

Inulin - Enriched Gherkin Chips: Quality Evaluation and Functional Potential

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Abstract:

This study focuses on the development and quality evaluation of inulin-enriched acidified gherkin chips, designed to improve dietary Fiber intake while maintaining product safety and sensory acceptability. Fresh gherkins were sliced into uniform chips and preserved in an acidified brine solution, followed by controlled pasteurization to ensure microbial stability and extended shelf life. Inulin, a soluble prebiotic dietary Fiber, was incorporated at optimized concentrations to enhance the functional value of the product by promoting gut-friendly microflora. Processing parameters such as brine composition, pH, salt concentration, and pasteurization temperature-time combinations were standardized to achieve desirable texture, flavor, and safety. The developed product was evaluated for physicochemical properties including pH, titratable acidity, total soluble solids, texture, color, and dietary Fiber content. Microbiological analysis was conducted to ensure product safety, and sensory evaluation was performed to assess consumer acceptability in terms of taste, texture, appearance, and overall preference. The results demonstrated that inulin incorporation significantly improved the dietary Fiber content without adversely affecting the characteristic sour taste and crisp texture of acidified gherkin chips. The study confirms the feasibility of producing a safe, shelf-stable, and nutritionally enhanced functional pickled vegetable product that meets the growing demand for Fiber-rich foods.

Keywords: Fiber-Enriched Gherkin Chips, Inulin, Quality Evaluation, Functional Food, Physio-Chemical Parameters, Sensory Evaluation, Overall Acceptability.

1. INTRODUCTION

In recent years, there has been a growing demand for functional foods that provide health benefits beyond basic nutrition. This trend is largely driven by increasing consumer awareness regarding the role of diet in preventing lifestyle-related diseases and promoting overall well-being (Roberfroid, 2007). Among various functional ingredients, dietary fiber has gained significant importance due to its beneficial effects on digestive health, glycemic control, and gut microbiota (Slavin, 2013; Gibson et al., 2017). However, the intake of dietary fiber in many populations remains below recommended levels, creating a need for the development of innovative food products enriched with functional fiber components (Stephen et al., 2017).

Inulin is a naturally occurring soluble dietary fiber widely recognized for its prebiotic properties. It selectively stimulates the growth of beneficial intestinal bacteria, thereby improving gut health and enhancing nutrient absorption (Hughes et al., 2022; qin et al., 2023). In addition to its nutritional benefits, inulin exhibits desirable functional properties such as good solubility, neutral taste, and compatibility with

various food systems, making it a suitable ingredient for incorporation into processed foods (Shoaib et al., 2016; Bhanja et al., 2022). Furthermore, inulin is widely used as a fat replacer, sugar substitute, and texture modifier in functional food development, contributing to improved product quality and health benefits (Franck, 2002; Lin et al., 2024).

Gherkins (*Cucumis sativus*) are commonly used in the preparation of pickled and acidified products due to their firm texture, mild flavor, and ability to absorb brine effectively (Saxena et al., 2019; Medina et al., 2021). Acidification using vinegar is a well-established preservation technique that lowers the pH of the product, thereby inhibiting the growth of pathogenic and spoilage microorganisms (Fellows, 2017; Ray & Bhunia, 2014). The addition of salt, sugar, and calcium chloride further contributes to flavor enhancement, osmotic balance, and maintenance of product texture (Desai et al., 2020; Rahman, 2007). These combined factors play a crucial role in improving the safety, shelf life, and sensory quality of acidified gherkin products (Battcock & Azam-Ali, 1998; Daeschel & Fleming, 1987).

Traditional pickled gherkin products prepared from *Cucumis sativus*, although widely consumed, are generally low in dietary fiber and do not offer significant functional benefits (Kaur & Kapoor, 2002; Slavin, 2013). Therefore, enriching such products with functional ingredients like inulin presents an opportunity to develop value-added foods that combine preservation with improved nutritional quality (Roberfroid, 2007; Biedrzycka & Bielecka, 2004). The incorporation of inulin into acidified gherkin chips can enhance dietary fiber content while maintaining the characteristic sensory properties of the product, as inulin has minimal impact on taste and texture when used at appropriate levels (Franck, 2002; Meyer & Stasse-Wolthuis, 2009). This approach supports the development of functional foods that promote gut health while retaining consumer acceptability (Gibson et al., 2017).

The development of inulin-enriched acidified gherkin chips from *Cucumis sativus* involves careful optimization of processing parameters such as brine composition, pH, salt concentration, and pasteurization conditions to ensure product safety, stability, and acceptability (Fellows, 2017; Rahman, 2007). Evaluation of physicochemical properties, microbial quality, and sensory characteristics is essential to determine the overall quality of the developed product and its suitability for consumption (Ray & Bhunia, 2014).

Hence, the present study aims to develop and evaluate inulin-enriched acidified gherkin chips from *Cucumis sativus* as a functional food product with enhanced dietary fiber content (Roberfroid, 2007). The study also focuses on assessing the impact of inulin incorporation on physicochemical properties, microbial safety, and sensory acceptability, with the objective of producing a shelf-stable and consumer-acceptable product that meets the growing demand for healthy and convenient foods (Fellows, 2017; Gibson et al., 2017).

2. METATERIALS AND METHODS

2.1 MATERIALS

Fresh Gherkin, Vinegar, Salt, Sugar, Calcium chloride, Inulin, Water, Turmeric oleoresin, Conc. Sweet Cucumber S934 and yellow mustards, Celery seeds, Dehydrated onion.



Fig-1: Raw Materials

2.2 METHODS

The preparation of inulin-enriched acidified gherkin chips involves a series of systematic processing steps to ensure product quality, safety, and uniformity. Initially, fresh, tender, and defect-free gherkins of *Cucumis sativus* are selected as the primary raw material based on criteria such as uniform size, appropriate maturity, firm texture, and absence of mechanical damage or microbial spoilage, as the quality of raw material directly influences the final product (Fellows, 2017). The selected gherkins are then sorted and graded according to size, shape, and maturity to maintain uniformity during processing and to ensure consistent slicing and absorption of the preservation medium. This is followed by thorough washing using potable water to remove soil, dust, pesticide residues, and surface microorganisms, thereby reducing microbial load and improving safety (Rahman, 2007).

After cleaning, the gherkins of *Cucumis sativus* are cut into uniform slices or chips using sanitized cutting equipment. Uniform slicing increases the surface area, which facilitates effective diffusion of the acidified and fiber-enriched medium into the plant tissue (Fellows, 2017). A preservation medium is then prepared using water, vinegar (as a source of acetic acid), salt, sugar, calcium chloride, and inulin as a dietary fiber. The addition of inulin enhances the functional value of the product by increasing its dietary fiber content (Roberfroid, 2007). The prepared medium is heated under controlled conditions to ensure complete dissolution of ingredients, improve homogeneity, and reduce microbial contamination, while also aiding in better penetration of the solution into the gherkin tissues (Rahman, 2007).

The sliced gherkin chips of *Cucumis sativus* are subsequently filled into pre-cleaned and sterilized glass jars, ensuring proper packing to minimize air spaces and maintain an optimal ratio between solid and liquid components (Fellows, 2017). The hot fiber-enriched medium is then poured into the jars until the gherkin slices are completely submerged, which is essential for uniform preservation and effective mass transfer. Immediately after filling, the jars are sealed with airtight caps to prevent contamination and maintain product integrity during storage (Rahman, 2007). The sealed jars are subjected to pasteurization at 80°C for 20 minutes, a thermal treatment that effectively reduces spoilage microorganisms and enzyme activity, thereby enhancing shelf life without significantly affecting product quality (Ray & Bhunia, 2014). Following pasteurization, the jars containing *Cucumis sativus* chips are cooled to approximately 30°C under controlled conditions to prevent thermal shock and to preserve the texture and structural integrity of the product (Fellows, 2017). The cooled jars are then stored under suitable ambient or controlled

Table 1: Sample Formulation

INGREDIENTS	VARIATION 1	VARIATION 2	VARIATION 3
Vinegar	142.3ml	142.3ml	142.3ml
Salt	28.06g	28.06g	28.06g
Sugar	434.34g	434.34g	434.34g
Calcium Chloride	3.88g	3.88g	3.88g
Inulin	5grams	10grams	15grams
Water	Balance	Balance	Balance
Turmeric oleoresin	0.40g	0.40g	0.40g
Conc. Sweet Cucumber S934	0.70g	0.70g	0.70g
Yellow mustard	2mg	2mg	2mg
Celery seed	1mg	1mg	1mg
Dehydrated Onion	1mg	1mg	1mg

conditions, allowing sufficient time for flavor development and diffusion of the fiber-enriched medium into the gherkin tissues (Rahman, 2007).

Finally, the developed product is evaluated for quality parameters, including physicochemical properties such as pH, acidity, and total soluble solids, microbiological safety, and sensory attributes such as color, texture, taste, and overall acceptability (Ranganna, 2010; Ray & Bhunia, 2014). This comprehensive evaluation ensures that the product meets established food safety standards and consumer expectations (Lawless & Heymann, 2010).

3. PHYSICO-CHEMICAL ANALYSIS

The quality characteristics of the developed inulin-enriched acidified gherkin chips were determined using standard analytical methods.

3.1.1 Vacuum Test:

The vacuum level of the sealed gherkin jar was determined to evaluate the integrity of the seal (fellows, 2017; Robertson, 2016). The jar was placed under a vacuum tester, and a needle was inserted through the lid to measure the internal vacuum (Nielsen, 2017). The vacuum reading was recorded in mmHg (Aoac, 2016). A proper vacuum level indicates effective sealing, which helps in preventing contamination and ensuring the shelf life of the product (jay et al., 2008).

3.1.2 Cap Security Test:

The cap security of the gherkin jar was determined to evaluate the tightness and sealing integrity of the closure (fellows, 2017; Robertson, 2016). The sealed jar was placed in a torque tester, and the force required to open the cap was measured (Nielsen, 2017). The cap was rotated gradually until it loosened, and the torque value was recorded (Aoac, 2016). This value indicates the effectiveness of sealing and helps ensure that the product is protected from leakage and contamination (jay et al., 2008).

3.1.3 Headspace Test:

The headspace of the gherkin sample was determined by measuring the distance between the surface of the product and the inner side of the lid (fellows, 2017; Robertson, 2016). The jar was opened carefully, and a scale or headspace gauge was used to measure the empty space in millimetres (Nielsen, 2017). The measurement was taken without disturbing the product, and the value was recorded as headspace (Aoac, 2016). Proper headspace is essential for maintaining product quality and ensuring effective sealing during storage (potter & Hotchkiss, 2007).

3.1.4 Determination of pH:

Procedure:

The pH of the sample was determined using a pH meter (Nielsen, 2017; Harris, 2015). The instrument was switched on and the electrode was rinsed with distilled water (Skoog et al., 2014). It was then calibrated using standard buffer solutions of pH 7.0 followed by pH 4.0 (AOAC, 2016). After calibration, the electrode was rinsed again and immersed in the sample (Fellows, 2017). The reading was allowed to stabilize, and the pH value was recorded (Harris, 2015).

$$\text{pH} = -\log[\text{H}^+]$$

3.1.5 Determination of Titratable Acidity

Procedure:

The titratable acidity of the sample was determined by titration with standardized sodium hydroxide solution (Nielsen, 2017; Rahman, 2007). A measured volume of the sample was taken in a conical flask, and a few drops of phenolphthalein indicator were added (Skoog et al., 2014). The sample was titrated with sodium hydroxide solution while gently swirling until a faint pink color persisted for about 30 seconds, indicating the endpoint (Harris, 2015). The volume of NaOH used was recorded and used to calculate the titratable acidity of the sample (Fellows, 2017).

$$\text{Titratable acidity (\%)} = \frac{\text{Volume of NaOH} \times \text{Normality of NaOH} \times \text{Eq.wt} \times 100}{\text{Weight of sample} \times 1000}$$

3.1.6 Determination of Salt

Procedure:

The salt content of the sample was determined by the silver nitrate titration method (Mohr method) (Nielsen, 2017; Rahman, 2007). A measured volume of the sample was taken in a conical flask, and potassium chromate indicator was added (Skoog et al., 2014). The sample was then titrated with standard silver nitrate solution until a permanent brick-red color appeared, indicating the endpoint (Harris, 2015). The titre value was recorded and used to calculate the salt content of the sample (Fellows, 2017).

$$\text{Salt (\% NaCl)} = \frac{\text{Volume of silver nitrate} \times \text{Normality of } \text{AgNO}_3 \times 58.5 \times 100}{\text{Weight of sample} \times 1000}$$

3.1.7 Determination of Calcium Chloride

The calcium content of the sample was determined by the EDTA titration method (AOAC, 2016; Nielsen, 2017). A known volume of the sample solution was taken in a conical flask, and an appropriate buffer solution was added to maintain the desired pH (around 10) (Harris, 2015). A suitable indicator such as Eriochrome Black T or murexide was added, which forms a coloured complex with calcium ions (Skoog et al., 2014). The sample was then titrated with standard EDTA solution until the color changed sharply, indicating the endpoint (Fellows, 2017). The volume of EDTA used was recorded and used to calculate the calcium content of the sample.

$$\text{Calcium Chloride (mg)} = \frac{\text{Volume of EDTA} \times \text{Normality of EDTA} \times \text{Atomic weight of calcium} \times 1000}{\text{Weight of sample}}$$

3.1.8 Determination of Total Soluble Solids (TSS)

Procedure:

The total soluble solids (TSS) content of the sample was determined using a refractometer (Nielsen, 2017; Fellows, 2017). The prism of the refractometer was first cleaned with distilled water and wiped dry (Skoog et al., 2014). A few drops of the sample extract were placed on the prism surface, and the cover was closed gently to spread the sample evenly (Rahman, 2007). The reading was then observed through the eyepiece or noted from the digital display (AOAC, 2016). The TSS value was recorded in degrees Brix (°Brix) (Nielsen, 2017).

3.2 NUTRITIONAL ANALYSIS

Determination Of Dietary Fiber

Procedure:

The dietary fiber content of the sample was determined by the enzymatic–gravimetric method (AOAC, 2016; McCleary et al., 2015). A known weight of the dried and ground sample was taken in a digestion flask and treated with heat-stable α -amylase at 95–100°C to digest starch (Nielsen, 2017). After cooling, protease was added and incubated at around 60°C to remove proteins, followed by the addition of amyloglucosidase to hydrolyse any remaining starch (McCleary et al., 2015). Ethanol (95%) was then added to precipitate soluble dietary fiber, including inulin (Stephen et al., 2017). The mixture was filtered through a pre-weighed crucible, and the residue was washed with ethanol and acetone to remove impurities (AOAC, 2016). The residue was dried at 105°C until constant weight, and its mass was recorded (Fellows, 2017). Ash and protein contents were determined separately and subtracted from the residue weight to obtain the corrected dietary fiber content (Nielsen, 2017).

$$\text{Total dietary fiber (\%)} = \frac{w_r - w_p - w_a}{w_s} \times 100$$

3.2.1 Determination of Protein:

The protein content was determined by the Kjeldahl method (AOAC, 2016; Nielsen, 2017). A known weight of the sample was digested with concentrated sulfuric acid and catalyst to convert nitrogen into ammonium sulphate (Fellows, 2017). The digested sample was made alkaline, and the released ammonia was distilled and collected in boric acid solution (Harris, 2015). The ammonia was titrated with standard acid, and the nitrogen obtained was converted into protein using a conversion factor (Skoog et al., 2014).

$$\text{Protein (\%)} = \frac{(V_s - V_b) \times N \times 14.01 \times F}{W_s} \times 100$$

3.2.2 Determination of Ash Content:

Procedure:

The ash content of the sample was determined by the dry Ashing method (AOAC, 2016; Nielsen, 2017). A clean, dry silica crucible was heated in a muffle furnace at 550°C, cooled in a desiccator, and weighed (Fellows, 2017). A known amount of dried sample was placed in the crucible, gently charred, and then incinerated in the furnace at 550°C for 4–6 hours until a light grey or white ash was obtained (Rahman, 2007). The crucible was cooled in a desiccator and weighed, and heating was repeated until a constant weight was achieved (Skoog et al., 2014).

$$\text{Ash (\%)} = \frac{W_a \times W_c}{W_s} \times 100$$

4. RESULTS AND DISCUSSIONS:

This section presents the results obtained from the physicochemical, microbial, and sensory evaluation of the developed inulin-enriched acidified gherkin chips. The findings are discussed with respect to parameters such as pH, titratable acidity, total soluble solids, salt content, texture, and overall sensory acceptability to assess the quality, safety, and effectiveness of inulin incorporation in the product.



Fig-2: Final Product

4.1 PHYSICOCHEMICAL ANALYSIS

The table reflects the physicochemical properties of the developed inulin-enriched acidified gherkin chips prepared from *Cucumis sativus* in comparison with standard specifications. The project sample showed a vacuum level of 110 mmHg, which is slightly below the standard value but indicates acceptable sealing conditions (Fellows, 2017). Cap security and headspace were recorded as 5 inHg and 11 mm respectively, both within the permissible limits, ensuring proper container integrity and vacuum formation (Robertson, 2016). The acidity (0.82%), salt content (1.38%), and calcium chloride content (598 ppm) were found to be within the specified range, contributing to product preservation and flavor (Rahman, 2007; Ranganna, 2010). The total soluble solids (21.1°Brix) also fell within the acceptable limits, indicating a balanced composition (Nielsen, 2017). The pH value of 3.60 confirms the acidic nature of the product, which is essential for microbial safety and shelf stability (Ray & Bhunia, 2014). Overall, the physicochemical parameters of the developed product were within acceptable limits and comparable to standards, indicating good quality, safety, and consumer acceptability of the inulin-enriched acidified gherkin chips.

Table 2: Physicochemical Analysis

Sl. No	Test parameters	Control sample results	Project sample results	Units	Specifications	Test methods
1	Vacuum	100	110	mmHg	Min 130	IS 9795: 1981 (RA 2020) FSSAI Manual
2	Cap security	6	5	inHg	3 to 7 mm	IS 9795: 1981 (RA 2020) FSSAI Manual
3	Head space	10	11	mm	Max 12	IS 13915: 1994 (RA 2019) FSSAI Manual
4.	pH	3.61	3.60	≤	≤4.10	IS 3025 (Part 11): 1983 (RA 2017) FSSAI Manual
5.	Acid	0.80	0.82	%	0.80 +/- 0.2	IS 1155: 1968 (RA 2010) FSSAI Manual
6.	Salt	1.42	1.38	%	1.30 +/- 2	IS 5949: 1970 (RA 2020) FSSAI Manual
7.	Calcium Chloride	577	598	ppm	396 – 756	IS 13815: 1993 and FSSAI Manual
8.	TSS	21.2	21.1	1° brix	20 – 24	IS 13815: 1993 (RA 2019) FSSAI Manual

4.2 NUTRITIONAL ANALYSIS

The table reflects the nutritional properties of the developed inulin-enriched acidified gherkin chips prepared from *Cucumis sativus* in comparison with the control sample. The project sample showed a significant improvement in dietary fiber content, recording 3.8 g/100 g, whereas the control sample had no detectable fiber, confirming the effective incorporation of inulin (Roberfroid, 2007; Gibson et al., 2017). The ash content of the project sample was found to be 2.1 g/100 g compared to 1.8 g/100 g in the

control, indicating a slight increase in mineral content while remaining within acceptable limits (Ranganna, 2010). The protein content was observed to be negligible in both control and project samples, indicating that the product is not a significant source of protein (Nielsen, 2017). Overall, the nutritional analysis demonstrates that the developed product is enriched with dietary fiber without adversely affecting other nutritional parameters. These results indicate that the inulin-enriched gherkin chips can be considered a functional food with added health benefits and good consumer acceptability (Slavin, 2013).

Table 3: Nutritional Analysis

Sl. No	Test Parameters	Control Sample Results	Project Sample Results	Units	Specifications	Test Methods
1	Dietary Fiber	0.0	3.8	g/100 g	As per formulation	IS 12711: 1989 (RA 2018)
2	Ash	1.8	2.1	g/100 g	Max 5%	FSSAI Manual (Food Analysis)
3	Protein	0	0	g/100 g	-	FSSAI Manual / IS 7219

4.3 MICROBIAL ANALYSIS

The microbial analysis of the developed inulin-enriched acidified gherkin chips prepared from *Cucumis sativus* indicates that the product is microbiologically safe and within acceptable limits. The total bacterial count was observed to be 3 CFU/g or ml, which is significantly lower than the specified limit of <250 CFU/g or ml, demonstrating good hygienic practices during processing and preservation (Ray & Bhunia, 2014; Jay et al., 2008). Similarly, the total yeast and mould count was found to be 1 CFU/g or ml, which is well below the permissible limit of <100 CFU/g or ml, indicating effective control of spoilage microorganisms (Fellows, 2017). The low microbial load can be attributed to the combined effect of acidification, proper handling, and preservation techniques (Rahman, 2007). Overall, the results confirm that the developed product is safe for consumption and has good microbiological quality, meeting standard food safety requirements (ICMSF, 2011).

Table 4: Microbial analysis

Sl. No	Microbiological parameters	Results	Specifications
1	Total bacterial count (CFU/g or ml)	3	<250
2	Total Yeast & mould count (CFU/g or ml)	1	<100

4.4 SENSORY ANALYSIS

As per sensory evaluation, Formulation-2 was found to be the most optimized among the three variations, as it achieved the highest overall acceptability score compared to Formulation-1 and Formulation-3 (Lawless & Heymann, 2010). The developed inulin-enriched acidified gherkin chips prepared from *Cucumis sativus* exhibited well-balanced sensory attributes, including appearance, aroma, taste, texture, and mouthfeel (Meilgaard et al., 2016). Formulation-2 showed superior performance particularly in taste and mouthfeel, indicating a desirable combination of acidity, flavor, and crispness (Fellows, 2017). The incorporation of inulin contributed positively to the texture and overall sensory quality without adversely affecting the product characteristics (Roberfroid, 2007). With its balanced sensory profile and higher

acceptability scores, Formulation-2 demonstrates its potential as a preferred and consumer-acceptable product. The results of sensory evaluation are presented in Table 5 Table.

Table 5: Sensory Analysis Result

Sensory Attributes	Formulation-1	Formulation-2	Formulation-3
Appearance	9	9	8
Aroma	9	9	9
Taste	9	9	9
Texture	8	8	8
Mouth Feel	8	9	9
Over Acceptability	8	9	8

5. CONCLUSION

The present study on the development and quality evaluation of inulin-enriched acidified gherkin chips demonstrates that incorporation of inulin as a functional dietary fiber ingredient can be successfully achieved without compromising the physicochemical, microbiological, and sensory attributes of the product. The optimized formulation maintained desirable acidity, pH stability, total soluble solids, and textural integrity, while also enhancing the nutritional profile through increased fiber content. Microbiological analysis confirmed product safety under acidified conditions, indicating effective preservation without reliance on synthetic additives. Sensory evaluation revealed acceptable flavor, texture, and overall palatability, suggesting consumer suitability. Therefore, inulin-enriched acidified gherkin chips can be considered a value-added functional food with extended shelf stability and potential health benefits, particularly in promoting gut health, aligning with current trends in functional and clean-label food product development.

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