Therapeutic Potential of Microgreen-Enriched Probiotic Gummies: Encapsulation, Survivability, and Functional Health Benefits

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Abstract

Microgreens are nutrient-dense functional foods that are collected 7–14 days after germination and are enhanced with health-promoting vitamins, minerals, and phytochemicals. In this work, probiotic-enriched gummies were enhanced with fenugreek (Trigonella foenum-graecum) and mustard (Brassica nigra) microgreens to improve their nutritional and medicinal value. With an encapsulation efficiency of 89.46%, Lactobacillus plantarum was encapsulated using sodium alginate hydrogel to increase vitality and stability during storage. The probiotic microgreen gummies (GC-E) demonstrated notable anti-inflammatory properties (albumin denaturation IC_{50} = 34.62 µg/mL), phenolic content (29.5 mg GAE/g), and antioxidant activity (DPPH IC_{50} = 27.27 µg/mL). After 48 days of storage, the gummies maintained 63.65% viable probiotic cells, indicating good delivery potential and survivability. Probiotics are important for gut microbiota regulation, better digestion, increased immunity, and decreased risks of inflammation and obesity. In the meantime, microgreens provide beta-carotene, vitamin C, flavonoids, and phenolic chemicals, all of which work together to support collagen synthesis, scalp microcirculation, and antioxidant defense systems that are good for strong, healthy hair. Thus, the combination formulation promotes both gut health repair through probiotics and hair vitality through microgreens

that are rich in micronutrients and antioxidants. High acceptability in flavor, texture, and general preference were found by sensory analysis, indicating that the product is a functional food that is easy for consumers to use. In order to bridge the gap between nutrition and wellbeing, this initial report focuses on the successful creation of a unique probiotic micro green gummy as a sustainable dietary supplement for contemporary health concerns.

Keywords: Micro greens, Probiotic gummies, Encapsulation, Functional nutraceutical, Therapeutic potential.

Introduction

Microgreens are usually picked 7–14 days after the cotyledon leaves emerge. Furthermore, microgreens are a viable alternative for urban agriculture and food security programs due to their capacity to be grown in regulated conditions with little resource input. Moreover, rapid and effective production combined with high nutritional content offers a remedy for malnutrition brought on by the fast-paced lifestyles of the contemporary world(Rai et al., 2022).

Microgreenss, which is small, delicate greens, are used to garnish a range of major courses and to add color, texture, and flavor to salads. The production includes typical microgreens including mustard, cabbage, radish, buckwheat, lettuce, and spinach. The use of microgreens has increased recently due to the fact that they contain higher levels of bioactive substances like vitamins, minerals, and antioxidants than mature greens, all of which are good for human health (Antony 2020). The functional quality and health advantages of various microgreens species are influenced by their differing amounts of nutritional and phytochemical characteristics. Members of the Brassicaceae family are among the most promising. Microgreens species are linked to antioxidant and anticancer qualities because of their high glucosinolate and phenolic content (Wojdyło et al., 2020). Probiotics may be essential for changing the gut microbiota's composition and preventing harmful bacteria from colonizing the gut, which helps the host develop a healthy intestinal mucosa, according to recent research [Kumar et al.,2020]. Primarily found in the human gut, probiotics function to maintain the equilibrium of intestinal microorganisms. Probiotics that include active microorganisms, such as Lactobacillus or Bifidobacterium, are frequently used [Kerry et al., 2018]. In the treatment of chronic inflammatory and metabolic illnesses, probiotics work as anti-obesity agents, have anti-cancer characteristics, increase immunity, and have anti-diabetic effects These dietary variables mainly affect host immunity by exerting regulatory effects on the makeup and organization of the gut microbiome.

Materials and methods

Growing of greens

The fenugreek (*Trigonella Foenu-Graecum Linn*) and black mustard (*Brassica nigra*) seeds were purchased from the nearby nursery in Namakkal, Tamil Nadu. The greens were cultivated in plastic trays, with seeds scattered on top and covered until germination occurred. Sometimes trays were irrigated. When the microgreens reached a height of 2.5–7.6 cm (1–3 inches) and had two fully formed cotyledon leaves, they were harvested. When the baby greens reached a height of 10 cm and one or two pairs of actual leaves emerged, they were picked. Mature greens were picked when they reached a height of 5 to 6 inches or when they began to produce mature leaves devoid of cotyledon(Sharma et al., 2020).

Sample preparation

The harvested leaves were dry in the shade for seven days. After being powdered, the leaves were kept in dry, cool places in zip-lock bags. 50g of the dried material was taken and placed in conical flasks to create the extract then added 100 milliliters of aqueous to it. It was stored in a cool, dark place for two days, stirring occasionally. Two days later, the extract was filtered into tubes that had been sterilized. The extract was kept for future research in a refrigerator.

Determination of macronutrients

The Anthrone technique was used to estimate carbohydrates(Thomas et al., 1986). Protein estimation was done using the Biuret method (Layne 1975) The approved AOAC method from 2005 was used to determine crude fiber(Official Methods of Analysis of AOAC International 2012).

Beta carotene Estimation

Each sample weighed five grams, which were then crushed using a pestle and mortar in ten to fifteen milliliters of acetone and a few anhydrous sodium sulfate crystals. Three to four minutes were spent centrifuging the solution at 3000 rpm. After transferring the supernatant to a test tube, 10–15 milliliters of petroleum ether were completely mixed with it and left undisturbed. The upper layer was collected in a test tube from the two separated layers, while the lower layer was thrown away. The optical density at 452 nm was determined using petroleum ether as a blank. (Karnjanawipagul et al., 2010)

Vitamin C Estimation

Ascorbic acid was estimated by Acid base titration method(Nielsen 2010)

Examination of phytochemicals qualitatively

The extracts were subjected to established methodology for analysis in order to reveal several phytonutrients. The following seven chemical classes were examined: phenols, alkaloids, anthroquinones, flavonoids, saponins, triterpenes, and tanins. To identify the phytochemicals, decolorized ethanolic extract was employed(Sagbo et al., 2017)

Culture probiotic preparation

Lactobacillus plantarum lyophilized powder was acquired from reputable commercial providers on Amazon. Powdered probiotic bacteria were activated in MRS broth at 37°C for 24 hours. Gram staining, catalase, and oxidase tests were performed to ensure the purity of each culture.

Preparation of sodium alginate solution

The sodium alginate (ALG) solution was made by adapting the [Gul & Dervisoglu 2017]. Six grams of ALG powder were gently added to 100 mL of boiling distilled water while stirring constantly to achieve complete dissolve. The mixture was agitated until a uniform and clear solution formed. The produced ALG solution was then allowed to cool to room temperature before being used in the experimental procedures.

Preparation of sodium alginate hydrogel capsules loaded with probiotics

ALG capsules containing probiotics were made following the extrusion process described by [Li et al., 2022] with modest modifications. The 0.5 mL Lactobacillus plantarum suspensions were thoroughly mixed with 9 mL sterilized ALG solution. The liquid was then agitated with a magnetic bar at room temperature for 20 minutes at 100 rpm until it formed a homogeneous solution. The ALG-bacteria mixture was added drop wise to 200 mL of 3% w/v $CaCl_2$ using a 6 mL syringe and 22-gauge needle. To harden the ALG hydrogel capsules, leave a 10 cm space between the syringe and the $CaCl_2$ solution for 30 minutes. Separate the capsules with a filter and rinse with SPS solution.

Viable cells count

The spread plate method [Zeashan et al., 2020] was used to count both viable encapsulated and free probiotic cells. To release the encapsulated cells, ALG/Ch capsules (1 g) were dissolved in 9 mL of 1% (w/v) sterile sodium citrate solution and stirred at 100 rpm for 10-15 minutes at ambient temperature. The suspension was serially diluted with 0.2% sterile peptone water. Diluted samples were then applied to MRS agar plates in triplicate. After 24-48 hours of incubation at 37°C, visible colonies were enumerated and represented as log CFU/mL. All measurements were taken in triplicate and the average

values were determined. The method ensured an accurate assessment of probiotic viability following encapsulation.

Encapsulation efficiency % measurement

The encapsulation efficiency percentage (EE%) was estimated using Equation 1 by[De et al., 2020].

EE % = N/ N0×100

N is the Log (CFU/ mL) of viable cells released from the hydrogel beads.

N0 is the initial Log (CFU/ mL) of the viable cells used for encapsulation.

Gummy preparation

All of the components for making Gummy candy were obtained from a local market in Namakkal, Tamil Nadu, India. The production process was changed in accordance with the protocol published by [Kamil et al., 2021]. Gelatin powder was dissolved in water and cooked in a water bath at 70-75°C for 15 minutes until thoroughly melted. Water, lemon juice, and honey, fruit pulp were mixed together to create a smooth and homogenous concoction. The fruit solution was then gradually added to the blooming gelatin, with constant stirring to achieve homogenate. The mixing process was done carefully to avoid lump formation. To prevent the gelatin from hardening prematurely, a consistent temperature was maintained throughout the mixing operation. When the mixture was uniform, it was put into molds and left to solidify. Texture, taste, and microbiological stability were further assessed using this formulation. The goal of the technique was to create a fruit-based, natural gummy that might have health advantages.

Probiotic gummy preparation

Probiotic encapsulated gummy candy and micro greens (GC-E) was made by putting the gummy mixture into silicone molds after it had cooled to 45°C (Kamil et al., 2021). Each mold well holding the semi-liquid mixture was carefully filled with a single probiotic capsule and micro greens. To guarantee adequate gelation, the molds were thereafter placed in a refrigerator and left there for two hours. To prevent breakage, the GC-E gummies were carefully taken out of the molds once they had hardened. To stop them from absorbing wet, they were then put on a piece of plastic wrap. To get the proper texture, the gummies were dried for three days at 4°C in the refrigerator. For targeted administration, our procedure made sure that entire probiotic capsules were included into the gummy matrix.

Determination of Total Phenolic Content (TPC) and Antioxidant Activity %

The normal procedure was slightly altered in order to prepare the extract. (Ben et al., 2020) Five milliliters of 80% methanol were combined with one gram of the probiotic encapsulated gummy candy with micro greens (GC-E) sample, which had been precisely weighed. To stop light-sensitive chemicals

from degrading, the mixture was agitated for two hours at room temperature in the dark while resting on a magnetic stirrer. To get rid of insoluble materials, the solution was filtered through Whatman No. 1 filter paper after the extraction period. After obtaining a clear supernatant, it was subsequently moved into centrifuge tubes. To make sure all of the suspended particles were separated, the filtrate was centrifuged for 10 minutes at 6000 × g. The top transparent layer was carefully removed after centrifugation. The extract was utilized right away for additional biochemical examination. The antioxidant activity (%) was determined using a suitable radical scavenging assay such as DPPH.

Total phenolic contents measurement

The Folin–Ciocalteu reagent, as described by (Ben et al., 2020) was used to quantify the total phenolic content (TPC) of the methanolic crude extracts of gummy candy with micro greens. After adding 1 mL of 7% Na_2CO_3, 300 µL of a crude extract was suspended with 300 µL of 10% Folin-Ciocalteu reagent and vortex for 1-2 minutes. The mixture was then let to stand for 30 minutes at room temperature in the dark to develop its color Whatman filter paper No. 1 was used to filter the mixture. The wavelength at which absorbance was measured was 760 nm. The final outcome was given as mg GAE per g of weight in gummy candy.

Stock gallic acid solution

A 100 mL volumetric flask was filled with distilled water after 0.500 g of gallic acid was dissolved in 10 mL of 80% methanol to create the stock solution, which had a 5 mg/mL concentration(Mahmood et al., 2022).

Colour intensity

A colour analyzer was used to measure the top and bottom GC-E samples' colours; lightness (L*), redness/greenness (+ a* / - a*), and yellowness/blueness (+b* / - b*) values were ascertained(Dag et al., 2017)

The survivability % of probiotics in the GC-E

The percentage of encapsulated probiotic cells that survived 48 days of refrigeration storage for GC with micro greens samples was ascertained (11). Days 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 36, 42, and 48 were used to count the number of surviving encapsulated and free cells. After being suspended in 1% sodium citrate for 15 to 20 minutes, the GC-E sample (about 1 gram, 1 block) was rapidly stirred at 30 °C. Before being plated on MRS plates using the spread plate technique and incubated for 48 hours at 37 °C,

tenfold was serially diluted in 0.2% peptone water. Each gram of bacteria was measured in colony-forming units (CFU/g). Three counts were made of each sample.

Survivability % = (Nt /N_0) x 100 (Ben et al., 2020)

N_0 = The Log (CFU/mL) of the viable cell counts at the zero time

Nt = The Log (CFU/mL) of the viable cells counts at various exposure times (t)

Sensory properties tests

A sensory study of the GC-E with micro greens was performed by ten assessors following a week of refrigeration. Taste, odor, color, mouthfeel, aftertaste, and overall acceptability were among the characteristics of the supplement sample that were assessed on a growing scale from 1 (strongly dislike) to 5 (strongly like).

ANTI OXIDANT ASSAY

DPPH ASSAY

Probiotic dark chocolate's antioxidant activity was evaluated using the DPPH free radical scavenging technique (Amalan *et al.,* 2015). The positive control in this experiment was ascorbic acid. To create concentrations ranging from 20 to 100µg/mL, 2mL of chocolate extract was diluted with DMSO. One milliliter of 0.1 mM DPPH solution was added to each diluted sample. After being well combined, the combinations were allowed to sit at room temperature in the dark. At 517 nm, the absorbance was measured following a 30-minute incubation period. The absorbance readings served as the basis for determining the radical scavenging activity

Where $A_{control}$ - Absorbance of DPPH solution without sample. A_{sample} -Absorbance of DPPH solution with the sample. DPPH scavenging activity was expressed as a percentage of inhibition by using the following formula: % of inhibition = $[(A_{control} - A_{sample})/A_{control}] \times 100$

ABTS SCAVENGING ACTIVITY

The antioxidant activity of probiotic dark chocolate was assessed using the ABTS radical scavenging assay. As the standard control, ascorbic acid was used(Batista *et al.,* 2016). Chocolate extract samples were produced in triplicate at dosages ranging from 20 to 100 µg/ml. Equivalent amounts of ascorbic acid and ABTS solution were combined with each 100 µL sample. For twenty minutes, the combinations were left undisturbed at room temperature. At 734 nm, absorbance was measured with a UV-Vis spectrophotometer. The absorbance measurements were used to calculate the radical scavenging activity.

(The $ABTS^{+}$ scavenging activity was expressed as a percentage of inhibition by using the following formula: %Inhibition= $[(A_{control} - A_{sample})/A_{control}] \times 100$

Lipid Peroxidation ASSAY

(Ohkawa*et al.,* 1979) described the TBA assay for malondialdehyde (MDA) as a method for measuring lipid peroxidation. Mix the sample in cold phosphate-buffered saline (PBS, pH 7.4) or Tris-HCl buffer (10 mM). Centrifuged at 3,000–10,000 rpm for 10 minutes at 4°C, then collected the supernatant. To precipitate proteins, probiotic dark chocolate at various concentrations (e.g., 100-20 µg/ml) was mixed with 1.5 mL of 10% TCA. Centrifuged at 3,000 rpm for 10 minutes, then collect the supernatant. Added 1.5 mL of 0.67% TBA solution to the supernatant. Incubated the mixture in a boiling water bath (90-100°C) for 15 minutes to allow the MDA-TBA complex to develop. Cooled the reaction mixture on ice for 5 minutes. Use a UV-Vis spectrophotometer to measure absorbance at 532 nm. Use a blank solution (TBA without a sample). %Inhibition= $[(A_{control} - A_{sample})/A_{control}] \times 100$

Hydrogen peroxide Radical Scavenging Assay

A common technique was used to evaluate the probiotic dark chocolate's antioxidant capacity (Lalicic*et al.,* 2016). To dissolve hydrogen peroxide, a phosphate buffer with a pH of 7.4 was made. 0.6 milliliters of H_2O_2 solution were combined with samples of chocolate extract (20–100 µg/mL). Each sample was made in triplicate and included 200 µL of the extract. After the mixes were incubated, the absorbance at 230 nm was measured. For baseline correction, a blank containing phosphate buffer (but not H_2O_2) was employed. The reference chemical was ascorbic acid at comparable amounts. Phosphate buffer was used as a blank. $A_{control}$ = Absorbance of H_2O_2 solution without sample. A_{sample}= Absorbance of H_2O_2 solution with sample.

% Scavenging = $[(A_{control} - A_{sample})/A_{control}] \times 100$

ANTI-INFLAMMATORY EFFECT

Bovine Serum Albumin (BSA) Denaturation Assay

Aspirin's anti-inflammatory properties and probiotic dark chocolate's albumin denaturation inhibitory activity were evaluated in order to explore the possible mechanism of action. (Radovanovi *et al.,* 2023).

A non-steroidal anti-inflammatory medication called aspirin was used as the comparison. Sterile tubes were constructed with different doses of probiotic dark chocolate extract (20–100 µg/mL) and 1% aqueous bovine serum albumin (BSA) solution. These mixes were incubated for 20 minutes at 37°C. To cause protein denaturation, the tubes were heated in a water bath at 71°C for 30 minutes following incubation. The samples were cooled, and their absorbance at 660 nm was compared to a blank that

contained only distilled water. Three duplicates of the experiment were run, and the average absorbance was determined.

The percentage of protein denaturation was determined using the following equation:

% Inhibition = (Absorbance of control - Absorbance of sample/Absorbance of control) x 100.

Membrane stability assay

A healthy volunteer's freshly taken blood samples were used to make the red blood cell (RBC) suspension, and conventional protocols were followed to make the erythrocyte suspension. (Giridasappa *et al.,* 2023). Each test solution had a total capacity of 2 mL and included 1 mL of probiotic dark chocolate extract for preventing heat-induced hemolysis and 1 mL of 10% RBC suspension. The chocolate extract was substituted with regular saline in the control sample. The typical medication was aspirin at a 200 µg/mL concentration. After carefully inverting the tubes to combine the contents, they were incubated for 30 minutes at 56°C in a water bath. The reaction mixtures were centrifuged at 2500 rpm and 37 °C following incubation. Under running water, the tubes were cooled. After collecting the supernatant, its absorbance at 560 nm was measured.Phosphate buffer was treated as blank.

The amount of haemoglobin released into the supernatant correlates with the degree of RBC membrane disruption.

$$\text{Inhibition Percentage} = \frac{(\text{Absorbance of control} - \text{Absorbance of sample}) \times 100}{\text{Absorbance of control}}$$

RESULT AND DISCUSSION

Development of micro greens (Fenugreek)



DAY- 1 FENUGREEK



DAY- 2 FENUGREEK



DAY- 3 FENUGREEK



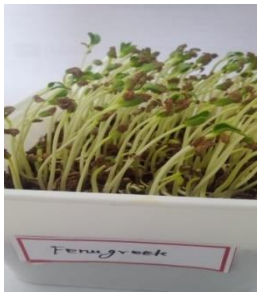
DAY- 4 FENUGREEK



DAY-7 FENUGREEK



DAY- 9 FENUGREEK



DAY- 10 FENUGREEK

Development of micro greens (Mustard)



DAY-1 MUSTARD



DAY-2 MUSTARD



DAY-3 MUSTARD



DAY-4 MUSTARD



DAY-5 MUSTARD



DAY-6 MUSTARD



DAY-7 MUSTARD



DAY-8 MUSTARD

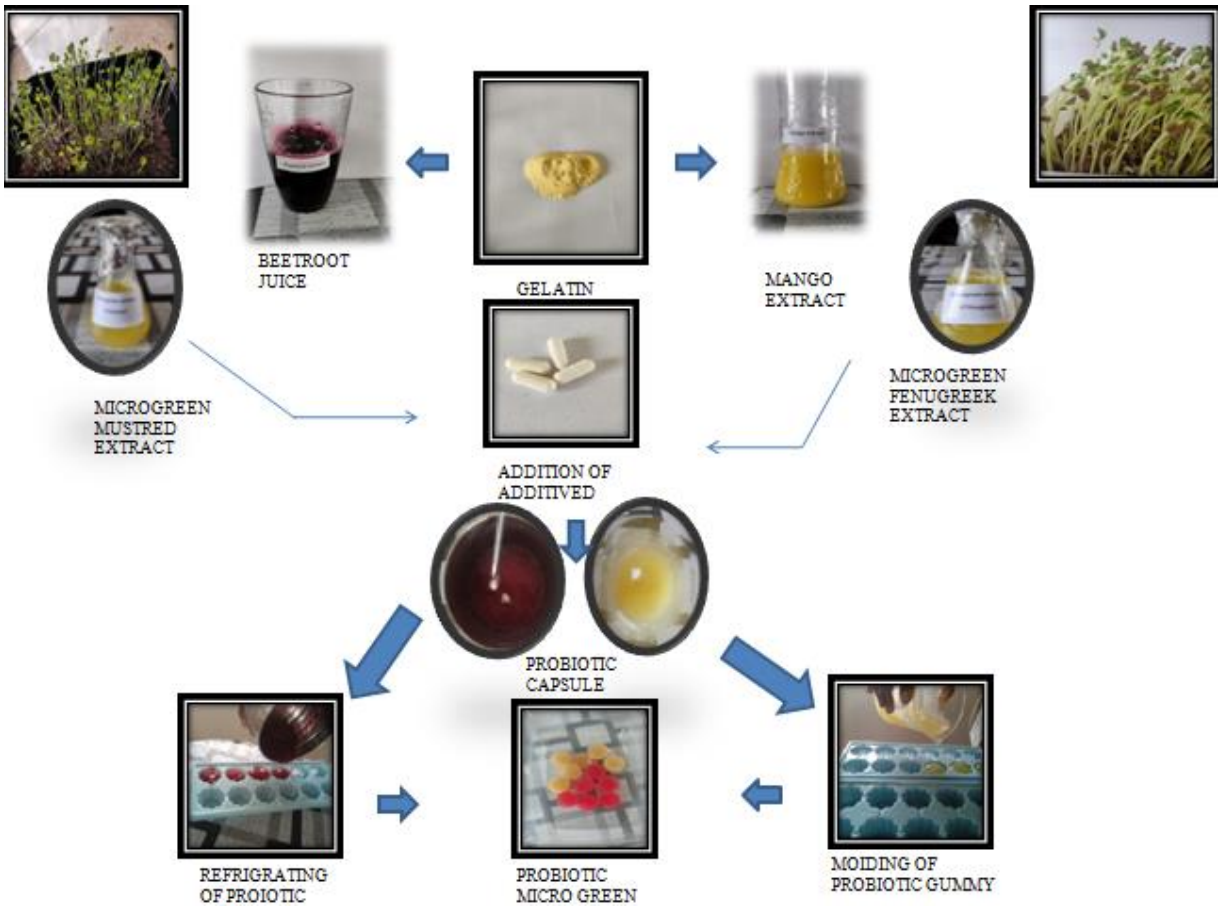


DAY- 10 MUSTARD





Development and Characterization of Probiotic Micro Greens From Fenugreek And Mustard seeds





Macronutrient estimation

Body growth, maintenance, and tissue repair all depend on macronutrients. The amounts of crude fiber, protein, and carbohydrates in microgreens, baby greens, and mature greens were measured. It has been observed that as plants mature, their macronutrient content rises (Kumar 2017)

Vitamin C and Beta carotene Estimation

Vitamins are chemical compounds that the body need in trace amounts for proper growth and operation. Vitamin C, also referred to as ascorbic acid, is essential for the growth, development, and repair of all body tissues. It contributes to several body functions, including wound healing, iron absorption, collagen synthesis, and a healthy immune system. Vitamin A is a fat-soluble vitamin that is naturally present in a wide variety of foods (Grosso et al., 2013). Our heart, lungs, and other organs work regularly with the aid of vitamin A. Beta carotene, a precursor to vitamin A, is converted by the human body into vitamin A. Both of the greens were predicted to contain beta-carotene and vitamin C (Arlappa 2011). The concentration of beta carotene and vitamin C was significantly higher in microgreens than in baby and mature greens, according to the results. When compared to mature greens, microgreens provide nearly twice as much beta carotene and vitamin C. Additionally, research findings indicated that the microgreens of celery and four Apiaceae species had higher levels of beta carotene and vitamin C than adult green (Singh et al., 2022)

	Mustard greens			Fenugreek greens		
Parameters(mg/100g)	Micro green	Baby green	Mature green	Micro green	Baby green	Mature green
Beta- carotene	4.5± 0.2	3.1 ± 0.4	2.2 ± 0.6	7.8 ±0.3	5.6 ± 0.5	3.4 ± 0.1
Ascorbic Acid(Vitamin C)	52.4± 3.5	34.6± 2.1	21.7± 2.4	65.2 ± 4.0	48.0 ± 3.3	29.3 ± 2.6

Phytochemicals

Plants contain compounds called phytonutrients, also known as phytochemicals, which are beneficial to health and can be utilized to treat and even prevent a number of illnesses. Phytochemicals have immense antioxidant potential and are of tremendous interest because of their beneficial effects on human health and substantial health benefits for consumers. Regular consumption of whole grains, fruits, and vegetables may reduce the risk of certain oxidative stress-related diseases, as shown by animal studies and epidemiological research(Cies et al., 2006).

S. No	Phytochemical Analysis for Mustard	Aqueous	Ethanol	Chloroform
1	Alkaloid	++	++	ND
2	Flavonoid	+	+++	ND
3	Triterpenoid	+	++	ND
4	Carbohydrates	++	++	+
5	Saponin	+++	++	++
6	Steroids	++	++	++
7	Amino acid	+	+++	ND
8	Tannin	+	+	+
9	Gums &Mucilage	ND	ND	ND
10	Phenolic compound	+++	+++	+

The existence of a variety of bioactive chemicals, with changes according on the solvent used, was discovered by phytochemical screening of mustard seed extracts. The hydrophilic nature of phenolic compounds (+++) and saponins was demonstrated by the high concentration of these compounds in ethanol and aqueous extracts. With the highest levels of flavonoids (+++) and amino acids (+++), ethanol extract was shown to have superior extraction efficiency for polar and moderately polar components. While the chloroform extract displayed a limited amount of phytochemicals, primarily carbohydrates, saponins, steroids, tannins, and phenolics, the aqueous and ethanol extracts exhibited considerable amounts of alkaloids, triterpenoids, carbohydrates, and tannins. Gums and mucilage are not present in

any of the extracts, indicating that mustard seeds contain very little of them. Mustard is recognized to have antioxidant properties, which are consistent with its high phenolic and flavonoid content.

S. No	**Phytochemical analysis** Fenugreek	**Aqueous**	**Ethanol**	**Chloroform**
1	Alkaloid	+++	+	ND
2	Flavonoid	+++	+++	ND
3	Triterpenoid	++	++	ND
4	Carbohydrates	+++	+++	ND
5	Saponin	+++	+	+
6	Steroids	ND	++	ND
7	Amino acid	+++	++	ND
8	Tannin	++	++	ND
9	Gums &Mucilage	ND	ND	ND
10	Phenolic compound	+++	++	ND

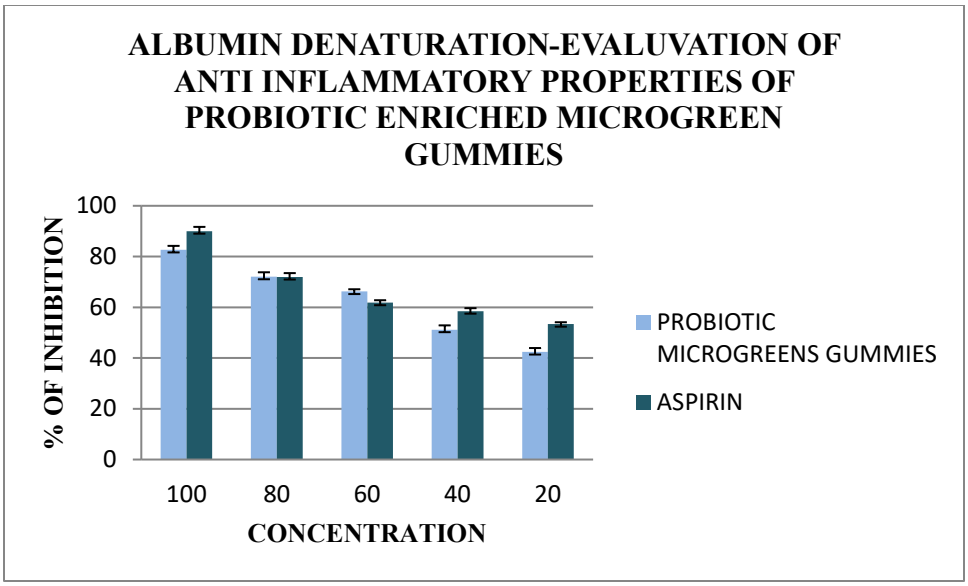
Extracts from fenugreek seeds that underwent phytochemical screening revealed a rich profile of bioactive components, especially in the aqueous extracts. The high concentrations (+++) of alkaloids, flavonoids, carbohydrates, saponins, amino acids, and phenolic compounds in the aqueous extract demonstrated its potent affinity for polar phytochemicals. The presence of notable flavonoids (+++), carbohydrates (+++), amino acids (++), and moderate levels of triterpenoids and tannins in the ethanol extract further demonstrated its effectiveness in extracting moderately polar chemicals. The chloroform extract only showed saponins (+), indicating that fenugreek contains few non-polar components. The fact that steroids were exclusively found in ethanol extract emphasizes solvent-specific extraction. Gums and mucilage are not present in any of the extracts, which suggests that seeds contain very little of them. The powerful phenolic and flavonoid concentration bolsters fenugreek's well-established antioxidant and medicinal properties.

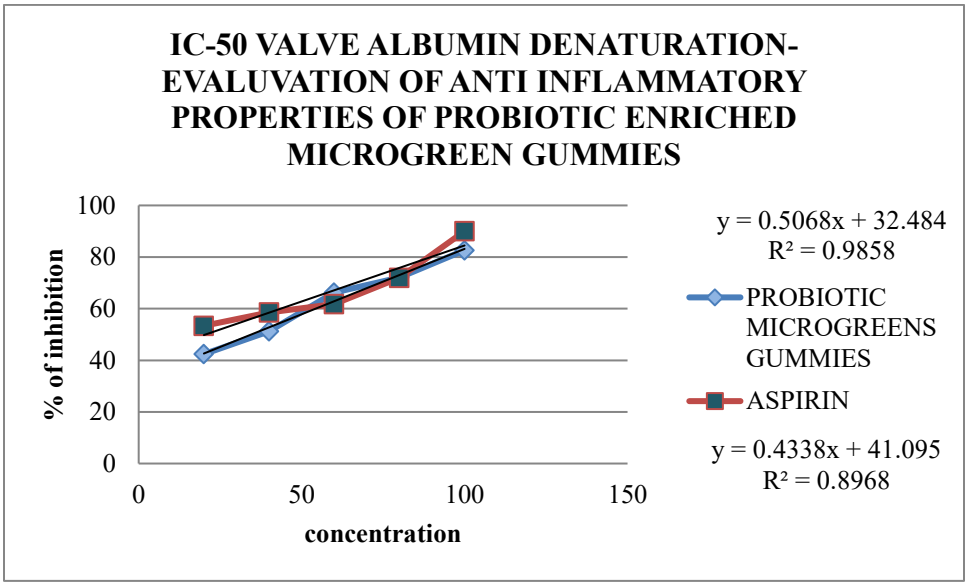
ANTI- INFLAMATION

ALBUMIN DENATURATION

S.NO	NAME OF DRUG	TEST CONC (µg/ml)	ALBUMIN DENATURATION	IC50 values
1	PROBIOTIC ENRICHED MICROGREEN GUMMIES	100	82.63± 1.58	34.62(µg/ml)
		80	72.05 ± 1.75	
		60	66.21 ± 0.9	
		40	51.19 ± 1.68	
		20	42.38 ± 1.56	
2	ASPIRIN	100	90.02± 1.67	20.57(µg/ml)
		80	71.94 ± 1.54	
		60	61.82 ± 0.97	
		40	58.49± 1.16	
		20	53.36 ± 0.74	

Probiotic Enriched Microgreen Gummies showed strong anti-inflammatory action in the albumin denaturation assay, with an IC_{50} of 34.62 µg/ml and a maximal inhibition of 82.63 ± 1.58% at 100 µg/ml. With a lower IC_{50} (20.57 µg/ml) and a somewhat higher inhibition (90.02 ± 1.67%), aspirin, the conventional medication, demonstrated stronger potency. A distinct dose-dependent impact was evident in both samples, with inhibition gradually declining at lower concentrations. Despite being greater than aspirin, the gummies' IC_{50} value indicates a remarkable ability to stabilize proteins, which may be caused by bacterial metabolites and bioactive phytochemicals. The formulation successfully inhibits heat-induced protein denaturation, a crucial mechanism in the regulation of inflammation, according to the data. Its potential as a natural functional food with anti-inflammatory properties is highlighted by its similar activity to aspirin.

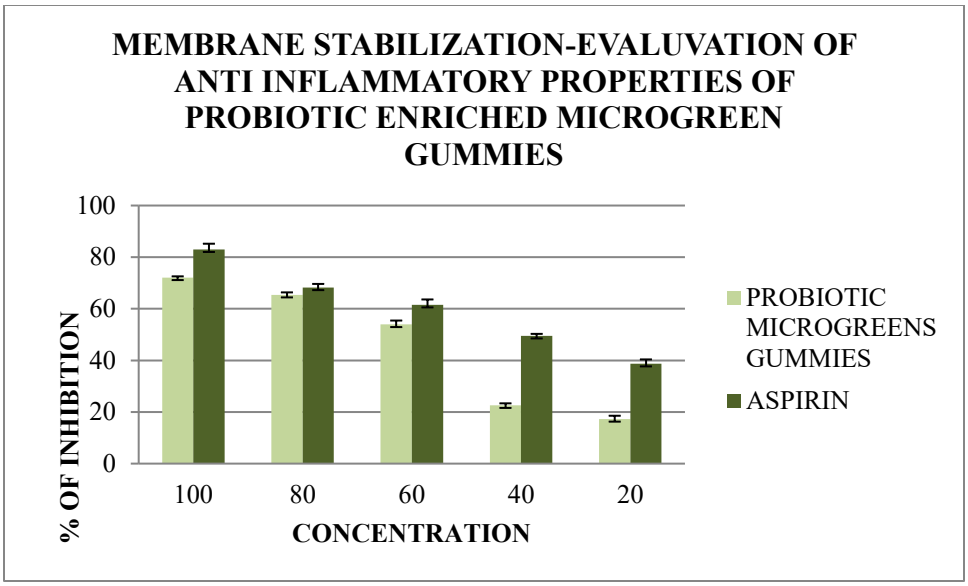


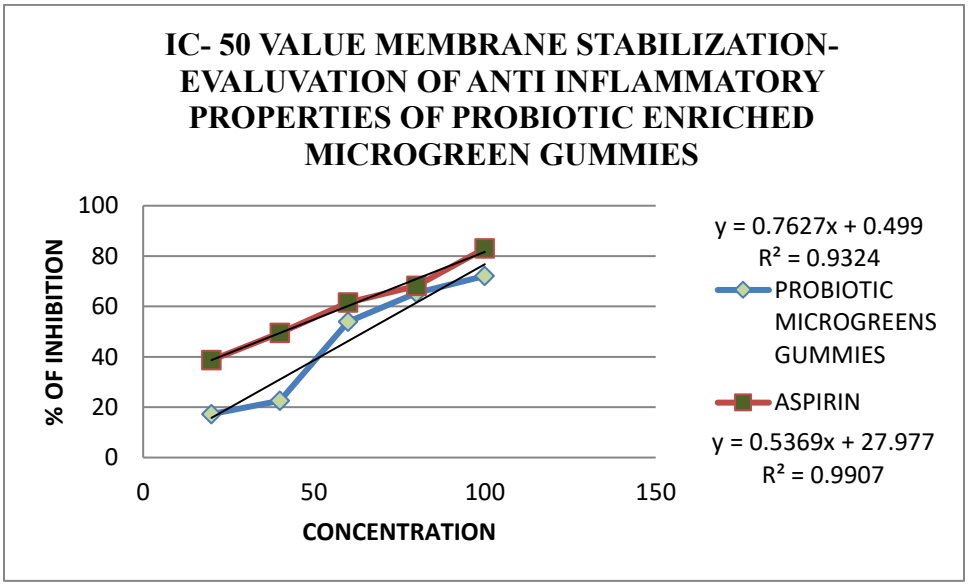


SL NO.	NAME OF DRUG	TEST CONC (µg/ml)	MEMBRANE STABILIZATION	IC50 values
1	PROBIOTIC ENRICHED MICROGREEN GUMMIES	100	72.12 ± 0.44	49.34(µg/ml)
		80	65.41± 0.94	
		60	53.91 ± 1.53	

		40	22.58 ± 0.78	
		20	17.27±1.28	
2	**ASPIRIN**	100	83.0 ±2.20	**41.10(µg/ml)**
		80	68 .23 ±1.39	
		60	61.53 ± 2.08	
		40	49.50 ± 0.77	
		20	38.68 ± 1.69	

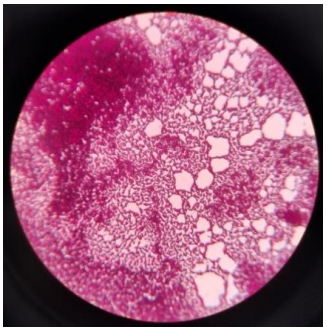
Probiotic Enriched Microgreen Gummies had dose-dependent anti-inflammatory efficacy, as demonstrated by the membrane stabilization assay, with an IC_{50} value of 49.34 µg/ml and a maximal inhibition of 72.12 ± 0.44% at 100 µg/ml. The typical medication, aspirin, had stronger potency with a lower IC_{50} (41.10 µg/ml) and a higher maximal inhibition (83.0 ± 2.20%). Nonetheless, the gummies showed a significant capacity for membrane stability, indicating a noteworthy level of anti-inflammatory effectiveness. Both samples showed a progressive decrease in activity at lower concentrations (20–60 µg/ml), indicating a concentration-dependent impact. The probiotic microgreen formulation's promising bioactive qualities are highlighted by the IC_{50} value being near that of aspirin. Probiotic metabolites and antioxidant phytochemicals that shield erythrocyte membranes from heat-induced lysis may be responsible for the activity.

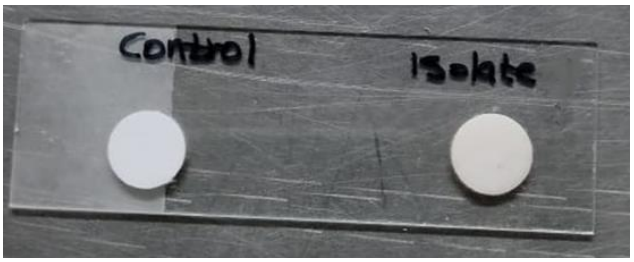




Morphology of Lactobacillus plantarum

A Gram-positive bacterium, Lactobacillus plantarum appears under a microscope as short to long rod-shaped cells Because of its thick peptidoglycan cell wall, it is able to hold onto the safranin stain. The cells are usually seen in short chains or alone. Since the catalase test is negative, it is not equipped to degrade hydrogen peroxide. Cytochrome c oxidase was not present, as evidenced by the negative results of the oxidase test(Mansouri et al., 2022).





THE CAPSULES' MORPHOLOGY, SIZES, AND ENCAPSULATION EFFICIENCY

The capsules that were produced using the sodium–alginate encapsulation method were all round and had a whitish-yellow hue. This appearance is explained by the sodium and alginate biopolymers' intrinsic pigmentation, which is inherent in the coating composition [Afzaal et al., 2022]. Proper blending and encapsulation of the probiotic or active ingredient is shown by the homogeneous shape and constant color. A crucial encapsulation parameter, capsule size affects consumer acceptability, protection effectiveness, and release kinetics. This investigation revealed that the sodium–alginate capsules' average diameter was 3.43 ± 0.10 mm, indicating consistency and accuracy in the encapsulating process. For both functional performance and industrial production, the tiny standard deviation suggests that there is little variation in capsule sizes.

Formulation	Initial loading of the cells Log (CFU/mL) before encapsulation	Final loading of cells Log (CFU/ mL) after encapsulation	Capsules' size average (mm)	*EE %
Encapsulated organism	11.02 ± 0.62	9.87 ± 0.34	3.43 ± 0.10	89.46%
A Means having the same letters in the row are not significantly different (p > 0.05) *EE% = Encapsulation efficiency %.				

Physicochemical characteristics of GC-E

The pH of the GC-E samples was 39± 0.6. The pH of the finished product dropped when lime juice was introduced to GC-E samples. These findings concurred with those of (Niam et al., 2022], who discovered that gummy candy had a pH between 3.9 ± 0.6. pH is commonly measured in confectionery factories to regulate the level of hydration and is also essential in inhibiting the growth of microbes [Tarahi et al.,

2023]. The overall sugar content as well as trace amounts of soluble proteins, amino acids, and other organic components are included in TSS [Bexiga et al., 2017]. Compared to commercial gummy candies (74–80 Brix), the GC-E samples had a total soluble solid (TSS) content that was 41 ± 1.2 ˚Brix lower [ge et al., 2020]. It is important to note that sucrose and glucose syrup are the primary sweeteners found in gummy candy products, as the composition of these sugars and their quantities may influence the TSS % [hartel et al., 2018]. Titratable acidity percentage (TA%) represents the overall amount of acid. It is more accurate than other techniques, like pH, at indicating how acid concentrations affect flavor [sadler & Murphy 2010]. (Chalak et al., 2014) showed that the titratable acidity ranged from 0.08% to 0.43%, whereas the GC-E titratable acidity was 1.10 ± 0.03 (% as citric acid). The findings of Abu et al.,) were in agreement with ours. According to the study, after four weeks of cold storage(e at 8 ± 2 °C, the titratable acidity (% citric acid) of red peel candy was 1.084%.

Physicochemical composition of GC-E	
pH	3.9 ± 0.6
TA%	1.10 ± 0.03
TSS%	41 ± 1.2
Protein%	4.5 ± 0.3
Moisture%	22.1 ± 0.8
TPC	29.5 ±0.01

The water content of gummy candies affects their texture, stability, shelf life, and microbiological development [Efe., 2018]. The GC-E sample had a high moisture level in comparison to commercial items, with a moisture content of 22.1 ± 0.8. Gummy candy usually has a moisture level of 8% to 22% or less, according to (Ergun et al., 2010). Gummy candies often have a longer shelf life because they get firmer when the moisture content drops. However, the ultimate moisture content of gummy candies can have a substantial impact on their quality, texture, and shelf life [Ge et al., 2021].Commercial gummy candies use corn syrup or glucose as a sweetener, whereas GC-E uses honey. This is why GC-E has a higher moisture content than commercial gummies. When the amount of dextrose equivalent (DE) increases, corn syrup can absorb moisture[Tas et al., 2022]. Gelatin, agar, and pectin are the primary constituents of gummies. The partial hydrolysis of collagen yields gelatin, a high molecular weight, water-soluble polypeptide [Liu et al., 2015].Gelatin also has special qualities that make it a thickening agent, gelling agent, and water-holding agent in food products [Burey et al., 2009]. The GC-E protein percentage was 4.5 ± 0.3%. The low protein content was caused by the GC-E formula's use of a small

quantity of gelatin; other low protein ingredients include mango pulp, lime juice, and thyme honey [Vincente et al., 2014]. The protein content of 100 g of orange and honey gummy jellies and berries mix gummy jellies was 4.04 g and 3.25 g, respectively, according to a study by Teixeira-Lemos et al., [Teixeira et al., 2021].

Total phenolic content

Phenolic compounds have a wide range of biological activities, such as hepato-protective, anti-inflammatory, antibacterial, vasodilator, anticarcinogenic, antiviral, antithrombotic, and antiallergic properties [Haggag et al., 2011]. TPC content was 29.5± 0.01mg GAE/g[Ruenroengklin et al., 2008]

Anti-oxidant

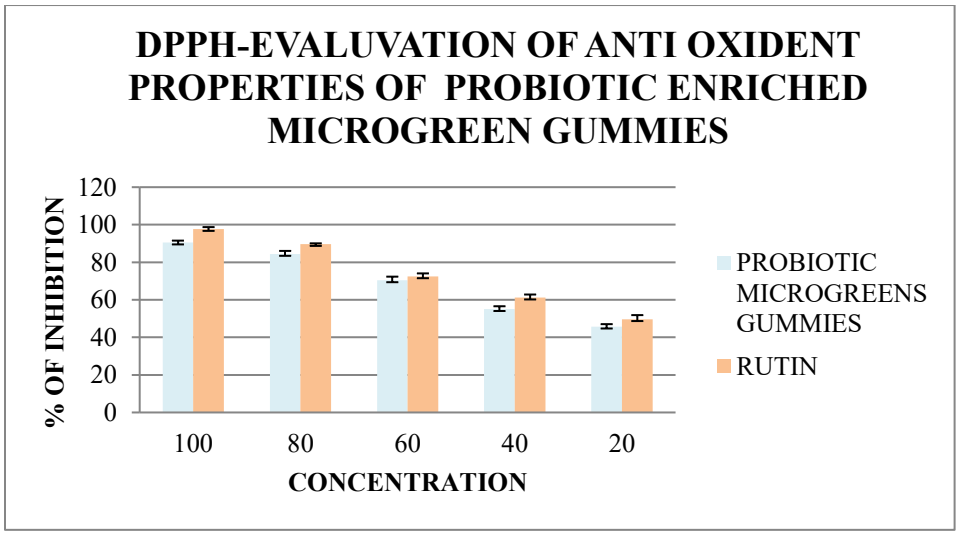
Lime juice may have contributed to the high antioxidant activity value in the GC-E recipe. Flavonoids, phenolic chemicals, ascorbic acid, and other antioxidant components found in citrus fruit are important in lowering the risk of cancer [Ashari et al., 2020]. The high percentage of antioxidant activity was observed in contrast to the low concentration of total phenolic content. Antioxidant activity does not necessarily decrease with a drop in TPC since phenolic compound degradation products can occasionally exhibit stronger antioxidant activity than the initial products [Murakami et al., 2004, Buchner et al., 2015]. The peel contains comparatively more flavonoids and total polyphenols [Madalageri et al., 2015] found that fruit pulp had lower levels of antioxidant activity. Furthermore, thyme honey has a high percentage of antioxidant activity (64.96%) and is an excellent source of phenolic compounds [Gyergyak et al., 2016]. Citric acid also has antioxidant properties; it is primarily found in Persian lime juice [Ali et al., 2022].

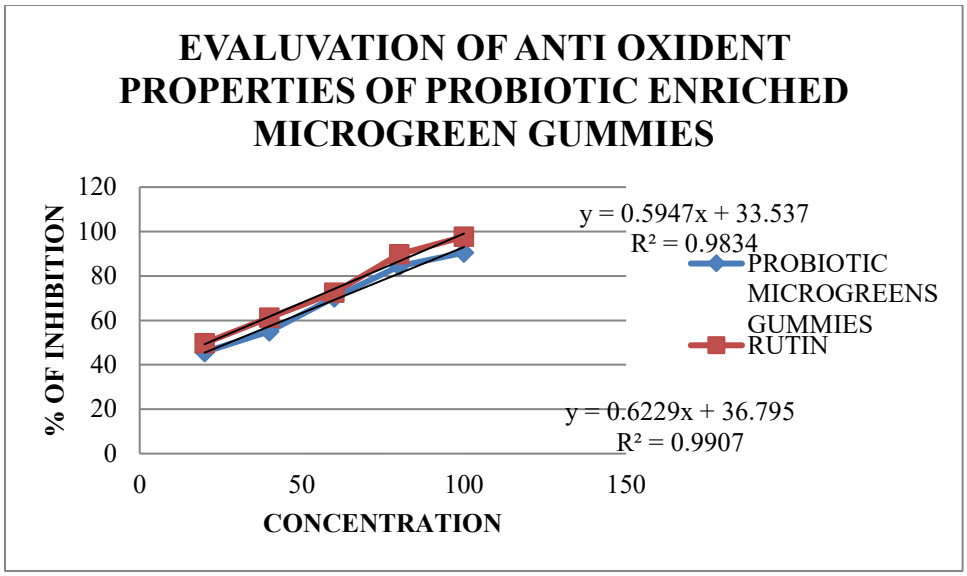
1) DPPH

GROUP	**CONCENTRATION (µg/ml)**	**% OF INHIBITION**	**IC_{50} VALUE**
PROBIOTIC ENRICHED MICROGREEN GUMMIES	100	90.51±1.02	27.27µg/ml
	80	84.44 ±1.60	
	60	70.38±1.96	

	40	55.05±1.52	
	20	45.73±1.31	
RUTIN	100	97.72±1.01	21.23µg/ml
	80	89.71±1.37	
	60	72.51±1.56	
	40	61.20±1.63	
	20	49.69±2.17	

The DPPH radical scavenging experiment was used to assess the antioxidant activity of probiotic-enriched microgreen gummies and compare them to rutin, a common antioxidant. With an IC_{50} value of 27.27 µg/ml and the greatest activity (90.51 ± 1.02%) at 100 µg/ml, the gummies showed a concentration-dependent increase in inhibition. With a lower IC_{50} value of 21.23 µg/ml and a 97.72 ± 1.01% inhibition at 100 µg/ml, rutin demonstrated greater activity and demonstrated a higher radical scavenging efficiency. The gummies' IC_{50} value was fairly close, indicating their significant antioxidant capability, even though rutin performed better. The microgreens' strong phenolic and flavonoid content most likely aided in this activity.



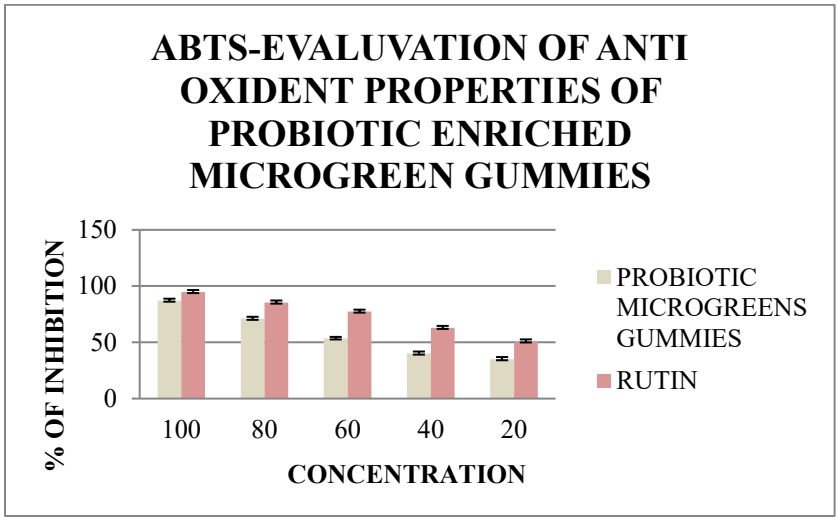


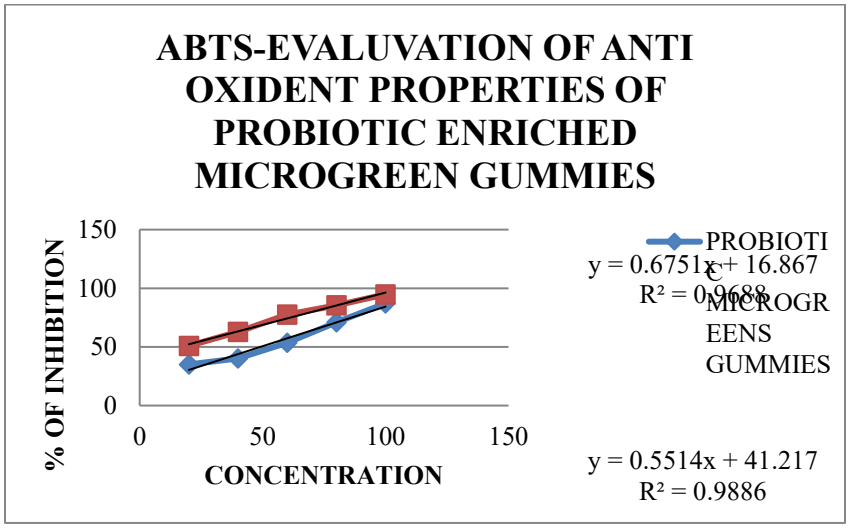
ABTS

GROUP	CONCENTRATION (µg/ml)	% OF INHIBITION	IC_{50} VALUE
PROBIOTIC ENRICHED MICROGREEN GUMMIES	100	87.13±1.66	49.09µg/ml
	80	70.99±1.72	
	60	53.57±1.28	
	40	40.08±1.76	
	20	35.08±1.85	
RUTIN	100	94.80±1.71	15.95µg/ml
	80	85.42±1.79	
	60	77.42±1.62	

	40	62.95±1.67	
	20	50.90±1.73	

Probiotic-enriched microgreen gummies' ability to scavenge ABTS radicals was evaluated and contrasted with that of regular rutin. With an IC_{50} value of 49.09 µg/ml and the maximum activity (87.13 ± 1.66%) at 100 µg/ml, the gummies demonstrated a concentration-dependent increase in inhibition. On the other hand, rutin demonstrated greater antioxidant efficacy with a significantly lower IC_{50} value of 15.95 µg/ml and higher activity (94.80 ± 1.71% at 100 µg/ml). The gummies' IC_{50} value indicates significant free radical scavenging capacity even though they showed less potency than rutin. The phenolic and flavonoid chemicals that are still present in the probiotic microgreens may be the cause of the activity. Probiotics may have synergistic benefits that further increase antioxidant capability.

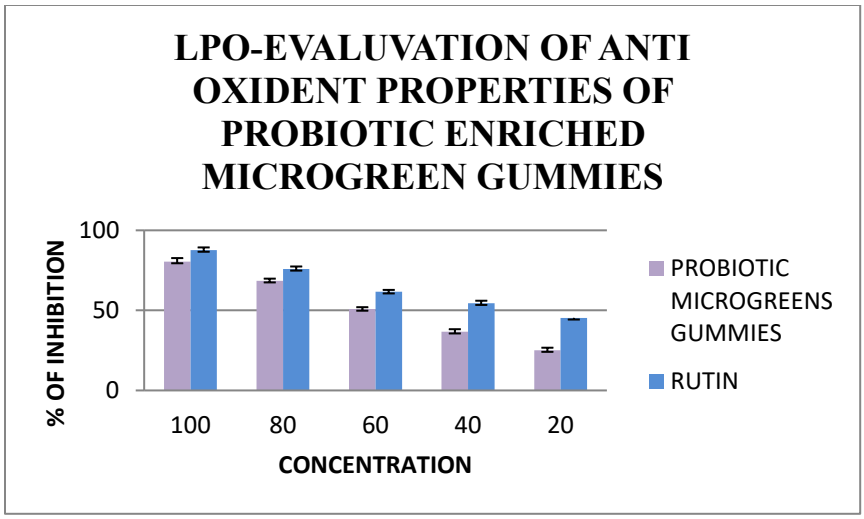


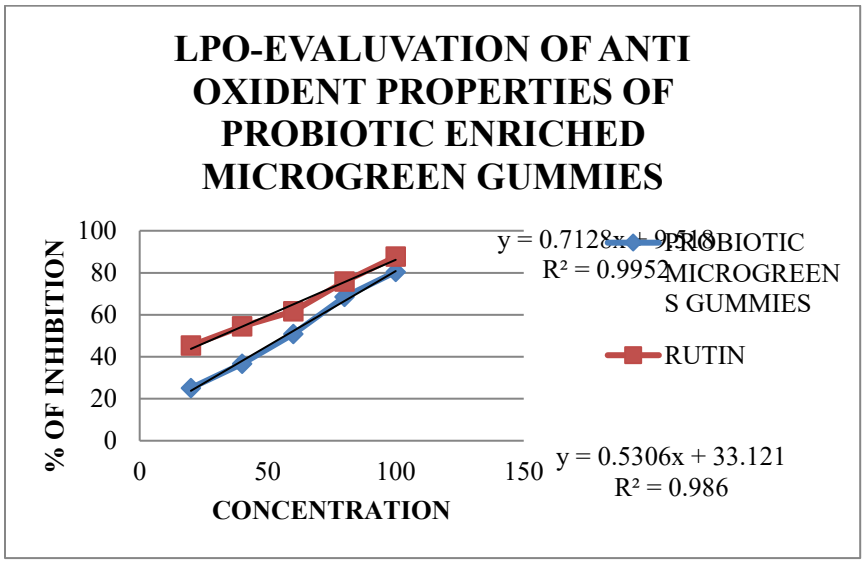


LPO

GROUP	CONCENTRATION (µg/ml)	% OF INHIBITION	IC_{50} VALUE
PROBIOTIC ENRICHED MICROGREEN GUMMIES	100	80.44.±1.82	56.85µg/ml
	80	68.48±2.22	
	60	50.81±1.35	
	40	36.60±1.19	
	20	25.10±1.64	
RUTIN	100	87.63±1.08	31.84µg/ml
	80	75.85 ±1.69	
	60	61.59±1.57	
	40	54.4±1.21	
	20	45.30±1.63	

Probiotic-enriched micro greens gummies' ability to reduce lipid peroxidation (LPO) was assessed and contrasted with rutin as a reference. With an IC_{50} value of 56.85 µg/ml, the gummies showed a concentration-dependent rise in inhibition, reaching 80.44 ± 1.82% at 100 µg/ml. Rutin showed stronger reduction of lipid peroxidation with a lower IC_{50} value of 31.84 µg/ml and a higher inhibition (87.63 ± 1.08% at 100 µg/ml). The gummies showed significant LPO inhibition despite being less effective than rutin, indicating the existence of bioactive phytochemicals that can shield lipids from oxidative degradation. The antioxidant-rich phenolic and flavonoid content of microgreens may be the cause of the activity. Using probiotics may also help because they produce metabolic byproducts that have antioxidative qualities.



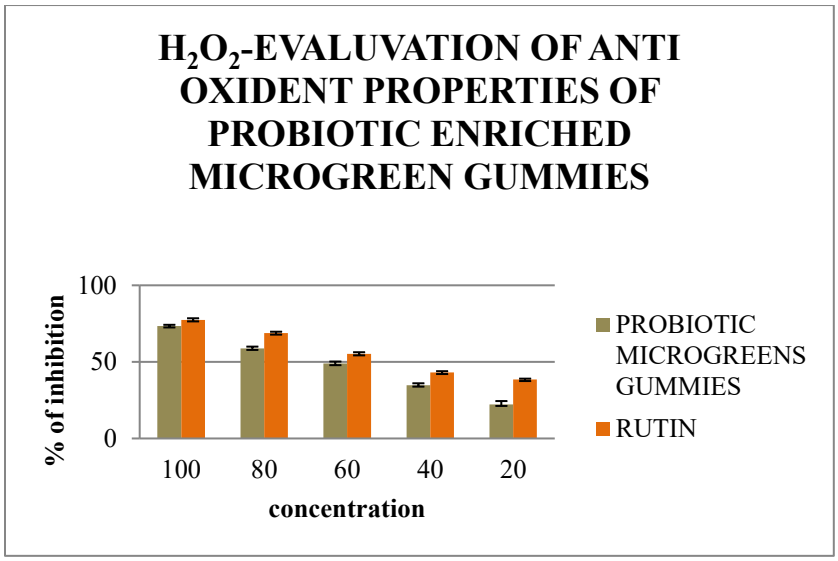


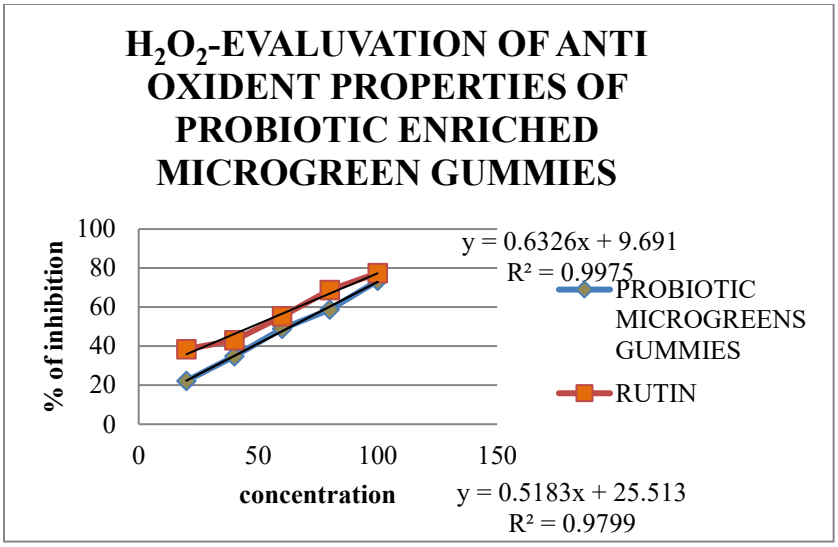
H_2O_2

GROUP	CONCENTRATION (µg/ml)	% OF INHIBITION	IC_{50} VALUE
PROBIOTIC ENRICHED MICROGREEN GUMMIES	100	73.49±0.72	63.78µg/ml
	80	58.81±1.15	
	60	48.86±1.35	

	40	34.84±1.18	
	20	22.22±2.21	
RUTIN	100	77.44±1.03	47.27µg/ml
	80	68.80±0.89	
	60	55.25±1.05	
	40	43.07±0.86	
	20	38.48±0.57	

Probiotic-enriched microgreen gummies' ability to scavenge hydrogen peroxide ($H2O_2$) was contrasted with that of rutin, a common antioxidant. With an IC_{50} value of 63.78 µg/ml and an inhibition of 73.49 ± 0.72% at 100 µg/ml, the gummies demonstrated a concentration-dependent rise in inhibition. Better H_2O_2 neutralizing effectiveness was shown by rutin's slightly higher activity (77.44 ± 1.03% at 100 µg/ml) and lower IC_{50} value of 47.27 µg/ml. The presence of phenolic and flavonoid chemicals in the microgreens probably contributed to the gummies' significant scavenging capability, even if rutin performed better. By generating antioxidant metabolites during fermentation, probiotics may intensify this impact even further. Since this reactive oxygen species can pierce cell membranes and result in oxidative damage, effective H_2O_2 scavenging is crucial.





Probiotic survivability % in GC-E

The encapsulated cells dropped from 8.50 ± 0.04Log CFU/g (100%) to 5.41 ± 0.02 (63.65%) during 48 days of refrigeration storage. The number of encapsulated cells varied significantly over the course of the storage period ($p < 0.05$). In GC-E, encapsulated probiotic organisms demonstrated significantly greater survival, demonstrating how well encapsulation preserves viability. The presence of oxygen in the GC-E product and the low pH of lime juice may be the cause of the decline in cell survival. By acting as a barrier, encapsulation protected the probiotic cells from acidic stress and mild heat [Talebzadeh et al., 2014]. Fruit juices with a pH between 2.5 and 3.7 raise the susceptibility of bacteria to environmental stress, according to[Sheehan et al., 2007].

Survival of encapsulated cells in the GC-E during refrigeration storage (~ 4 °C) for 48 days		
Days	The number of encapsulated cells Log (CFU/g)	Survivability %
0	8.50 ± 0.04	100
3	8.36 ± 0.06	98.35
6	8.4 ± 0.01	96.94
9	8.12 ± 0.07	95.52
12	7.95 ± 0.03	93.50
15	7.81± 0.05	91.88

18	7.60± 0.04	89.41
21	7.40 ± 0.06	87.05
24	7.12 ± 0.01	83.76
27	6.94± 0.7	81.65
30	6.78 ± 0.06	79.76
36	6.32 ± 0.08	74.35
42	5.91 ± 0.03	69.53
48	5.41 ± 0.02	63.65

Texture parameters

Comparing the texture of GC-E to the control (commercial gelatin-based candy), the results of the compression test revealed that cohesion and resilience (elasticity) were unaffected ($p > 0.05$). In contrast, the following characteristics show significant variations ($p < 0.05$) fracturability, gumminess, chewiness, gumminess, hardness, and adhesiveness (stickiness). Based on our findings, the hardness of the GC-E texture was decreased by every ingredient that was employed, including thyme honey, mango pulp, lime juice, and probiotics[Lele et al., 2018]. Because honey is used in place of sugar, the hardness value of GC –E is lower than that of control gummy candy. Recent research has shown that the gelled structure becomes firmer and harder when sweeteners (xylitol) are added at relatively modest concentrations (3% to 5%) [Cai et al., 2017]. Commercial gummy candy requires more energy to deform, which is a feature that consumers, particularly adults, do not like. Consequently, lowering the hardness increased the product's acceptability.The GC-E samples generated were homogeneous, as evidenced by the low variability between the two sides. According to (Teixeira-Lemos et al., 2021] the two sides of the fruit-and-honey gummy jellies were exceptionally consistent. The difference in the two products constituents may be the reason why the GC-E is less resilient than the control sample [Guiné et al., 2020]. Accordingly, honey will affect the rheological characteristics and product structure in gelatin systems [Nguyen et al., 2019, Belay et al., 2017, Kulmyrzaev & McClements., 2000]. The effort needed to resist the attraction forces between the food's surface and the surface of the material it comes into contact with, like the tongue, teeth, or palate, is sometimes referred to as adhesiveness or stickiness [Mutlu et al., 2018]. These values depend on the characteristics of the surface as well as the interaction of cohesive and adhesive forces [Hamedi et al., 2018]. The commercial gummies' higher hardness and gumminess values were caused by the use of glucose syrup and sucrose [Tireki et al., 2021], but the GC-E usage of honey resulted in lower chewiness, gumminess, and hardness values. The samples were

made with fruits and honey, the gumminess of the samples decreased when compared to the control, indicating that less energy was needed to break GC-E. Our findings align with those of (Moghaddas et al., 2020], who found that the introduction of gellan gum and red beet extract decreased the gumminess of the samples.

Texture profile analysis (TPA) on both sides of the control and GC-E product.				
Texture parameters	GC-E		Control	
	Top	Down	Top	Down
Hardness N	4.31 ± 0.19	4.42 ± 0.75	10.21 ± 0.32	10.21 ± 0.98
Adhesiveness mJ	0	0	0.15± 0.5	0.12± 1.52
Resilience	0.45 ± 0.5	0.41 ± 0.9	0.50 ± 0.2	0.52 ± 0.06
Fracturability N	4.32 ± 0.23	4.68 ± 0.13	12.09 ± 1.56	12.27 ± 1.3
Cohesiveness	0.97 ± 0.2	0.83 ± 0.5	0.93 ± 0.6	0.89 ± 0.7
Springiness mm	3.15 ± 0.5	3.61 ± 0.4	3.52 ± 0.15	3.59 ± 0.27
Gumminess N	4.51 ± 0.26	4.35± 0.15	11.69 ± 0.81	11.54 ± 1.6

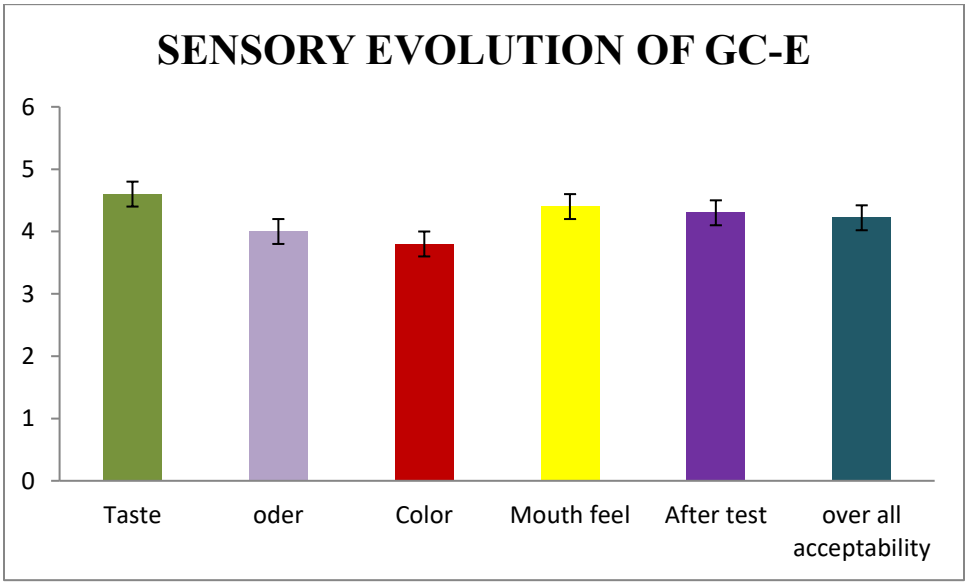
Color intensity

Display the color coordinates of the GC-E on the top and bottom sides that were studied; the outcomes on both sides were quite comparable. The GC-E samples had positive values for the color coordinates a*(15.24-15.09). On both sides of the sample, the color coordinates b* displayed positive values (21.90-22.16). L* had positive values (25.03–26.51). The color evaluation's overall findings supported the notion that the GC-E was transparent, more yellow, and redder than usual. Due to the modest heat utilized during GC-E manufacture, no non-enzymatic browning reactions were also noticed. It has been noted that the GC-E on both sides is consistent. Good homogeneity between the two sides of the product has also been observed in prior results for gummy jellies created with a mixture of berries and oranges with honey [Teixeira et al., 2021]. Furthermore, ripe mango fruit contains carotenoid pigments, which have other positive health effects and offer an alternative to artificial coloring [Rumainum et al., 2018].

Sensory evaluation

Taste, odor, color, mouth feel, aftertaste, and overall acceptability are the basic values for sensory evaluation of GC-E. The panelists selected taste, texture, and overall acceptability since they received the highest ratings. Respondents were aware of the advantages of probiotics derived from fermented dairy, and assessing the GC-E required consideration of nutritional value. The GC-E product caters to all customer types and offers a perfect dessert for kids and adults who enjoy nutritious sweets. Because natural ingredients were used instead of artificial food additives, color and odor scores were the lowest when compared to other parameter scores [Dey & Nagababu 2022].

Sensory evolution of GC-E product.	
Parameters	**Scores average**
Taste	4.6 ± 0.85
Odor	4.0 ± 0.62
Color	3.8 ± 0.54
Mouth feel	4.4 ± 0.39
After taste	4.3 ± 0.24
Overall acceptability	4.22 ±0.53



CONCLUSION

Probiotic-enriched microgreen gummies are a promising natural supplement with two uses, as this study shows. In addition to promoting better digestion, immunology, and gut microbiome balance, the encapsulated Lactobacillus plantarum successfully withstood storage conditions. Essential phytochemicals, vitamins, and antioxidants from fenugreek and mustard microgreens improved the gummies' anti-inflammatory and antioxidant properties while also supporting follicular strength, collagen production, and scalp health, all of which led to the creation of new hair. This novel functional food exemplifies a synergistic approach to nutrition, in which nutrient-dense microgreens support outward wellbeing like hair vibrancy and probiotics restore digestive health. The results pave the way for future nutraceutical applications aimed at holistic health by positioning probiotic microgreen gummies as a unique, sustainable, and consumer-acceptable functional food.

Reference

1. Gul O, Dervisoglu M. Application of multicriteria decision technique to determine optimum sodium alginate concentration for microencapsulation of Lactobacillus casei Shirota by extrusion and emulsification. Journal of Food Process Engineering. 2017;40(3):e12481. Available from: https://doi.org/10.1111/jfpe.12481

2. Dag D, Kilercioglu M, Oztop MH. Physical and chemical characteristics of encapsulated goldenberry (Physalis peruviana L.) juice powder. LWT-Food Sci Technol. 2017; 83:86-94. Available from: http://dx.doi.org/10.1016/j.lwt.2017.05.007

3. Talebzadeh S, Sharifan A. Developing probiotic jelly desserts with Lactobacillus acidophilus. J Food Process Preserv. 2017;41(1). Available from: https://doi.org/10.1111/jfpp.13026

4.Niam MLQ, Amin RS, Utami N, Wahyuni AS. Formulation of dietary supplement chewable gummy with bastard cedar leaves (Guazuma ulmifolia), senna leaves (Cassia angustifolia) and lime extracts using a simplex lattice design. In: Proceedings of the International Conference on Sustainable Innovation on Health Sciences and Nursing ICOSI-HSN. 2022; 122-135. Available from: https://doi.org/10.2991/978-94-6463-070-1_17

5. Tarahi M, Mohamadzade Fakhr-davood M, Ghaedrahmati S, Roshanak S, Shahidi F. Physicochemical and sensory properties of vegan gummy candies enriched with high-fiber jaban watermelon exocarp powder. Foods. 2023;12(7):1478. Available from: https://doi.org/10.3390/foods12071478

6.Bexiga F, Rodrigues D, Guerra R, Brázio A, Balegas T, Cavaco AM, et al.,. A TSS classification study of 'Rocha' pear (Pyrus communis L.) based on non-invasive visible/near infra-red reflectance spectra. Postharvest Biol Technol. 2017;132:23-30. Available from: http://dx.doi.org/10.1016/j.postharvbio.2017.05.014

7.Ge H, Wu Y, Woshnak LL, Mitmesser SH. Effects of hydrocolloids, acids and nutrients on gelatin network in gummies. Food Hydrocoll. 2021;113:106549. Available from: http://dx.doi.org/10.1016/j.foodhyd.2020.106549

8.Hartel RW, von Elbe JH, Hofberger R. Jellies, gummies, and licorices. In: Hartel RW, von Elbe JH, Hofber R, editors. Confectionery Science and Technology. Cham, Switzerland: Springer International Publishing AG; 2018. Available from: https://link.springer.com/book/10.1007/978-3-319-61742-8

9. Sadler GD, Murphy PA. pH and titratable acidity. In: Food Analysis. Boston: Springer; 2010. p. 219-238. Available from: https://link.springer.com/book/10.1007/978-1-4419-1478-1#page=219

10. Chalak L, Younes J, Rouphael S, Hamadeh B. Morphological characterization of prickly pears (Opuntia ficus indica (L.) Mill.) cultivated in Lebanon. Int J Sci Res. 2014;3(6):2319-7064. Available from: https://www.ijsr.net/archive/v3i6/MjQwNjE0MDU=.pdf

11. Abu-shama HS, Ahmed FA, Abd El-magied HED. Assessment of jelly candy manufactured from prickly pear fruits (Opuntia spp.). World J Adv Res Rev. 2022;16(1):767-783.

12. Li W, Chen W, Wang Z, Chen W, Zhang M, Zhong Q, et al.,. Preparation and characterization of beads of sodium alginate/carboxymethyl chitosan/cellulose nanofiber containing porous starch embedded with gallic acid: an in vitro simulation delivery study. Foods. 2022;11(10):1394. Available from: https://doi.org/10.3390/foods11101394

13. Efe N. Characterization and formulation of gelatin-based soft candies. MSc thesis, Middle East Technical University; 2018. p. 125. Available from: https://hdl.handle.net/11511/27416

14.Ergun R, Lietha R, Hartel RW. Moisture and shelf life in sugar confections. Crit Rev Food Sci Nutr. 2010;50(2):162-192. Available from: https://doi.org/10.1080/10408390802248833

15.Tas O, Ertugrul U, Grunin L, Oztop MH. Investigation of the hydration behavior of different sugars by time domain-NMR. Foods. 2022;11(8):1148. Available from: https://doi.org/10.3390/foods11081148

16.Liu D, Nikoo M, Boran G, Zhou P, Regenstein JM. Collagen and gelatin. Annu Rev Food Sci Technol. 2015;6:527-557. Available from: https://doi.org/10.1146/annurev-food-031414-111800

17.Burey P, Bhandari BR, Rutgers RPG, Halley PJ, Torley PJ. Confectionery gels: A review on formulation, rheological and structural aspects. Int J Food Prop. 2009;12(1):176-210. Available from: https://doi.org/10.1080/10942910802223404

18.Vincente AR, Manganaris GA, Ortiz CM, Sozzi GO, Crisosto CH. Nutritional quality of fruits and vegetables. In: Florkowski J, Shewfelt RL, Stanly E, editors. Postharvest Handling. Academic Press; 2014;69-169.

19.Teixeira-Lemos E, Almeida AR, Vouga B, Morais C, Correia I, Pereira P, et al.,. Development and characterization of healthy gummy jellies containing natural fruits. Open Agric. 2021;6(1):466-478. Available from: http://dx.doi.org/10.1515/opag-2021-0029

20. Haggag EG, Kamal AM, Abdelhady MI, El-Sayed MM, El-Wakil EA, Abd-El-hamed SS. Antioxidant and cytotoxic activity of polyphenolic compounds isolated from the leaves of Leucenia leucocephala. Pharm Biol. 2011;49(11):1103-1113. Available from: https://doi.org/10.3109/13880209.2011.568623

28. Ruenroengklin N, Zhong J, Duan X, Yang B, Li J, Jiang Y. Effects of various temperatures and pH values on the extraction yield of phenolics from litchi fruit pericarp tissue and the antioxidant activity of the extracted anthocyanins. Int J Mol Sci. 2008;9(7):1333-1341. Available from: https://doi.org/10.3390%2Fijms9071333.