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Formulation and Evaluation of Curcumin Incorporated Jamun Fruit based Gummies

Vijaya Vahini R[1], Ajmul Reema N[2], Jayashree R[3] and Pon Kirthika K[4]

[1-4] P. G. Department of Home Science – Food Science, Nutrition and Dietetics, Shrimathi Devkunvar Nanalal Bhatt Vaishnav College for Women, Chromepet, Chennai - 600 044 Chennai, Tamil Nadu, India

Abstract

Gummies, renowned for their chewy texture and vibrant colors, have long been a beloved treat enjoyed by both children and adults. Historically categorized as sources of empty calories, these confections have undergone a transformation in response to evolving consumer preferences towards healthier options. Traditionally crafted from gelatin and flavored with fruit extracts, gummies are now being reimagined with a focus on plant-based ingredients, natural flavors, and functional additives. This shift reflects a growing awareness of the importance of nutrition, particularly in children's diets. New formulations, such as fruit-based alternatives, offer sensory-friendly options with enhanced nutritional profiles, catering to health-conscious consumers. Current investigation aims to explore the transition of gummy candies (GCs) from conventional sugary treats to functional food by addition of nutraceuticals. The study encompasses one such innovation which involves the incorporation of curcumin extracted from turmeric into jamun fruit-based gummy formulations. Curcumin, the primary bioactive compound in turmeric is extracted employing Soxhlet extraction. The extraction yield was found to be 82.39%, presents a myriad of health benefits, ranging from anti-inflammatory to antioxidant effect. With its antioxidant, antimicrobial, and antidiabetic properties, Jamun fruit contributes to the development of functional gummy candies aimed at supporting health and wellness. Furthermore, the inclusion of palm sugar, a minimally processed sweetener rich in nutrients and antioxidants, adds depth to the nutritional profile of the newly formulated curcumin-incorporated gummies. The findings of this study shows that the formulated curcumin incorporated jamun based gummies has favorable physicochemical properties and nutritional parameters, including TCL confirmation of curcumin (0.56±0.08), energy content (298.42±1 kcal), protein (3.86±0.01 g), fat (1.62±0.01 g), calcium (15.9±0.1%), carbohydrates (67.16±0.20g), moisture (56.02±0.02%), ash (4.42±0.02%) and notably high levels of total flavonoid content (5921.13±0.21 mg/ml). In conclusion, the formulation of the curcumin incorporated jamun based gummies from traditional confections to functional nutraceuticals reflects a broader trend towards healthier indulgences. By leveraging innovative ingredients and formulations, gummies are poised to not only delight the taste buds but also contribute to overall health and well-being.

***Key words*:** Gummy candies, Turmeric, Curcumin, Jamun Fruit, Fruit based Gummies

The turmeric (*Curcuma longa* L) belongs to Zingiberaceae family and it is a perennial plant with pulpy, tuberous roots with orange flesh. The leading cultivators of turmeric are India, Indonesia, China, Philippines, Taiwan, and Jamaica [33]. India is the world's largest producer of turmeric accounting for nearly 90% of the total production of turmeric [26]. Turmeric, a versatile spice employed in culinary practices, food preservation, and as a natural dye, has entrenched itself in traditional medicine for its therapeutic properties and demonstrates a wide array of biological effects. Curcumin is a liposoluble yellow compound that can be isolated from turmeric rhizome and can be easily dissolved in organic solvents. Curcuminoids refer to a group of phenolics present in curcumin and they are responsible for yellow colour [22]. Four decades of scientific research has proved the pharmacological and therapeutic properties of curcumin [24].

The rhizomes of *Curcuma longa* L., commonly referred to as Turmeric or Haldi, hold significant esteem in traditional medicine due to their therapeutic attributes. These rhizomes not only impart a distinct flavor but also contribute to preserving freshness when incorporated into various culinary preparations. Throughout medicinal practices such as Ayurveda, Siddha, and Unani, formulations containing *C. longa* rhizomes are widespread. Particularly in Ayurveda, turmeric is administered internally as a stomachic, tonic, and blood purifier, while externally it is employed for the prevention and treatment of skin ailments. Variations in phytoconstituent content within herbal extracts present a significant challenge for ensuring the quality of herbal products. To assess the safety and efficacy of plant materials, qualitative and quantitative analyses are vital techniques, often focusing on the presence and quantity of specific marker compounds within the plant [22].

***Correspondence to:** Ajmul Reema N, E-mail: ajmulreema24@gmail.com

While various methods such as maceration, digestion, microwave, and infusion have historically been employed to extract natural-colored compounds from turmeric rhizomes, this study sought to isolate and characterize curcumin from rhizomes sourced from Chennai utilizing the Soxhlet extraction technique with ethanol as the solvent. Curcumin, the active component in turmeric, has gained attention for its potent health benefits. Also, the curcumin acts as the antioxidant, protecting the body against oxidative stress and inflammation, which are implicated in various chronic diseases [21].

Syzygium cumini, commonly known as Jamun or black plum, stands out as a rich source of bioactive compounds like flavonoids, polyphenols, antioxidants, iron, and vitamin C. This tropical evergreen plant, belonging to the Myrtaceae family, holds significant medicinal value and has been a staple in Indian and traditional medicines worldwide for generations. Cultivated mainly in Asian countries, Jamun has been historically used to address various ailments and health conditions. Today, it is prominently recognized for its therapeutic potential in managing metabolic issues like diabetes, hyperlipidemia, hypertension, and obesity. The plethora of clinical evidence underscores Jamun's antioxidative, antidiabetic, anti-inflammatory, anticarcinogenic, and hyperlipidemic effects [3].

Additionally, the utilization of indigenous and native fruit such as Jamun, renowned for its diverse pharmacological properties and natural sweeteners such as palm sugar signify a broader trend towards incorporating traditionally available and minimally processed ingredients in confectionery production. To capitalize on the health benefits of curcumin and jamun fruit, researcher have developed a novel formulation of jamun fruit-based gummies by incorporating curcumin extract to enrich the product with phytochemical and antioxidant content. This innovative approach not only enhances the nutritional value of gummies but also offers consumers a convenient way to obtain beneficial compounds. The study introduces a comprehensive exploration into the evolution and diversification of confectionery, with a particular focus on gummy candies and their adaptations to meet changing consumer demands and health trends. It delves into the historical roots of gummies, their composition, and their rise in popularity, with contemporary concerns regarding their nutritional content and health implications, especially among children [1]. It highlights the emergence of functional foods, including confectionery, as a prominent category in response to consumer preferences for healthier options [19].

MATERIALS AND METHODS

Procurement of ingredients

In the first phase, the ingredients needed for the formulation of curcumin incorporated jamun fruit-based gummies such as Jamun, Turmeric (Suroma Variety), Gelatin, Pectin and Palm sugar were procured from the local supermarket (Chennai). In particular Suroma variety of turmeric was selected by the researcher due to the high content of curcumin present. The project has been approved by the Institutional Human Ethical Committee (IHEC) of Shrimathi Devkunvar Nanalal Bhatt Vaishnav College for Women on 20/11/2023. The Protocol No – SDNBVC/ IHEC/2023/07.

Extraction of curcumin

Soxhlet extraction, pioneered by German chemist Soxhlet, continues to be a prevalent method for extracting bioactive compounds from botanical sources. Various studies, including those by [8] have leveraged this technique to isolate curcumin from plants. In a comparative investigation conducted by [31], Soxhlet extraction demonstrated superior curcumin yield in comparison to Ultrasonic-Assisted Extraction (UAE) and maceration extraction methods. However, the traditional Soxhlet extraction process typically entails prolonged durations and higher temperatures than UAE, prompting advancements in extraction methodologies. Considering the technical advantages, Soxhlet method was employed to extract curcumin from turmeric. The extraction process of curcumin is depicted in the (Fig 1).

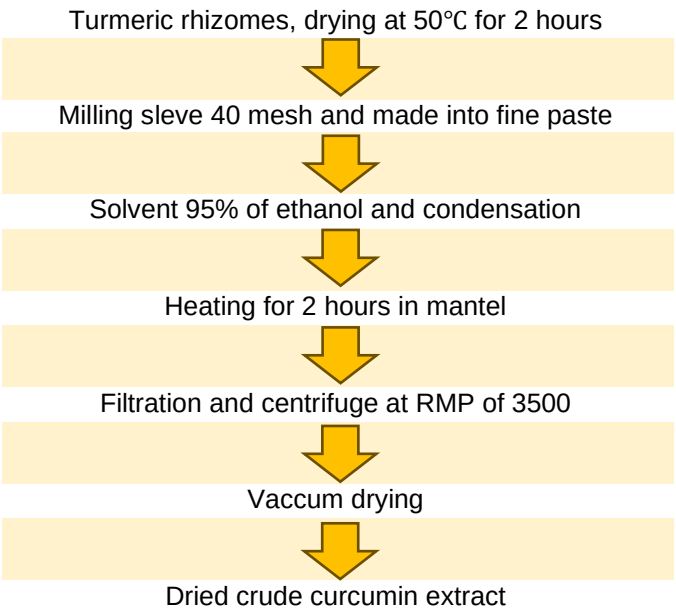


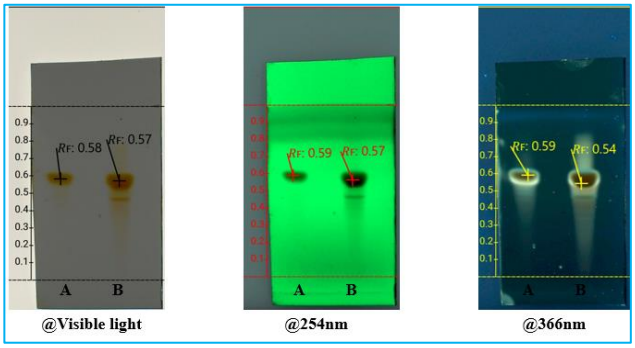
Fig 1 Extraction of curcumin, Source [12]

Crude turmeric Before extraction After extraction

Confirmation of the extracted curcumin

Curcumin, the principal active constituent responsible for the therapeutic efficacy of *C. longa*, serves as a notable marker compound. In recent years, advancements in chromatographic and spectral fingerprinting techniques have played a crucial role in the quality control of herbal medicines. Chromatographic fingerprint analysis has emerged as a practical and reliable method for assessing the quality and authenticity of various herbal medicines (14). The presence of curcumin in sample was detected by thin layer chromatography. Curcumin standard (1mg/ml) and crude ethanol turmeric extract (1mg/ml) dissolved in ethanol were applied on 10×10 mm silica plates with a 5µl sample syringe using a Linomat V automated spray-on system. Samples of 5µl were applied as 5 mm bands with a 10 mm distance between the centres of bands. Plate with Samples and Standard (curcumin) were developed for 20 min in a presaturated vertical glass chamber with using–Toluene: Ethyl acetate: Formic acid: methanol (5.5:3:1:0.5 v/v/v) as a mobile phase. The mobile phase's migration distance was calculated. After development, the plates were dried and visualized in TLC Visualizer under white light illumination, long wavelength UV light at 366nm and in short wavelength UV light at 254nm. The Retention factor was calculated using the below formula:

$$\text{Retention factor} = \frac{\text{Distance moved by the sample}}{\text{Distance moved by the solvent}}$$



Thin Layer Chromatography (Confirmation of Curcumin)

Formulation of the curcumin incorporated novel jamun based gummies

After several works of literature review, Formulation of curcumin incorporated Jamun fruit-based Gummies was done by the method suggested [35] with slight modification. The curcumin incorporated jamun based gummies was prepared. The (Fig 2) indicates the steps involved in the gummies production.

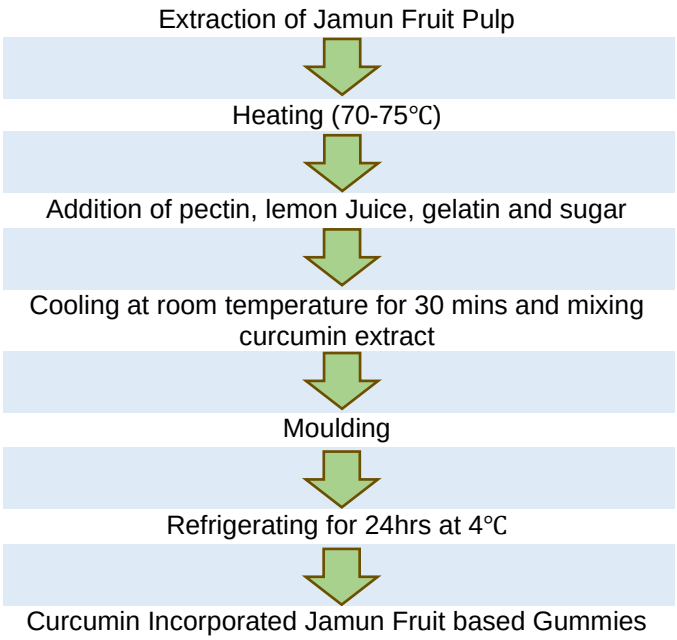


Fig 2 Formulation of gummies, Source: [35]

Physiochemical properties of the extracted curcumin and gummies

The physiochemical properties such as confirmation of the extracted curcumin, viscosity, total titratable acidity, pH and colour analysis and pH, colour and texture of the gummies were evaluated. The physiochemical properties of the extracted curcumin were analyzed following standardized procedures [38]. Thin layer chromatography (TLC) was conducted in accordance with the AOAC official methods of analysis (2016) standard methods. To determine viscosity, the line spread test (LST) was employed, where the spread distance of the sample was measured using a cylindrical tube placed on a plastic board marked with concentric circles. The tube was allowed to stabilize, and then the sample was allowed to expand outward for 60 seconds, with the expanded distance being calculated as the average of readings for the four quadrants of the spread. Total titratable acidity (TTA) was determined using the potentiometric titration method as suggested by [36], wherein one gram of curcumin was diluted in 25 ml of distilled water, followed by the addition of phenolphthalein and titration with 0.1N sodium hydroxide (NaOH) until reaching pH 8.1. The titratable acidity was expressed as g citric acid/curcumin. The pH of the extracted curcumin sample and gummies was measured using a digital pH meter (ELICO LTD Li - 120). Additionally, the color of the extracted curcumin and the formulated Gummies was determined using the CIE color scales L*, a*, and b* with a Hunter Lab digital colorimeter [11]. Texture analysis of the gummies was performed using a TA-XT2 Texture Analyzer and Texture Expert Software v. 1.11.

Nutritional property analysis of the curcumin incorporated jamun based gummies

The formulated curcumin incorporated jamun based gummies was evaluated for the nutritional properties such as energy, protein, fat, ash, moisture, carbohydrates, fiber, iron, calcium and vitamin-C content and the method followed for the same is exhibited in (Table 1).

Table 1 Proximate analysis

Parameters	Methods
Energy (By Calculation)	IS 12711:1989 RA 2015
Protein (Nx6.25)	
Total Fat	
Total Ash	
Moisture	
Carbohydrates	IS 1656:2007 (RA2012)
Dietary Fibre	IS 12711:1989
Iron as Fe	ISO/IEC 17025:2017
Calcium	Complex metric titration
Vitamin - C	AOAC method, 2012

Functional property analysis of the curcumin incorporated jamun based gummies

The functional property such as qualitative phytochemical analysis (Flavonoids, Alkaloids, Saponins, Tannins, Phenols, Terpenoids, Steroids, and Glycosides), Total Flavonoids content, Total Phenolic content and Antioxidant activity of the formulated gummies was assessed. The method followed for the analysis is exhibited in (Table 2).

Table 2 Functional analysis

Functional parameters	Methods
Phytochemical analysis	As per methods by Shaikh [30]
Total phenol content	Folic- Ciocalteu Assay
Total flavonoid content	Colorimetric Assay
Antioxidant properties	DPPH radical scavenging activity

Statistical analysis

The collected data were coded, categorized, and analyzed utilizing SPSS software (version 20.0 for Windows, Chicago, IL, USA). All experiments were conducted in triplicate and presented as mean ± SD. Analysis of Variance (ANOVA) was employed to validate the study data.

RESULTS AND DISCUSSION

Physio-chemical analysis of the extracted curcumin

The (Table 3) presents the physio-chemical properties of the extracted curcumin sample such as thin layer chromatography (TLC) confirmation of curcumin, viscosity, total titratable acidity, pH, and color parameters (L*, a*, b*). These analyses provide insights into the composition and characteristics of the extracted curcumin, essential for understanding its potential applications and suitability for various purposes.

Table 3 Physio-chemical properties of extracted curcumi

Analysis	Extracted curcumin sample
Thin layer chromatography (TLC)	0.56 ± 0.08
Viscosity	2.9 ± 0.15
Total titratable acidity (%)	3.84 ± 0.02
pH	7.9 ± 0.15
Color	
L*	47.63 ± 0.04
a*	28.31 ± 0.02
b*	41.6 ± 0.01

Values are represented as mean and standard deviation
All values are the mean of triplicate determination ± standard deviation (SD)

Confirmation of curcumin

A Thin Layer Chromatography (TLC) technique has been developed and optimized for the analysis of drugs and medicinal plants, including species from the Curcuma genus. This method offers both qualitative and semi quantitative analysis capabilities, requiring minimal organic solvent and less time for analysis. Specifically, TLC optimization can be effectively utilized for the analysis of curcumin, aiding in the authentication of medicinal plants [9]. In our study, the extracted curcumin from Suroma variety of turmeric exhibited a TLC value of 0.56±0.08 %, which aligns with the range of other extraction results reported by [27], at 0.55%. Such congruence in TLC values further supports the reliability and consistency of the extraction process for curcumin analysis.

Viscosity

The viscosity of the extracted curcumin was found to be 2.9±0.15 centipoises. Subsequently, upon diluting the extracted curcumin powder with water in 1:5 ratio during the formulation of gummies, its viscosity decreased. This reduction in viscosity can be attributed to the addition of water, which is a common practice aimed at mitigating the adverse effects associated with toxic organic solvents. Water, being safe and readily accessible, serves as a recommended alternative to organic solvents. A similar result was documented in previous research investigations who revealed that the viscosity of the extracted curcumin as 3.8±0.02 centipoises [37].

Total titratable acidity

The Total Titratable Acidity of the extracted curcumin was found to be 3.84 ± 0.02%. A study done by [4], noticed that the Total Titratable Acidity value of extracted curcumin as 4.78 ± 0.99% which was slightly higher than our findings with a slight variation. The difference in the values could be attributed to variations in variety of turmeric used and extraction techniques followed. The pH of the extracted curcumin sample was found to be 7.9 ± 0.15 and our research findings agreed with the findings of [16] who reported similar pH value (8.17) in extracted curcumin.

Colour analysis

In our study, the color of curcumin was assessed using a Hunter Lab digital colorimeter. The L*, a*, and b* values were analyzed to gauge the lightness, redness, and yellowness of the extracted curcumin. The L*, a*and b* value of the extracted curcumin was found to be 47.63±0.04, 28.31±0.02 and 41.6±0.01 respectively. The L*, a*, and b* values of curcumin previous reported by [4] was found to be 46.58±3.44, 23.68 ± 1.10, and 60.40 ± 2.98 respectively and the results were substantially similar with our research findings. These variations highlight the impact of the extraction process on the color characteristics of curcumin, which are crucial factors in determining its overall quality and consumer appeal.

Physio-chemical analysis of the formulated curcumin incorporated jamun based gummies

Data in (Table 4) outlines the physio-chemical properties of the control Jamun gummies and the treatment Curcumin incorporated Jamun based gummies. These properties include pH, color parameters (L*, a*, b*), and textural properties (hardness, gumminess, chewiness, adhesiveness). Understanding these properties provides valuable insights into the characteristics and quality attributes of the gummies, aiding in assessing their suitability and potential benefits for consumption.

Table 4 Physio-chemical properties of gummies

Analysis	Curcumin incorporated jamun fruit-based gummies
pH	6.7 ± 0.3
Colour	
L*	41.63 ± 0.2
a*	22.53 ± 0.30
b*	39.73 ± 0.30
Textural properties	
Hardness	146.14 ± 18.99
Gumminess	3997.6 ± 2.08
Chewiness	52.3 ± 0.3
Adhesiveness	-3.7 ± 1.1

Values are represented as mean and standard deviation
All values are the mean of triplicate determination ± standard deviation (SD)

Analysis of physiochemical properties of formulated curcumin incorporated jamun based gummies

pH

The pH of the curcumin incorporated jamun fruit-based gummies was found to be 6.7 ± 0.3. The similar results were obtained by [41], in the formulation of gummies, a pH value of 5-6 was achieved.

Colour analysis

The color analysis of the formulated curcumin-incorporated jamun-based gummies revealed significant findings. Using the L*, a*, and b* values to assess lightness, redness, and yellowness respectively and observed a distinct color profile. For the gummy sample, the L*, a*, and b* values were found to be 41.63±0.2, 22.53±0.30, and 39.73±0.30 respectively. However, notable color differences were observed in the formulated gummy sample. The L*, a*, and b* values were recorded as 32, 34.4, and 4.3, respectively, as reported by [7]. These variations underscore the impact of curcumin enrichment on the color attributes of the gummies, which are crucial factors influencing their visual appeal and consumer preference.

Texture analysis

Hardness

The hardness of the formulated curcumin incorporated Jamun based gummies was found to be 146.14 ± 18.99. However, notable hardness difference were observed in the formulated gummy sample was recorded as 586.4, as reported by [18]. The variation in the result obtained could be attributed to restricted use of other additives in the gummies.

Gumminess

Gumminess of the formulated curcumin-incorporated jamun based gummies was found to be 3997.6±2.08, reflecting the density that remains during mastication or the energy required to disintegrate the semisolid food into a swallow able state. This value contrasts notably with the gumminess of 527.3 reported by [18] for their gummy formulation. Such differences in gumminess values may stem from variations in ingredients, processing techniques, or other formulation factors, highlighting the importance of precise formulation methods in achieving desired textural properties in gummy products. Further investigation into the specific factors influencing gumminess could provide valuable insights for optimizing the texture and overall consumer experience of such functional gummy formulations.

Chewiness

The chewiness of the formulated curcumin-incorporated jamun based gummies was measured at 52.3 ± 0.3, representing the amount of energy required to chew the gummy before it becomes swallow able. This value stands in contrast to the chewiness value of 525.8 reported by [18] for their gummy formulation. The significant difference in chewiness between the two formulations could be attributed to variations in ingredients, processing methods, or other formulation parameters. Understanding the factors influencing chewiness is crucial for optimizing the texture and palatability of gummy products. Further research into these factors could offer valuable insights for enhancing the sensory attributes and consumer acceptance of functional gummies.

Adhesiveness

The adhesiveness of the formulated curcumin-incorporated jamun-based gummies, representing the energy needed to overcome attractive forces between the food surface and other materials, was measured at -3.7±1.1. This value contrasts notably with the adhesiveness of – 0.32±0.20 reported by [35] for their gummy formulation. Texture profile analysis revealed that these gummies exhibited characteristics of being gummier, moderately chewy, harder, and more adhesive.

Proximate analysis

The (Table 5) presents the nutrient composition of both the control Jamun gummies and the treatment Curcumin incorporated Jamun based gummies. The parameters analyzed include energy content (Kcal), protein (g), total fat (g), total ash (%), moisture (%), carbohydrates (g), dietary fiber (g), iron as Fe (mg), calcium (mg), and vitamin C (mg).

Table 5 Nutrient composition of curcumin incorporated jamun based gummies

Parameters	Curcumin incorporated jamun fruit-based gummies
Energy (Kcal)	298.42 ± 1
Protein (g)	3.86 ± 0.01
Total Fat (g)	1.62 ± 0.01
Total Ash (%)	4.42 ± 0.02
Moisture (%)	56.02 ± 0.02
Carbohydrates (g)	67.16 ± 0.20
Dietary fiber (g)	7.36 ± 0.25
Iron as Fe (mg)	6.2 ± 0.1
Calcium (mg)	15.9 ± 0.1
Vitamin C (mg)	25.56 ± 0.02

Proximate analysis

Proximate analysis is a critical component of any food product formulation or production. It aids in comprehending the gummies proximal and chemical compositions, which depict the nutritional density of the formulated food product.

Energy

The energy content of curcumin-incorporated jamun-based gummies was found to be 298.42 ± 1 kcal. This observation aligns with findings by [25], who reported an energy content of 302.4 kcal per 100 grams of gummy sample, further supporting the results of this study. Previous research work by [35] reported comparatively lower energy value (166.4 Kcal) in their formulation. The high energy content in the curcumin-incorporated gummies was attributed to the variation in raw ingredients used such as curcumin, Jamun fruit, and palm sugar, all of which contribute significantly to the carbohydrate content.

Protein

The protein content of curcumin-incorporated jamun-based gummies contained 3.86 ± 0.01g of protein. These findings differ with those of (13), who low protein content ranging from 1.33 to 1.6 milligrams per 100 mg in amla based gummies. The higher protein content in the curcumin-incorporated gummies was attributed to the presence of raw ingredients such as curcumin, Jamun fruit, and palm sugar.

Fat

The lipid content of the formulated curcumin-incorporated jamun-based gummies was determined to be 1.62 ± 0.01g. These findings align with those reported by [31], who observed lesser total fat content ranging from 0.07% to 0.11% in samples with varying percentages of sugar. Thus, it can be inferred that the formulated curcumin-incorporated jamun-based gummies exhibit higher fat content.

Ash

The ash content of formulated curcumin-incorporated jamun-based gummies was determined to be 4.42±0.02%, respectively. This finding contrasts with the results reported by [34], who observed ash values ranging from 0.39% to 0.48%. The higher ash content in the curcumin-incorporated gummies compared to the jamun fruit gummies could be due to the inherent high ash composition of the ingredients used along with incorporation of curcumin extract.

Moisture

The moisture content of the curcumin-incorporated jamun-based gummies was observed to 57.83±0.20%, respectively. These findings align with the moisture content of 35.013% reported by [17]. This higher moisture content in the jamun fruit gummies can be attributed to a lower total solids count and the inclusion of water during the extraction process.

Carbohydrate

The carbohydrate content of the formulated curcumin-incorporated jamun-based gummies was found to be 67.16±0.20 g. These findings are consistent with the research conducted by [17] who reported a carbohydrate content of 64.52g in their developed fibre rich gummy jelly. The higher carbohydrate content in the curcumin-incorporated jamun-based gummies can be attributed to the presence of curcumin, Jamun fruit pulp, and palm sugar, which are known to be rich sources of carbohydrates.

Fiber

The fiber content of the formulated curcumin-incorporated jamun-based gummies contained 7.36±0.25g of

fiber. These results indicate a higher fiber content compared to the gummies formulated by [25], who reported a fiber content of 3.11g in their study as jamun fruit are good sources of fibre.

Iron

The curcumin incorporated jamun based gummies contained 6.2±0.1 mg of iron. These findings contrast slightly with those reported by [10] for iron-fortified gummies, where the iron content was found to be 3.5mg. Thus, the iron content in the curcumin incorporated jamun based gummies surpassed that reported for iron-fortified gummies, indicating a potentially enhanced nutritional profile in the curcumin incorporated formulation.

Calcium

The calcium content analysis revealed that the curcumin incorporated jamun based gummies possessed calcium content of 15.9 ± 0.1mg. However, it's noteworthy that the calcium content in formulation was notably lower compared to the findings reported by [25], whose gummies exhibited a calcium content of 71.36 mg. This variance underscores the potential of further optimization and fortification strategies to enhance the calcium content in curcumin incorporated jamun based gummies, thereby enriching their nutritional profile.

Vitamin-C

The ascorbic acid content analysis revealed that the formulated curcumin incorporated jamun based gummies contained 25.56±0.02 mg of ascorbic acid. These findings differ with previous studies conducted by [25], which reported lower vitamin C content of 20.3 mg in formulated gummies. The slightly higher ascorbic acid content in the curcumin incorporated jamun based gummies highlights the potential for these gummies to serve as a source of dietary vitamin C, contributing to overall nutritional intake and potentially offering additional health benefits.

Functional properties

The functional properties of the curcumin incorporated jamun based gummies such as antioxidant property, total phenol content, total flavonoid content and qualitative phytochemical properties were analyzed and the result are exhibited in (Table 7).

Antioxidant property

Antioxidants are described as substances that specifically prevent or delay the oxidation of physiologically important molecules that quench the free radicals formed in the body. Foods contain lipids, saccharides, and vitamins that can be attacked by free radicals causing their oxidation. The free radical oxidation may be interrupted by several kinds of antioxidants. The antioxidants used in foods are chemical compounds that can denote hydrogen ions to neutralize free radicals and prevent rancidity and lipid peroxidation [32]. Curcumin, a potent antioxidant, falls into two categories: phenolics and β-diketones. To address its limitations, a series of curcumin analogs were synthesized by modifying groups in the benzene ring and β-diketones linkers to enhance antioxidant activity. When the body is stimulated, whether internally or externally, it generates excessive free radicals, leading to lipid peroxidation, protein denaturation, and various pathological changes. Overproduction of reactive oxygen species (ROS) and reactive nitrogen species (RNS) can cause DNA damage and lipid oxidation, resulting in oxidative stress and cellular damage. Oxidative stress plays a pivotal role in aging and the development of various diseases, including neurodegenerative disorders, diabetes, cardiovascular diseases, and cancer [42]. The antioxidant property of the Formulated curcumin incorporated jamun based gummies is depicted in (Table 6). The curcumin incorporated gummies obtained 52.59% which denotes a good radical scavenging activity as the plant-based ingredients are generally rich in polyphenols and antioxidants. These findings align with previous studies, such as those conducted by [5]. The potential antioxidant efficacy of curcumin enrichment in jamun based gummies, indicating their potential as functional foods with enhanced antioxidant properties. These findings underscore the importance of curcumin enrichment in improving the antioxidant profile of food products, thereby offering potential health benefits to consumers.

Table 6 Functional properties of curcumin incorporated jamun based gummies

Parameters	CIJG
Antioxidant activity	52.59 %
Total phenol content	32.30 ± 0.6 µg/mg
Total flavonoid	5921.1 ± 0.25µg/mg

Total flavonoid and phenol content

The Phenols and the flavonoids are the naturally occurring compounds present in the plants and they exhibit antioxidant effects on human consumption. The depicts the total phenolic and the total flavonoid content in the formulated curcumin incorporated jamun based gummies. The analysis revealed that the phenol content of the curcumin incorporated jamun based gummies contained 32.30±0.6 µg/mg. However, it is noteworthy the sample exhibited relatively lower phenolic values compared to the gummies formulated by [39], which reported a phenolic content of 84.1 ± 0.15. This disparity in phenolic content could be attributed to variations in formulation, processing methods, or ingredient sources. Further investigation is warranted to explore the factors influencing phenol content in these gummy formulations and their potential implications for health benefits.

The investigation conducted in this study involved the assessment of the total flavonoid content present in the formulated curcumin incorporated jamun based gummies, yielding a measured content of 5921.1±0.25µg/mg. These results are consistent with prior findings reported by [2], where variations in flavonoid content ranging from 7.06 ± 0.31 milligrams per 100 milligrams were observed in their samples. This reaffirms the significance of curcumin incorporated jamun based gummies as a potential source of flavonoids, highlighting their potential health benefits and nutritional value.

Qualitative phytochemical analysis

The detailed results of the qualitative phytochemical analysis of the formulated curcumin incorporated jamun based gummies are presented in (Table 7).

Table 7 Qualitative phytochemical analysis

Phytochemicals	Control	Treatment
Flavonoid	-	++
Alkaloid	-	-
Saponin	-	-
Tannin	-	-
Phenol	+	+
Terpenoid	-	-
Steroid	-	-
Glycoside	-	-

+- Low presence, ++-Moderate presence, +++-High presence

The analysis of the phytochemical composition of the formulated curcumin-incorporated jamun-based gummies revealed the presence of various bioactive compounds, including glycosides, phenols, proteins, carbohydrates, quinones, starch and alkaloids. These phytochemicals hold considerable interest due to their potent antioxidant properties, which can have significant health benefits for consumers. Epidemiological and animal studies have indicated that regular consumption of fruits, vegetables, and whole grains may help reduce the incidence of various diseases associated with oxidative stress.

CONCLUSION

The introduction of curcumin-incorporated jamun-based gummies marks a significant milestone in the evolution of gummy candies, transitioning from conventional sugary treats to functional nutraceuticals. Through innovative ingredients and formulations, these gummies offer a healthier alternative to traditional confections, while maintaining their beloved chewy texture and vibrant colors. The incorporation of curcumin, extracted from turmeric using the Soxhlet extraction method, imbues the gummies with potent antioxidant and anti-inflammatory properties, enhancing their functional appeal. Furthermore, the addition of jamun fruit pulp and palm sugar further elevates the nutritional profile of the gummies, providing consumers with a convenient and enjoyable way to access beneficial phytochemicals and antioxidants. High levels of total flavonoid content underscore the potential health benefits of these gummies, which have garnered high overall acceptability among consumers in sensory evaluations. This successful formulation process aligns closely with consumer preferences, reflecting a broader trend towards healthier indulgences for health-conscious consumers seeking functional foods with enhanced nutritional profiles. By harnessing natural ingredients and innovative formulations, these gummies not only satisfy taste preferences but also contribute to overall health and well-being. As consumer demand for healthier options continues to grow, the development of functional gummy candies presents promising opportunities for the confectionery industry to meet evolving preferences and promote healthier lifestyles. The evolution of gummy candies from traditional confections to functional nutraceuticals signifies a broader shift towards healthier indulgences, with curcumin-incorporated jamun-based gummies serving as a prime example. Further research and development in this field hold potential for the creation of even more functional and nutritious gummy options, addressing the rising demand for healthier snack alternatives. The combination of curcumin extract and jamun fruit in gummy formulations presents exciting prospects for crafting products with enhanced nutritional value, appealing to health-conscious consumers seeking both flavor and wellness benefits.

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