



Development of Instant Moringa Soup Mix using Factorial Design and its Physico-chemical Evaluation

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Abstract: The present study was conducted to develop an instant soup mix utilizing *Moringa oleifera* leaf powder. Four variants of moringa soup mix were prepared and subjected to sensory and the best variant was selected and optimized using 2*4 factorial design. The soup mix consisting of corn flour (20%), potato starch (5%), sugar (8%) and moringa powder (5%) was found most acceptable on a 9 point Hedonic scale. The soup mix was subjected to physico-chemical-nutritive analysis. The instant moringa soup was found rich in protein content (8.27 g/100g) and low in fat content (3.44 g/100g). It was also found to be rich in carotenoid (7.92 mg/100g) and total chlorophyll content (0.147 mg/g) besides having good antioxidant potential (phenolic content 6.88 mg GAE/g and flavonoid content 22.13 mg CE/g) and vitamins (B₁ 12.74 mg/100g, B₂ 4.68 mg/100g, B₃ 1.67 mg/100g, B₆ 37.65 mg/100g and Vitamin C 5.16 mg/100g). These findings underscore *Moringa oleifera* potential as a powerful and effective additive to enhance the nutritional value of food formulations, offering a viable solution to address diets deficient in essential nutrients through its successful incorporation into convenient food products such as instant soup mixes.

Keywords: *Moringa oleifera*, functional food, soup mix, nutritional profile.

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1. Introduction

Modern lifestyles, urbanization, the rising prevalence of nuclear families, time constraints and increasing commodity prices have all contributed to a growing trend of instant food consumption. This trend is further amplified by the increasing number of working women who, lacking time to cook, often rely on fast food and food delivery services. Consequently, many people are becoming

accustomed to consuming these readily available but often nutritionally deficient foods, which are typically high in sugar, fat, and salt, while being low in fiber, vitamins, protein and minerals (Kaushik *et al.*, 2011). Malnutrition and related health problems are a direct consequence of consuming diets lacking essential nutrients. *Moringa oleifera*, a member of the Moringaceae family, offers a potential solution to this issue. *M. oleifera* can be used as a functional food. Functional foods are whole, fortified, enriched, or enhanced items that, when regularly eaten at efficacious levels as part of a varied diet, offer health advantages beyond basic nutrition (e.g., vitamins and minerals) (Hasler., 2002). This highly nutritious plant is rich in a variety of essential phytochemicals found in its leaves, pods and seeds. Notably, *M. oleifera* is remarkably adaptable and can flourish in diverse environments, tolerating harsh conditions such as high temperatures and drought, making it a particularly valuable resource (Yadava *et al.*, 1996). In fact, moringa was found to have 25 times more iron than spinach and 25 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yogurt, and 7 times more vitamin C than oranges (Rockwood *et al.*, 2013). The leaves contain greater quantities of proteins, calcium, potassium and amino acids including arginine and histidine (Mahmood *et al.*, 2010). Infants who are not breastfed frequently exhibit signs of malnutrition. Lactogogues are often prescribed to breastfeeding mothers to enhance milk production. Phytosterol-based lactogogues work by providing precursors for hormones involved in reproductive development. *Moringa* is a rich source of phytosterols, including stigmasterol, sitosterol and kampesterol which serve as these hormone precursors. These compounds are believed to stimulate estrogen production, which in turn promotes the proliferation of mammary gland ducts, ultimately leading to increased milk production (Mutiarra *et al.*, 2013). It is rich in bioactive compounds, such as vitamins, minerals, carotenoids, phenolic acids, flavonoids, alkaloids, polysterols and organic acids. It is also recognized as a vibrant and affordable source of phytochemicals having potential application in medicines, functional foods preparation, water purification and biodiesel production. One of the easy-to-cook foods that are available in our country is dried soup powder which is playing an important role in meeting current and future social consumer demands (Krejцова *et al.*, 2007). Dried soup powder offers significant benefits including extended shelf life due to protection from deterioration, convenient and rapid reconstitution, and ease of storage and transportation, making it a versatile and practical food product suitable for a wide range of consumers and applications (Faruk *et al.*, 2020). *Moringa oleifera*

leaf powder finds application as an ingredient in biscuits, cakes, brownies, meats, juices and sandwiches (Ariani *et al.*, 2023). Giuberti *et al.* (2021) reviewed studies indicating that the addition of moringa leaves to various products can improve their protein, lipid/fat, mineral and fiber content as well as their antioxidant activity. This research explores the development and optimization of a novel instant beverage powder fortified with dehydrated *Moringa oleifera* leaf using statistical methods for ingredient optimization as well as physico-chemical-nutritive characterization of the final product.

2. Materials and Methods

2.1. Raw Materials

Raw materials and ingredients required for the development of the product were purchased from local markets of Mysore, Karnataka. Chemicals and reagents used for analysis were of AR grade and procured from SRL Chemicals (Chennai, India) and HiMedia Laboratories Private limited (HiMedia, Mumbai).

2.2. Moringa Powder Preparation

Moringa oleifera leaves were carefully destalked and then washed to ensure cleanliness. Blanching was performed for 3 minutes using 2000 ppm potassium metabisulfite, followed by draining the water. Drying was carried out in a cabinet tray drier at a temperature of 60°C over a 9-hour period to reduce moisture content 3%. The dried leaves were subsequently ground into a fine powder using a Prett mixer. The final product, *Moringa oleifera* leaf powder, was then stored in LDPE pouches for preservation (Fig. 1).

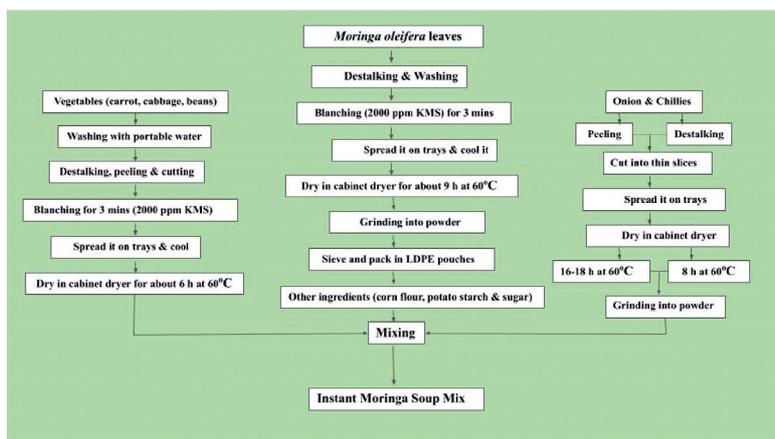


Figure 1: Flow Chart for the preparation of moringa soup mix

2.3. Preliminary Trials

Five variants of soup formulations (mushroom, mixed vegetable, corn soup, hot and sour and tomato soups) incorporating moringa powder were developed and subjected to sensory evaluation to determine their OAA acceptability (Fig.2). Based on the sensory scores obtained, the most preferred formulation was identified and was subsequently selected as the final variant for statistical optimization of ingredients (%) such as corn flour, potato starch, sugar and moringa powder.

2.4. Optimization of Instant Moringa Soup by using Factorial Experiments

The optimization of the instant moringa soup formulation was carried out using 2*4 factorial design, where four factors corn flour, potato starch, sugar and moringa powder were tested at two levels (low and high) (Table 1). Statistical analysis was done to understand and interpret the dependence of factors (corn flour, potato starch, sugar and moringa powder) on responses (appearance, colour, consistency, taste, flavour and OAA) studied.

2.5. Cooking procedure/reconstitution of soup powder

10 grams of the developed soup powder was added into the 150 ml of hot water and stirred continuously for 30 seconds to avoid lump formation. It was subjected to boiling for 2 minutes and simmered for 1 minute to obtain the desirable consistency.

2.6. Physico-chemical Analysis

2.6.1. *Water Activity*: Measurement of water activity was carried out using a water activity meter (Aqualab series 3 manual version 5). Water activity was measured in duplicates for 24 h.

2.6.2. *pH*: The pH meter was calibrated with standard buffer solutions, and the electrodes and glassware were rinsed with distilled water. 1.00 g sample was precisely weighed and transferred to a 150 mL beaker. The rinsed electrode was inserted into the sample, which was gently stirred and pH was recorded by using SSS8-040 pH meter (Saraswati Scientific Surgicals, Ambala, India).

2.6.3. *Color*: Color parameters (L*: brightness, a*: red - green, and b*: yellow - blue) were measured by using (Color meter, Hunter lab, Color management company, Virginia, United States).

2.6.4. *Rehydration Ratio*: It is a measure of water absorption by the dehydrated product, calculated using the following equation as given by Basantpure *et al.* (2003). Rehydration ratio = X/Y

Where, X = Final weight after reconstitution Y = Initial weight before reconstitution

2.6.5. *Bulk Density and Tapped density*: To measure bulk density, 25.00 g of powder was accurately weighed and placed into a 100 mL graduated cylinder. The bulk density was calculated by dividing the mass of the powder by the volume occupied in the cylinder. For the Tapped density (ρ_t), the cylinder was tapped steadily and continuously on the surface by hand until there was no further change in volume (Jinapong *et al.*, 2008)

2.6.6. *Titrateable acidity*: To determine titrateable acidity, a 10g sample was quantitatively transferred to a 250mL beaker and diluted with distilled water. A phenolphthalein indicator was added, and the resulting solution was titrated with standardized 0.1N sodium hydroxide (NaOH) delivered from a burette. The volume of NaOH required to reach the phenolphthalein endpoint was recorded. Titrateable acidity was subsequently calculated using the following formula

Titrateable acidity = Volume of NaOH used \times 0.1N \times 0.067/ volume of sample \times 100

2.6.7. *Thermal characteristics*: Thermal characterization by thermogravimetric analysis (ASTM D 3418) and differential scanning calorimetry were carried out using TGA-NET2SCH STA 449F3A-110-M at temperature range of 30° C/10.0 (k/min)/1200° C.

2.7. Proximate Analysis

Moisture, protein, fat, ash and crude fiber content of moringa soup powder mix were determined by following standard methodology (AOAC, 2019). Total carbohydrate was calculated by difference method. Carbohydrate (%) = 100-(sum of % moisture, fat total ash, crude fiber and protein).

2.8. Chlorophyll

Total chlorophyll was determined as per Ranganna *et al.* (1986). A 2 g sample of powder was mixed with 20 ml of 80% acetone. The mixture was then centrifuged at 5000 rpm for 5 minutes, and the supernatant was transferred to a volumetric flask. The remaining residue was ground with an additional 20 ml of 80% acetone, centrifuged again and the resulting supernatant was added to the same volumetric flask. This process was repeated until the residue became

colorless. All the washings were collected in the volumetric flask and the final volume was made with 80% acetone. The chlorophyll was thus extracted and its absorption was measured at 663 nm and 645 nm using a spectrophotometer to calculate the total amount of chlorophyll.

2.9. Carotenoid

A 2g powder sample is crushed in a pestle and mortar with acetone. The mixture is filtered through filter paper into a conical flask. The extraction and filtration steps are repeated until the residue becomes colorless. The combined filtrate is then transferred to a separating funnel, where 10-15 ml of petroleum ether and distilled water are added to transfer the pigments to the petroleum ether phase. The aqueous phase is drained and the petroleum ether extract is filtered through anhydrous sodium sulphate. The final volume of the petroleum ether extract is made up to 100 ml in a volumetric flask using petroleum ether. The absorption of this solution is measured at 450 nm.

3. Antioxidant Activity

3.1. Determination of Total phenolic content (TPC): Total phenolic contents were determined based on Folin–Ciocalteu colorimetric modified method described by Mokhtar *et al.* (2018). They were expressed as gallic acid equivalents (mg GAE mg/100 g).

3.2. Estimation of Total flavonoid content (TFC): The total flavonoid content of the extracts was determined using the procedure described by Mokhtar *et al.* (2021).

4. Vitamins Estimation

An Agilent Technologies Model 1260 HPLC system (USA), equipped with an auto-injector, PDA detector and ChemStation software, was used for analysis. Water-soluble vitamins separated by RP C-18 column (250 mm×4.5 mm, 0.5 µm particle size) using a gradient mobile phase of 0.1% trifluoroacetic acid (TFA) in water and 0.1% TFA in acetonitrile. The flow rate was 1.0 mL/min, and detected it at 268 nm. For sample extraction, weighed 10 gm of each sample and digested it with an acetonitrile and glacial acetic acid solution (diluted with double-distilled water) at 40°C for 45 mins. After digestion, centrifuged the samples at 5000 rpm for 15 mins at room temperature using a Beckman Coulter-Avanti J-26SXP centrifuge. Finally, samples were filtered through 0.22 µm PTFE membrane filters and injected 20 µL into the HPLC for separation (Rajendran *et al.*, 2019).

5. Sensory Evaluation

Sensory evaluation is a scientific discipline employing experimental design and statistical analysis. It was conducted to assess product acceptability. The parameters of the sensory evaluation were decided upon based on the nature and composition of the sample kept for evaluation. A trained panel evaluated the samples using a 9-point hedonic scale, ranging from 'like extremely' (9) to 'dislike extremely' (1) (Wichchukit and O'Mahony, 2015).

6. Statistical Analysis

All the analytical assays were conducted in triplicates. Mean and standard deviation (SD) were calculated using Microsoft Excel 2010. Data obtained after conducting fractional factorial experiments in 16 runs and data was assessed statistically for analysis of variance. All the results were statistically processed using Statistica Version 7.0 (Statsoft, USA).

7. Results and Discussion

7.1. Preliminary Trails

Tomato soup, mixed vegetable soup, hot and sour soup, creamy mushroom soup and sweet corn soup were prepared with the incorporation of moringa powder (5.0%). These variants were assessed based on their Overall Acceptability (OAA) scores. Among the evaluated variants, the hot and sour soup received the highest overall acceptability (OAA) score (7.9). As a result, hot and sour soup variant was selected as the final formulation for the instant moringa soup (Fig. 2).

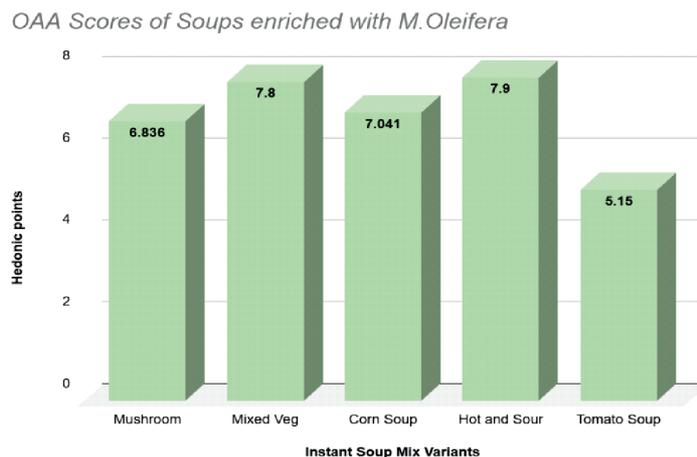


Figure 2: OAA scores of soups enriched with *M. oleifera*

7.2. Optimization of Instant moringa soup powder

Ingredients for the formulation of finalized products were designed as 2*4 factorial with two levels each of cornstarch, potato starch, sugar and moringa powder. After product preparation, OAA was studied. Among the experimental runs, Run 3, which consisted of corn flour (20.0%), potato starch (5.0%), sugar (8.0%) and moringa powder (5.0%) achieved the highest OAA score of 7.9 (Table 1). The optimized concentration of moringa powder in this formulation prevented a bitter taste and helped maintain a desirable color which supports the findings of Milla *et al.* (2021), excessive concentrations of *M. oleifera* leaf powder can negatively impact a food organoleptic properties. The formulation in Run 13, which included corn flour (30.0%), potato starch (10.0%), sugar (8.0%) and moringa powder (10.0%), resulted in a lowest score (5.2) for sensory analysis.

Table 1: Optimization of Ingredients for Instant Moringa Soup using RSM

Runs	Corn flour (%)	Potato starch (%)	Sugar (%)	Moringa powder (%)	Appearance	Colour	Consistency	Taste	Flavour	OAA
1	20	05	08	10	7.1	7.2	7.3	6.8	7.0	7.0
2	20	05	10	05	6.9	7.2	7.2	6.9	6.6	7.0
3	20	05	08	05	8.0	8.1	7.7	7.7	7.4	7.9
4	20	05	10	10	7.7	7.6	7.9	7.5	7.0	7.7
5	20	10	08	05	7.3	7.2	6.9	7.4	7.3	7.0
6	20	10	10	10	7.0	5.0	6.0	7.5	7.8	6.2
7	20	10	08	10	6.5	5.5	5.7	5.2	5.5	5.5
8	20	10	10	05	6.0	6.5	6.5	6.4	6.5	6.5
9	30	05	08	05	6.9	7.2	6.2	5.7	5.8	6.3
10	30	05	10	10	6.7	6.5	5.7	6.0	6.1	6.2
11	30	05	08	10	6.9	6.8	6.3	6.6	6.1	6.0
12	30	05	10	05	6.6	7.0	6.1	6.5	6.1	6.4
13	30	10	08	10	6.6	5.4	5.2	5.7	5.4	5.2
14	30	10	10	05	6.3	6.4	5.1	5.5	5.6	5.6
15	30	10	08	05	5.9	6.2	4.5	5.8	5.4	5.8
16	30	10	10	10	5.6	5.8	4.0	5.1	4.9	5.3

Among the independent variables, corn flour ($p = 0.015$) and potato starch ($p \leq 0.008$) demonstrated statistically significant effects on the appearance of the product. For the 'Color' variable, statistical analysis showed a significant predictive model, with potato starch and moringa powder as the main factors. The highly significant p-values associated with potato starch ($p \leq 0.000$) and moringa powder ($p \leq 0.007$) suggested that these ingredients have a substantial

impact on the color of the product. The exceptionally low p-values associated with corn flour ($p \leq 0.000$) and potato starch ($p \leq 0.000$) indicated a highly significant impact of these ingredients on product consistency. For Taste, corn flour was found to have a significant main effect ($p \leq 0.007$). The analysis of variance revealed a significant main effect for corn flour ($p \leq 0.001$) on the flavor of the product. Significant main effects on OAA were observed for corn flour and potato starch, suggesting that alterations in their respective levels result in significant changes in product acceptability.

A study by Punfujinda *et al.* (2024) on gelatin-free pudding products investigated the effect of corn starch levels (4%, 6%, and 8%). While the 4% corn starch pudding received the highest accepted sensory scores, indicating optimal functionality at lower concentrations, higher levels were generally not preferred by consumers. This directly supports our finding that exceeding an optimal corn flour level can lead to negative sensory outcomes, likely due to altered texture (e.g., increased viscosity) or a masking of the soup's natural flavor.

Box plot provides a visual representation of how different sensory attributes of moringa soup are affected by the amount of corn flour. It highlights the negative impact of higher corn flour content on taste and consistency, while showing changes in other attributes (Fig. 3). Box plot indicates that while increasing potato starch, it thickens the moringa soup, it seems to negatively affect other sensory characteristics (Fig.3). Studies show that at greater concentrations, potato starch can create an undesirable "stringy" or "slimy" texture due to its unique rheological properties, specifically the generation of high normal stresses (Singh & Singh., 2001).

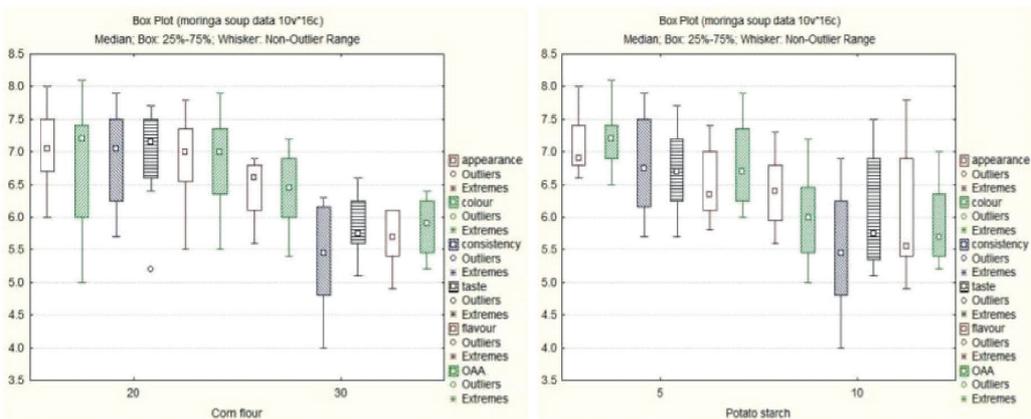


Figure 3: Box plot for sensory attributes of addition of corn starch and potato starch

Table 2: Composition of the optimized moringa soup

Ingredients	Quantity (%)
Moringa powder	5.0
Corn flour	25.0
Milk powder	13.0
Dehydrated vegetables	5.0
Potato starch	10.0
Salt	16.0
Onion powder	8.0
Sugar	8.0
Garlic powder	5.0
Chillies	1.5
Citric acid	1.5
Coriander	1.0
Pepper	0.5
Flavor enhancer	0.2
Gum	0.3

7.3. Physico-chemical Parameters

7.3.1. *Water activity*: Water activity quantifies the availability of water for chemical and physical interactions. It was observed (0.35 ± 0.00) indicating extended storage capability. Lowering water activity in food below certain thresholds stops enzyme activity (below 0.85), prevents bacteria growth (below 0.91) and inhibits yeast growth (below 0.80). This reduction also slows down browning and improves the stability of powdered foods (Nurrahman *et al.*, 2024)

7.3.2. *pH*: A pH value, between 1 and 14, indicates the level of acidity or alkalinity in a food or solution. It was observed that pH value for instant moringa soup mix (5.82 ± 0.02). pH value indicates that the soup mix is slightly acidic. A slightly acidic pH is generally beneficial for the microbial stability of food products. According to Abo Zaid & Saleh (2021), pH of soup prepared with germinated chia, flaxseed and Psyllium seeds flour ranged from 5.82 to 6.37.

7.3.3. *Acidity*: Instant moringa soup mix presented an acid value of 0.832. Low acid value represents the quality and stability of the fatty components within the soup mix. Since fats can significantly impact the overall flavor and aroma of a food product, a low level of acids is a positive indicator (Sarmila., 2023).

7.3.4. *Color*: Color plays a dominant role in determining quality and consumer acceptance, notably in sensory evaluations. Instant moringa soup

mix had a Lightness (L^*) of 65.35 ± 1.6 , indicating a moderately light color. It showed a greenish hue ($a = -3.71 \pm 0.17^*$) and yellowish tint ($b = 14.71 \pm 0.36^*$). A soup mix with rice flour and moringa, studied by Yadav *et al.* (2022), was moderately light ($L = 59.73 \pm 0.05$). It was noticeably green ($a = -6.32 \pm 0.02$) and quite yellow ($b = 24.18 \pm 0.03$). Researchers found that more rice flour made it lighter. Another study by Govender and Siwela. (2020) on bread found that adding 10% Moringa powder made the bread darker (L values of 55.8 ± 0.4 and 51.7 ± 2.0) compared to white bread ($L = 67.14 \pm 0.77$). A study on instant soup mixes derived from moringa flower powder (MFP) presented L^* values ranging from 58.76 to 63.43. Instant moringa soup mix lightness, though slightly higher, falls within the general range of the MFP samples. Similarly, the yellowish tint (b^*) of the instant moringa soup mix (14.71) is almost within the range of the MFP flower powder (13.87-15.6). However, the most significant difference lies in a^* . Instant moringa soup mix consistently displayed a negative a^* value (-3.71). In contrast, the moringa flower powder consistently showed positive a^* values (6.12-8.25)(Ansari *et al.*, 2020). Moringa characteristic green color was better preserved in the instant moringa soup mix.

7.3.5. Rehydration ratio: Rehydration ratio is a critical parameter in evaluating the quality of instant foods. A higher rehydration ratio generally indicates better instant food quality, as it suggests that the product can be easily reconstituted to its original form (Ren *et al.*, 2024). The rehydration ratio of 10.35 indicates that the instant moringa soup mix exhibits excellent rehydration properties, allowing for complete reconstitution within 2- 3 minutes. This suggests that the mix is capable of absorbing a significant amount of water, resulting in a rapid and uniform reconstitution of the soup. The high rehydration ratio can be attributed to the optimal formulation of the mix, which includes ingredients such as corn flour, potato starch and moringa powder. Bhargavanandha *et al.* (2021) observed rehydration ratio of 3.18 to 3.65 for tomato cream soup and AboZaid & Saleh. (2021) reported values of 3.9 to 4.9 for dry soup mixes enriched with germinated chia, flax and psyllium seeds flour. In comparison to other soup mix formulations an instant moringa soup mix exhibited superior rehydration (10.35). According to Jokic *et al.* (2009), products demonstrating a high rehydration capacity are generally considered tastier and better at preserving their fresh appearance.

7.3.6. Tapped and Untapped Density

Tapped density of instant moringa soup mix was found to be 0.708 g/ml, which is within the range of tapped densities observed for moringa leaf powder-

based mixes (0.72 to 0.80 g/ml) (Ansari *et al.*, 2022). An untapped density of instant moringa soup mix was 0.581 g/ml. A flow character of the powder can be indexed by the Hausner Ratio, which is the ratio of tapped to poured bulk density. An instant moringa soup mix exhibited fair flowability, as indicated by a Hausner Ratio of 1.21 and a Carr Index of 17.9%. In comparison to the findings of Jefrin *et al.* (2022), an instant moringa soup mix exhibited higher untapped density (0.581 g/ml) and tapped density (0.708 g/ml), whereas Jefrin *et al.* (2022) reported bulk density ranging from 0.37 to 0.42 g/ml and tapped density between 0.55 and 0.61 g/ml. Powders with fair to good flowability are preferred in automated filling and packaging operations, reducing the risk of blockages and ensuring uniformity in product weight and quality (Peleg, 1977).

7.3.7. Thermal Properties

Thermogravimetric analysis (TGA) was employed to characterize the thermal decomposition behavior and stability of the samples. The abscissa (x axis) was displayed as temperature and the ordinate (y axis) was displayed TG percent. A weight loss is indicated by the falling TGA thermal curve. Initially, below approximately 150°C, a minor weight loss is observed, due to the evaporation of moisture. A more substantial degradation phase occurs between 200°C and 400°C, signifying the breakdown of lower-molecular-weight organic compounds. A period of thermal stability from around 400°C to 600°C suggests the formation of a thermally resistant intermediate, likely a carbonaceous residue. Finally, between 600°C and 900°C, another significant degradation event occurred, indicating the decomposition of more complex macromolecular structures. Residual mass was found to be 14.53 percent at 1198.8 °C, representing mineral content and thermally stable inorganic compounds (Fig. 4). Jeyakumar *et al.* (2020) reported two major thermal degradation phases in *M. oleifera*: an initial mass loss between 150–200 °C (peak at 171.96 °C) attributed to saponin decomposition, followed by a significant loss from 200–375 °C (peak at 318.58 °C) due to the breakdown of antioxidant compounds. A final decomposition phase occurred between 600–700 °C, indicating the degradation of residual organic matter.

DSC thermograms of a powder provide an insight into the structure of the powder particles (Teunou *et al.*, 1999). The curve, representing heat flow versus temperature, initially exhibits a significant endothermic event (absorption of heat) as indicated by the downward trend from ambient temperature up to approximately 600°C. This is primarily attributed to the evaporation of residual moisture present in the dried powder, which requires

energy input. Following this, a broad and pronounced endothermic valley is observed, extending roughly from 600°C to 900°C. This broad feature indicates complex and overlapping thermal degradation processes, characteristic of the decomposition of various organic macromolecules (such as carbohydrates, proteins, and lipids) that constituted moringa and other ingredients in the soup powder. Finally, beyond approximately 900°C, the thermogram showed a sharp upward trend, signifying a strong exothermic event (release of heat). This is typically associated with the oxidative combustion of the remaining residues that formed during the earlier decomposition stages. DSC analysis comprehensively illustrated the thermal stability and decomposition behavior of the moringa soup powder components across a wide temperature range. A broader thermal degradation pattern was observed extending up to 900 °C and indicating the decomposition of complex organic macromolecules within the instant moringa soup mix. This finding differs from Jeyakumar *et al.* (2020), who reported four distinct endothermic peaks in moringa powder corresponding to the thermal stability of specific antioxidant compounds during heating.

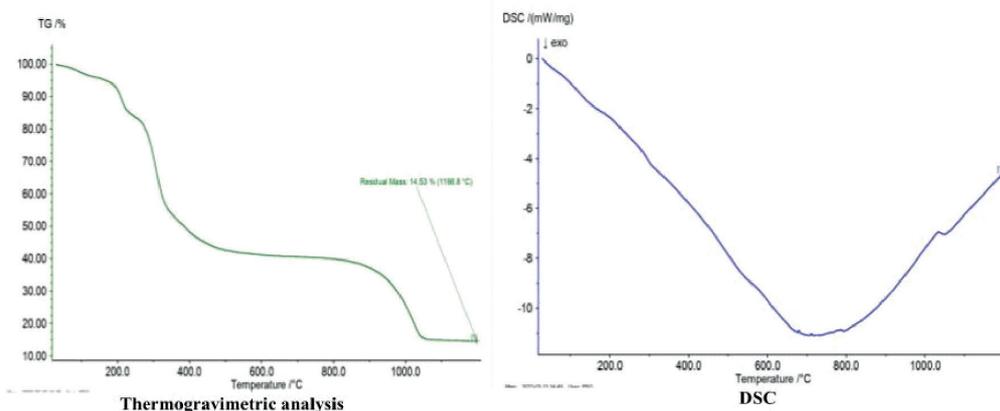


Figure 4: Thermogravimetric analysis and DSC of instant hot and sour moringa soup

7.4. Proximate Composition

Proximate refers to a method for determining the levels of macronutrients in food samples. In general, those values are reported as nutritional facts, which are typically displayed on the labels of finished food products (Noh *et al.*, 2020). A study conducted by Rajput *et al.* (2019) on dried *Moringa oleifera* leaf powder revealed a moisture content of 7.43 percent, ash content of 9.53 percent, protein content of 20.42 percent, carbohydrate content of 50.16 percent

and crude fiber content of 22.03 percent indicating that *M. oleifera* powder can be used as a nutritional supplement in food due to its high nutritional content. According to the Indian Food Composition Tables (IFCT 2017) by the National Institute of Nutrition (NIN), fresh moringa leaves provide significant amounts of protein (6.41 g), dietary fiber (6.12 g), vitamins such as vitamin C (51.7 mg), vitamin A (378 μ g as beta-carotene), riboflavin (0.66 mg), and vitamin B6 (1.2 mg) per 100 grams. These nutrients are essential for maintaining good health and addressing common deficiencies.

Moisture content (%) of the Instant moringa soup mix (3.96 ± 0.145) was significantly lower than the range reported by Jefrin *et al.* (2022) for similar instant soup formulations incorporating *Moringa oleifera* (4.07-5.37%). Moisture content of Instant moringa soup mix was found under the maximum moisture specification limits of dried powders in food industry which were 3–4 % (Zungur *et al.*, 2016). Instant moringa soup mix exhibited a fat content of $3.44 \pm 0.154\%$, which is not on par with the 1.84% to 2.64% range reported by Jefrin *et al.* (2022). Protein content (%) was found to be 8.27 ± 0.01 and it is within the range provided by Farzana *et al.* (2017) (6.92 - 16.05 %). According to Ansari *et al.* (2020) the protein content in different formulations of instant soup mix enriched with *Moringa oleifera* ranged from 9.76% to 13.67%. Protein content of *Moringa oleifera* varies depending on climate, cultivation practices, plant maturity, and post-harvest processing methods. These factors can significantly affect the nutritional quality of moringa leaves (Castillo-Lopez *et al.* 2017).

Instant moringa soup mix had an ash content (4.55 %). Ash content of the instant moringa soup mix aligns with the findings of Hanan *et al.* (2020), who reported an ash content of $4.61 \pm 0.28\%$ for an instant pea soup powder. Studies on moringa leaf powder show a wide range of ash contents, typically from 4.4% to over 9% (Ansari *et al.*, 2022;). The difference in data may be due to difference in recipe and ingredient formulation (Gurung, 2024). Ash content reflects a mineral profile that is likely enriched by the moringa leaf component of the soup. The higher ash content of the soup powder suggests that it is a better source of minerals. A study on an optimized instant soup mix made with water-chestnut and vegetable waste (possibly including mushroom) by Pal. (2021) reported a relatively low ash content of 2.18 ± 0.53 . Instant moringa soup mix had 2.97 ± 0.00 of crude fibre. Instant moringa soup mix exhibited a carbohydrate content of 77.81 percent. The elevated carbohydrate level in the instant moringa soup mix may be attributed to the inclusion of carbohydrate-rich ingredients such as potato starch, corn starch & sugars.

7.5. Nutritional value

Total flavonoid content and phenolic content were determined as 22.13 mg CE/g and 6.38 mg GAE/g respectively. These bioactive molecules, particularly flavonoids, are increasingly recognized for their potential to contribute to human health by neutralizing harmful free radicals in the body. According to the scientific literature, *M. oleifera* contain a wide spectrum of flavonoids molecules with known nutraceutical properties (Makita *et al.*, 2016). A study by KC *et al.* (2022) investigated the impact of substituting 15 parts of wheat flour in a control sample with moringa flower and leaf blend at specific ratios on the total flavonoid content (TFC) of experimental biscuits. Their findings ranged from 308-347 mg CE/100g. Instant moringa soup mix contained total phenolic content (TPC) that substantially exceeds the 35–74 mg GAE/100 mL range reported for moringa leaf tea infusion by Ilyas *et al.* (2015). Fontana *et al.* (2023) highlighted that *Moringa oleifera* leaves are rich in flavonols and phenolic acids. These compounds are present in high concentrations in dried leaves and extracts, supporting the high antioxidant activity observed in moringa-based products.

7.6. Vitamins

Instant moringa soup mix revealed a notable presence of several essential water-soluble vitamins (mg/100g) such as vitamin B₁ (thiamine) at a concentration of 12.74, vitamin B₂ (riboflavin) at 4.68, vitamin B₃ (niacin) at 1.67, vitamin B₆ (pyridoxine) at 37.65, vitamin B₉ (folic acid) at 5.30 and vitamin C (ascorbic acid) at 5.16. Vitamin C content of instant moringa soup mix (5.16 mg/100g) was found to be consistent with the value reported by Farzana *et al.* (2017), documented 6.4 mg/100g for soy-mushroom-moringa soup powder, indicating that fortification of instant soups with moringa can reliably enhance vitamin C levels. Studies have shown that moringa leaf powder is a particularly rich source of pyridoxine (B6), folic acid (B9), and nicotinic acid (B3), among other B vitamins (Islam *et al.*, 2021; Lakshmipriya *et al.*, 2016)

7.7. Chlorophyll

Chlorophyll is a key bioactive compound in moringa leaves, recognized for its antioxidant properties and potential health benefits (Kashyap *et al.*, 2022). The presence of chlorophyll in the instant moringa soup mix highlighted the potential of this product as a source of valuable phytochemicals. These pigments, naturally abundant in *Moringa oleifera* leaves, contributed not only to the visual appeal but also to the potential health benefits of the soup

mix. Instant moringa soup mix contained 0.147 of total chlorophyll (mg/g). Bhattarai (2024) observed a substantial decrease in chlorophyll concentration (mg/g) during the processing of fresh moringa leaves into powder, reporting a reduction from 20.956 ± 1.04 in fresh leaves to 3.770 in the moringa powder. The observed chlorophyll reduction is mainly due to thermal processing, oxidative degradation and reduced concentration resulting from inclusion of other ingredients. However, partial chlorophyll retention in the powder may be attributed to protective interactions among bioactive compounds. Adebayo and Abdus (2022) reported that dried moringa leaves had chlorophyll contents ranging from 110.24 ± 6.21 mg/100g to 56.37 ± 2.24 mg/100g, with the decrease attributed to storage time and processing methods.

Table 3: Analysis of instant moringa soup mix

Sl. No	Parameters	Moringa soup
1	Moisture (%)	3.96 ± 0.14
2	Fat (%)	3.44 ± 0.15
3	Protein (%)	8.27 ± 0.01
4	Ash (%)	4.55 ± 0.19
5	Crude fiber (%)	2.97 ± 0.00
6	Carbohydrates	76.81 ± 0.02
7	Energy (Kcal)	375.28 ± 0.01
8	Water activity	0.35 ± 0.00
9	pH	5.82 ± 0.02
10	Acidity	0.832 ± 0.00
11	Tapped density (g/ml)	0.708 ± 0.5
12	Untapped density (g/ml)	0.581 ± 1.0
13	Rehydration ratio	10.35 ± 0.1
14	Color	L*
		65.35
		a*
	b*	14.71 ± 0.36
15	Total phenolic content (mg GAE/g)	6.38 ± 0.2
16	Total flavonoid content (mg CE/g)	22.13 ± 0.3
17	Carotenoid (mg/100g)	7.92 ± 0.5
18	Total Chlorophyll (mg/g)	0.147 ± 0.2
19	Vitamin B ₁ (mg/100g)	12.74 ± 0.1
20	Vitamin B ₂ (mg/100g)	4.68 ± 0.01
21	Vitamin B ₃ (mg/100g)	1.67 ± 0.01
22	Vitamin B ₆ (mg/100g)	37.65 ± 0.00
23	Vitamin C (mg/100g)	5.16 ± 0.01
*Values are mean \pm standard deviation		

7.8. Carotenoids

Carotenoids are a class of fat-soluble pigments known for their antioxidant properties and their role as precursors to vitamin A (in the case of beta-carotene and other provitamin A carotenoids). Vitamin A is crucial for vision, immune function, cell growth and differentiation (Jiri *et al.*, 2024). According to Saini *et al.* (2022), fresh moringa leaves contain approximately 473.3 µg/g fresh weight of total carotenoids, which is nearly four times higher than lettuce (86.3–116.1 µg/g) and about twice as high as spinach (218.5 µg/g) and fenugreek (214.2 µg/g). Instant moringa soup mix contained 7.93 mg of total carotenoids per 100g. Sengeev *et al.* (2013) investigated the effect of moringa leaf powder supplementation on wheat bread. Their study reported an increased β-carotene content (mg/100g) from 0.02 in control bread to 3.27 in bread fortified with 5 percent moringa leaf powder. Scientific reviews and clinical evidence confirm that regular dietary intake of carotenoid-rich foods is linked to a lower risk of chronic diseases, improved immune response, and better overall health (Crupi *et al.*, 2023; Cicero & Colletti, 2017; Bohn *et al.*, 2021) .

8. Conclusion

The developed instant moringa soup mix with optimal formulation, comprising corn flour (20%), potato starch (5%), sugar (8%) and moringa powder (5%) exhibited excellent sensory properties and was found to be rich in protein, ash, carotenoids, vitamins and antioxidant while being low in fat. The study highlighted the significant potential of *Moringa oleifera* as a functional ingredient to enhance the nutritional quality of convenient food products and create healthier options that address nutritional deficiencies while appealing to consumers.

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