hedonic scale was used to evaluate sensory characteristics such as colour and appearance, consistency, mouth feel, flavour, taste, and overall acceptability for all samples. The following was the order of the hedonic scale: like extremely - 9, like very much - 8, like moderately 7, like slightly - 6, neither like nor dislike - 5, dislike slightly 4, dislike moderately - 3, dislike very much - 2, dislike extremely – 1.

2.9 Shelf-life Evaluation of Instant TSM

Thirty days of environmental circumstances were used to test the immediate TSM's storage stability. Every

Table 2. Physical properties of instant TSM

Physical properties		Control	TSM1	TSM2	TSM3	TSM4
Reconstitution Index (g/ml)		14.75±0.89^{a}	14.96±0.95^{ab}	15.01±0.86^{b}	15.06±0.86^{d}	15.8±0.82^{c}
Solubility (%)		28.89±1.52^{b}	30.24±2.65^{a}	30.58±2.68^{c}	30.89±2.16^{b}	30.96±2.01^{ab}
pH		7.2±1.96^{c}	5.59±2.38^{ab}	5.55±1.35^{b}	5.53±1.65^{c}	5.51±0.86^{a}
Water absorption capacity(ml/100g)		295±21.35^{a}	298±23.58^{ab}	300±23.59^{a}	305±20.15^{c}	306±21.35^{b}
Bulk density(g/ml)		0.99±0.05^{ab}	0.72±0.02^{b}	0.70±0.86^{a}	0.65±0.03^{c}	0.60±0.02^{d}
Rehydration ratio		2.8±0.85^{a}	3.6±1.65^{b}	4.6±2.68^{ab}	5.4±1.65^{c}	6.5±1.68^{b}
Swelling index		1.45±0.48^{a}	1.55±0.86^{ab}	1.63±0.74^{b}	1.75±0.85^{c}	1.80±0.67^{d}
Water activity(a_w)		0.49±0.03^{a}	0.52±0.02^{ac}	0.51±0.25^{b}	0.53±0.02^{c}	0.55±0.01^{d}
Colour profile	**L***	76.89±12.15^{c}	75.99±20.5^{bc}	75.95±21.35^{b}	75.75±13.45^{ab}	75.64±12.58^{a}
	a*	9.46±6.45^{c}	8.15±6.49^{bc}	8.10±3.49^{b}	7.95±2.08^{ab}	7.82±1.68^{a}
	b*	15.08±2.65^{c}	13.86±2.15^{b}	13.48±2.56^{b}	13.25±3.54^{a}	13.08±5.68^{a}

$^{a\text{-}c}$ Means in a column with common superscript are not significantly different at the p <0.05 level of probability by Duncan's multiple range test.
L* Represents the brightness from white (100) to black (0) a* Represents the red to green colour. b* Represents the yellow to blue colour. TSM -Tamarind seed kernel powder Soup Mix.

sample was taken at intervals of 0, 15, and 30 days, and its TPC and fungal count were determined. The researcher Aneja[26] approach was utilised to count all of the plates.

2.10 Statistical Analysis

The different parameters' means and standard deviations were calculated. To do the analysis, the SPSS Statistical Analysis Tool Pack was used. A calculation was made to determine the Least Significant Difference (LSD) at 5% when comparing the parameters.

3. Results and Discussion

3.1 Physical Properties of Instant TSM

Functional characteristics are important to the overall characteristics and industrial uses of food materials[27]. The rehydration ratio of TSM was determined to be lowest in the control group (14.75 g/ml) and highest in TSM4 (15.8 g/ml) when several combinations of TSM were assessed (Table 2). Fang *et al.*,[28] states that for food powder to be functional and beneficial, it must have good solubility. Being the final step of powder dissolution, solubility plays a critical role in defining the overall quality of reconstitution. The solubility improved with increasing degrees of tamarind seed kernel powder inclusion, ranging from 28.89% to 30.96%. TSM's pH changed from 7.2 to 5.5 as the level of incorporation was increased, indicating a noticeable drop in pH.

Within 295 to 306 ml/100 g, the produced soup mix's Water Absorption Capacity (WAC) varied. As indicated by Table 2, TSM4 had the highest value (306 ml/100 g), TSM3 was next (305 ml/100 g), and the control had the lowest value (295 ml/100 g). Proteins are capable of interacting with water in meals since it is both hydrophobic and hydrophilic, and flour with high water absorption may have additional hydrophilic ingredients like polysaccharides. The consistency and bulking qualities of flour are influenced by its water absorption ability[29]. The capability of flour to bind with water in a situation when water is scarce is known as its water absorption capacity. This ability is mostly reliant on proteins at room temperature and to a lesser degree on starch and cellulose[30].

The soup mix's bulk density varied from 0.60 to 0.99 g/ml. The TSM formulations' bulk densities were notably lower than the control. Foods may have different amounts of starch depending on their bulk densities. As the starch concentration rises, so does the probability of an increase in bulk density. Among the factors influencing bulk density are particle size, geometry, measurement technique, surface characteristics, and solid density of the materials. Particle size reduction, appropriate vibration/taping, compatibility, and appropriate packing material can all lead to its improvement[29].

Soup mix rehydration ratios varied from 2.8 to 6.5, with TSM4 having the greatest ratio (6.5) and the control mix having the lowest (2.8) (Table 2). In TSM formulations, TSM4 had the greatest swelling index (1.80) whereas control had the lowest (1.45).

The soup mix's water activity ranged from 0.49 to 0.55; TSM4 had the highest water activity (0.55) and the control had the lowest (0.49). Aw, or water activity, rose dramatically as tamarind seed kernel powder was added to the soup mixtures in greater amounts. One of the few significant factors that affect how stable a product's shelf life is its water activity (Aw), which raises questions about food safety.

According to the TSM hunting colour profile, TSM4 had the lowest L* and b*value (75.64 and 13.08respectively) compared to other TSM formulations and the control had the highest values (76.89 and 15.08 respectively), indicating that the control soup mix was very bright. Following the drying process, the L* value was examined to determine the lightness value, Suyatma[31] and Nur *et al.*,[32] studies corroborated our results. Brighter samples are indicated by a higher value of L*. It is well known that this number describes how food quality varies following treatment. TSM4 produced the lowest a* values (7.82) and the control soup mix had the highest values (9.46). At the 5% level, significant variations were seen amongst the formulations (Table 2). These values hinder the opacity of the formulated instant soup mix powder. Soup mix powder colour is important because it affects the crumb colour of the finished product.

3.2 Chemical Properties of Instant TSM

Table 3 displays the chemical composition of instant TSM. The moisture content of TSM varied from 0.45% to 1.96%, indicating that the formulations contained moisture. TSM1 and TSM2 could deteriorate quickly if not stored properly due to their high moisture content. However, TSM4 had a low moisture content (0.45%) and differed significantly from the other TSM formulations and the control at a 5% level. The newly designed soup had decreased moisture content compared to previous research, where a moisture content of less than 8% is necessary to prevent microorganisms from proliferating, and moisture content exceeding 18% may promote gradual microbial growth. Gandhi *et al.* (2017)[33] study also suggests that the increase in moisture content was within the safe limit (< 14%).

The ash levels varied from 2.01% to 2.19%. TSM4 differed significantly from the control and had a high ash level, indicating the presence of minerals in TSM. Essential elements must be obtained from food sources for the human body to function correctly physiologically. According to Bennett *et al.*,[34] findings - a deficiency in specific minerals may cause illnesses and abnormal growth.

The carbohydrate content of TSM1, TSM2, TSM3, and TSM4 was the lowest, while the control had the highest content (89.44%). Statistically, the control was better than the other formulations.

Table 3. Chemical properties of instant TSM

Chemical properties	Control	TSM1	TSM2	TSM3	TSM4	F test
Moisture (%)	1.53±0.08^{a}	1.96±0.02^{ab}	1.45±0.04^{b}	0.56±0.01^{ac}	0.45±0.02^{c}	32.68*
Ash (%)	2.01±0.01^{ab}	1.24±0.05^{ab}	1.63±0.69^{ac}	2.12±0.01^{c}	2.19±0.02^{a}	10.68**
Total carbohydrate (%)	89.44±6.15^{c}	87.48±5.47^{b}	86.29±6.46^{ab}	85.86±6.79^{ac}	83.95±7.15^{b}	13.48*
Protein (%)	4.98±0.54^{a}	5.77±0.98^{ab}	7.25±1.65^{b}	10.13±1.68^{c}	11.31±2.64^{ac}	25.67**
Total fat (%)	2.94±0.02^{c}	2.82±0.01^{bc}	2.67±0.02^{a}	2.66±0.85^{ab}	2.21±0.01^{b}	11.52**
Total dietary fibre (%)	0.45±0.01^{b}	0.52±0.03^{a}	0.83±0.14^{c}	1.01±0.58^{ab}	1.06±0.65^{ac}	12.98*
Caloric value (Kcal/100g)	396.04±25.31^{c}	397.03±26.15^{a}	399.54±24.65^{ab}	403.85±23.48^{c}	404.99±22.68^{ac}	43.68*

$^{a\text{-}c}$ Means in a column with common superscript are not significantly different by Duncan's multiple range test.
* -Significant at 5% level; ** -Significant at 1% level.

The range of protein in the control and variant TSM formulations was 4.98% to 11.31%. TSM4 had the highest protein content (11.31%), followed by TSM3, TSM2, TSM1, and the control. Each formulation was distinct from the others.

TSM formulations contained fat levels ranging from 2.04% to 2.82%. TSM1 differed significantly from the other formulations and had the greatest fat content. This soup is suitable for all diets due to its reduced fat level. A low-fat diet may also aid in preventing major illnesses such as diabetes, high cholesterol, and heart disease.

In TSM formulations, the amount of dietary fibre varied from 0.45% to 1.06%. The formulation with the greatest fibre content, TSM4, differed significantly from the others. Research suggests[35,36] that dietary fibre is essential in preventing several illnesses, such as diabetes, cancer, diverticulosis, constipation, irritable colon, and cardiovascular disorders. As a result, the soup powder being produced may be beneficial in preventing certain illnesses.

TSM formulations had caloric values ranging from 396.04 Kcal/100g to 404.99 Kcal/100g. TSM4 had extremely few carbohydrates and a significant calorie value. TSM 1formulations differed significantly from the control and demonstrated superiority. Our findings conflicted with Farzana *et al.*,[37] who studied soup mixes containing mushrooms and found that powdered mushrooms had a low fat and carbohydrate content.

3.3 Mineral Compositions of Instant TSM

Tamarind is a great source of minerals, such as magnesium, copper, and potassium, according to research by Almeida *et al*[38]. Selenium, iron, phosphorus, and calcium are also present. These minerals are very similar to those present in tamarind seeds. The calcium levels ranged from 157.44mg to 203.4mg, with the TSM4 formulation showing a significantly higher calcium content at a 5% level. TSM4 formulations also had high concentrations of magnesium, phosphorus, potassium, and iron, (126.83mg, 163.58mg, 506.77mg, and 8.98mg respectively).

With 126.83 mg of magnesium, 2.6 times more than the control, TSM4 had the highest magnesium level. It had 2.4 times more phosphorous (163.58 mg) in it than the control. Table 4 indicates that TSM4 had a potassium content of 506.77 mg, which was substantially greater than the control at a 5% level.

The soup mixes contained iron and sodium in the range of 6.04mg to 8.98mg and 1.09g to 1.39g, respectively. TSM4 formulation had the highest iron content (8.98mg) and the lowest sodium content (1.09mg). The study suggests that roasted tamarind seed can be used in food formulations up to 40%, as it provides essential mineral components that are beneficial to consumers.

Table 4 displays a significantly significant difference ($p<0.05$) in the mineral compositions of TSM. This outcome is in line with the research conducted by

Table 4. Mineral compositions of instant TSM

Mineral composition	Control	TSM1	TSM2	TSM3	TSM4	F test
Calcium (mg/100g)	157.44 ± 21.65^{a}	177.27 ± 20.15^{ab}	210.54 ± 11.68^{ac}	212.07 ± 12.47^{b}	203.4 ± 10.35^{c}	12.21^{*}
Magnesium (mg/100g)	47.98 ± 12.51^{ab}	66.86 ± 13.24^{b}	89.16 ± 14.15^{c}	118.73 ± 15.16^{a}	126.83 ± 24.68^{ac}	10.54^{**}
Phosphorus (mg/100g)	69.26 ± 20.35^{ac}	92.92 ± 23.54^{c}	118.68 ± 20.64^{a}	150.33 ± 24.65^{b}	163.58 ± 20.15^{ab}	8.95^{*}
Potassium (mg/100g)	257.51 ± 28.45^{c}	344.12 ± 31.54^{ab}	366.28 ± 30.62^{b}	503.42 ± 27.45^{a}	506.77 ± 29.45^{ac}	11.35^{**}
Iron (mg/100g)	6.04 ± 1.62^{a}	8.1 ± 2.54^{ac}	8.39 ± 3.54^{c}	8.52 ± 2.68^{b}	8.98 ± 2.64^{b}	10.26^{**}
Sodium (g/100g)	1.39 ± 0.85^{ac}	1.34 ± 0.96^{a}	1.21 ± 0.98^{c}	1.13 ± 0.74^{b}	1.09 ± 0.65^{ab}	14.65^{**}

$^{a-c}$ Means in a column with common superscript are not significantly different by Duncan's multiple range test. * -Significant at 5% level; ** -Significant at 1% level.

Kayode *et al.*,[39] who discovered that various traditional soups under investigation had high phosphorus values. All of the prepared TSM had significant mineral contents, which shows the impact of additional components. According to a previous study[40], minerals are required for human growth and nourishment as well as for the proper functioning of tissues.

3.4 Antioxidant Activities of Instant TSM

The findings of TSM's antioxidant activity are shown in Table 5. The soup mix's Total Flavonoid Content (TFC) ranged from 0.05 mg to 23.12 mg. TFC was greatest in TSM4 (23.12 mg/100 g), and lowest in the control group (0.05 mg/100 g). At each level of roasted tamarind seed kernel powder addition, TFC demonstrated a substantial ($p<0.05$) increase. There was a noticeable distinction between the control and other TSM formulas in TSM2 and TSM4. The Total Phenolic Content (TPC) of the soup mix varied from 0.08mg to 14.08mg, with TSM4 having the highest TPC content (14.08mg/100g) and also showing a significant difference between the control and other formulations. DPPH activity of the soup mix ranged from 56.23% to 112.41%. TSM4 had the highest DPPH activity with an antioxidant powder of 112.41%, and a lower level was noted in TSM1. However, for the control soup mix, the DPPH level was detected at below levels. The incorporation of 40% roasted tamarind seed kernel powder into the soup mix formulations resulted in double-time increased content of the TFC, TPC, and DPPH activity compared to the control.

The quantity of flavonoid and phenolic compounds as well as other phenolic compounds produced by the non-enzymatic browning reaction throughout the procedure determines the samples' antioxidant activity in major part[41]. *Tamarindus indica* L. seeds are known for their high phenolic, flavonoid, and antioxidant content, which is why there was a reported increase in TFC, TPC, and DPPH in soup mix powder. The best antioxidant components found in fruits, vegetables, and grains are polyphenol and flavonoid chemicals, as shown by several studies.

The primary reasons antioxidant activity is important for human health are that it scavenges free radicals and protects against oxidative stress, which can lead to illnesses like cancer and heart disease. Research has indicated that flavonoid and polyphenol molecules are useful in avoiding certain illnesses. Similar findings were reported by Mastrodi *et al.*,[42] who found that adding pomegranate peel (*Punica granatum*) extract, which is high in antioxidants, to orange and tomato juice increased the activity of antioxidants.

3.5 Glycemic Responses of Instant TSM

Table 6 and Figure 2 demonstrate the glycemic responses of TSM. The TSM glycemic index ranged from 53.40% (TSM1) to 51.24% (TSM4); it decreased when corn flour was replaced by roasted tamarind seed kernel powder. Depending on these GI values, the glycemic load ranged from 9.23% (TSM1) to 8.56% (TSM4). The control and the four variations of formulated TSM showed low glycemic index and low glycemic load and also showed a significant difference between the control and the formulations at a 5%

Table 6. Glycemic responses of instant TSM

Soup mix variations	Glycemic Index	Glycemic Load
Control	54.28 ± 2.14^{a}	9.54 ± 0.86^{a}
TSM1	53.40 ± 1.89^{b}	9.23 ± 0.86^{a}
TSM2	52.78 ± 2.61^{ab}	9.12 ± 0.88^{ab}
TSM3	52.69 ± 1.68^{ab}	8.78 ± 0.85^{b}
TSM4	51.24 ± 1.56^{ab}	8.56 ± 0.95^{b}

$^{a-c}$Means in a column with common superscript are not significantly different at the $p<0.05$ probability level by Duncan's multiple range test.

Table 5. Antioxidant activities of instant TSM

Antioxidant activities	Control	TSM1	TSM2	TSM3	TSM4	F test
Total flavonoids content (mg/100g)	0.05 ± 0.01^{a}	15.26 ± 1.57^{ac}	15.78 ± 1.59^{ac}	22.89 ± 2.368^{ab}	23.12 ± 0.98^{ab}	6.58^{**}
Total phenolic content (mg/100g)	0.08 ± 0.01^{a}	5.12 ± 1.36^{c}	7.85 ± 1.57^{b}	12.41 ± 2.97^{ac}	14.08 ± 2.48^{ab}	12.68^{**}
DPPH (IC_{50}) (%)	BLQ	56.23 ± 4.56^{b}	85.04 ± 5.39^{a}	92.45 ± 4.68^{ac}	112.41 ± 21.65^{ab}	16.75^{**}

$^{a-c}$ Means in a column with common superscript are not significantly different at the $p<0.05$ probability level by Duncan's multiple range test. ** -Significant at 1% level. BLQ- Below Lower Quantification.

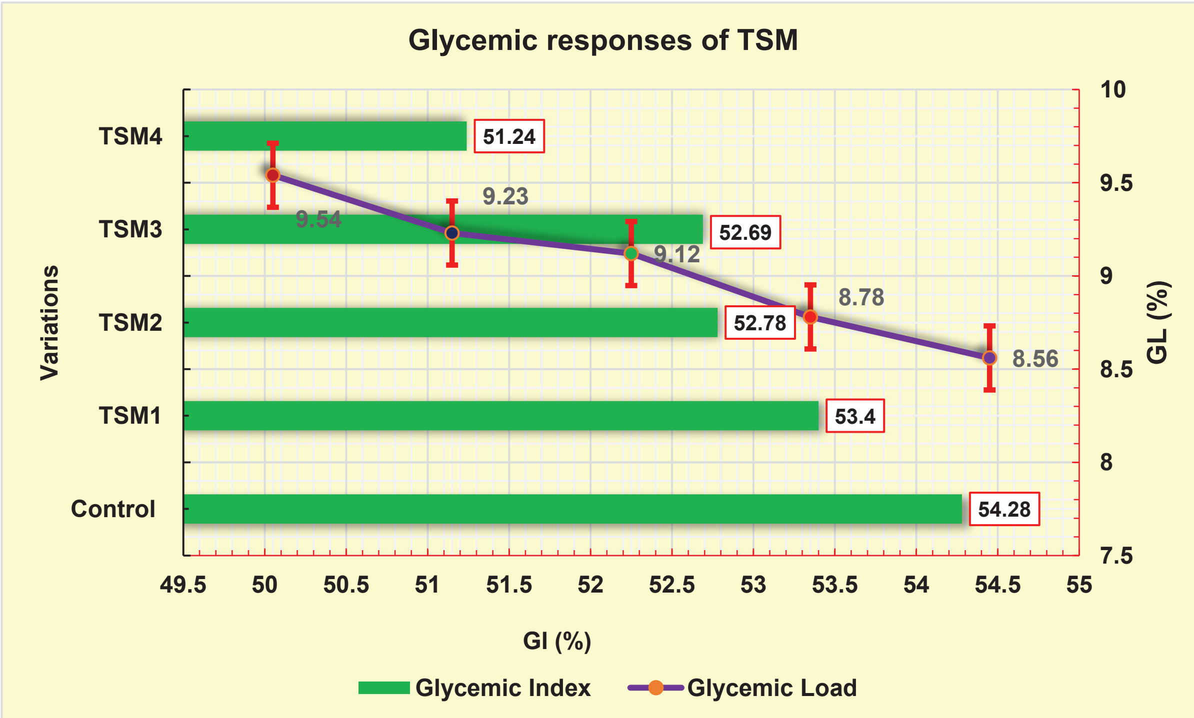

Figure 2. Glycemic responses of TSM.

level. Studies in clinical settings have demonstrated the beneficial effects of low GI and GL meals on glycaemic management, possible weight reduction, and cardiovascular health outcomes[43-47].

3.6 Sensory Analysis of Instant TSM Soups

An assortment of sensory characteristics, including colour, appearance, consistency, mouthfeel, flavour, taste, and overall acceptability, were used to evaluate several formulations of instant TSM soups. Table 7 displays the findings from the sensory assessment. The soup prepared with 30% roasted tamarind seed kernel powder incorporation (TSM3) received the highest scores in all sensory parameters, with scores of 8.00±0.93, 7.79±0.95, 8.10±0.82, 8.12±0.80, 8.26±0.81, 8.36±0.85, and 8.04±0.93 for colour, appearance, consistency, mouthfeel, flavour, taste, and overall acceptability, respectively. The second-highest scores were obtained by the soup prepared with a 40% incorporation of roasted Tamarind Seed Kernel Powder (TSM4). However, as the incorporation rate of roasted tamarind seed kernel powder increased, the sensory scores increased by 10%, 20%, and 30%. When the level of incorporation rose to 40%, the sensory scores declined drastically. The sensory characteristics and the soup with 30% inclusion (TSM3) differed significantly at the 1% level, as demonstrated by the results of Duncan's multiple range test. 8.04 was determined to be TSM3's overall acceptability score.

3.7 Shelf-life Evaluation of Instant TSM

As indicated in Table 8, total viability and fungal growth were employed as indicators of microbiological quality to assess the total amount of bacterial contamination. TSM1 reported that, in comparison to the control, the TPC count had no growth on day 1, rising to 1.01 x 10^8 cfu/g on day 15, and on day 30 the count raised to 3.25 x 10^5. TSM2, TSM3, and TSM4 were also discovered with raised the TPC count during 30 days of storage period. Results on fungal growth, control had high fungal growth of 2.82 x 10^6 on 30 days of storage and lowest fungal growth was noted in TSM4 (2.63 x 10^7). For a dry soup mix product to be deemed microbiologically safe, its concentration must be less than 19 x 10^4cfu/g. The findings of this investigation are consistent with those obtained from assessing the young corn soup mix's shelf life[33]. These findings verified that the TSM formulation had a maximum storage life of

Table 7. Sensory analysis of instant TSM soups

Sensory parameters	Control	TSM1	TSM2	TSM3	TSM4	F test
Colour	6.06±1.30^{a}	6.56±1.09^{b}	6.68±1.09^{b}	8.00±0.93^{c}	7.89±0.79^{c}	32.82**
Appearance	6.40±1.03^{ab}	6.32±0.85^{a}	6.72±0.85^{bc}	7.79±0.95^{e}	6.97±0.82^{d}	22.28**
Consistency	6.46±1.11^{a}	6.60±0.98^{a}	6.72±0.92^{a}	8.10±0.82^{c}	7.18±0.95^{b}	23.52**
Mouth feel	6.00±0.72^{a}	6.50±0.81^{b}	6.90±0.88^{c}	8.12±0.80^{d}	7.12±1.26^{c}	36.65**
Flavour	5.80±0.75^{a}	6.50±0.54^{b}	6.74±1.15^{b}	8.26±0.81^{d}	7.34±0.94^{c}	56.76**
Taste	6.54±0.81^{a}	6.60±0.96^{ab}	6.94±0.99^{b}	8.36±0.85^{c}	6.73±0.67^{ab}	37.45**
Overall acceptability	6.58±0.78^{a}	7.00±0.88^{b}	6.96±0.90^{b}	8.04±0.93^{c}	6.36±0.75^{a}	27.92**

$^{a\text{-}c}$ Means in a column with common superscript are not significantly different at the p<0.05 probability level by Duncan's multiple range test. ** -Significant at 1% level.

Table 8. Shelf-life evaluation of instant TSM

Soup mix variations	Total Plate Count (cfu/g)			Fungal count (cfu/g)		
	Initial	15th day	30th day	Initial	15th day	30th day
Control	Nil	1.69 x 10^{9}	2.26 x 10^{9}	1.72 x 10^{5}	2.45 x 10^{6}	2.82 x 10^{6}
TSM1	Nil	1.01 x 10^{8}	3.25 x10^{5}	1.03 x10^{6}	2.15 x 10^{7}	2.80 x 10^{9}
TSM2	Nil	1.32 x10^{6}	2.89 x10^{6}	1.32 x10^{6}	2.69 x10^{6}	2.75 x10^{5}
TSM3	Nil	1.43 x10^{7}	3.18 x10^{7}	1.86 x10^{7}	2.35 x10^{7}	2.65 x10^{6}
TSM4	Nil	1.65 x10^{6}	2.15 x10^{8}	2.59 x10^{6}	2.44 x10^{8}	2.63 x10^{7}

Nil – No growth; cfu- Colony forming units

15 days. A class of dehydrated meals known as instant soups is vital to human nutrition because it meets the needs of both current and future societal consumers[48]. Moreover, they may be preserved without the need for refrigerators or preservatives[49].

4. Conclusion

Tamarind seeds are a crop that is often overlooked and underutilized, but they have numerous benefits for both growers and consumers. Roasted tamarind seed kernel powder can be used in instant soup mixes at levels of 10-40% to produce delicious blends. TSM4, in particular, has impressive physical properties such as a reconstitution index of 15.8 g/ml, a solubility of 30.96%, pH 5.51, a water absorption capacity of 306 ml/g, bulk density of 0.60g/ml, rehydration ratio of 6.5, swelling index of 1.80, the water activity of 0.55, and colour profile of L*-75.64, a*-7.82, b*-13.08. Its chemical properties also indicate a significant difference where we observed the low moisture (0.45%), maximum ash content (2.19%), low carbohydrate (83.95%), high protein (11.31%), low fat (2.21%), high dietary fibre (1.06%), and caloric value (404.99Kcal/100g). Mineral compositions also showed significant differences in TSM4 formulation. TSM4 has a higher TFC (23.12 mg/100g), TPC (14.08 mg/100g), and maximum DPPH activity (112.41%) compared to the control. Low glycemic index and low glycemic load were displayed by all TSM formulation variants, and at the 5% level, there was a significant difference between the formulations and the control. Sensory analysis confirmed that TSM3 was more acceptable than other formulations with a 30% incorporation (8.04±0.93).TSM's shelf-life assessment revealed that although it can be kept for up to 15 days, fungal development and total plate count rose noticeably throughout storage days. As a result, the commercial use of the instant roasted tamarind seed kernel powder soup mix is feasible, and it also benefits the health of its customers.

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