Formulation and evaluation of plant-based flavoured tofu as a sustainable protein source

Prathakshana.VA[1], Krithiga. KS [2], Mekavarshine.V[3], Aravinthan V[4,] Senthamizhselvam.D[5,] Dikshinth.U[6]

[1,2,3,4,5,6]*Department of Food Technology, Sri Shakthi Institute of Engineering and Technology*

Abstract- Alternatives to tofu made from legumes such as chickpeas have emerged as appealing options due to the increasing demand for allergen-free and sustainable plant-based proteins. Chickpea milk, which is produced from soaked and mashed chickpeas, provides a soy-free alternative with beneficial nutritional and functional properties, serving as a nutrient-dense foundation for tofu production. This research focused on the creation and evaluation of the sensory attributes of flavoured tofu made from chickpea milk. The incorporation of natural flavour combinations into coagulated chickpea milk tofu resulted in two distinct flavour profiles: Ginger-Garlic and Chilli-Mint. A semi-trained panel conducted a sensory analysis to assess taste, aroma, texture, appearance, and overall acceptability. While the chili-mint variant was less flavour primarily due to its overpowering mint flavour and inconsistent texture, the ginger-garlic tofu exhibited superior sensory qualities and attracted more consumer interest. These results indicate the potential of chickpea milk tofu as a viable soy-free, plant-based protein alternative that aligns with the current consumer trend towards health-conscious and allergen-aware food options, especially when it features a well-balanced flavour.

Index terms: **Plant-based tofu, soy free, flavoured tofu, sustainable alternative, plant-based protein.**

I.INTRODUCTION

As people are becoming more aware of the health benefits of plant proteins, the environmental issues related to plant sustainability, and the ethical concerns surrounding animal farming, there has been a noticeable global shift towards plant-based diets [7]. Among the many plant protein sources, tofu has been cherished for centuries due to its impressive ability to provide protein. Traditionally produced from soy milk through coagulation, tofu boasts a complete amino acid profile and is incredibly versatile in the kitchen [4]. However, soy allergies affect a significant portion of the global population, limiting tofu consumption for some individuals. This reliance on soy has spurred research into other legumes to expand plant protein sources and reduce the impacts of monoculture farming [2]. A staple legume in many regions of the world, chickpeas (*Cicer arietinum*) are drawing interest as a possible soy-free protein source because of their high protein level, nutritional profile, and functional qualities. Chickpeas have about 20-25% protein as well as dietary fiber, vitamins, minerals, and bioactive chemicals including polyphenols and phytosterols, which have been connected to several health advantages including cholesterol lowering and better glycemic control [8]. Made by soaking, grinding, and filtering chickpeas, chickpea milk provides a rich, creamy foundation appropriate for coagulation into tofu-like products, therefore replacing soy milk. The growth of chickpea milk-based tofu fits consumer preferences for allergen-friendly, plant-based, and minimally processed foods [3]. The sensory qualities of such new tofu products, therefore, present one difficulty in their acceptance. Whether soy-based or from other legumes, plain tofu often has a mild or bland flavour that might turn off people not familiar with its preparation. Improving tofu with natural flavourings not only increases palatability but may also provide functional advantages. Widely used culinary herbs and spices like ginger, garlic, chili, and mint have acknowledged antioxidant, antibacterial, and digestive qualities [6]. The objective of this research emphasizes the formulation, manufacture, and sensory evaluation of flavoured tofu produced from chickpea milk, including two particular flavour profiles: Ginger-Garlic and Chilli-Mint. The goal is to explore how these natural flavour infusions influence sensory characteristics including taste, scent, texture, and general acceptability. The study intends to evaluate consumer preference and show the possibility of chickpea milk tofu as a healthy, soy-free substitute satisfying the rising need for functional and tasty plant-based foods.

II.MATERIALS AND METHODS

Chickpea, lemon, ginger, garlic, mint leaves, green chili, and salt were purchased from local (Coimbatore, Tamil Nadu). The legumes used were upto moisture standard (<13%). Drinking water used for tofu production was qualified by Central Pollution control board (CPCB) and the Indian Standards. The tofu manufacturing involves steps namely milk extraction from chickpea, boiling, coagulating, pressing, and cutting into cubes. Different chickpea varieties were chosen to evaluate their suitability for tofu production. The protein content, starch composition, and water absorption capacity were considered during the selection process. Chickpeas were cleaned to remove impurities. Chickpea was soken in water (6–12 hours) to improve softness and hydration. Determining the optimal soaking time by measuring water uptake and swelling ratio. The soaked chickpeas were ground with a fixed water-to-seed ratio to produce chickpea milk. The mixture was filtered to separate solids (*okara*) from chickpea milk. Different coagulants were tested (e.g., calcium sulfate, magnesium chloride, citric acid, lemon juice, or vinegar). Chickpea milk was heated to a specific temperature (e.g., 80–90°C). Coagulants were added at different concentrations and curd formation was observed. Coagulation temperatures were optimised for best yield and texture. The coagulated curds were separated from whey using a cheesecloth or tofu mold. Different pressing weights and durations were applied to evaluate firmness. The chickpea tofu was stored at refrigeration temperature (4°C) and texture and microbial stability was monitored over time.

A. NUTRITIONAL ANALYSIS

1.Crude protein:
The protein amount was measured using the Kjeldahl method, modified by [5]. One gram of fresh tofu was broken down by heating it with 15 ml of concentrated H_2SO_4 (98% w/w) along with one selenium catalyst tablet. The protein breakdown took place in a fume hood for two hours. The mixture was combined with 80 ml of distilled water and 50 ml of 40% NaOH solution in a Kjeldahl apparatus and then distilled. The liquid collected was placed in 25 ml of 4% boric acid solution that had a mixed indicator (methyl red/bromocresol green). A total of 50 ml of green liquid was gathered and titrated with 0.1N HCl to a deep red endpoint. A reagent blank was also processed, distilled, and titrated as described above. The total nitrogen (N_2) was calculated, and the protein amount was determined using the soy conversion factor of 5.71 based on glycinin. The average percentage of crude protein was based on three separate tests.

2. Crude fiber:
Crude fiber was determined by Weende method for crude fiber determination (*AOAC*). In this method the sample was subjected to acid and alkaline digestion to stimulate the human digestion process. The resulting residue was dried, weighed, ashed in muffle furnace and reweighed. The Association of Official Analytical Chemists (*AOAC)* has approved the Weende method, also known as the classical or conventional crude fiber method, for determining crude fiber. A moisture-free sample was successively digested using 1.25% sulfuric acid and then 1.25% sodium hydroxide in order to mimic the chemical breakdown that occurs in the digestive system. The residue was then filtered, cleaned, dried at 105°C, weighed, and finally burned in a muffle furnace at 550°C. The weight loss after ashing indicates the amount of crude fiber.

B. CHEMICAL ANALYSIS
1. pH
The determination of the pH value of tofu was carried out following this method. The sample was blended with a high-speed blender and then the mixture was wrapped with sheet cloth and manually squeezed to obtain a filtrate. The filtrate was analysed pH value using a pH meter.

2.Moisture content
In our analysis, moisture content was determined in chickpea tofu by the hot air oven method, which is regarded as the most reliable method and is also simple for food analysis. Approximately 5 g of the homogenized chickpea tofu was weighed in pre-dried and pre-weighed crucibles and dried in a hot air oven at 105 ± 1 °C for 4 to 6 h or until a constant weight was attained. Immediately after drying, the samples were cooled in a desiccator to prevent them from absorbing moisture from the atmosphere and were thereafter weighed. This method is a gravimetric method and follows the AOAC Official Method 925.10 commonly performed for moisture determination of food products [1]. Since moisture contents are known to affect the texture, microbial stability, and overall quality of the chickpea tofu, determining it accurately is imperative for product development and quality control.

C. SENSORY ANALYSIS

Sensory analysis was conducted to assess the sensory attributes of chickpea-based tofu incorporated with two different flavours ginger-garlic and chilly-mint. The sensory analysis was carried out in a controlled laboratory setting under ambient conditions. A panel of ten individuals, were selected who are familiar with basic sensory analysis procedures. Prior to analysis, chickpea tofu samples were prepared using standardised formulations with two different flavour combinations: ginger-garlic and chilly-mint. The samples were marked with random three-digit numbers to ensure fair analysis and were presented in a random manner to minimize positional selections. In between samples, the panellists were told to wash their palates with water. Each sample was analysed based on five sensory attributes such as appearance, texture, aroma, flavour, and overall acceptability using a 9- point hedonic scale, where 1 represented "dislike extremely" and 9 represented "like extremely." The data collected were then statistically analysed to determine the acceptability of each flavoured variant.

III. RESULT AND DISSCUSSION

A.Chemical analysis

The study identified how different natural additives affected the pH and moisture content of chickpea tofu. Four different formulations were tested: (1) with citric acid, (2) without any additives, (3) with ginger and garlic flavour added, and (4) with chilli and mint flavour added. The observations were tabulated in the table I.

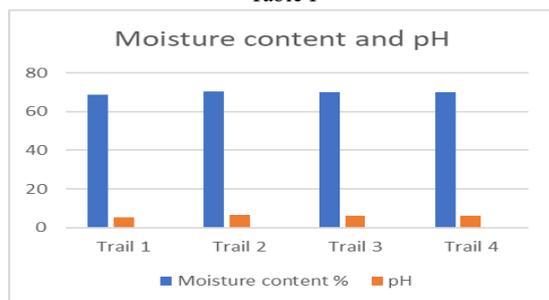| Trail no	Appearance	Texture	Flavour	Taste	Overall acceptability
1	7.0	5	5	4	6.8
2	7.2	7.0	4	4	7
3	7.4	7.1	7.5	7	7.3
4	7	6	5	5.5	6.7
Mean± SD	7.15	6.38	5.38	5.13	6.95

Table I

Fig I

The fig I explains the moisture content and pH of the four trails. The results represent that the formulation significantly influenced both the parameters. The moisture content values varied across the samples ranging from 68.7% in Trail 1 to 70.3% in trail 2. The trail 2 exhibited highest moisture retention due to absence of acidic coagulants which cause removal of moisture during tofu formation. Whereas the trail 1 showed the lowest moisture content and acid induced denaturation of proteins due to strong coagulation.

The pH values showed that trail 1 had the lowest pH (5.41) due to the presence acid which reduces the pH of the mixture. The trail 2 had the highest pH (6.33), which indicated the neutral composition without acid intervention.

B. Sensory analysis

To determine the acceptability of chickpea-based tofu combined with two distinct flavour profiles—ginger-garlic and chilly-mint—a sensory evaluation was carried out. Ten members of a semi-trained panel used a nine-point hedonic scale to rate the samples, concentrating on appearance, texture, flavour, aroma, and overall acceptability. The ginger-garlic variety scored highly on the acceptability scale because it was well-received by panellists for its balanced aroma and complementary flavour, among other qualities. On the other hand, the chilly-mint variety received a low rating, with reviews praising its strong minty scent and uneven flavour profile that didn't go well with the chickpea base. These findings suggest that garlic and ginger work well as flavour enhancers for chickpea tofu, but that the chilly-mint combination needs to be reformulated for better sensory appeal. The observations are tabulated in table II.

Trail no	Formulation details	Moisture content (%)	pH value
Trail 1	With citric acid	68.7%	5.41
Trail 2	Without citric acid	70.3%	6.33
Trail 3	With ginger and garlic	69.9%	6.03
Trail 4	With chilly and mint	70.2%	6.13
Mean ±SD	_	69.78±0.67	5.98±0.34

Table II

Fig II

The obtained observations were plotted on a radar chart (fig II) to visually differentiate the sensory attributes. From the radar chart it was observed that the Trail 3 obtained high score when compared to other trails. Trail 2 received medium scores for appearance and texture but received low scores for taste and flavour, showing the importance of flavour enhancers in tofu-based formulation. Trial 1 scored the lowest on flavour and texture. It's possible that the sourness of the citric acid affected the mouthfeel and palatability, making it less desirable than the other types. There was some variation in the response to Trial 4 (with mint and chilli). Although it tasted and looked good, the harsh minty overtones may have clashed with the chickpea foundation, requiring reformulation for better balance, according to the flavour score and overall acceptability.

IV. CONCLUSION

This study aimed to develop and evaluate chickpea-based tofu using different natural additives and flavours like citric acid, ginger and garlic, chilly and mint by comparing with the control. The chemical analysis of moisture and pH proved that the addition of citric acid reduced both the parameters due to enhanced coagulation and acidification. The flavours such as ginger-garlic and chilly-mint also modified the pH and moisture without adversely affecting the textural properties. Sensory analysis showed that the tofu sample with ginger and garlic flavour received the highest score which indicate strong consumer preference. The sample with citric acid as a coagulant scored lower due to unfavourable texture and sour taste. The chilly and mint showed moderate acceptability but require further modification in the concentration. Overall the research demonstrate that chickpea tofu is an alternative plant-based protein with good nutritional quality and sensory appeal.

REFERENCE

[1] AOAC INTERNATIONAL. (2019). *Official Methods of Analysis of AOAC INTERNATIONAL* (21st ed.). Rockville, MD: AOAC INTERNATIONAL

[2] Hefni, M., & Bekhit, A. E. D. A. (2023). High-pressure homogenisation improves food quality of plant-based milk alternatives. *Journal of Food Science and Technology*, 60(5), 1234–1245. https://doi.org/10.1007/s13197-023-05432-1

[3] Joshi, V. K., & Kumar, S. (2015). Meat analogues: Plant-based alternatives to meat products—A review. *International Journal of Food and Fermentation Technology*, 5(2), 107–119 10.5958/2277-9396.2016.00001.5

[4] Messina, M. (2016). Soy and health update: Evaluation of the clinical and epidemiologic literature. *Nutrients*, 8(12), 754. https://doi.org/10.3390/nu8120754

[5] Onwuka, G.I. (2005). *Food Analysis and Instrumentation: Theory and Practice*. Naphtali Prints, Lagos, Nigeria

[6] Ranasinghe, P., Pigera, S., Premakumara, G. A. S., Galappaththy, P., Constantine, G. R., & Katulanda, P. (2013). Medicinal properties of 'true' cinnamon (Cinnamomum zeylanicum): A systematic review. *BMC Complementary and Alternative Medicine*, 13, 275. https://doi.org/10.1186/1472-6882-13-275

[7] Sethi, S., Tyagi, S. K., & Anurag, R. K. (2016). Plant-based milk alternatives: An emerging segment of functional beverages—A review. *Journal of Food Science and Technology*, 53(9), 3408–3423. https://doi.org/10.1007/s13197-016-2328-3

[8] Wang, X., Li, Y., Zhang, H., & Chen, J. (2020). Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability and product characteristics. *Critical Reviews in Food Science and Nutrition*, 60(11), 1973–1987. https://doi.org/10.1080/10408398.2019.1651185