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Original Research Article

Development and Stability Assessment of Guava-Moringa Sauce with Nutritional, Microbial and Physicochemical Analysis

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Abstract: *Moringa (Moringa oleifera), belonging to the Moringaceae family, is a nutrient-dense plant rich in essential phytochemicals that effectively combat malnutrition. Similarly, guava (Psidium guajava L.), often termed the "Apple of the Tropics," is recognized for its year-round production, affordability, and high nutritional value. The combination of guava and moringa presents an innovative approach to developing a functional food product with enhanced nutritional and sensory attributes.* ***Objective:*** *This study aimed to develop and characterize guava–moringa sauce and to evaluate its shelf stability by analyzing its nutritional, microbial, physicochemical, and sensory properties.* ***Methods:*** *A laboratory-based experimental study was carried out from February to July 2025. Four treatment formulations were prepared: T_0 (100% guava), T_1 (98% guava + 2% moringa), T_2 (96% guava + 4% moringa), and T_3 (94% guava + 6% moringa). The sauce was prepared following the procedure of Ritthiruangdej et al. (2011) with slight modifications. Physicochemical parameters including moisture, ash, fat, crude fiber, crude protein, and color were analyzed on days 0, 7, and 14. Color was determined using a handheld spectrocolorimeter (Lovibond LC-400), and viscosity was measured using a BDV-8S viscometer (No.18DN3270, Shandong Co., Ltd). Microbial stability was assessed through bacterial and mold counts, while sensory evaluation was performed by a trained panel of 10 members using a 9-point hedonic scale. Data were analyzed with Statistix 8.1, and results were considered significant at $p < 0.05$.* ***Results:*** *The addition of moringa significantly enhanced the crude fiber content in T_2 and T_3 compared with the control (T_0). T_3 exhibited the highest fiber content but had slightly lower sensory scores for taste and texture. T_2 and T_3 demonstrated the most favorable balance between enhanced nutritional quality and acceptable sensory attributes. Throughout the 14-day storage, all formulations remained microbiologically safe. However, T_2 maintained better moisture and texture stability, while T_3 exhibited improved sensory parameters including color and consistency, though with minor flavor alterations as moringa concentration increased.* ***Conclusion:*** *Incorporation of moringa leaves, particularly at 4–6% concentration, improved the nutritional profile and shelf stability of guava-based sauces without compromising sensory acceptability. T_3 showed superior overall sensory quality, including texture, flavor, aroma, and color, suggesting that moringa can serve as a natural stabilizer and functional additive in plant-based sauces, offering both nutritional and gastronomic benefits.*

Keywords: Moringa oleifera Psidium guajava Sauces Food Microbiology Sensory Evaluation

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Introduction

Moringa (Moringa oleifera), a member of the Moringaceae family, is a very effective treatment for malnutrition. It is a nutritious powerhouse because of the numerous vital phytochemicals found in its leaves, pods, and seeds. According to Rockwood et al. (1), Moringa oleifera contains 25 times more iron than spinach, 17 times more calcium than milk, 9 times more protein than yogurt, 15 times more potassium than bananas, 7 times more vitamin C than oranges, and 10 times more vitamin A than carrots. Nearly every part of the Moringa oleifera plant—including its roots, bark, seeds, flowers, pods, seed oil, leaves, and resin—has valuable applications in food, agriculture, and industry (2).

A popular crop in tropical and subtropical areas across the world, guava (Psidium guajava L.) is frequently referred to as the "Apple of the Tropics." Progressive farmers find it to be a desirable option due to its year-round production, high nutritional content, accessibility, and affordability when compared to other fruit crops (3-5). Guava fruit contains five times more vitamin C than citrus fruits, with over 260 mg of ascorbic acid per 100 g. Along with citric, lactic, malic, oxalic, and acetic acids, as well as sugars and mineral salts, it is an excellent source of vitamins A and C (6).

Phenolic compounds, particularly flavonoids, are also abundant in guava. Lycopene and flavonoids serve as powerful antioxidants, aiding in the treatment of cancer cells and preventing premature skin aging (7). Additionally, guava can influence myocardial inotropism (8), and its skin extract has been shown to regulate blood sugar levels after 21 days of treatment (9, 10). Guava pulp is also utilized in the production of ethanol (11).

Although the fruit pulp of guava (Psidium guajava L.) is not visually appealing due to its strong flavor and taste, it is high in vitamin C and possesses excellent nutritional advantages. Therefore, it is widely used to generate ready-to-serve (RTS) drinks (12). A mixture of guava extract and carrot juice in a 75:25 ratio has been identified as the best option for making fruit jelly (13). Mango, guava, papaya, fig, jackfruit, and other fruits with a high pulp content can also be used to make toffee (14). It has been observed that guava can be transformed into wine of acceptable standards; the best results were achieved using a 1:4 dilution with DAHP, although this wine's quality is inferior to that of grape wine (15). Firm and ripe guava fruits can further be used to make dehydrated guava products that are ready to use, such as dehydrated guava slices (14).

Incorporating various parts of moringa could enhance their nutritional qualities, leading to products high in plant-based protein. Consumer choices regarding guava and moringa sauce are influenced by aspects such as flavor, health advantages, and practicality. Guava (Psidium guajava) is widely recognized for its sweet and tangy taste, while moringa (Moringa oleifera) adds a slightly earthy, mildly bitter flavor along with

high nutritional content. Individuals looking for functional foods value the mix of guava's vitamin C-rich characteristics and moringa's plentiful antioxidants, amino acids, and micronutrients (16).
Guava and moringa have not been extensively utilized in the manufacturing of condiments, leading to lost opportunities to create functional foods that appeal to health-conscious consumers. Moringa seed oil, for instance, has been effectively added to salad dressings, increasing their nutritious content without sacrificing flavor (17). This aim of the study is to **d**evelopment and characterization of moringa guava sauce and evaluation of the shelf stability of sauce by analyzing physicochemical properties, nutritional, sensory and microbial properties.

Methodology

Procurement of raw material for moringa guava sauce production: Moringa, guava, and spices were purchased from local and supermarkets in Lahore, Pakistan.
To assess the physicochemical and antioxidant properties, nutritional, sensory and microbial properties of sauce various formulations of these ingredients were created and compared to the control group across several parameters. The treatment plan is as follows:

Control	To=	100%guava
Treatment 1	T1=	2% moringa, 98% guava
Treatment 2	T2=	4%moringa, 96% guava
Treatment 3	T3=	6%moringa, 94% guava

Table***:*** **1 Formulation of Dairy-Free Guava**

Ingredients	To (no moringa)	T1(2%moringa)	T2(4%moringa)	T3(6%moringa)
Guava	44.4g	42.3g	40.3g	38.3g
Moringa	0	2g	4g	6g
Mint	0.5g	0.5g	0.5g	0.5g
Ginger	0.6g	0.6g	0.6g	0.5g
Lemon juice	1.3g	1.3g	1.3g	1.3g
Water	46ml	46ml	46ml	46ml
Garlic powder	0.16g	0.16g	0.16g	0.16g
Red Chilli	0.13g	0.13g	0.13g	0.13g
Black pepper	0.003g	0.003g	0.003g	0.003g
Salt	0.3g	0.3g	0.3g	0.3g
Jaggery	7g	7g	7g	7g

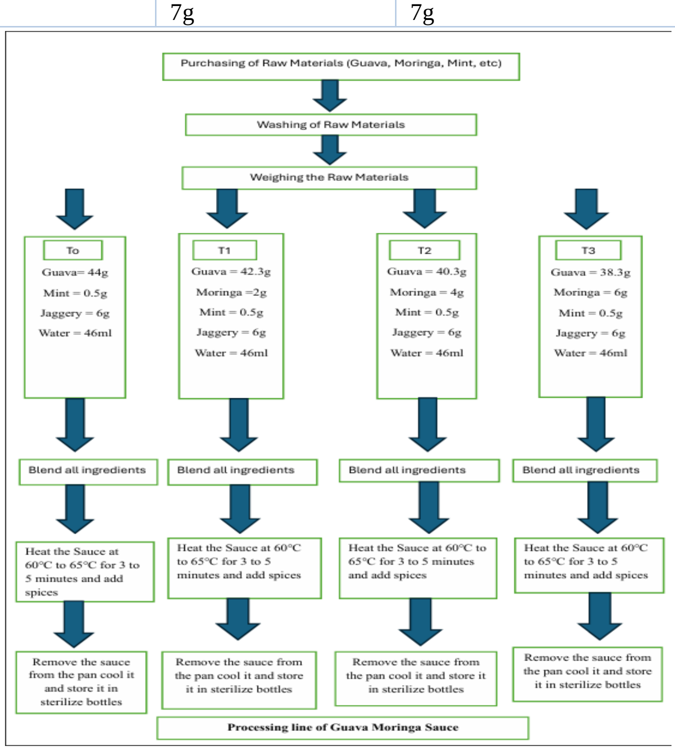

Figure 1: Processing of Guava-moringa Sauce

Following the above flowchart sauce was made the proportion of moringa and guava were altered, but the other ingredients stayed the same.

Proximate Analysis of Sauce

Determination of Moisture Content
The moisture content was determined by BIOBASE®(BOV-V125F) oven drying the 20g of sample at 65°C to 70°C for 12 to 24 hours after it was weighed in a previously weighed petri plate.

$$\text{Moisture (\%)} = \frac{\text{Final weight of the sample}}{\text{Initial weight of the sample}} \times 100$$

Determination of Ash Content Using the AOAC international technique, the amount of ash was ascertained. Weighing 5g of sauce sample into the crucible. At 550°C, the crucible containing the samples was ignited in the muffle furnace for 4h.
Ash (%) = Wt. of crucible+sample after ashing – wt. of crucible+sample before ashing ×100 weight of sample

Determination of Fat Content

Fat content was determined by extracting a moisture-free sample with hexane, following the method of Imoisi et al. (2020) (18). After evaporating the solvent, the remaining fat was weighed from the bottom of the Pyrex beaker.

$$\text{Fat\%} = \frac{\text{Weight of fat in sample}}{\text{Weight of dried sample}} \times 100$$

Determination of Crude Fiber

Crude fiber content was determined using the AOAC method by boiling 2 g of sample with 15% H_2SO_4, followed by filtration and neutralization. The residue was then boiled with 5% NaOH, filtered, washed, dried, and weighed. Finally, the dried residue was incinerated in a muffle furnace, cooled, and reweighed to calculate fiber content.

$$\text{Crude fiber (\%)} = \frac{W2-W3}{W1} \times 100$$

Determination of protein content

Crude protein content in the sauce sample was determined using the Kjeldahl method as per AOAC guidelines. The sample was digested with nitric acid, neutralized with NaOH, and the released ammonia was distilled into boric acid. The distillate was then titrated with hydrochloric acid, and protein percentage was calculated from the titer value.

$$\text{\% of Nitrogen} = \frac{\text{Titration} \times \text{total vol.} \times \text{normality of acid} \times 14}{\text{Vol. taken} \times \text{wt. of sample}} \times 100$$

% of Protein = % of Nitrogen × factor (6.25) (protein nitrogen conversion factor

Physicochemical Analysis of Guava Sauce

Determining the pH of Moringa Guava Sauce

The pH of the samples was measured using a calibrated digital pH meter with glass and reference electrodes, following the methods of Shetgar et al. (2017) and Rasheda Khatun (2021) (19,20)

Figure 2: Moisture analysis of T_0, T1, T2 and T3 by pH meter meter performed in FST Lab II at University of Central Punjab, Lahore

Figure 3: Determining the ash of T_0, T1, T2 and T3 by p performed in FST Lab II at University of Central Punjab, Lahore

analysing the pH of T_0 analysing the pH of T1 analysing the pH of T_2 analysing the pH of T_3

Figure 4: Determination of fat by washing the samples with ethanol of T_0, T1, T2 and T3 by pH meter performed in FST Lab II at University of Central Punjab, Lahore

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Determining the Color of Moringa Guava Sauce Color analysis was performed at 25 °C using a Hunter Lab color difference meter in reflectance mode, following X. Chen et al. (2023), measuring L (lightness), a (red-green), and b (yellow-blue) values. (21)

Determining the Viscosity of Moringa Guava Sauce

Viscosity of the sauce is measured by using (BDV-8S viscometer No.18DN3270 Shandong Co., Ltd) that is used in the laboratory. The spindle SPL3 is places inside the jar containing the sauce the spindle rotates at the speed of 30.0rpm

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Determination of Reducing Sugar in Moringa Guava Sauce

Reducing sugars in moringa guava sauce were qualitatively determined using the Benedict test, as described by Alejandro Hernandez et al. (2020), based on color change upon heating. (22)

Determining the Acidity of Moringa Guava Sauce

Titratable acidity was determined by titrating a homogenized and filtered sample with 0.1N NaOH using phenolphthalein indicator, following the method of Rasheda Khatun (2021).

Percent titratable acidity was calculated using the following formula:

$$\% \text{ Titratable acidity} = \frac{T \times N \times V1 \times E}{V2 \times W \times 100} \times 100$$

Determining the Total Soluble Solids in Moringa Guava Sauce

Total soluble solids (TSS) of the sauce were measured using an HI96800 Brix Refractometer, following Rasheda Khatun (2021), by placing a drop on the prism and reading the %TSS directly. (10)

Determining the Total Dissolve Solids in Moringa Guava Sauce

At room temperature, TDS was measured with a digital handheld TDS meter. The TDS meter is set into the sample beaker, and the digital display screen indicates how much TDS is in the sauce.

Figure 8: Determining the TDS of T_0, T1, T2 and T3 by TDS meter performed in FST Lab II at University of Central Punjab, Lahore

Microbial Analysis

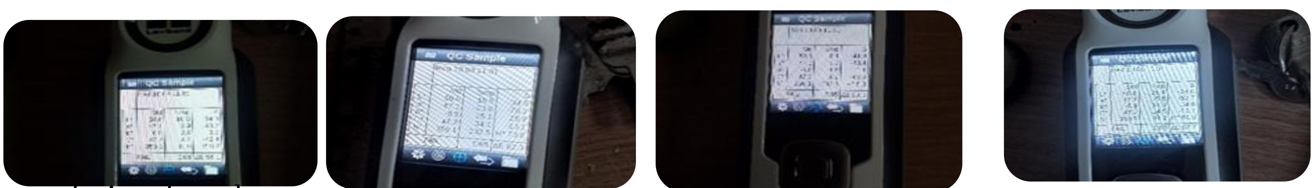
Microbiological analysis of the sauce, including aerobic mesophiles, yeast, and mold, was performed following Zia et al. (2018) with slight modifications. Samples were serially diluted in 0.85% saline and plated on appropriate agar media. Aerobic mesophiles were incubated at 35 ± 1°C for 48 hours, while yeast and mold were counted after 120 hours at 25 ± 1°C, and CFU was calculated accordingly. (23)

Sensory Evaluation

Sensory evaluation of the guava-moringa dip sauce was conducted to assess its acceptability and quality during storage at intervals of 0, 7, 15, and 30 days. A semi-trained panel of ten faculty members from the Department of Food Science and Technology evaluated key sensory attributes including color, aroma, flavor, texture, mouthfeel, and consistency. Samples were coded to minimize bias and served at room temperature under controlled lighting in individual booths. A 9-point Hedonic scale was used for scoring, ranging from "liked extremely" to "disliked extremely." Panelists were briefed beforehand and provided with palate cleansers to ensure accurate evaluation.

Storage Study

A storage stability study was conducted on guava-moringa dip sauce to evaluate its shelf life and quality under refrigerated (4 ± 1°C) and ambient (25 ± 2°C) conditions over 30 days. The sauce, packed in sterilized airtight glass jars, was analyzed at 0, 7, and 15 days for physicochemical (pH, titratable acidity, browning index), microbial (TPC, yeast and mold counts), and sensory attributes. Standard methods were used for each test, ensuring accuracy and safety, with microbial counts expressed in CFU/g. Sensory evaluation by a semi-trained panel assessed appearance, aroma, taste, and texture using a 9-point hedonic scale. All tests were performed in triplicate and statistically analyzed to validate shelf stability, safety, and consumer acceptance.



analysing the color of T_0 | analysing the color of T_1 | analysing the color of T_2 | analysing the color of T_3

Figure 5: Determining the color of T_0, T1, T2 and T3 by Tintometer performed in FST Lab II at University of Central Punjab, Lahore

Determining the viscosity of To | Determining the viscosity of T_1 | Determining the viscosity of T_2 | Determining the viscosity of T_3

Figure 6: Determining the viscosity at 30 rpm of T_0, T1, T2 and T3 by viscometer performed in FST Lab II at University of Central Punjab, Lahore

Determining the reducing sugars in sauce

analysing the reducing sugar in T_1

analysing the reducing sugar in T_2 sample

analysing the reducing sugars in T_3 sample

Figure7: Determining the reducing sugars of T_0, T1, T2 and T3 by Benedict Solution performed in FST Lab II at University of Central Punjab, Lahore

Determination of TDS in T_0 sample

Determination of TDS in T_1 sample

Determination of TDS in T_2 sample

Determination of TDS in T_3 sample

Figure 8: Determining the TDS of T_0, T1, T2 and T3 by TDS meter performed in FST Lab II at University of Central Punjab, Lahore

Results

Because it affects the microbiological stability, shelf life, texture, and general acceptance of food products, moisture content is an essential quality criterion in food processing. In sauces, where water activity affects consistency and resistance to spoiling, moisture retention is very important. The current study assessed the impact of different concentrations of moringa on the moisture content of guava-moringa sauce throughout a 14-day storage period. T1 had the highest moisture content at day 0 (83.934±0.16%), with T0 coming in second (83.321±0.16%). With T0 peaking at 84.682±0.85% on day 14, a general upward trend was noted, indicating better water retention that may be brought on by the guava's inherent pectin content (24). Over the course of the storage period, however, formulations containing higher levels of moringa (T2 and T3) showed relatively reduced moisture concentrations. Because moringa is fibrous and hygroscopic, it binds less free moisture, which may be why T3 in particular consistently displayed the lowest values, reaching 81.139±0.41% by day 14 (25). Ash readings at day 0 varied slightly between treatments, ranging from 0.351% in T3 to 0.391% in T0. It's interesting to note that throughout the storage time, the amount of ash decreased in all treatments. T0 showed the most decline by day 14, falling to 0.286%, whereas T1, T2, and T3 ultimately reached 0.299%, 0.297%, and 0.299%, respectively. On day 14, the average amount of ash in all treatments decreased from 0.37675% on day 0. At day 0, the initial fat content varied between 4.9970±0.03% in T0 and 5.6360±0.03% in T3. All therapies, however, showed a general decline with time. The fat percentage decreased to 4.0770±0.02% in T0 and 5.2540±0.02% in T3 at day 14. T3 had the highest mean fat content (5.4477±0.02%), whereas T0 had the lowest (4.5167±0.02%). This implies that moringa's own lipid component and its structural ability to hold onto lipids during formulation may be the reason why higher concentrations of moringa may result in higher fat content (Saini *et al*., 2016). T0 (0% moringa) had the lowest fiber content at the start of storage, at 2.4600±0.03%, whereas T3 (6% moringa) had the highest, at 3.8800±0.03%. Throughout the 14-day storage period, this pattern persisted. T0 continued to have the lowest fiber content (2.4500±0.02% and 2.4100±0.02% on days 7 and 14), while T3 continued to have the greatest fiber content (3.8400±0.02% and 3.8100±0.02%, respectively). The increasing percentage of moringa leaf powder, which is naturally abundant in both soluble and insoluble fibers like cellulose and hemicellulose, is responsible for the gradual rise in fiber content from T0 to T3 (Oyeyinka & Oyeyinka, 2018) (26). Average data demonstrate that when moringa concentrations rise, the protein content gradually increases. Protein levels were lowest at all-time points for T0 (0% moringa) (2.5100±0.03% from 0 days to 2.5120±0.03% at 14 days). The moderate protein content of T1 (2% moringa) ranged from 2.7130±0.02% to 2.7873±0.03%. T3 (6% moringa) had the highest protein content, with values peaking at 3.2370±0.02% on the seventh day, whereas T2 (4% moringa) had slightly higher levels (2.9030±0.02% to 2.9100±0.02%). Because of moringa's high protein content and rich amino acid profile, the overall pattern shows a clear correlation between higher moringa incorporation and elevated protein content (Moyo *et al*., 2016) (27).

Physicochemical Analysis of Guava-Moringa sauce

The mean values of pH for T_0 that contain 100٪ guava and 0٪ moringa at 0,7and 14 days of storage are 4.06±0.12abcd, 3.80±0.08de and 3.43±0.12f respectively. The mean values for T1 that contain 98٪ guava and 2٪ moringa at 0,7 and 14 days of storage are 4.22±0.01ab,3.93±0.12abcde and 3.82±0.02cde respectively. The mean values for T2 that contain 96٪ guava and 4٪ moringa are 4.22±0.01ab, 3.93±0.12abcde and 3.82±0.02cde respectively, while the mean values for T3 that contain 94٪ guava and 6٪ moringa are 4.27±0.02a, 4.05±0.04abcd and 3.81±0.08cde respectively. The result shows that highest mean value for pH was observed in T3 that is $4.04±0.04^{a}$ while the lowest mean value for pH was observed in T_0 that is $3.76±0.10^{c}$. The mean values of Brix for T_0 that contain 100٪ guava and 0٪ moringa at 0,7and 14 days of storage are 8.55±0.01d, 8.80±0.03c and 9.15±0.04ab respectively. The mean values of Brix for T1 that contain 98٪ guava and 2٪ moringa at 0, 7 and 14 days of storage are 8.57±0.03d, 8.82±0.02c and 9.12±0.02b respectively. The mean values for T2 that contain 96٪ guava and 4٪ moringa are 8.62±0.02d, 8.85±0.02c and 9.17±0.02ab respectively, while the mean values for T3 that contain 94٪ guava and 6٪ moringa are8.63±0.01d, 8.88±0.06c and 9.24±0.03a respectively. The result shows that highest mean value for TSS was observed in T3 that is 8.92±0.03[a] while the lowest mean value for Brix was observed in T_0 that is 8.83±0.02[c]. This shows a clear increasing trend with higher moringa levels. Mean values are presented in table 2 The mean values of TDS for T_0 that contain 100٪ guava and 0٪ moringa at 0,7and 14 days of storage are 11.50±0.41e, 11.90±0.29de and 12.26±0.21cde respectively. The mean values for T1 that contain 98٪ guava and 2٪ moringa at 0, 7 and 14 days of storage are 12.01±0.01cde, 12.33±0.12cd and 12.60±0.16bcd respectively. The mean values for T2 that contain 96٪ guava and 4٪ moringa are12.05±0.02cde, 12.55±0.23bcd and 12.68±0.13bc respectively, while the mean values for T3 that contain 94٪ guava and 6٪ moringa are 12.66±0.21bcd, 13.20±0.24ab and 13.53±0.21a respectively. The result shows that highest mean value for TDS was observed in T3 that is13.13±0.22a while the lowest mean value for TDS was observed in T_0 that is 11.88±0.30c. This shows a clear increasing trend with higher moringa levels. Acidity in a sauce tells us how sharp, tangy, or sour it tastes, and it also plays a key role in keeping the product fresh and safe. Mean values are presented in table 2. The mean values for T_0 that contain 100٪ guava and 0٪ moringa at 0,7and 14 days of storage are 0.39±0.02a, 0.41±0.01de and 0.44±0.02a respectively. The mean values for T1 that contain 98٪ guava and 2٪ moringa at 0, 7 and 14 days of storage are 0.36±0.03a, 0.40±0.02a and 0.44±0.03arespectively. The mean values for T2 that contain 96٪ guava and 4٪ moringa are0.35±0.02a, 0.38±0.04a, 0.43±0.02arespectively, while the mean values for T3 that contain 94٪ guava and 6٪ moringa are 0.35±0.03a, 0.37±0.04a and 0.42±0.02arespectively. The result shows that highest mean value for acidity was observed in T_0 that is0.41±0.01a while the lowest mean value for acidity was observed in T2 that is 0.38±0.02a this shows that acidity slightly decreased with increasing moringa levels from T0 to T3

Analysing the Viscosity of Moringa Guava Sauce

Viscosity refers to the thickness or flow behavior of a sauce, which directly influences its texture, appearance, and consumer acceptability. In moringa-guava sauce, changes in viscosity are often linked to variations in fruit pulp, fiber, and solid content. Mean values are presented in table 3. The mean values for T_0 that contain 100٪ guava and 0٪ moringa at 0,7and 14 days of storage are 3501.4±3.18a, 3360.4±3.27b and, 3120.5±3.35c respectively. The mean values for T1 that contain 98٪ guava and 2٪ moringa at 0, 7 and 14 days of storage are 1696.2±3.51d, 1620.3±3.59e and1480.5±3.67g respectively. The mean values for T2 that contain 96٪ guava and 4٪ moringa are 1696.2±3.51d, 1620.3±3.59and 1480.5±3.67g respectively, while the mean values for T3 that contain 94٪ guava and 6٪ moringa are 1480.0±3.76g, 1425.2±3.18h and 1330.3±3.68j respectively. The result shows that highest mean value for viscosity was observed in T_0 that is 3327.4±3.26a while the minimum mean value for acidity was observed in T3 that is 1411.8±3.54d this shows that viscosity of the sauce has decreased sharply from T_0 to T3 as T_0 have 100٪ guava content it has the thick texture while T3 that contain 94٪ guava and 6٪ moringa has thin texture.

Clor Analysis of Moringa Guava Sauce

According to these findings, the color of samples changed dramatically over time, becoming redder and less bright. The color of samples characteristics has changed, as evidenced by the decline in yellowness and overall color difference. This is probably due to the presence of moringa as moringa contributes strong green and yellow tones due to chlorophyll and carotenoids, which overpower guava's pink hue. Findings are consistent with Saini *et al*., 2016 on moringa's pigment impact in functional foods (25). The results show that the L (lightness) values of samples To made up of 100% guava, T1 made up of 98% guava and 2% moringa, T2 made up of 96% guava and 4% moringa and T3 made up of 94% guava and 6% moringa mean values were16.00±0.06b, 15.50±0.07c, 8.10±0.02d and 25.1±0.07a respectively indicating a highly significant variation in lightness. The a (redness) values of samples To made up of 100% guava, T1 made up of 98% guava and 2% moringa T2 made up of 96% guava and 4% moringa and T3 made up of 94% guava and 6% moringa mean values were 3.89±0.06a, -23.00±0.05d, 3.70±0.03b and -5.5±0.02c signifying a notable difference in the red-green axis among the samples. Additionally, the b (yellowness) values of samples To made up of 100% guava, T1 made up of 98% guava and 2% moringa, T2 made up of 96% guava and 4% moringa and T3 made up of 94% guava and 6% moringa mean values were 2.6±0.01c, 25.1±0.07b, -1.9±0.03d and 34.00±0.05a reflecting a significant difference in the yellow blue axis among the samples. According to these findings, the color of samples changed dramatically over time, becoming redder and less bright. The color of samples characteristics has changed, as evidenced by the decline in yellowness and overall color difference. This change in color is directly related to environmental factors and cooking conditions.

Microbial Analysis of Moringa Guava Sauce

The mean values for TPC of moringa guava sauce (T0) samples made from 100 ٪ guava were 35.66±0.47[f] (Log_{10}cfu/g) at the start of storage and 69.33±1.25e and 82.00±1.22b (Log_{10}cfu/g) at 7 and 14 days of storage, respectively. The mean values for TPC of moringa guava sauce (T1) samples made from 98% guava and 2% moringa were36.00±1.06f (Log_{10}cfu/g) at the start of storage and 73.00±1.22cde and 98.00±0.82a (Log_{10}cfu/g) at 7 and 14 days of storage, respectively. The mean values for TPC of moringa guava sauce (T2) samples made from 96% guava and 4% moringa were 72.66±2.62de (Log_{10}cfu/g) at the start of storage and 73.00±2.16cde and 78.00±0.82bc (Log_{10}cfu/g) at 7 and 14 days of storage, respectively. The mean values for TPC of moringa guava sauce (T3) samples made from 94% guava and 6% moringa were 37.66±1.25f at the start of the storage and 72.00±1.63de and 76.33±1.25cd (Log_{10}cfu/g) at 7 and 14 days of storage. TPC of moringa guava sauce shows that the maximum mean value74.55±1.86a (Log_{10}cfu/g) was observed in T2 samples made from 96% guava and 4%moringa, while the minimum mean value62.00±1.37c (Log_{10}cfu/g) was observed in T3 sauce samples made from 94% guava and 6٪ moringa The mean values show that TPC increases from 62.33±0.98c (Log_{10}cfu/g) to 74.55±1.86a (Log_{10}cfu/g) during the storage period. The mean values for total mold and yeast count of moringa guava sauce (T0) samples made from 100٪ guava were 26.00±0.82d (Log_{10}cfu/g) at the start of storage and 37.00±1.41c and 46.66±1.25b (Log_{10}cfu/g) at 7 and 14 days of storage. The mean values for total mold and yeast count of moringa guava sauce (T1) samples made from 98% guava and 2% moringa were 26.33±1.25d (Log_{10}cfu/g) at the start of storage and 39.00±0.82c and 51.33±0.47a (Log_{10}cfu/g) at 7 and 14 days of storage. The mean values for total mold and yeast count of moringa guava sauce (T2) samples made from 96% corn flour and 4% moringa were 37.66±1.25c (Log_{10}cfu/g) at the start of storage and 37.33±1.25c and 51.33±1.25a (Log_{10}cfu/g) at 7 and 14 days of storage. The mean values for total mold and yeast count of moringa guava sauce (T3) samples made from 94% corn flour and 6% moringa were 26.00±0.82d (Log_{10}cfu/g) at the start of storage and36.33±1.25c and 52.33±1.25a (Log_{10}cfu/g) at 7 and 14 days of storage. The total mold and yeast count of sauce samples made from moringa, and guava shows that the maximum mean value of 42.11±1.25a (Log_{10}cfu/g) was observed in T2 sauce samples made from 96% guava and 4% moringa, while the minimum mean value 36.55±1.16b (Log_{10}cfu/g) was observed in T_o sauce samples made from 100% guava. The mean values show that the total mold count increases from36.55±1.16b (Log_{10}cfu/g) to 42.11±1.25a (Log_{10}cfu/g) during the storage period.

Sensory Analysis of Guava-Moringa Sauce

The mean texture score of the moringa-free control sample (T0) dropped dramatically from 8.33±0.94 on day 0 to 6.00±0.82 after 7 days, and then to 4.33±0.47 by day 14. Comparable declines were also seen in T1 (2% moringa), which decreased from 7.67±0.62 to 6.00±0.82 at day 7 and 4.67±0.94 at day 14. These reductions are frequently ascribed to oxidative changes in plant-based sauces, moisture loss, or gel breakdown. However, T2 (4% moringa) and T3 (6% moringa) showed better texture retention; While T3's texture score increased steadily from 6.67±0.47 to 7.17±0.00 and then 7.67±0.47 by day 14, T2's texture score increased from 7.17±0.86 on day 0 to 7.67±0.47 on day 7 before slightly declining to 6.33±0.94 on day 14. According to these findings, which are corroborated by substantial treatment, storage, and interaction effects (p-values 0.0004, 0.0341, and 0.0017, respectively), a higher moringa content improves texture stability by binding water and fortifying the sauce matrix. In the majority of treatments, aroma, a key component affecting consumer preference, also decreased over time. Scent scores on day 0 were 7.33±0.24 for T3 and 8.00±0.41 for T1. On day 14, T3 maintained its high fragrance score of 7.33±0.48, whereas T0 dropped to the lowest value of 4.67±0.47. Because of oxidation and the loss of volatile chemicals, the average scent scores fell from 7.708 on day 0 to 5.750 on day 14. Moringa's antioxidant qualities, which prevent the breakdown of aromatic molecules, are probably responsible for T2 and T3's excellent scent retention. Scores for flavor showed a similar trend. Over the same time period, T0 fell from 7.33±0.47 on day 0 to 4.67±0.47 on day 14, while T1 fell from 7.67±0.47 to 5.33±0.94. T3 displayed the greatest flavor scores, increasing from 7.00±0.81 to 7.67±0.47 on days 7 and 14, while T2 maintained consistent flavor scores of 7.67±0.47 on days 0 and 7, declining to 6.33±0.94 on day 14. The mean flavor score decreased from 7.417 to 6.000 across all treatments; however, moringa significantly improved flavor stability, extending sensory shelf life. Consistency, which is essential for product acceptability, decreased substantially in T1 from 7.67±0.47 to 5.33±0.94 and considerably in T0 from 8.17±0.62 (day 0) to 4.33 by day 14. On days 7 and 14, T3 improved from 7.00±0.82 to 7.67±0.47, whereas T2 shown a less severe decline (7.17±0.85 to 6.00±0.82). The fiber, protein, and polysaccharides in moringa are thought to promote water retention and structural integrity by interacting with guava pectin and lowering gel breakdown and syneresis during storage. Overall, mouthfeel scores decreased as well, albeit in different ways. By day 14, T0 had fallen sharply from its peak of 8.00±0.41 to 4.33±0.47, while T1 had fallen from 7.67±0.00 to 5.00±0.82. On the other hand, T2's mouthfeel ratings remained comparatively constant from 7.50±0.41 on day 0 to 6.33±0.94 on day 14, with an average of 7.167±0.61, while T3's improved marginally from 6.67±0.47 to 7.00±0.82. Higher levels of moringa preserve mouthfeel by retaining moisture and improving texture through natural fibers and phytochemicals, according to analysis of variance, which also showed highly significant effects of moringa content and storage duration ($p < 0.01$). Consumer appeal is largely determined by color scores, which dropped significantly in T0 from 8.33±0.47 to 4.67±0.47 and in T1 from 7.83±0.62 to 5.33±0.47. By day 14, T3 was noticeably steady, even rising marginally from 7.00±0.82 to 7.33±0.47, whereas T2 showed greater color stability (7.17±0.85 to 6.00±0.82). Because of its flavonoids, chlorophylls, and antioxidant qualities, a higher moringa content maintained pigment integrity, minimizing oxidative browning and discoloration. Overall, the mean color dropped from 7.583 to 5.833 across treatments. In conclusion, over a 14-day period, guava-moringa sauces with 4–6% moringa leaf powder (T2 and T3) continuously surpassed low-level inclusion (T1) and controls (T0) in preserving sensory qualities such texture, flavor, aroma, consistency, mouthfeel, and color. These enhancements, which eventually boost the sauce's shelf life, nutritional content, and consumer appeal, are attributed to moringa's water-binding ability, antioxidant activity, and interactions with the guava matrix.

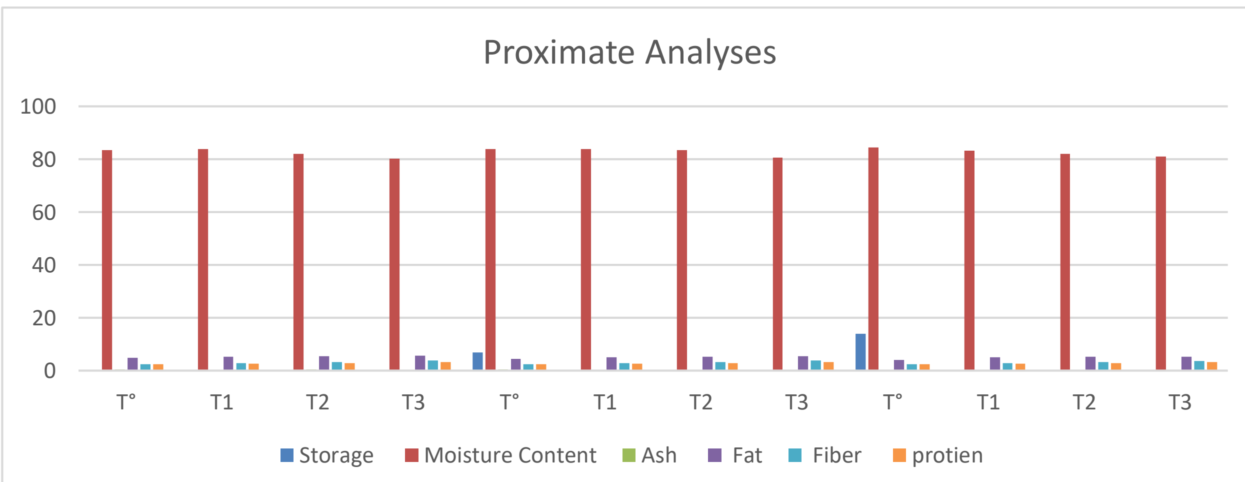


Figure 9: Present the Proximate analyses of to (100% guava), T1 (98% guava & 2% moringa), T2 (96% guava & 4% moringa) T3 (94% guava & 6% moringa) with storage of 0, 7 and 14 days

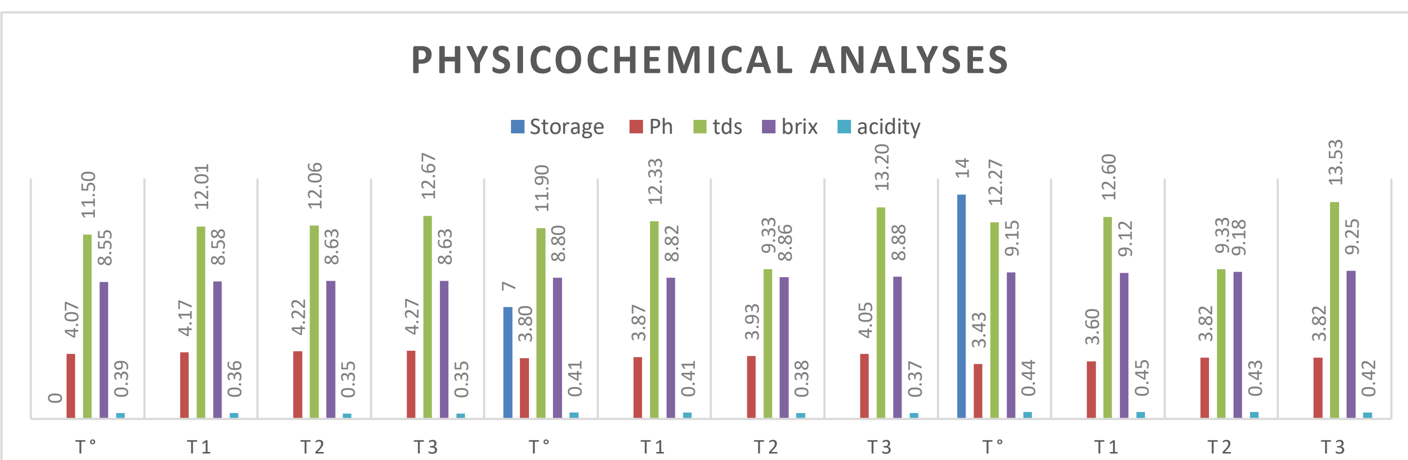


Figure 10: Present the Physicochemical analyses of to (100% guava), T1 (98% guava & 2% moringa), T2 (96% guava & 4% moringa) T3 (94% guava & 6% moringa) with storage of 0, 7 and 14 days.

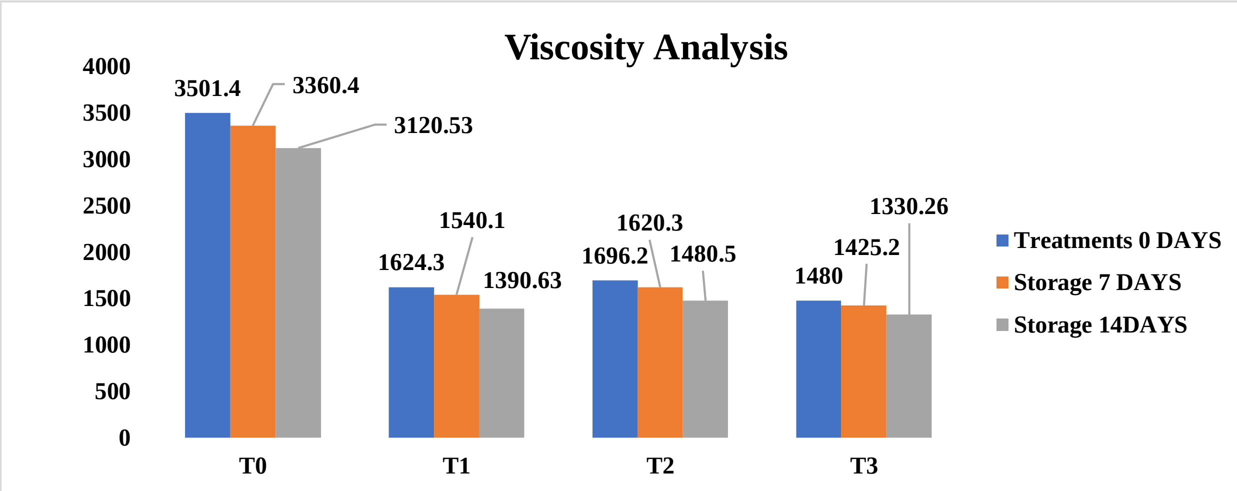


Figure 11: Present the Viscosity analysis of to (100% guava), T1 (98% guava & 2% moringa), T2 (96% guava & 4% moringa) T3 (94% guava & 6% moringa) with storage of 0, 7 and 14 days

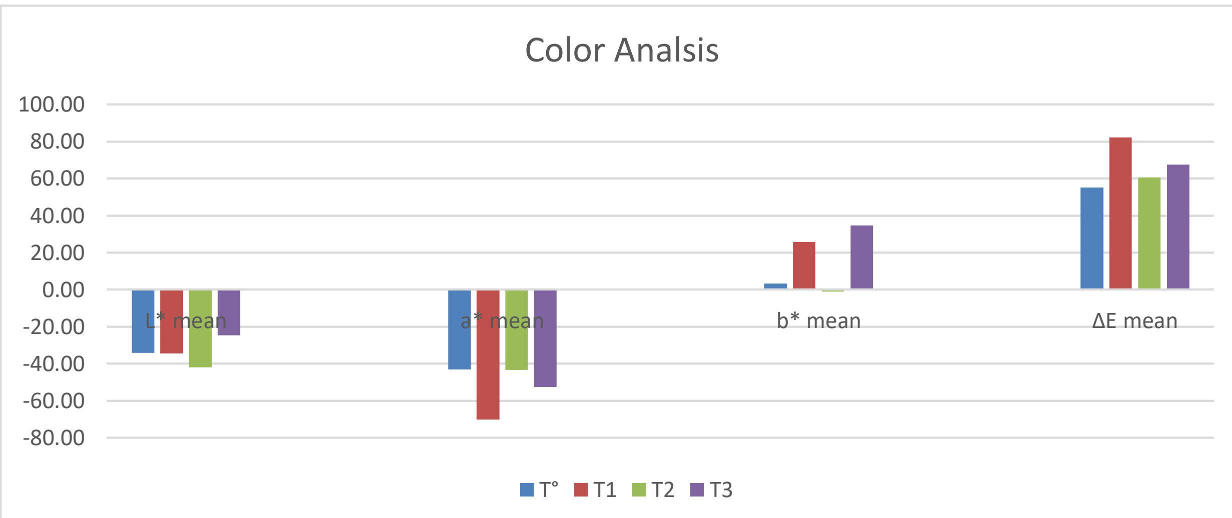


Figure 12: Present the Color analysis of to (100% guava), T1 (98% guava & 2% moringa), T2 (96% guava & 4% moringa) T3 (94% guava & 6% moringa) with storage of 0, 7 and 14 days

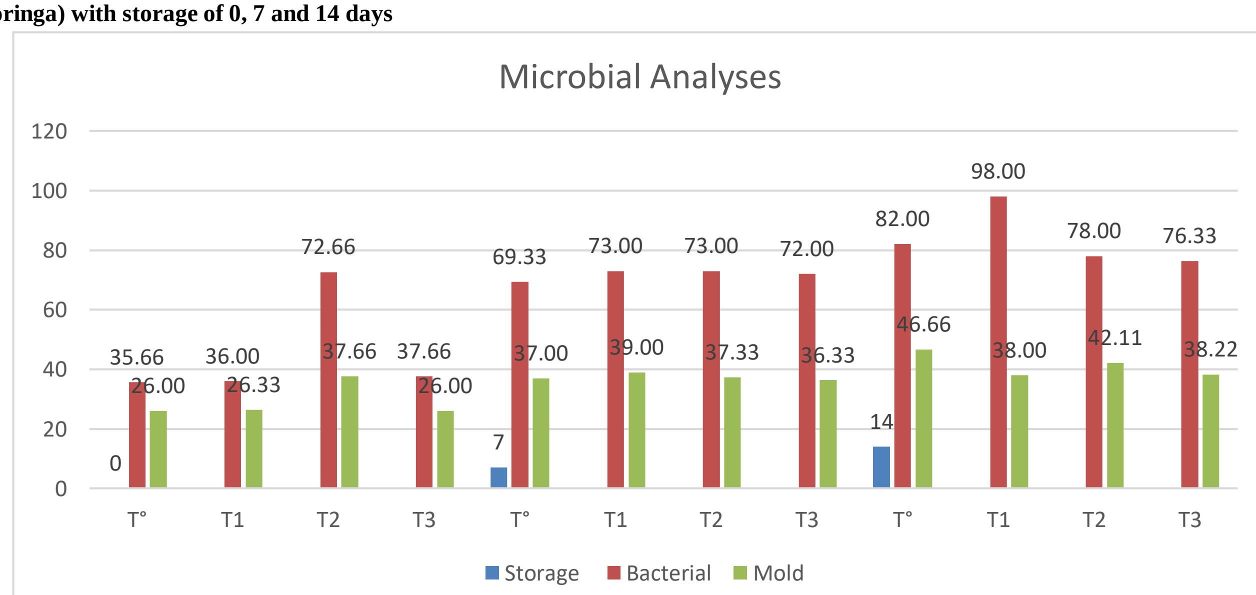


Figure 13: Present the Microbial analyses of to (100% guava), T1 (98% guava & 2% moringa), T2 (96% guava & 4% moringa) T3 (94% guava & 6% moringa) with storage of 0, 7 and 14 days

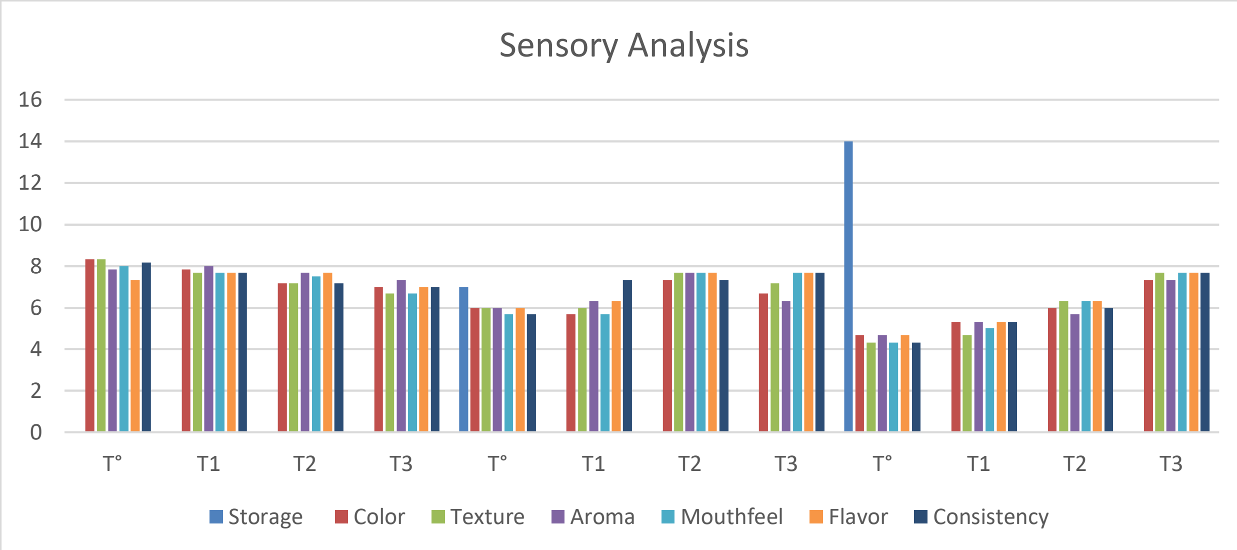


Figure 14: Present the Sensory analysis of to (100% guava), T1 (98% guava & 2% moringa), T2 (96% guava & 4% moringa) T3 (94% guava & 6% moringa) with storage of 0, 7 and 14 days

Conclusion

The present study successfully developed and evaluated a guava-moringa-based sauce by analyzing its nutritional, physicochemical, microbial, and sensory properties over a 14-day storage period. Moringa oleifera, known for its exceptional nutritional profile, significantly enhanced the nutritional quality of the sauce, particularly in terms of crude fiber and protein content, as the concentration of moringa increased. Among all formulations, the T3 treatment (6% moringa, 94% guava) demonstrated the highest enrichment of essential nutrients, showcasing the functional potential of moringa in condiment development. Physicochemical parameters, including pH, total soluble solids, total dissolved solids, viscosity, and titratable acidity, revealed that the inclusion of moringa influenced product stability and structure. T3 exhibited a consistent rise in TSS and TDS, while a notable decrease in pH and viscosity was observed across all formulations, particularly with increased moringa content. Despite a slight decline in viscosity, T2 and T3 maintained favorable texture and flow characteristics suitable for sauces. Microbial analysis confirmed that all samples remained within safe microbial limits throughout the storage duration. However, T3 demonstrated slightly lower microbial counts, possibly due to moringa's natural antimicrobial properties, which contribute to improved preservation and extended shelf life. Sensory evaluation indicated that while T0 (control) and T1 (2% moringa) experienced a decline in quality attributes over time, T2 (4% moringa) and T3 (6% moringa) maintained better sensory characteristics. T3 consistently scored the highest in aroma, flavor, texture, color, consistency, and mouthfeel due to the synergistic effect of guava's pectin and moringa's fiber, pigments, and antioxidants. Incorporating moringa leaf powder at 4–6% in guava sauce formulations not only enhances nutritional and functional value but also extends shelf stability and preserves sensory appeal. These findings advocate for the use of moringa as a viable, plant-based stabilizer and nutrient enhancer in functional condiment production. The guava-moringa sauce developed in this study holds promising potential for commercialization as a health-promoting, shelf-stable product targeting health-conscious consumers.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned.
Consent for publication
Approved
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Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

AN
Manuscript drafting, Study Design,
AS
Review of Literature, Data entry, Data analysis, and drafting article.
FM
Conception of Study, Development of Research Methodology Design,
MER
Study Design, manuscript review, critical input.
SN
Manuscript drafting, Study Design,
MU
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SB
Conception of Study, Development of Research Methodology Design,.

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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