Use of wormwood essential oil in ginger gelatin candies: sensory, physical, and chemical characterization

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Abstract

Research in the food sector has expanded to cater to consumers who prioritize natural products, seeking sensory quality and antioxidant potential. As such, this study developed gelatin candies with ginger powder and different amounts of wormwood essential oil (0; 0.1; 0.2, and 0.3 mL to the total ingredients in the formulation). Evaluating sensory acceptance, purchase intention, instrumental color (L*, a*, b*, and ΔE*), total phenolic and flavonoid contents, and antioxidant activity (ABTS^{+} and DPPH methods). Candy formulations with up to 0.2 mL of essential oil achieved higher acceptance regarding appearance and texture, not differing from the control. Adding essential oil showed no influence on the aroma attribute. Flavor acceptance was highest for the control candy, decreasing at volumes over 0.1 mL. Formulation containing 0.2 mL achieved an average score equal to the control for overall impression, and attained a positive purchase intention frequency. Formulation prepared with 0.3 mL exhibited a color change, becoming darker, redder, and yellower compared to the others, resulting in the highest ΔE* (4.92) relative to the control candy. Incorporating 0.2 mL of wormwood essential oil into the formulation of gelatin candies, compared to the control, resulted in increased levels of bioactive compounds and enhanced antioxidant activity, showing its potential as a functional ingredient. This evinces the feasibility of using wormwood essential oil to develop food products with satisfactory sensory acceptability.

Keywords: *Artemisia absinthium* L. Acceptability. Color. Antioxidant activity. Bioactive compounds.

Introduction

A growing demand in the food industry landscape concerns products that combine sensory quality, functionality, and the use of natural ingredients. Such movement is directly linked to trends in conscious consumption and the pursuit of healthier eating, going beyond the mere provision of nutrients to promote beneficial effects on human health. Functional foods have gained prominence in this scenario because they consist of matrices rich in biologically and physiologically active substances, known as bioactive compounds, that are capable of offering health benefits (Daliri & Lee, 2015; Konstantinidi, Koutelidakis, 2019; Parham *et al*., 2020).

Functional foods and nutraceuticals represent a wide variety of food options rich in bioactive compounds with the potential to promote health and aid in disease prevention. Advances in research have expanded the scientific evidence regarding the mechanisms of action in the human body of these compounds and their potential applications (Vignesh *et al*., 2024). Moreover, the pursuit of quality of life, longevity, and health has sparked interest in these foods, reinforcing their role in promoting body-related benefits beyond their basic nutritional functions.

Formulating candies using plant-based ingredients can be a promising approach for the nutritional enrichment of foods and the delivery of compounds with therapeutic potential. According to Collegiate Board Resolution (RDC)

No. 723/2022 of the Brazilian Health Regulatory Agency (ANVISA), a candy is defined as a product made of sugar or other ingredients, which may feature various fillings, coatings, shapes, and consistencies (Brasil, 2022a). According to the Brazilian Association of the Chocolate, Peanut, and Candy Industry (ABICAB, 2025), member companies represent around 68 % of the national candy and gum industry and produce over 1 million tons of products annually.

Color (appearance), flavor, and texture of soft confectionery products are critical factors for consumer acceptance and the success of these products. Demand for products with more natural ingredients, free from synthetic components, and containing fewer calories and health-beneficial active ingredients is significant (Gunes *et al*., 2022). According to ANVISA RDC No. 725/2022, which addresses flavoring food additives, an essential oil consists of a volatile natural flavoring of plant origin obtained via physical processes, such as steam distillation, reduced-pressure distillation, or another suitable physical process, and may be used alone or mixed with other essential oils (Brasil, 2022b).

Medicinal plants such as *Artemisia absinthium* L., popularly known as wormwood, stand out among the natural ingredients. Traditionally used in folk medicine, this species possesses digestive, antiparasitic, and anti-inflammatory properties, attributed to the presence of bioactive compounds such as thujone, absinthin, and flavonoids. Additionally, its essential oil is rich in monoterpenes, particularly α- and β-thujone, associated with antioxidant, antimicrobial, and antifungal activities, highlighting its potential as a source of bioactive compounds with applications in the pharmaceutical, agricultural, and food sectors (Batiha *et al*., 2020; Kordali *et al*., 2005; Lopes-Lutz *et al*., 2008). In accordance with RDC No. 725/2022, α-thujone and β-thujone cannot be added directly to foods or flavorings; only their natural occurrence—derived from raw materials used to prepare flavorings—is permitted, subject to a maximum limit of 0.5 mg/kg in the food (Brasil, 2022b).

Another significant ingredient is ginger (*Zingiber officinale* Roscoe), a rhizome widely used in cooking and phytotherapy due to its phytochemical profile rich in gingerol, shogaol. and zingerone. These compounds are recognized for their antioxidant, anti-inflammatory, antiemetic, and thermogenic activities, potentially contributing to digestion, nausea relief, immune system strengthening, and metabolic balance (Ersedo *et al*., 2023). In addition to its health-promoting properties, ginger also possesses a characteristic pungent flavor that can add sensory value to food products. According to Modi and Modi (2024), a daily intake of up to 4 g of ginger is considered safe for adults, whereas higher doses may increase the risk of adverse effects, primarily gastrointestinal discomfort.

The combination of ginger and wormwood essential oil, containing a natural flavoring agent, in the formulation of gelatin candies therefore represents an innovative approach to developing confections with distinct sensory characteristics. According to Day *et al*. (2009), foods can serve as vehicles for delivering bioactive substances and micronutrients at adequate levels, providing health benefits and promoting greater well-being. Thus, this study developed and evaluated the quality of ginger gelatin candies with different amounts of wormwood essential oil by means of sensory, physical, and chemical analyses.

Material and methods

Essential oil extraction

Leaves and inflorescences of the wormwood plant were harvested from a garden in Machado city, Minas Gerais. After harvesting, the plant material was manually sorted to remove impurities

(dry twigs, dry leaves, and soil residues) and subsequently used for essential oil extraction.

Oil extraction was performed at the Bromatology Laboratory, Federal Institute of Education, Science and Technology of Southern Minas Gerais (IFSULDEMINAS) – Machado Campus, using a steam-assisted hydrodistillation technique with a Clevenger apparatus. The essential oil was separated from the aqueous phase using a hypodermic syringe and stored in amber glass vials, properly sealed and kept frozen.

Candies formulation

Ginger gelatin candies were prepared using the following ingredients: 200 g of refined sugar, 200 g of water, 36 g of unflavored powdered gelatin, 20 g of powdered ginger, 5 g of powdered citric acid, and 20 g of glucose syrup.

After mixing all ingredients gently with a spatula until completely homogenized, the mixture was heated and continuously homogenized for 5 minutes until reaching 60 °C. The ideal consistency point was reached when a thin, whitish layer formed on the surface. After this process, the mixture was allowed to reach 25 °C. Wormwood essential oil was added to the formulation using a 1 mL hypodermic syringe in the following amounts: 0 mL (control), 0.1 mL, 0.2 mL, and 0.3 mL relative to the total ingredients, and was subsequently homogenized to ensure uniform oil distribution. Ingredient quantities were determined based on preliminary tests. Next, the mixture was poured into silicone molds with 1.5 cm × 1.5 cm × 1.0 cm cavities and left to cool at room temperature. Each formulation yielded 179 candies, with an average mass of approximately 2.7 g per unit. Considering the amounts of essential oil added to the formulations (0.1 mL, 0.2 mL, and 0.3 mL), each candy contained, on average, 0.56 μL, 1.12 μL, and 1.68 μL of wormwood essential oil, respectively.

The silicone molds were placed under refrigeration (6 °C) for 12 h, allowing the candies to reach a gelatinous consistency. Afterwards, the candies were unmolded and packed in airtight containers for subsequent evaluation.

Sensory evaluation

The study was approved by the Research Ethics Committee of IFSULDEMINAS (CAAE: 84864024.8.0000.8158, approval number: 7.393.139). Sensory acceptability evaluation of gelatin candies containing ginger and wormwood essential oil was conducted at the Sensory Analysis Laboratory of IFSULDEMINAS – Machado Campus, with the participation of 80 consumers aged 18 years or older, of both genders, comprising students, staff members, and individuals from outside the institution. Regarding consumer profile, 51.3 % were male (n = 41), 47.5 % were female (n = 38) and 1.2 % identified themselves with another gender (n = 1). As for age group, most participants were between 18 and 30 years old (72.4 %; n = 58), followed by the 31–40 (10.0 %; n = 8), 41–50 (8.8 %; n = 7), and over-50 (8.8 %; n = 7) age groups.

To evaluate the acceptability of the candies' appearance, aroma, flavor, texture, and overall impression, consumers completed an evaluation form after tasting each sample, using a 9-point mixed structured hedonic scale ranging from 'disliked extremely' (1) to 'liked extremely' (9) (Meilgaard, Civille, & Carr, 1999). Purchase intention was assessed by a 5-point mixed structured purchase intention scale ranging from 1 (certainly would not buy) to 5 (certainly would buy) (Reis & Minim, 2006). The candies, totaling four samples (approximately 2.7 g per candy), were served at room temperature (25 °C) in individual booths under white light. Each sample was coded with three random digits and presented in a balanced manner to minimize the effect of presentation order (Wakeling & Macfie,

1995). All samples were accompanied by water to minimize the effect exerted by one sample on the evaluation of the next.

Physical and chemical analysis

Instrumental color analysis was performed at the Food Analysis Laboratory of IFSULDEMINAS – Machado Campus, L*, a*, and b* values were measured at the center of 20 candies using a Konica Minolta CR-400 colorimeter, with D65 illuminant, a 2° viewing angle, and the CIE L*a*b* color system. Color difference (ΔE*) of the candy formulations containing wormwood essential oil relative to the control was calculated using the formula: $\Delta E^* = [(\Delta L^{*2}) + (\Delta a^{*2}) + (\Delta b^{*2})]^{1/2}$ (Konica Minolta Sensing, 1998).

Chemical analyses were performed at the Nutrition Laboratory, Federal University of Alfenas (UNIFAL-MG). To obtain the ethanolic extracts, the samples were ground and extracted using 80 % ethanol at a 1:20 (w/v) ratio. After stirring for 60 min under refrigeration at 5 ºC, the samples were centrifuged at 7,000 rpm for 15 min at 5 ºC. Supernatants were set aside, and the precipitates were subjected to two re-extractions using a 1:10 (w/v) ratio. After filtration, the reserved ethanolic extracts (supernatants) were pooled and used for the analysis of total phenolic content, total flavonoid content, and antioxidant potential.

Total phenolic contents were determined by UV-Vis spectrophotometry using the Folin-Ciocalteu reagent (Boateng *et al*. 2008). Results were expressed in μg of gallic acid equivalents (GAE) per g. Total flavonoid contents were determined by UV-Vis spectrophotometry, as described by Boateng *et al*. (2008). Results were expressed in μg of catechin equivalents (CE) per g.

Antioxidant potential was determined using the $ABTS^+$ method, as described by Shalaby and Shanab (2013). Scavenging activity of the DPPH radical was determined according to Boateng *et al*. (2008). Both methodologies were modified, adopting a Trolox standard curve to express the results in nmol of Trolox equivalents (TE) per g.

Experimental design and statistical analysis

The experiment was conducted using a completely randomized design, consisting of four treatments (essential oil) with five replicates. Sensory analysis employed a randomized block design with 80 blocks (consumers). Statistical analyses were performed using the Sisvar program (Ferreira, 2011). After the analysis of variance, means were compared using the Scott-Knott test at 5 %.

A frequency histogram was constructed using a spreadsheet to compare the frequency distribution of responses obtained in the purchase intention test between the evaluated formulations.

Results and discussion

Table 1 presents the sensory analysis results of ginger gelatin candies formulated with different amounts of wormwood essential oil (0 mL, 0.1 mL, 0.2 mL, and 0.3 mL).

The gelatin candies formulation with 0 mL (control), 0.1 mL, and 0.2 mL of wormwood essential oil received the highest scores for appearance, demonstrating good visual acceptance by consumers (Table 1). Conversely, the sample with 0.3 mL per formulation obtained a significantly lower score (6.6) compared with the others, indicating a reduced appearance acceptance for this amount of wormwood essential oil. Adding up to 0.2 mL wormwood essential oil did not significantly affect sample appearance (Figure 1), whereas higher amounts can alter characteristics such as color, turbidity, and surface appearance of the candy.

Table 1. Mean values for appearance, aroma, flavor, texture, and overall impression (scores*) of ginger gelatin candies with varying amounts of wormwood essential oil in the formulations. Machado – MG, 2025.

Wormwood essential oil	Appearance	Aroma	Flavor	Texture	Overall impression
0.0 mL	7.0 a	6.3	6.7 a	6.8 a	6.9 a
0.1 mL	6.9 a	6.2	5.9 b	6.6 a	6.2 b
0.2 mL	6.9 a	6.4	6.1 b	6.8 a	6.6 a
0.3 mL	6.6 b	6.2	5.9 b	6.5 b	6.3 b
Ftrat	0.0500	0.6949	0.0004	0.0105	0.0040

Means followed by the same letter, in the column, do not differ from each other as per Scott-Knott test at 5 %. *(9) Liked extremely; (8) Liked very much; (7) Liked moderately; (6) Liked slightly; (5) Neither liked nor disliked; (4) Disliked slightly; (3) Disliked moderately; (2) Disliked very much; (1) Disliked extremely.

Source: authors (2025).

Suman *et al*. (2021) observed that jelly candies containing 3 % ginger powder achieved the highest mean scores for the evaluated attributes, including color (8.0), texture (7.8), flavor (8.4), aroma (8.1), and overall acceptability (8.0) on a nine-point hedonic scale, indicating high acceptance by the tasters. Increasing the ginger concentration to this level contributed positively to developing desirable sensory characteristics. However, higher concentrations like 6 % resulted in lower acceptance, particularly regarding flavor and overall acceptability, likely due to enhanced pungency and spiciness.

Gelatin candies in the present study contained 4.16 % ginger powder on average, a value higher than the 3 % used by Suman *et al*. (2021) who reported high sensory acceptance for this formulation. However, the evaluated formulations of gelatin candies containing different amounts of wormwood essential oil received lower scores (Table 1) than those containing 3 % ginger powder. Such score differences may be related to the amounts of wormwood essential oil and ginger powder used in the formulations.

Figure 1. Ginger gelatin candies with different amounts of wormwood essential oil in the formulations (0 mL, 0.1 mL, 0.2 mL and 0.3 mL). Machado – MG, 2025.



0 mL 0.1 mL 0.2 mL 0.3 mL

Amount of wormwood essential oil

Source: authors (2025).

Regarding aroma, no difference among the four candy formulations (Table 1) indicates that the presence of wormwood essential oil, at the levels used, did not perceptibly affect the aroma profile of the gelatin candies.

Conversely, flavor was the attribute most noticeably affected by the addition of wormwood essential oil. Control candies obtained the highest mean (6.7), significantly higher than the formulations with 0.1 mL (5.9), 0.2 mL (6.1), and 0.3 mL (5.9) (Table 1). This indicates that adding wormwood essential oil, especially at levels of 0.1 mL or higher in the formulation, reduced flavor acceptance, possibly due to its distinctive characteristics which may have overpowered the sweetness and characteristic notes of the ginger. Thus, all gelatin candies containing wormwood essential oil received lower sensory scores than the control (no addition), indicating that the oil imparted distinct flavor characteristics like bitterness and intense herbaceous notes.

Regarding texture, the candy formulations containing 0 mL (control), 0.1 mL, and 0.2 mL of wormwood essential oil did not differ from one another and received better ratings than the one containing 0.3 mL, achieving higher mean scores (Table 1), which influenced the perception of texture. This suggests that larger amounts of essential oil may interfere with the structure of the gelled matrix, altering its consistency and tactile perception.

As for overall impression, the gelatin candy formulations containing 0.2 mL of wormwood essential oil received a mean score statistically equal to that of the control sample, and higher than those of the other candies (Table 1). Formulations with 0.1 mL and 0.3 mL obtained the lowest scores, reinforcing that the overall acceptability of a product depends on a balance between the different sensory attributes.

Other studies on the use of essential oils evinced positive effects on the sensory properties of the products developed. Shukla, Bhise, and Gaikwad (2018) observed that the herbal candy formulation containing 2.5 % ginger essential oil achieved the highest overall acceptability score. But this concentration also resulted in lower scores for color, texture, and mouthfeel attributes when compared with the herbal candy formulated with 2.0 % ginger essential oil. Classified as a spice, ginger is recognized for its distinctive aroma; gingerols and shogaols are the primary pungent compounds found in the rhizomes of fresh and dried ginger, respectively (Semwal *et al*., 2015).

Bartkiene *et al*. (2018) concluded that the formulation of gummy candies containing fermented bovine colostrum (up to 3 %) and thyme essential oil (up to 0.2 %), combined with tangerine or grapefruit essential oil (up to 0.2 %) for flavor masking, resulted in products with suitable textural properties and high sensory acceptability. Duong *et al*. (2025) found that hard candy formulations with 10 μL and 20 μL of ginger essential oil obtained the best overall sensory ratings. Higher amounts of ginger essential oil resulted in an unpleasant taste and a strong acidic flavor, with lower scores for the candies.

Choudhary *et al*. (2024) also found that the use of ginger in beetroot candy formulations showed promising potential for enhancing both sensory and nutritional attributes. According to these same authors, the use of medicinal plants in candy formulations has yielded positive results, enhancing both flavor and medicinal value. Incorporating medicinal plants into candy formulation, particularly the use of ginger with stevia, provided the best results.

Adding 0.2 mL of wormwood essential oil to the gelatin candy formulation represented the limit of sensory acceptability, at which negative effects on acceptance were minimized. Above this amount, increases significantly compromised the product's sensory quality, especially regarding

the overall impression. Notable alternatives to overcome these limitations include application of technologies such as nanoencapsulation and nanoemulsification. Incorporating essential oils into foods is challenging due to their volatility, susceptibility to chemical degradation, strong aroma and flavor, and their cost. Encapsulation can therefore be an effective approach to overcoming some of these disadvantages, as this technique protects the oil, provides for the controlled release of active compounds, and mitigates the intense odors associated with essential oils. Nanoemulsified essential oils can exhibit greater physicochemical stability, a reduced sensory impact on the products into which they are incorporated, and enhanced antimicrobial activity (Pinelli *et al*., 2021; Scapinello *et al*., 2024).

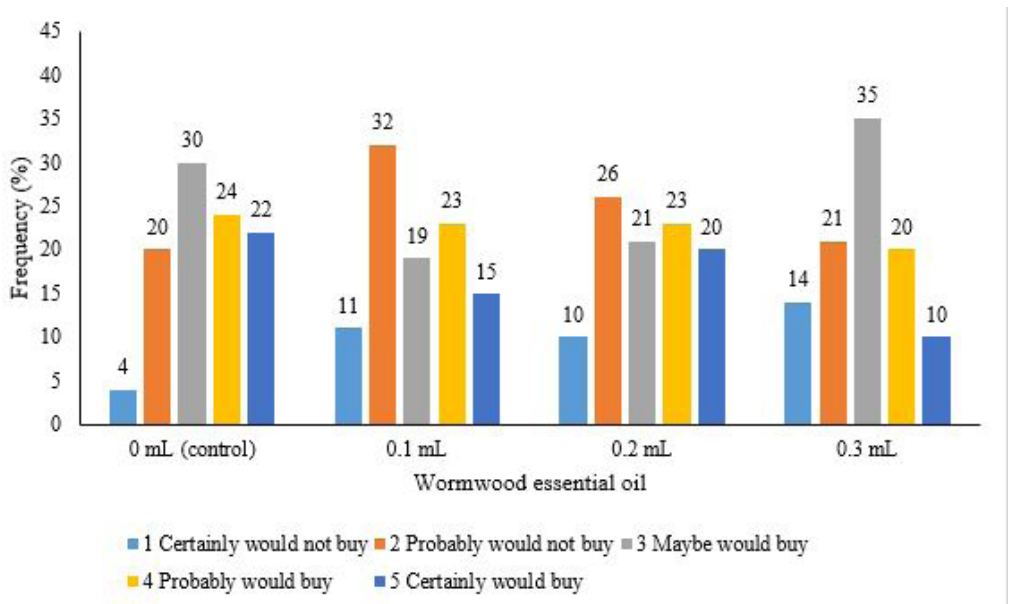
Looking at the frequency distribution histogram of purchase intention responses for ginger gelatin candies containing varying amounts of wormwood essential oil (Figure 2), the formulation containing 0.2 mL achieved the highest positive purchase intention, corresponding to the categories 'certainly would buy' (23 %) and 'probably would buy' (20 %), totaling 43 %, alongside the control candy (46 %). These results are consistent with the higher overall acceptability of the control formulations and the 0.2 mL formulation regarding global impression when compared with the other samples (Figure 2).

Purchase uncertainty regarding the 0.3 mL formulation increased significantly, with 35 % of participants opting for the "maybe would buy" response, alongside a decline in positive purchase intentions. The higher amount of wormwood essential oil compromised the product's overall acceptance.

Similarly, Presente and Schmidt (2016) reported that fresh cheeses produced with ginger and oregano essential oils exhibit a longer shelf life (21 days) and good acceptance by consumers, reflected in the purchase intention. These results reinforce the feasibility of using essential oils to improve both the functional profile and the sensory characteristics of foods.

The purchase intention results thus corroborate the sensory evaluation data, indicating that 0.2 mL formulation is most

Figure 2. Frequency distribution of intention-to-purchase responses for ginger gelatin candies with different amounts of wormwood essential oil in the formulations. Machado – MG, 2025.



Source: authors (2025).

promising from a marketing perspective since incorporating the wormwood essential oil in this amount did not compromise the overall product perception by consumers.

Gelatin candy formulations containing 0 mL (control), 0.1 mL, and 0.2 mL of wormwood essential oil did not differ statistically and presented the highest L* value, i.e., lighter, since this parameter varies from 0 (black) to 100 (white), whereas the 0.3 mL one exhibited the lowest value and was therefore darker than the others (Table 2).

Adding up to 0.2 mL of wormwood essential oil did not alter the L* value of the gelatin candy formulations, thus the L* value of the samples was preserved at these levels. Conversely, the 0.3 mL formulation exhibited a real reduction in the L* value.

Gelatin candy formulations containing 0.3 mL of wormwood essential oil presented significantly higher a* and b* values (Table 2). Thus, a more reddish (a*) and yellowish (b*) coloration is observed compared with the other candies, considering that the a* value indicates chromatic variation from green (negative values) to red (positive values), whereas b* varies from blue (negative values) to yellow (positive values).

Duong *et al*. (2025) observed similar results, reporting L*, a*, and b* values of 35.85 ± 0.07, 7.62 ± 0.26, and 6.71 ± 0.22, respectively, for hard candies formulated with 10 μL of ginger essential oil. Ciurlã *et al*. (2025) also observed that adding plant extract (apple pomace) to jelly candies resulted in a lower L* value compared with the control formulation, indicating product darkening. Additionally, the a* and b* values increased, indicating a more reddish and yellowish coloration, respectively, directly influenced by the color of the extract used. According to the same authors, the increased a* value may be related to the presence of phenolic compounds. Thus, the extract promoted a higher concentration of bioactive compounds and an increase in the antioxidant capacity of the candies, reinforcing their potential as a natural alternative to synthetic additives.

According to the results, the gelatin candy formulations containing ginger and up to 0.2 mL of wormwood essential oil were lighter and less red and yellow, which may be associated with greater appearance acceptability of these samples compared with the 0.3 mL formulation (Table 1).

Regarding ΔE*, the formulations with 0.1 mL and 0.2 mL of wormwood essential oil exhibited values lower than 1 compared with the control, indicating that the color changes were imperceptible to the human eye. Conversely, the ΔE* value for the gelatin candy formulation

Table 2. Mean L*, a*, b* values and color difference (ΔE*) of ginger gelatin candies with different amounts of wormwood essential oil in the formulations. Machado – MG, 2025.

Wormwood essential oil	L* value	a* value	b* value	ΔE*
0.0 mL	37.23 a	4.90 b	9.40 b	-
0.1 mL	37.77 a	4.46 c	9.96 b	0.89
0.2 mL	36.76 a	4.80 b	10.25 b	0.98
0.3 mL	33.47 b	6.31 a	12.25 a	4.92

Means followed by the same letter, in the column, do not differ statistically as per Scott-Knott test at 5 %.
Source: authors (2025).

with 0.3 mL was 4.92, indicating a visually perceptible color difference compared with the control formulation and evincing that higher amounts of essential oil have a more pronounced influence on the product's colorimetric parameters. According to Mokrzycki and Tatol (2011), ΔE* values below 1 are considered imperceptible, whereas values above 2 indicate a perceptible difference.

Thus, the inclusion of 0.3 mL of wormwood essential oil in the formulation compromised the product's visual appearance and acceptance, becoming a limiting factor for the technological application of this amount. This result is corroborated by the sensory analysis (Table 1), in which this formulation exhibited a significant reduction in the mean scores for appearance (6.6) and overall impression (6.3).

Thus, the higher amount of wormwood essential oil used in the formulation influenced the color of the gelatin candies, making them darker, redder, and more yellow than the other formulations (Figure 1). In other words, there was a perceptible change in coloration, which negatively impacted consumers' visual assessment of the product.

Incorporating 0.2 mL of wormwood essential oil into the gelatin candy formulation did not compromise sensory acceptance, yielding results statistically equivalent to the control regarding appearance, texture, and overall impression (Table 1). Similarly, based on the instrumental color analysis results (L*, a*, and b* values), it is evident that the addition of this amount of oil did not result in changes to the sample's color parameters compared with the control (Table 2).

Given that the control formulation and the one containing 0.2 mL of wormwood essential oil stood out in terms of overall impression acceptability (Table 1), both were evaluated for total phenolic and total flavonoid content, as well as antioxidant potential (Table 3). Adding 0.2 mL of wormwood essential oil to the formulation increased total phenolic and total flavonoid contents in the gelatin candies compared with control. Consequently, an increase in antioxidant activity was observed in the $ABTS^{+}$ and DPPH assays, particularly the latter, which showed an increase of approximately 40 % compared with the control without the added wormwood essential oil. Thus, adding 0.2 mL of wormwood essential oil to the ginger gelatin candy formulations resulted in a formulation with satisfactory sensory acceptability, combined with the presence of bioactive compounds and antioxidant properties (Table 3).

According to Szopa *et al*. (2020), wormwood exhibits high antioxidant activity, attributed to the presence of flavonoids and other phenolic compounds. Polyphenols in the plant possess significant reducing properties, capable of neutralizing free radicals through electron donation, thereby preventing the oxidation of biological structures induced by reactive oxygen species. Additionally, a synergistic antioxidant effect is observed among the different plant compounds. According to Suman *et al*. (2021), incorporating ginger into jelly candies led to a significant increase in the total phenolic content and antioxidant activity of the product. Total phenolic content ranged from 6.98 ± 0.11 to 10.32 ± 0.13 mg/100 g in the ginger-containing formulations, whereas the control sample had 4.46 ± 0.12 mg/100 g, highlighting that adding ginger enriched the bioactive compounds. Notably, the phenolic compounds present in ginger play a significant role in the product's antioxidant capacity, reinforcing its potential as a source of bioactive substances with functional properties.

Silveira *et al*. (2025) found that the diet fruit jelly candy containing 11.5 % concentrated orange juice exhibited higher total phenolic content and antioxidant capacity, even after cooking. Moreover, the use of essential oils as

Table 3. Mean values of total phenolic content (μg GAE/g), total flavonoid content (μg CE/g), and antioxidant potential determined by ABTS⁺ and DPPH assays (nmol TE/g) for ginger candies (control) and formulations containing 0.2 mL of wormwood essential oil, as well as the percentage variation relative to the control. Machado – MG, 2025.

Wormwood essential oil	Total phenolic (μg GAE/g)	Total flavonoid (μg CE/g)	Antioxidant potential	
			ABTS⁺ nmol TE/g	DPPH nmol TE/g
0.0 mL	239.99	88.62	2964.14	1300.00
0.2 mL	269.26	92.36	3458.37	1817.10
Variation (%)	+12.20	+4.22	+16.67	+39.78

Source: authors (2025).

functional ingredients in confectionery products can impart not only aroma and flavor but also functional benefits, as reported by Duong *et al*. (2025), in which the combination of propolis and ginger essential oil enhanced the antioxidant activity of honey candy and increased total polyphenol content compared with commercial hard candies.

The increased total phenolic compound levels in the wormwood essential oil-containing formulation may also have directly contributed to enhancing the product's antioxidant capacity. According to Mohammadi *et al*. (2015), total phenolic content is directly related to the antioxidant activity of *A. absinthium*, since samples with a higher phenolic concentration possess a greater capacity for free radical scavenging.

Artemisia species are characterized by their antioxidant, anticancer, antibacterial, and antidiabetic activities, due to their phenolic and flavonoid content. These bioactive compounds eliminate free radicals and reduce oxidative stress, which helps protect against many diseases. In addition to acting as an antibacterial agent, they help prevent cancer, hyperglycemia, and diabetes (El Rabey & Almutairi, 2025).

Incorporating 0.2 mL of wormwood essential oil into gelatin candy formulations represents an innovative strategy for enriching foods with antioxidants, such as bioactive compounds, while offering health benefits. Thus, the addition of natural ingredients to gelatin candies represents a promising alternative for developing new products, aligning with current demands for healthier, natural, and value-added foods.

Conclusion

Of the evaluated formulations, adding 0.2 mL of wormwood essential oil resulted in satisfactory sensory acceptability, increased bioactive compounds (phenolics and flavonoids), and antioxidant activity. Thus, the use of wormwood essential oil as an ingredient, even in small quantities, in producing food products such as candies evinces its ability to impart distinctive sensory characteristics and significant antioxidant activity.

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