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Combining gelatin and kappa-carrageenan improves the texture of *Centella asiatica* extract–vitamin C gummies

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ABSTRACT

Background: *Centella asiatica* extract may support cognitive function as a functional food ingredient, but its bitterness limits its use. Gummies combined with vitamin C offer a convenient dosage form whose quality depends largely on the gelling agent.

Objective: To compare the effects of gelatin alone and in combination with pectin or kappa-carrageenan on the physicochemical quality, safety, and texture profile of *C. asiatica* extract–vitamin C gummies.

Methods: A 30% ethanolic extract of *C. asiatica* herb and 4.5% vitamin C were formulated into four gummies: 20% gelatin (F1), 20% gelatin–1% pectin (F2), 20% gelatin–1% kappa-carrageenan (F3), and 20% gelatin–3% kappa-carrageenan (F4). The gummies were evaluated according to SNI 3547.2:2008 (organoleptic properties, weight uniformity, moisture, ash, pH, reducing sugar, lead, and total plate count) and by texture profile analysis against a commercial product (ANOVA and Duncan's test, $\alpha = 0.05$).

Results: All formulations met the SNI requirements for moisture (12.19–14.54%), ash (2.71–2.90%), reducing sugar (10.96–11.04%), lead (<0.025 mg/kg), and total plate count ($1.0–2.8 \times 10^2$ CFU/g). Adding 1% kappa-carrageenan increased hardness from 283.99 gf (F1) to 571.95 gf (F3), approximately 70% of the hardness of the commercial product. Increasing kappa-carrageenan to 3% (F4) or using pectin (F2) produced softer gels. Chewiness and springiness did not differ significantly among samples.

Conclusion: Combining 20% gelatin with 1% kappa-carrageenan produced *C. asiatica* extract–vitamin C gummies that met the SNI quality requirements and had the texture closest to that of a commercial product, supporting their further development as a functional food.

Keywords: Centella asiatica, gummy candies, kappa-carrageenan, texture profile, vitamin C

Introduction

Aging is often accompanied by cognitive decline, which, if left unaddressed, increases the risk of dementia [1]. Prevention through nutritional interventions and natural products is therefore an attractive strategy. One plant with potential to support cognitive function is *Centella asiatica* (L.) Urb., which contains triterpenoids such as asiaticoside, madecassoside, asiatic acid, and madecassic acid with neuroprotective and antioxidant activities [2,3].

Preclinical studies have shown that *C. asiatica* extract and its major constituents improve antioxidant status, protect mitochondrial function, and enhance memory in animal models [2,3]. However, evidence in humans remains limited. A meta-analysis of randomized controlled trials found no significant differences in cognitive domains compared with placebo, although *C. asiatica* improved alertness and mood without reported

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adverse effects, and the authors emphasized the need for standardized products at appropriate doses [4]. Developing a dosage form that is easy to consume regularly is therefore a relevant first step.

Vitamin C is a water-soluble antioxidant that protects neurons from free radical damage. A systematic review reported an association between higher vitamin C status and better cognitive function [5], and a population-based study in older adults showed a nonlinear dose–response relationship between vitamin C intake and cognitive performance [6]. In formulations, ascorbic acid also imparts a sour taste that is expected to help mask the bitterness of *C. asiatica* extract.

Gummy candies are a popular functional food format because of their soft texture, pleasant taste, and ease of consumption across age groups [7]. Their quality is largely determined by the gelling agent. Gelatin provides the characteristic elasticity, whereas polysaccharides such as pectin and carrageenan are widely used to modify gel strength, texture, and product stability [7,8]. In gelatin–kappa-carrageenan systems, protein–polysaccharide interactions produce a denser and more rigid composite gel network than gelatin alone [9].

Several studies in Indonesia have formulated gummies from natural products, such as *Phyllanthus niruri* herb extract [10], *Hydrilla verticillata* juice [11], papaya seeds [12], and dragon fruit with varying gelatin–carrageenan ratios [13]. For *C. asiatica*, Amaria et al. formulated gummies containing *C. asiatica* herb extract using pectin from green cincau (*Cyclea barbata*) leaves [14]. However, no study has combined *C. asiatica* extract with vitamin C in a gummy formulation and directly compared gelatin alone, gelatin–pectin, and gelatin–kappa-carrageenan at two concentrations in terms of SNI quality requirements and instrumental texture profile relative to a commercial product.

This study aimed to formulate gummies combining *C. asiatica* extract and vitamin C and to compare the effects of gelatin alone and in combination with 1% pectin or 1% and 3% kappa-carrageenan on physicochemical quality, safety (lead and microbial contamination), and texture profile, in order to identify the formulation with the texture closest to that of a commercial product.

Methods

Materials

The materials were *C. asiatica* herb simplicia (dried plant material), vitamin C (ascorbic acid, analytical grade), gelatin, pectin, kappa-carrageenan, potassium sorbate, and citric acid (all food grade, Brataco, Indonesia), Tropicana Slim Gula Buah® sweetener, apple essence (food grade, Kupu-kupu, Indonesia), 30% ethanol, distilled water, and a commercial gummy as the reference product (brand "Y").

Preparation of *C. asiatica* extract

Dried simplicia powder was macerated in 30% ethanol for three days with stirring every 6–8 h. A water–ethanol mixture was chosen because it dissolves triterpenoid glycosides such as asiaticoside [3,15]. The filtrate was filtered stepwise through muslin cloth, and the marc was pressed to maximize filtrate recovery. The filtrate was concentrated in a vacuum dryer (Maksindo VD-12) at 70 °C to obtain a thick extract, and the yield was calculated relative to the dry weight of the simplicia.

Characterization of simplicia and extract

Loss on drying of the simplicia was determined by drying 1 g of simplicia in an oven (Memmert UN 75) at 105 °C to constant weight. The moisture content of the extract was determined gravimetrically in the same manner using 1 g of extract. Total ash of the simplicia and extract was determined by igniting 2 g of sample in a furnace (SNOL 3/1100) at 600 ± 25 °C until completely ashed, cooling it in a desiccator, and weighing it. All tests were performed in duplicate, and the results were compared with the requirements of the Indonesian Herbal Pharmacopoeia: extract yield not less than 7.3%, loss on drying and moisture content less than 10%, and total ash not more than 11.6% for simplicia and 16.6% for extract [16].

Gummy formulation

Four formulations were prepared using 20% gelatin as the base, either alone (F1) or combined with 1% pectin (F2) or 1% (F3) or 3% (F4) kappa-carrageenan (Table 1). Tropicana Slim Gula Buah® was used as a low-calorie sucrose substitute. With an extract content of 2.4% and a unit weight of approximately 2 g, each gummy contained approximately 48 mg of *C. asiatica* extract and 90 mg of vitamin C; a daily intake of four gummies therefore corresponds to approximately 192 mg of extract and 360 mg of vitamin C. Clinical studies of *C. asiatica* have not reported adverse effects at the doses tested [4].

Table 1. Composition of *C. asiatica* extract–vitamin C gummies

Ingredient	Formula (% w/w)			
	F1	F2	F3	F4
C. asiatica extract	2.4	2.4	2.4	2.4
Vitamin C	4.5	4.5	4.5	4.5
Gelatin	20	20	20	20
Pectin	-	1	-	-
Kappa-carrageenan	-	-	1	3
Potassium sorbate	0.5	0.5	0.5	0.5
Citric acid	0.3	0.3	0.3	0.3
Tropicana Slim Gula Buah®	0.1	0.1	0.1	0.1
Apple essence	1	1	1	1
Distilled water to	100	100	100	100

The gummies were prepared by the molding (casting) method [10,17,18]. The *C. asiatica* extract and vitamin C were dissolved in part of the water until homogeneous. Gelatin and the accompanying gelling agent (pectin or carrageenan) were sprinkled into hot water at approximately 50 °C, allowed to swell for 10 min, and stirred until homogeneous. Potassium sorbate, citric acid, and the sweetener were dissolved separately and added to the gel base, followed by the extract–vitamin C solution and the apple essence. The mass was poured into silicone molds and left at room temperature for 24 h to set.

Quality evaluation of the gummies

Quality was evaluated according to SNI 3547.2:2008 [19]. Unless otherwise stated, each test was performed in duplicate.

Organoleptic properties. The shape, color, odor, taste, and texture of the gummies were assessed visually and sensorially [11].

Weight uniformity. Twenty gummies were weighed individually, and the mean weight and coefficient of variation were calculated. The requirement was met if no more than two gummies deviated by >5% and none deviated by >10% from the mean weight [20].

Moisture and ash content. Moisture content was determined gravimetrically by oven drying at 105 °C to constant weight. Ash content was determined by ignition in a furnace at 600 ± 25 °C. The maximum limits for moisture and ash were 20% and 3%, respectively [19].

pH. The pH of the gel mass was measured with a pH meter (Eutech PH 150) before the mass was poured into the molds.

Reducing sugar. Reducing sugar content was determined by the Luff–Schoorl method. The sample was extracted with distilled water, clarified, reacted with Luff–Schoorl solution, and boiled. After addition of KI and H_2SO_4, the solution was titrated with $Na_2S_2O_3$ using starch as an indicator. The maximum limit for reducing sugar was 25% [19].

Lead contamination. Samples were dry-ashed at approximately 500 °C until white ash was obtained, dissolved in HCl, and analyzed for lead by atomic absorption spectrophotometry at 217 nm [21]. The maximum limit for lead was 2.0 mg/kg [19].

Total plate count (TPC). Samples were serially diluted in buffered peptone water, inoculated onto plate count agar, and incubated at 35 ± 1 °C for 48 h. Counts were expressed as colony-forming units per gram (CFU/g), with a maximum limit of 5×10^4 CFU/g [19].

Texture profile analysis. Texture was measured using a texture analyzer (CT3, Brookfield AMETEK) with a TA4/1000 probe. Hardness (gf), chewiness (mJ), gumminess (gf), and springiness (mm) were recorded. A commercial gummy (brand "Y") was used as the reference.

Data analysis

Data are presented as mean ± standard deviation. Texture profile data were analyzed using one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at $\alpha = 0.05$ when significant differences were found.



Figure 1. Powdered *C. asiatica* herb simplicia used as the raw material for extraction

Table 2. Characteristics of *C. asiatica* simplicia and extract

Sample	Loss on drying ± SD (%)	Moisture ± SD (%)	Total ash ± SD (%)
Simplicia	8.62 ± 1.18	-	4.54 ± 1.35
Extract	-	4.81 ± 0.47	3.17 ± 1.45

Table 3. Organoleptic properties of the gummies

Parameter	F1	F2	F3	F4
Shape				
Taste	Sweet	Sweet	Sweet	Sweet
Color	Dark green	Dark green	Dark green	Dark green
Texture	Very chewy	Slightly chewy	Chewy	Chewy
Odor	Apple	Apple	Apple	Apple

Results

Extract yield and characteristics

Maceration of the *C. asiatica* simplicia (Figure 1) produced a dark green, bitter, aromatic thick extract with a yield of 23%. The characteristics of the simplicia and extract are presented in Table 2. Loss on drying of the simplicia (8.62 ± 1.18%) and the moisture content of the extract (4.81 ± 0.47%) were below 10%, and the total ash of the simplicia (4.54 ± 1.35%) and extract (3.17 ± 1.45%) were below the limits of the Indonesian Herbal Pharmacopoeia.

Organoleptic properties

All four formulations had a uniform shape, dark green color, sweet taste, and apple odor (Table 3). The gummies were darker than the extract. The formulations differed in texture: F1 was very chewy, F3 and F4 were chewy, and F2 was slightly chewy.

Weight uniformity

The mean gummy weight ranged from 1.92 g (F2) to 2.20 g (F1), with coefficients of variation of 2.27–2.83% (Table 4). All formulations met the weight uniformity requirement, and their weights were comparable to that of the reference gummy (approximately 2 g).

Moisture and ash content

Moisture content ranged from 12.19 ± 1.62% (F3) to 14.54 ± 1.09% (F2), and ash content ranged from 2.71 ± 0.21% (F3) to 2.90 ± 0.05% (F2) (Table 5). All formulations met the maximum limits for moisture (20%) and ash (3%). The formulations containing kappa-carrageenan (F3 and F4) had lower moisture contents than F1 and F2.

Table 4. Weight uniformity of the gummies

Formula	Weight range (g)	Mean (g)	CV (%)
F1 gelatin (20)	2.1075-2.2905	2.20	2.27
F2 gelatin:pectin (20:1)	1.8130-2.0184	1.92	2.60
F3 gelatin:carrageenan (20:1)	1.9984-2.2598	2.12	2.83
F4 gelatin:carrageenan (20:3)	1.9566-2.1590	2.02	2.47

Table 5. Moisture and ash content of the gummies

Formula	Moisture (%) ± SD	Ash (%) ± SD
F1 gelatin (20)	13.67 ± 1.00	2.85 ± 0.04
F2 gelatin:pectin (20:1)	14.54 ± 1.09	2.90 ± 0.05
F3 gelatin:carrageenan (20:1)	12.19 ± 1.62	2.71 ± 0.21
F4 gelatin:carrageenan (20:3)	12.88 ± 1.15	2.78 ± 0.01

Table 6. pH and reducing sugar content of the gummies

Formula	pH ± SD	Reducing sugar (%)
F1 gelatin (20)	4.95 ± 0.02	11.04
F2 gelatin:pectin (20:1)	4.86 ± 0.03	10.96
F3 gelatin:carrageenan (20:1)	4.66 ± 0.04	10.98
F4 gelatin:carrageenan (20:3)	4.74 ± 0.05	11.02

Table 7. Lead contamination and total plate count of the gummies

Formula	Lead (mg/kg)	TPC (CFU/g)
F1 gelatin (20)	<0.025	1.0×10^2
F2 gelatin:pectin (20:1)	<0.025	2.8×10^2
F3 gelatin:carrageenan (20:1)	<0.025	1.45×10^2
F4 gelatin:carrageenan (20:3)	<0.025	1.4×10^2

Table 8. Texture profile of the gummies

Formula	Hardness (gf)	Chewiness (mJ)	Gumminess (gf)	Springiness (mm)
F1	283.99^{b}	7.41^{a}	270.59^{a}	2.65^{a}
F2	198.53^{a}	6.34^{a}	158.21^{a}	2.74^{a}
F3	571.95^{d}	8.66^{a}	445.02^{a}	2.73^{a}
F4	387.74^{c}	7.98^{a}	331.39^{ab}	2.75^{a}
Reference (brand “Y”)	818.52^{e}	12.31^{a}	675.14^{b}	2.71^{a}

Values with the same superscript letter within a column are not significantly different (Duncan's test, $p > 0.05$).

pH and reducing sugar

All formulations were acidic, with pH values ranging from 4.66 ± 0.04 (F3) to 4.95 ± 0.02 (F1) (Table 6). Reducing sugar content was nearly identical across formulations (10.96–11.04%) and below the maximum limit of 25%.

Lead contamination and total plate count

Lead levels in all formulations were below the limit of quantitation of the method (<0.025 mg/kg). The TPC ranged from 1.0×10^2 CFU/g (F1) to 2.8×10^2 CFU/g (F2) (Table 7). Both parameters met the SNI limits.

Texture profile

The type and concentration of the gelling agent significantly affected hardness ($p < 0.05$; Table 8). Hardness decreased in the order F3 (571.95 gf) > F4 (387.74 gf) > F1 (283.99 gf) > F2 (198.53 gf), and all formulations were softer than the reference product (818.52 gf). The hardness of F3 was approximately 70% of that of the reference product. Gumminess did not differ significantly among F1–F4 (158.21–445.02 gf), although F1–F3 differed from the reference product (675.14 gf). Chewiness (6.34–8.66 mJ for the test formulations; 12.31 mJ for the reference) and springiness (2.65–2.75 mm) did not differ significantly among samples.

Discussion

This study showed that all four *C. asiatica* extract–vitamin C gummy formulations met the SNI quality requirements for all parameters tested, but that the type and concentration of the accompanying gelling agent strongly determined their texture. Combining 20% gelatin with 1% kappa-carrageenan (F3) doubled the hardness relative to gelatin alone and produced the texture closest to that of the commercial product. In contrast, increasing kappa-carrageenan to 3% reduced hardness, and the combination with pectin produced the softest gel with the highest moisture content and TPC.

The raw material met the requirements of the Indonesian Herbal Pharmacopoeia [16]. The extract yield (23%) far exceeded the minimum of 7.3%. This high yield can be explained by the stepwise filtration and pressing of the marc, which maximized filtrate recovery, and by the use of 30% ethanol, whose high water content also dissolves inactive polar compounds. A loss on drying and moisture content below 10% are important because low water content minimizes degradation of active compounds and microbial growth during storage [16,22].

Adding 1% kappa-carrageenan more than doubled the hardness of the gelatin gel (F3 vs. F1). This finding is consistent with Makarova et al., who showed that kappa-carrageenan–gelatin composite gels have a much higher density of polymer chains than gelatin gels because of increased protein–polysaccharide intermolecular contacts, making the gel more rigid [9]. The same study also reported that the composite gel was more brittle [9]. This property may explain the lower hardness of F4: at 3% kappa-carrageenan, larger polysaccharide aggregates may form a less homogeneous network that fractures more easily under compression, particularly because the carrageenan was dispersed at approximately 50 °C and may not have been fully hydrated. Conversely, the gelatin–pectin combination (F2) produced the lowest hardness. Pectin gelation requires specific conditions, namely high soluble solids and low pH for high-methoxyl pectin, or calcium ions for low-methoxyl pectin [7,8]. Because this formulation contained almost no sugar (0.1% sweetener) and no added calcium salt, neither mechanism was adequately fulfilled. Under these conditions, pectin likely acted as a thickener that diluted the gelatin network rather than as a gelling agent.

The absence of significant differences in chewiness and springiness indicates that gel elasticity was governed mainly by gelatin, whose concentration was the same in all formulations. Gumminess is the product of hardness and cohesiveness and therefore tends to follow the hardness pattern [23]; F3 had the highest gumminess among the test formulations, although the difference was not significant. With a hardness of approximately 70% of that of the reference product, F3 remained softer than the commercial gummy; optimizing the gelatin–kappa-carrageenan ratio within 1–2% carrageenan or increasing the gelatin concentration should therefore be explored to bring its texture closer to the reference.

The lower moisture content of the kappa-carrageenan formulations is consistent with their denser composite gel network [9], which restricts free water within the matrix. Conversely, F2, which had the weakest gel network, had the highest moisture content and TPC, in line with the principle that greater water availability supports microbial growth [7]. Nevertheless,

all values were well below the SNI limits [19]. The relatively uniform ash content (2.71–2.90%) reflects mineral contributions from the extract, potassium sorbate, and gelatin, which were present in equal amounts in all formulations, whereas lead levels below the limit of quantitation indicate that neither the raw materials nor the production process were significant sources of lead contamination.

The acidic pH of the gummies (4.66–4.95) was mainly attributable to the 4.5% vitamin C and the citric acid in the formulation. Acidic conditions are advantageous because they inhibit microbial growth and improve the stability of ascorbic acid [7]. The reducing sugar content of approximately 11% was relatively high for formulations containing only 0.1% sweetener. In addition to a possible contribution of sugars from the extract, ascorbic acid is a reducing agent that may also reduce the Luff–Schoorl reagent and increase the measured reducing sugar value. Because the values were nearly identical across formulations, the gelling agent variation did not affect reducing sugar content. The darker color of the gummies compared with the extract can be explained by the conversion of chlorophyll to pheophytin, which is accelerated by heating under acidic conditions [24], and by nonenzymatic browning involving ascorbic acid.

Compared with an earlier *C. asiatica* extract gummy that used pectin from green cincau leaves [14], this study shows that kappa-carrageenan is a more effective accompanying gelling agent than pectin in a low-sugar gelatin system. This is relevant to the development of low-sugar functional gummies, because pectin cannot gel optimally without high soluble solids or calcium ions [7,8].

This study has several limitations. First, the vitamin C and asiaticoside contents of the final product were not determined, so the stability of both active ingredients after heating remains unknown. Second, storage stability and consumer acceptance were not evaluated. Third, the physicochemical tests were performed in duplicate, and other SNI microbiological parameters (coliforms, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella*, and yeasts and molds) were not tested. Future studies should determine the content and stability of vitamin C and asiaticoside in the product, conduct stability and consumer acceptance tests with ethical approval, and optimize the gelatin–kappa-carrageenan ratio.

Conclusion

All four *C. asiatica* extract–vitamin C gummy formulations met the SNI 3547.2:2008 requirements for weight uniformity, moisture, ash, reducing sugar, lead, and total plate count. The type and concentration of the accompanying gelling agent determined the texture of the gummies. Combining 20% gelatin with 1% kappa-carrageenan produced the highest hardness (571.95 gf) and the texture closest to that of the commercial product, whereas increasing kappa-carrageenan to 3% or replacing it with 1% pectin reduced gel hardness. This formulation is recommended for further development as a functional food once the content and stability of vitamin C and asiaticoside in the product have been established.

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Conflict of interest

The authors declare no conflicts of interest in this study.

Author contributions

ER: conceptualization, methodology, supervision, project administration, and writing – review and editing. BLS: methodology, validation, supervision, and writing – review and editing. FRA: investigation (extraction, formulation, and testing), data curation, formal analysis, visualization, and writing – original draft. All authors have read and approved the final manuscript.

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