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Sweet Potato Leaf Extract Gummy Candy as an Antioxidant-Rich Functional Food for Stunting Prevention in Children

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ABSTRACT

Stunting remains a major public health concern linked to oxidative stress and micronutrient deficiencies. This study aimed to develop and evaluate gummy candy formulations containing sweet potato leaf extract (Ipomoea batatas L.) as a functional food candidate for stunting prevention in children. The extract was obtained by maceration, and the formulation was evaluated through phytochemical screening, sensory evaluation, weight uniformity, antioxidant activity using the DPPH method, and mineral content analysis with atomic absorption spectrophotometry (AAS). Phytochemical analysis confirmed the presence of flavonoids, tannins, and saponins. Sensory evaluation by 30 panelists indicated observable differences between formulations: F0 (control) was preferred in terms of color and taste, while F1 (with extract) presented a darker green-purple appearance and a slightly bitter aftertaste, though texture remained similar in both. Weight uniformity results met pharmacopeial standards, with coefficient of variation values below 5%. Antioxidant activity testing revealed strong radical scavenging potential of the extract (IC_{50}: 29.263 ppm), moderate activity in the F1 gummy (IC_{50}: 108.245 ppm), and very weak activity in F0 (IC_{50} > 200 ppm), compared to ascorbic acid as a positive control (IC_{50}: 6.426 ppm). Mineral analysis of F1 showed iron content of 168.94 ppm and zinc content of 28.05 ppm, contributing significantly to daily nutritional requirements. In conclusion, the incorporation of sweet potato leaf extract into gummy candy provides bioactive compounds with antioxidant activity and essential minerals, while maintaining acceptable sensory quality. These findings support its potential development as a functional food to contribute to stunting prevention strategies in children.

Keywords:
Stunting; Gummy candy; Sweet potato leaf; 2,2-Diphenyl-1-Picrylhydrazyl (DPPH); Functional food; Stunting prevention

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1. Introduction

Stunting represents one of the most serious health problems in Indonesia and has become one of the key points in the global agreement within the Millennium Development Goals (MDGs). This condition is characterized by a reduced length or height in children under the age of five, when compared to the standard growth parameters for their age cohort [1]. Globally, approximately 148.1 million children under the age of five, or 22%, experience stunting. In Indonesia, the 2019 National Nutrition Survey indicated a stunting prevalence of 27.7%, which decreased to 24.4% in 2021 and further dropped to 21.6% by 2022 [2]. Children under five with growth retardation face a higher risk of degenerative diseases, reduced intellectual capacity, lower productivity, and the likelihood of preterm or low-birth-weight births [3].

Malnutrition accounts for 50% of deaths among children under the age of five, making it one of the world's most serious health problems. Children are more vulnerable to diseases because their immune systems are still in development and not fully mature. Children with stunted growth have significantly lower levels of blood oxidative stress markers, including antioxidant enzymes like catalase, SOD, plasma glutathione, total protein, Cu, TAC, Zn, also ascorbic acid, indicating increased oxidative stress and diminished antioxidant defenses ($p < 0.01$). Oxidative stress and inflammation are crucial elements in the pathophysiology of stunting, contributing to the onset of growth hormone resistance [4]. Fruits and vegetables represent valuable natural resources with significant potential to modulate reactive oxygen species (ROS) and antioxidant balance [5]. Oxidative stress occurs when there is an imbalance between oxidants and antioxidants in the body, favoring an excess of oxidants [6]. The utilization of natural products as antioxidants presents minimal adverse effects, making them a promising alternative in therapeutic applications [7]. A compound is considered a very strong antioxidant if its IC_{50} value is less than 50 ppm, strong if it ranges from 50-100 ppm [8].

Given the potential of plant-based antioxidants in addressing oxidative stress-related stunting, sweet potato (*Ipomoea batatas*) emerges as a promising candidate due to its exceptional nutritional profile and antioxidant properties. Sweet potato leaves are rich in essential minerals, particularly sodium (Na), magnesium (Mg), phosphorus (P), calcium (Ca), and potassium (K), with concentrations in 100 g of dried leaves ranging from Na (8.06–832.31 mg), Mg (220.20–910.50 mg), P (131.10–2639.80 mg), Ca (229.70–1958.10 mg), and K (479.30–4280.60 mg) [9]. Additionally, these leaves also contain small amounts of minerals such as copper (Cu) 0.70–1.90 mg, zinc (Zn) 1.20–3.20 mg, manganese (Mn) 1.70–10.09 mg, and iron (Fe) 1.90–21.80 mg per 100 g of dried leaves [10]**.** Sweet potato leaves have a high concentration of anthocyanins and flavonoids that are stronger than alpha tocopherol and have more phytochemicals and antioxidants than its tubers [11]. Flavonoid compounds can promote the regulation of growth hormone, which has a growth-promoting effect [12]. Nutraceuticals specifically refer to the delivery of nutrients as well as the medicinal effects of food components [13]. The oral route is the most convenient method for administering active ingredients in dietary supplements and functional foods because of its high compliance rate, especially among children and the elderly. However, liquid formulations often have limited dosage due to solubility issues and require additional sweeteners, buffers, and preservatives to maintain stability and taste [14].

To overcome these limitations, gummy candies were chosen because they are able to deliver active ingredients in a stable form that is easy to consume, visually appealing, and liked by children. Additionally, their soft texture makes them comfortable to chew for consumers without swallowing difficulties or dysphagia [14].

These naturally based gummy candies are made from a mixture of active ingredients, gelling agents, and sweeteners, with the advantage of attractive color, aroma, taste, and shape [15].

This study aims to develop a formula for sweet potato leaf extract gummy candy as a functional food to support the Supplementary Feeding Program (PMT) for toddlers. Processing sweet potato leaves into gummy candies is a natural innovation that is beneficial in preventing stunting [16]. Therefore, this study supports the PMT program through sweet potato leaf extract gummy candies, which are expected to serve as a source of antioxidants to support optimal growth and development while preventing stunting in infants.

2. Materials and Methods

Study design

This research was an experimental study with a quantitative approach using a completely randomized design (CRD). The study aimed to formulate and evaluate gummy candy containing sweet potato leaf extract as a functional food with antioxidant properties for stunting prevention in children. Two formulations were developed and compared: F0 (control without sweet potato leaf extract) and F1 (containing 3 g sweet potato leaf extract). Each formulation was evaluated for phytochemical content, antioxidant activity, mineral content (Fe and Zn), weight uniformity, and organoleptic properties to determine the optimal formula with acceptable quality parameters.

Materials

Raw materials: Fresh sweet potato (*Ipomoea batatas*) leaves were obtained from Manikliyu Village, Kintamani District, Bangli Regency, Bali Province. Food-grade gelatin, propylene glycol, granulated sugar, citric acid, potassium sorbate, food essences, and distilled water were purchased from local suppliers.

Chemical reagents: DPPH (2,2-Diphenyl-1-picrylhydrazyl) powder (≥95% purity, Sigma-Aldrich), ascorbic acid (≥99% purity, Merck), methanol p.a. (≥99.8% purity, Merck), and 96% ethanol (analytical grade, Merck) were used for analytical procedures.

Equipment: Analytical balance (Ohaus Pioneer PA214), rotary evaporator (BUCHI R-300), drying oven (Memmert UF30), UV-Vis spectrophotometer (UV-1800 Shimadzu, Japan), atomic absorption spectrophotometer (AAS), candy molds, water bath, and standard laboratory glassware.

Preparation of Sweet Potato Leaf Extract

Sweet potato leaves were processed into dried simplisia, then powdered and macerated using 96% ethanol solvent with a 1:10 ratio. Soaking was carried out for three times 24 hours, with stirring for five minutes every 12 hours. Then remaceration was performed using the same solvent, shaken for five minutes, and filtered through filter paper. After maceration, evaporation was carried out at 40°C to remove the solvent present in the filtrate [17].

Formulation of Gummy Candy

Two formulations were prepared according to **Table 1**. The preparation process began by soaking gelatin in distilled water for 10 minutes to allow swelling [18]. Sweet potato leaf extract (3 g for F1) was dissolved in propylene glycol (solution A), while sugar, citric acid, and potassium sorbate were dissolved in distilled water (solution B). Solutions A and B were mixed to form solution C. The swollen gelatin was heated in a water bath at 40-50°C for 5 minutes until completely dissolved. Solution C was then added to the liquefied gelatin along with 2-3 drops of essence, and the mixture was stirred until homogeneous. The final mixture was poured into silicone molds (approximately 2.5 g per gummy) and allowed to set at room temperature (15-30°C) for 2 hours before demolding.

Table 1. Gummy Candy Sweet Potato Leaf Extract Formulation

Material Composition	Material Weight (gram)	
	F0	F1
Sweet potato leaves extract	-	3
Gelatin	20	20
Propylene glycol	10	10
Sugar	40	40
Citric acid	0.1	0.1
Potassium sorbate	0.1	0.1
Essens	2-3 drops	2-3 drops
Aquadest	10 mL	10 mL

Phytochemical Screening

Qualitative phytochemical screening was performed on the sweet potato leaf extract to identify secondary metabolites including alkaloids, steroids, triterpenoids, flavonoids, tannins, saponins, and quinones. Standard phytochemical protocols were followed: alkaloid detection using Dragendorff's reagent (precipitation reaction), steroid identification through Liebermann-Burchard test (color change reaction), flavonoid detection using Shinoda test (magnesium powder and HCl), tannin identification with $FeCl_3$ reagent (blue-black coloration), and saponin detection through foam test (persistent foam formation). Results were recorded as positive (+) for presence or negative (-) for absence of each compound class [19].

Organoleptic (Hedonic) Test

Sensory evaluation of gummy candy formulations was conducted using a descriptive hedonic test. Thirty semi-trained adult panelists assessed five sensory parameters, namely shape, color, aroma, taste, and texture. Panelists provided descriptive observations of the sensory attributes for each formulation, and the results were presented qualitatively in tabular form without statistical analysis [22].

Weight Uniformity Test

Weight uniformity testing followed pharmacopeial standards with 20 randomly selected gummy samples from each formulation (F0 and F1). Individual weights were measured using analytical balance with 0.0001 g precision. The average weight, standard deviation, and coefficient of variation (CV) were calculated. Acceptance criteria required CV ≤5% with no more than two units deviating beyond ±5% of average weight and no unit exceeding ±10% deviation [27].

Antioxidant Activity Assay

Antioxidant activity was evaluated using DPPH free radical scavenging assay. Stock solutions of samples (F0, F1) and positive control (ascorbic acid) were prepared in methanol. Five different concentrations (60, 80, 100, 120, and 140 ppm for gummy samples; 1, 2, 3, 4, and 5 ppm for ascorbic acid) were tested in triplicate. Each sample solution (1 mL) was mixed with 1 mL of 0.1 mM DPPH solution in methanol and incubated in darkness for 30 minutes at room temperature. Absorbance was measured at 517 nm wavelength using UV-Vis spectrophotometer with methanol as blank [17].

Iron (Fe) and Zinc (Zn) Analysis

Mineral content analysis was performed using Atomic Absorption Spectrophotometry (AAS). Gummy samples (1 g) were digested using wet digestion method with concentrated HNO_3 and $HClO_4$ (3:1 v/v) at 200°C until clear solution was obtained. The digestate was diluted to 25 mL with distilled water and filtered. Iron and zinc concentrations were measured using AAS with appropriate hollow cathode lamps (Fe: 248.3 nm, Zn: 213.9 nm wavelengths). Calibration curves were prepared using standard solutions (0-5 ppm for both elements) with correlation coefficients ≥0.995. Results were expressed as mg/kg (ppm) dry weight basis [38].

3. Results and Discussion

Phytochemical Screening

The phytochemical screening of sweet potato leaf extract provides valuable insights into the bioactive compounds present in this botanical material. The extraction process utilizing 96% ethanol through maceration method proved effective, yielding 10.87% extract which meets the standard requirement of not less than 10% for good extract yield. This maceration approach offers distinct advantages including simple equipment requirements and the absence of heating processes that could potentially degrade heat-sensitive compounds in the sample. The yield percentage can be influenced by various factors including maceration duration, temperature conditions, stirring speed and duration, and the surface area of the sample material used [20].

Table 2. Phytochemical Screening Results of Gummy Candy Sweet Potato Leaf Extract

No	Phytochemical test	Method	Results
1	Alkaloids	Precipitation reaction	Detected
2	Steroids	Color reaction	Detected
3	Triterpenoids	Color reaction	Not Detected
4	Flavonoids	Color reaction	Detected
5	Tannins	Color reaction	Detected
6	Saponins	Color reaction	Detected
7	Quinones	Color reaction	Not Detected

The phytochemical analysis revealed the presence of several important secondary metabolites, including alkaloids, steroids, flavonoids, tannins, and saponins in the ethanol extract of sweet potato leaves (**Table 2**). The successful detection of these compounds is attributed to their solubility characteristics in semi-polar solvents such as ethanol. However, certain compound classes were notably absent from the extract, particularly triterpenoids and quinones, which were not detected in the 96% ethanol extract. The absence of triterpenoid compounds is explained by their insolubility in semi-polar solvents, as these compounds typically require non-polar solvents for effective extraction. Similarly, quinone compounds were not identified, likely due to their poor solubility in semi-polar systems, as they generally demonstrate better solubility in non-polar solvents [21]. This selective extraction pattern highlights the importance of solvent polarity in determining the phytochemical profile of plant extracts.

Hedonic Test

The descriptive organoleptic evaluation of gummy candy formulations containing sweet potato leaf extract (F1) and without extract (F0) is presented in **Figure 1** and **Table 3**. Both formulations had the same heart-shaped appearance; however, they differed in color. F0 appeared transparent, whereas F1 exhibited a darker purple-green tone, which can be attributed to the presence of chlorophyll and other pigments from the sweet potato leaf extract [22].

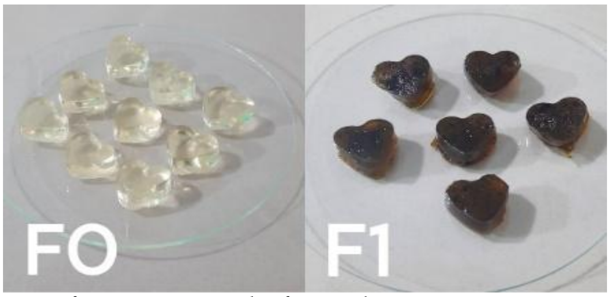

Figure 1. Appearance of gummy candy formulations containing sweet potato leaf extract (F1) and without extract (F0)

In terms of aroma, both F0 and F1 were perceived to have a sweet fragrance. Nevertheless, panelists noted that F1 carried a slightly distinct herbal note derived from the extract, while F0 retained a typical sweet aroma profile [23]. Taste evaluation indicated that F0 was characterized by a purely sweet flavor, whereas F1 was described as sweet with a slight bitter aftertaste. This bitterness is likely caused by tannins and alkaloids contained in the extract, consistent with previous studies reporting the influence of phenolic compounds on sensory perception [24].

Table 3. Hedonic evaluation results of gummy candy formulations with and without sweet potato leaf extract

Parameter	Formula 0	Formula 1
Shape	Heart	Heart
Color	Transparent	Purple dark
Aroma	Sweet aroma	Sweet aroma
Taste	Sweet	Sweet with slight bitter aftertaste
Texture	Chewy	Chewy

he texture of both formulations was reported as chewy, suggesting that the addition of sweet potato leaf extract did not alter the fundamental gummy texture. This observation aligns with previous research indicating that gummy texture is primarily influenced by the concentration of gelatin and mannitol: higher gelatin levels enhance chewiness and transparency, while mannitol tends to increase firmness and reduce transparency [25],[26].

Weight Uniformity Test

Weight uniformity testing serves as an indirect indicator of active ingredient content homogeneity in pharmaceutical preparations, measuring the consistency of production weight across formulations. As shown in **Table 4**, both F0 and F1 formulations met the pharmacopeial standards, with coefficient of variation (CV) values of 1.839% and 0.965%, respectively, both well below the 5% threshold. According to pharmacopeial requirements, no more than two preparations should deviate beyond column A (5%) and no preparation should exceed column B (10%) deviation limits. The low CV values obtained indicate excellent manufacturing consistency and adherence to weight uniformity standards across all tested formulations [27].

Table 4. Weight Uniformity Test Results

Formula	Average weight (gram)	CV (%)	Allowable deviations	
			F0	F1
F0	2.379	1.839	2.260 ± 2.497	2.141 ± 2.616
F1	2.394	0.965	2.274 ± 2.513	2.154 ± 2.633

Several factors can contribute to weight non-uniformity in gummy candy production, including unstable heating conditions during the mixing process, calibration difficulties with molding equipment, and variations in pouring speed into molds [28]. Despite potential manufacturing challenges such as mold calibration issues and temperature fluctuations during production that could affect the pouring process into molds, the results indicate that variations in gelatin and mannitol concentrations had no evident effect on the weight uniformity of the produced gummy candy [28]. This finding suggests that the manufacturing process maintained adequate control over critical parameters, ensuring consistent product quality regardless of formulation differences in the concentration ratios of key excipients.

Antioxidant Activity

The antioxidant activity evaluation of sweet potato leaves extract demonstrated exceptional potency with an IC_{50} value of 29.263 ppm, categorized as very strong antioxidant activity (<50 ppm). As shown in **Table 5**, the gummy candy formulation containing extract (F1) exhibited moderate antioxidant activity with an IC_{50} of 108.245 ppm, whereas the control formulation (F0) showed very weak activity (IC_{50} > 200 ppm). In comparison, ascorbic acid (reference standard) displayed the highest antioxidant activity with an IC_{50} of 6.426 ppm. The high correlation coefficient (R^2) approaching 1 indicates that approximately 98% of the antioxidant content is attributed to bioactive compounds present in the extract, while less than 1% variation may result from analytical factors such as weighing accuracy, pipetting precision, and sample impurities [29]. This strong antioxidant capacity is primarily attributed to the presence of secondary metabolites including flavonoids, tannins, and saponins identified through phytochemical screening [30],[31].

The antioxidant mechanisms of these bioactive compounds operate through multiple pathways involving free radical scavenging and oxidative stress mitigation. Flavonoids demonstrate their antioxidant properties through direct neutralization of reactive oxygen species (ROS) including superoxide anions, peroxyl radicals, and hydroxyl radicals via hydrogen atom transfer, facilitated by their multiple phenolic hydroxyl groups and low redox potentials [32],[33]. Saponins contribute to antioxidant activity through their phenolic hydroxyl groups that interrupt free radical chain reactions by forming stable semi-keto radical structures, while tannins function as secondary antioxidants that inhibit lipid peroxidation and scavenge various radical species through rapid electron transfer and slower hydrogen atom transfer mechanisms [31],[33].

Table 5. Antioxidant Activity Results of Gummy Candy of Sweet Potato Leaves Extract Using DPPH Method and Ascorbic Acid

Sample	Concentration (ppm)	Abs.	%Inhibition	IC_{50}
F0	60	0.471	4.765	521.453
	80	0.459	6.176	
	100	0.444	7.265	
	120	0.412	9.168	
	140	0.428	10.865	
F1	60	0.288	39.238	108.245
	80	0.256	43.348	
	100	0.244	45.111	
	120	0.218	56.236	
	140	0.202	58.537	
Ascorbic acid	1	0.313	14.144	6.426
	2	0.343	22.146	
	3	0.290	35.413	
	4	0.239	39.468	
	5	0.278	51.423	

The comparative analysis between formulations revealed F1 showed higher antioxidant capacity than F0, with F1 (containing 3% sweet potato leaves extract) exhibiting moderate antioxidant activity (IC_{50} in the 100-150 ppm range) compared to F0 (negative control) which showed very weak activity (IC_{50} >200 ppm) [34]. Although the gummy candy formulations demonstrated lower antioxidant activity compared to ascorbic acid reference standard (IC_{50}: 6.426 ppm), the incorporation of sweet potato leaves extract provides meaningful antioxidant benefits that may contribute to stunting prevention through enhanced immune function and oxidative stress reduction [35],[36],[37]. The presence of moderate antioxidants in the gummy candy formulation represents a significant nutritional enhancement, particularly valuable for pediatric populations where oxidative stress plays a crucial role in growth impairment and developmental challenges [36].

Iron (Fe) and Zinc (Zn) Analysis

Mineral analysis of the F1 gummy candy formulation showed iron levels of 168.94 ppm and zinc levels of 28.05 ppm, consistent with the nutritional profile of sweet potato leaves, which are rich in minerals and vitamins. As presented in **Table 6**, the iron and zinc contents were determined using the Atomic Absorption Spectrophotometry (AAS) method, confirming that the incorporation of sweet potato leaf extract enhanced micronutrient density of the formulation. Previous studies have reported that sweet potato leaves contain 73.7681 mg/100 g of iron (Fe) and 5.647 mg/100 g of zinc (Zn), although these values may vary depending on growth conditions [38],[39]. According to the WHO, in populations with an anemia prevalence of ≥40% among infants or pregnant women, daily iron supplementation is recommended at 2 mg/kg body weight [40]**.** The Institute of Medicine recommends an iron RDA of 7 mg/day for children aged 1–3 years, 10 mg/day for ages 4–8 years, and 8 mg/day for ages 9–13 years. With a content of 168.94 mg/kg, consuming 10 g of gummy candies can contribute approximately 1.7 mg of iron, or about 24% of the RDA for children aged 1–3 years, thereby potentially supporting the prevention of anemia [41]. Iron plays a vital role in hemoglobin formation, and its supplementation has been shown to reduce the incidence of stunting and the risk of low birth weight [42].

Table 6. Iron and zinc analysis purple sweet potato leaves gummy candy

Parameter	Concentration (ppm)	Method
Iron (Fe)	168.94	AAS
Zinc (Zn)	28.05	AAS

The essential mineral content at therapeutic concentrations makes sweet potato leaf gummy candies a potential intervention for preventing stunting, where zinc plays an important role in immune system development through its influence on T cell function, B cell maturation, and enzyme activity [43]. Zinc was detected at 28.05 ppm, along with iron, which can be absorbed by the body through supplementation or other food sources, making the gummy a convenient medium for delivering micronutrients [30]. The Institute of Medicine reports that the Adequate Intake (AI) for zinc is 3 mg/day for children aged 1–3 years, 5 mg/day for children aged 4–8 years, and 8 mg/day for children aged 9–13 years, with the upper intake level (UL) for zinc being 7 mg/day for children aged 1–3 years and 12 mg/day for children aged 4–8 years [41]**.** With a concentration of 28.05 mg/kg, a 10 g portion of gummy candy contributes approximately 0.28 mg of zinc or ±9% of the RDA for children aged 1–3 years. Although the contribution of zinc is relatively small, its presence still supports immune function in accordance with its biological role. The mineral profile of the F1 formulation shows that the addition of sweet potato leaf extract not only provides phytochemical benefits but also increases micronutrient density, thereby reducing the risk of nutritional deficiencies and supporting comprehensive malnutrition prevention strategies [44].

This study has several limitations. The in vitro design without clinical validation limits assessment of bioavailability and therapeutic efficacy in children. Antioxidant activity was evaluated only through DPPH assay, which may not reflect complex biological antioxidant mechanisms. The study did not examine bioactive compound stability during storage or component interactions within the gummy matrix. Long-term safety evaluation and assessment of potential adverse effects were not conducted. Additionally, organoleptic evaluation involved adult panelists rather than the target pediatric population, limiting acceptability generalizability. Future research should include clinical trials, comprehensive stability testing, and age-appropriate sensory evaluation methods.

5. Conclusions

This study successfully developed sweet potato leaf extract gummy candy as a potential antioxidant-rich functional food for stunting prevention in children. The F1 formulation demonstrated moderate antioxidant activity (IC_{50} 108.25 ppm), contained essential micronutrients including iron and zinc, and provided bioactive compounds such as flavonoids, tannins, and saponins. The gummies met pharmaceutical quality standards and were organoleptically acceptable for pediatric consumption. These findings highlight the potential of sweet potato leaf gummy candy as a novel functional food approach to support stunting prevention. Future research should focus on clinical validation through randomized controlled trials to evaluate bioavailability, safety, and effectiveness on growth parameters in children, alongside long-term stability testing and sensory evaluation in the target pediatric population.

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Conflicts of Interest:
The authors declare that there is no conflict of interest regarding the publication of this paper.

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