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Original Research Article

Tablet Development of Cemcem (*Spondias pinnata* (L.f) Kurz): Primojel® Variation and Assessment of Antioxidant Properties

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ABSTRACT

Oxidative stress is a major contributor to degenerative diseases. *Spondias pinnata* (L.f.) Kurz, commonly known as the Indian hog plum, is locally called *Cemcem* by the Balinese. *Loloh cemcem*, a traditional Balinese herbal drink, is rich in phenolics, tannins, vitamin C, and flavonoids, and is believed to possess antioxidant properties. Due to its high water content and limited stability, developing *Cemcem* leaf extract (CLE) tablets offer a more practical alternative. This study aimed to determine the optimal concentration of Primojel® as a disintegrant and evaluate the antioxidant activity of CLE tablets. Primojel® was tested at 2% (F1), 4% (F2), and 6% (F3). Evaluations included granule (moisture, flowability) and tablet properties (appearance, weight uniformity, friability, disintegration time, hardness). The optimal formula (F3) was reformulated with 2% and 5% CLE (F4 and F5), and antioxidant activity was measured using the DPPH assay, expressed as Ascorbic Acid Equivalent Antioxidant Capacity (AEAC). F3 showed ideal physical characteristics: friability (0.71%), disintegration time within acceptable limits, and appropriate hardness (5.77 kg). In contrast, F1 was too hard (8.58 kg), F2 was too soft (3.63 kg) and unstable over time. Antioxidant activity of F4 and F5 was 83.54 ± 0.29 and 170.78 ± 5.71 mg AEAC/100 g, respectively. A 6% Primojel® concentration produced CLE tablets with optimal physical properties and antioxidant potential. These findings support future research to optimize formulation components, enhancing efficacy and stability.

Keywords: Antioxidant, Primojel®, *Spondias Pinnata* Leaf Extract, Tablet.

Introduction

Oxidative stress, caused by excessive exposure to free radicals, is a major contributor to the development of degenerative diseases.[1] According to data from the Thematic Report of the 2023 Indonesian Health Survey, degenerative diseases are the leading cause of death in the country.[2] Many of these conditions, including stroke, coronary heart disease, diabetes mellitus, cancer, and chronic respiratory diseases, are closely linked to chronic oxidative stress, which damages cells and tissues.[3] Oxidative stress occurs due to an imbalance between the body's pro-oxidants (free radicals) and antioxidants. This imbalance can be triggered by two main conditions: insufficient antioxidant defences and excessive free radical production.[4] In everyday life, exposure to free radicals is common and originates from endogenous (internal metabolic processes) and exogenous (external environmental factors) sources.[5] If there are excess free radicals in the body, it can cause oxidative stress, which ultimately has the potential to cause oxidative damage at the cellular and tissue level.[1]

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The human body cannot handle the large number of radicals formed due to the absence of excess antioxidant reserves, so exogenous antioxidants are needed. Natural antioxidants are a much-needed alternative due to the possibility of unknown side effects of synthetic antioxidants.[6,7] Many studies have shown that some plants and fruits have the potential to protect against the threat of free radicals to the human body.[8–11] Indonesia is a tropical country that has many types of plants. The high diversity of these plant types produces various health benefits, including antioxidant properties. Bali is one of the regions in Indonesia that uses a lot of traditional medicine. Traditional medicine is expected to improve the quality of life of the community by helping to revitalise body cells to reduce the possibility of illness. In Bali, traditional medicine, *loloh*, is still the drink that keeps the body fresh. One of the *lolohs* widely circulated in the market is the typical "loloh don cemcem" of Penglipuran Village, which is believed to be a drink that relieves heat and can make the body feel fresher.[12–14] This effect is related to a large amount of phenolic compound content, especially flavonoids, in *Cemcem* leaves (*Spondias pinnata* (L.f) Kurz), which is responsible for free radical scavenging activity with an IC_{50} concentration of ethanol extract of 33.15 µg/mL, which is categorised as very strong.[15,16] This shows the great potential of *Cemcem* leaves as a natural source of antioxidants. However, *loloh* preparations have physical stability problems because high moisture content can cause preparations to change physical quality during storage. A study reported that the traditional *loloh* beverage exhibits flavour, colour, and aroma instability due to variations in raw materials, production processes, and formulation precision.[17] Its shelf life is limited to 24–48 hours, with notable sensory changes including colour alteration, sedimentation, bubble formation, and increased acidity occurring within 3–4 hours at room temperature. Colour instability is particularly challenging when using *Cemcem* leaves, a typical Balinese plant. This study addresses this issue by formulating *Cemcem* leaf extract into tablet preparations to enhance public interest in practical natural medicinal products. Tablets

offer several advantages, including practicality, efficiency, improved dosage accuracy, cost-effectiveness, and superior physical stability compared to other dosage forms.[18]

The main excipients in tablet formulations include fillers, binders, disintegrants, lubricants, and glidants.[19] The main excipient functions are to facilitate the mass of drug preparation, to facilitate the process of making or improving the dissolution of active substances, and to produce quality products. Therefore, to get a good physical quality of *cemcem* leaf tablets, this formulation's concentration of Primojel® (Sodium Starch Glycolate) as a disintegrant agent is varied. Primojel® is a super disintegrant with a mechanism of rapid water absorption followed by rapid swelling to work effectively in low concentrations. In addition, the efficiency of Primojel® is not affected by the presence of hydrophobic excipients such as lubricant, and stable even though it is very hygroscopic.[20] The incorporation of Primojel® as a disintegrant in tablet formulations is intended to enhance the disintegration rate of the dosage form, thereby accelerating drug dissolution and improving the absorption of the active substance. Varying Primojel® concentrations optimises the tablet's physical quality and maximises patient therapeutic effects.

Historically, excipients in drug development were primarily viewed for their role in enhancing drug solubility, facilitating manufacturing, and regulating drug release both in vitro and in vivo, as determined through dissolution testing. However, increasing evidence reveals that excipients may impact physiological processes, including gastrointestinal transit time, intestinal permeability, active transport mechanisms, and pre-systemic metabolism once deemed biologically inert.[21] Different types or varying amounts of excipients between formulations may cause discrepancies in pharmacological responses, potentially leading to significant differences in clinical outcomes.[22]

Some studies have been conducted on *Cemcem* (*Spondias pinnata*) with regard to its potential benefits for diabetes,[23] regarding its antibacterial activity,[24,25] hepatoprotective activity,[26] antioxidant activity,[16,24,27] and also formulated into gel preparations as burn wound healing.[28] However, a literature review over the past decade reveals an absence of studies evaluating the antioxidant activity of *Cemcem* leaf extract formulated in tablet dosage form, particularly as a preparation with high stability and practical use. Therefore, this study's initial objective was to formulate tablets containing *Cemcem* leaf extract (CLE) using the optimal concentration of Primojel®, aiming to achieve tablets with superior physical quality. Subsequently, the study assessed the antioxidant capacity of the CLE tablets to determine whether the formulation meets its intended purpose as an alternative source of antioxidants.

Materials and Methods

Materials

The plant material used in the study was *Cemcem* leaves (*Spondias pinnata* (L.f) Kurz) collected from Penglipuran Village (8.42227°S, 115.35980°E), Bangli Regency, in January 2022, and identified under Identification No: ID 27881. Materials for qualitative flavonoid testing included 70% ethanol, concentrated hydrochloric acid, and magnesium powder (all sourced from PT. Brataco, Indonesia). The additives include maltodextrin (DE 10-12, Subur Kimia Jaya, Indonesia), lactose monohydrate (30320-Lactose-Edible-200M-25 KG FB, Grade A, Dairy Road & Hwy 49), Primojel® (Sigachi Industries LTD.), PVP and magnesium stearate (Fadjar Kimia, Bogor), and talc (PT. Karunia Sejahtera Abadi, Bali, Indonesia).

Preparation and extraction of plant material.

Fresh *Cemcem* (*Spondias pinnata* (L.f) Kurz) leaves were collected from Penglipuran Tourism Village, Bangli, Bali, residential areas. Botanical identification was conducted at the Indonesian Institute of Sciences, Characterisation Laboratory, Eka Karya Botanical Garden, Bali National Research and Innovation Agency, to confirm plant identity and prevent potential errors in the research.[29] Fresh *Cemcem* leaves were thoroughly washed under running water to remove impurities and then drained to remove excess moisture. The cleaned leaves were oven-dried (MEMMERT GmbH+Co., KG, Germany) at 50°C for 24 hours. Following drying, the leaves were ground using a blender and sieved through a 60-mesh sieve (Standard Test Sieve, CV. Total Equipment Pharmacy, Indonesia) to produce a fine powder. The resulting *Cemcem* leaf powder was stored in airtight containers until used for extraction.

Dried *Cemcem* leaf powder (40 g) was mixed with 400 mL of 70% ethanol in a beaker. The mixture was subjected to ultrasonic-assisted maceration using Elmasonic® S 40 H (Hans Schmidbauer GmbH & Co. KG, Germany) for three cycles of 3 minutes each, with intermittent stirring. This maceration process was repeated twice using the same procedure. The resulting extract was filtered using filter paper, and the filtrate was concentrated using a rotary evaporator (BUCHI R-300) at 40°C[10] and 100 rpm. The extract yield was calculated using the formula:[30]

$$Extract\ yield\ (\%) = \frac{weight\ of\ crude\ extract\ (g)}{weight\ of\ dried\ powder\ (g)} x100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Flavonoid qualitative test

Qualitative identification of flavonoids was conducted by dissolving 0.5 g of concentrated *Cemcem* leaf extract in 5 mL of distilled water and heating the solution for 5 minutes. The mixture was then filtered, and the filtrate was combined with 0.1 g of magnesium powder and 1 mL of concentrated hydrochloric acid, followed by vigorous shaking. The appearance of red, yellow, or orange colouration confirmed the presence of flavonoids.[31]

Formulation and production of Cemcem Leaf Extract (CLE) Tablets

CLE tablets were prepared by wet granulation using the formulation in Table 1, following the procedure of Rahmatullah *et al*.[32] with some modifications. Lactose and maltodextrin were weighed using a 500 g scale (ACIS BC) and blended until homogeneous.

Table 1: CLE Tablet Formulas with Varying Concentrations of Primojel®

Ingredients	Concentration (%)			Function	Phase
	F1	F2	F3		
CLE	2	2	2	Active ingredient	Internal phase
Polyvinylpyrrolidone	2	2	2	Binder	
Ethanol 70%	q.s*	q.s*	q.s*	Binder solvent	
Maltodextrin	5	5	5	Binder	
Lactose monohydrate	87.5	85.5	83.5	Filler	
Primojel®	2	4	6	Disintegrant	External phase
Magnesium stearate	0.5	0.5	0.5	Lubricant	
Talc	1	1	1	Glidant; anti-adherent	

*q.s. (*quantum sufficiat*) means "a sufficient quantity"; in this context, the amount of binder solvent is adjusted as needed to achieve a kneadable mass in the internal phase.

Polyvinylpyrrolidone (PVP) was dissolved in 70% ethanol, and the Cemcem leaf ethanol extract was incorporated into this solution. The dry powder blend was gradually moistened with the PVP-extract solution to form a kneadable mass, passed through a 12-mesh sieve (Standard Test Sieve, CV. Total Equipment Pharmacy, Indonesia), and dried at 45 ± 2°C for 15 minutes. Semi-dry granules were sieved through a 16-mesh sieve (Standard Test Sieve, CV. Total Equipment Pharmacy, Indonesia) and dried to a 1–5% moisture content. The dried granules were weighed, mixed with Primojel® (disintegrant), magnesium stearate, and talc in specified proportions, and homogenised. Granules were evaluated for moisture content, compressibility, and flowability and then compressed into 500 mg tablets. The tablets were assessed for organoleptic properties, weight uniformity, friability, disintegration time, and hardness.

Physical quality tests of CLE granules
Before proceeding to compression, the granules were subjected to physical quality evaluations to ensure their suitability for tablet compression. These evaluations included tests for moisture content, flow properties, and compressibility, each conducted triplicate.

Moisture Content
Approximately 3 g of CLE granules were placed on the moisture analyser plate (MB90, Ohaus Corporation) and heated at 105°C until a constant weight was achieved. Measurements were recorded once the device stabilised.[33]

Flow Properties and Compressibility
For flow rate determination, 100 g (W) of CLE granules were poured into a flow tester (CV. Mitra Medika Utama Solo, Indonesia), and the time taken for complete flow was recorded (T). The angle of repose (α) was calculated by measuring the base diameter, the radius (r), and the pile height (h) formed.[33,34]

$$Flow\ rate = \frac{W}{T} \quad \text{..... (2)}$$

$$\tan \alpha = \frac{h}{r} \quad \text{..... (3)}$$

To assess compressibility, 40–50 g of granules were poured into a 100 mL graduated cylinder (Pyrex), tilted at a 45° angle, levelled, and the bulk volume (V_0) was measured. The cylinder was then tapped up to 500 times to determine the tapped volume (V_f).[34–36] The compressibility percentage of the CLE granules was determined using Carr's index, which directly measures the potential strength and stability of granule arch formation or bridging.[37]

$$Compressibility\ index\ (\%) = 100\ x\ [\frac{V_0 - V_f}{V_0}] \quad \text{..... (4)}$$

CLE tablet physical quality tests
Following the physical quality evaluation of the CLE granules, the granules were compressed into tablets, each with a target weight of 500 mg. After compression, the tablets were evaluated for physical quality on days 1, 14, and 28, including the following tests.

Organoleptic test
The physical characteristics of the CLE tablets, including aroma, taste, colour, and overall appearance, were assessed.[38] The observed tablet shape encompassed measurements of diameter and thickness.

Weight uniformity test
A total of 20 tablets were weighed using an analytical balance (Ohaus Pioneer PA 224C) and simultaneously to determine the average tablet weight. Subsequently, each tablet was weighed, and its weight was recorded. The deviation of each tablet's weight from the average weight was then calculated.[39,40]

Disintegration time test
The disintegration tester (BJ-3, Flight Pharmaceutical Machinery Co. Limited) was activated, and the temperature was adjusted to 37°C ± 2°C. Approximately 800 mL of distilled water was added to the vessel to ensure complete submersion of the six disintegration test tubes. One tablet was placed into each tube, and a disc was positioned over each tablet. The timer was set for 15 minutes, and the apparatus was operated to allow the tubes to move vertically. During this period, all tablets were expected to disintegrate completely. For research purposes, the disintegration time for each tablet was recorded and measured from the top of the tube.[40,41]

Friability test
A total of 20 tablets were cleaned of dust and weighed to determine their initial mass, (W_0). The tablets were then placed in a rolling and impact durability tester (CS-0, UniLab, California), set to rotate at 25 rpm for 4 minutes. After the apparatus stopped, the tablets were cleaned of dust once more, reweighed (W_f). The weight loss percentage before and after the test was calculated.[40,42]

$$Friability\ (\%) = 100\ x\ [\frac{W_0 - W_f}{W_0}] \quad \text{..... (5)}$$

Hardness test
A total of 20 tablets were selected, and the tablet hardness tester (Graigar YD-1, Mitra Medika, Solo, Indonesia) was switched on by pressing the on button. A tablet was placed horizontally in the centre of the tester, and the screw was turned forward until the tablet broke and the tester emitted a sound. The hardness of the tablet was displayed in kilograms (kg) on the screen at the moment of breakage.[42]

CLE tablets were subsequently reformulated with varying extract concentrations
The optimal concentration of Primojel® was determined by evaluating the physical quality of the CLE tablets, aiming to obtain tablets exhibiting the best physical characteristics. Based on the identified optimal formulation, CLE tablets were subsequently reformulated using varying extract concentrations of 2% (F4) and 5% (F5). The tablets were prepared via the wet granulation method,[32] following the composition outlined in Table 2.

Table 2: CLE Tablet Formulation with Varying CLE Concentrations

Ingredients	Concentration (%)		Function	Phase
	F1	F2		
CLE	2	5	Active ingredient	Internal phase
Polyvinylpyrrolidone	2	2	Binder	
Ethanol 70%	q.s*	q.s*	Binder solvent	
Maltodextrin	5	5	Binder	
Lactose monohydrate	83.5	80.5	Filler	
Primojel®	6	6	Disintegrant	External phase
Magnesium stearate	0.5	0.5	Lubricant	
Talc	1	1	Glidant; anti-adherent	

* q.s. (*quantum sufficiat*) means "a sufficient quantity"; in this context, the amount of binder solvent is adjusted as needed to achieve a kneadable mass in the internal phase

Evaluation of the antioxidant capacity of CLE tablets
A stock solution of DPPH was prepared by weighing 0.0039 grams of DPPH powder into a 100 mL volumetric flask, dissolving it with methanol up to the mark, and homogenising the solution. The maximum wavelength (λ_{max}) of DPPH was determined by pipetting 4 mL of the stock solution, incubating it in a closed container for 30 minutes, and scanning the absorbance from 400–800 nm. A stock solution of vitamin C at a concentration of 100 ppm was prepared by weighing 5 mg of vitamin C, dissolving it in methanol in a 50 mL volumetric flask, and mixing until homogeneous. Serial dilutions of the vitamin C standard were prepared by pipetting 0.5, 1, 1.5, 2, and 2.5 mL of the stock solution into separate 10 mL volumetric flasks, diluting each with methanol to 10 mL, and homogenising to obtain concentrations of 5, 10, 15, 20, and 25 ppm, respectively. For the sample preparation, 0.5

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grams of powdered CLE tablets were weighed and dissolved in 25 mL of methanol (PA) in a volumetric flask, homogenised, and centrifuged (centrifuge 800-1, Yescom, China) at 3500 rpm for 10 minutes. The supernatant was then filtered to obtain a clear filtrate. The absorbance of the vitamin C standards and the CLE tablets samples were measured using a UV-Vis double-beam spectrophotometer (Shimadzu UV-1800®). Each standard solution (0.5 mL) was pipetted into a test tube, mixed with 3.5 mL of the DPPH stock solution, incubated for 30 minutes, and the absorbance was measured at the predetermined λ_{max}. Similarly, 0.5 mL of each sample solution was mixed with 3.5 mL of DPPH solution, incubated, and measured. As a control, 3.5 mL of DPPH solution was mixed with 0.5 mL of methanol and incubated for the same period.[43] Measurements were performed in triplicate to ensure accuracy and reliability.

Data Analysis

The data from the physical quality tests of the granules and tablets were analysed in comparison with the requirements outlined in various references, including Indonesian Pharmacopoeia, 6th edition,[41] and guidelines issued by relevant authorities specified in this article to conclude the physical quality of the granules and tablets. Furthermore, statistical analysis of the data was conducted using basic statistical methods, including the calculation of the mean and standard deviation (SD).[10]

The antioxidant capacity of the CLE tablets was calculated based on their equivalence to vitamin C and expressed as the ascorbic acid equivalent antioxidant capacity (AEAC) in mg AEAC/100 g. This calculation utilised the standard calibration curve equation, represented by y = ax + b. The formula for determining AEAC[44] is as follows:

$$AEAC = \frac{C \times V}{W} \quad (6)$$

Where:

AEAC = the ascorbic acid equivalent antioxidant capacity (mg ascorbic acid/ g sample)

C = concentration of Vitamin C equivalent (mg/ml) obtained from the standard curve corresponding to the sample's absorbance (x value, from y = ax + b)

V = volume of the extract solution used (ml)

W = weight of the extracted sample (g)

Results and Discussion

The identification results confirmed that the plant species used is *Spondias pinnata* (L.f) Kurz (ID No. 27881). This identification test aimed to verify the accuracy of the plant's identity to ensure it aligns with the species desired by the researchers, thereby minimising the possibility of errors in material collection for subsequent research stages.[29]

The ultrasonic-assisted maceration extraction yielded 51.3 g of crude extract (18.32%). This yield is higher than that reported by Azizah *et al*.,[45] which involved extracting *Cemcem* leaves through maceration for three days, yielding 5.10%. Applying ultrasonic waves enhances the solvent's penetration through the cell membrane, leading to a higher production of secondary metabolites and an increased extract yield compared to traditional methods like maceration.[46]

A qualitative test was performed to identify flavonoids in the CLE, recognising them as secondary metabolites that contribute to numerous medicinal properties, including antioxidant activity.[11,31] The results indicated that CLE tested positive for flavonoids, as evidenced by the appearance of an orange colour. The addition of magnesium powder and concentrated hydrochloric acid aimed to reduce the benzopyrone core in the flavonoid structure, forming a red or orange flavylium salt.[47]

The focus of secondary metabolite identification was limited to flavonoids, given their well-established contribution to the antioxidant potential of plant extracts. Flavonoids effectively scavenge free radicals, reducing oxidative stress and contributing to the protective effects against cellular damage.[11,48]

All physical quality tests of the granules were conducted in triplicate for each formulation on day 0, immediately after the granules were prepared. Three tests were performed: moisture content, compressibility, and flowability tests. The moisture content test results for the granules indicated that all formulations met the criteria for good granule moisture content, falling within the range of 1-5%,[35] where the average moisture content of the CLE granules ranged from 1.41% to 1.58% (Table 3). A study conducted by Andriani *et al*.,[36] which utilised leaf extract as the active ingredient in a granule formulation similar to this study, reported a moisture content ranging from 3.30% to 4.11%. This higher moisture content is likely due to the higher concentration of extract used (35%), whereas the formulation in this study only incorporated 2% and 5% of *Cemcem* leaf extract. Therefore, the moisture content of the CLE granules in this study is lower than that of other similar studies. Granules that are too moist may exhibit poor flowability and cause adhesion to the die walls, while excessively dry granules can produce brittle tablets with minimal hardness.[49] The flow properties of the CLE granules were further assessed by measuring the flow rate and angle of repose. The flow rate measurements indicate that all granules' formulations exhibit free-flowing granules, with flow rates exceeding 10 grams per second (Table 3). These results are consistent with the study by Pratama *et al*.,[33] which reported that all five granule formulations derived from pomegranate peel extract exhibited flow rates exceeding 10 g/s. The angle of repose measurements also reveal that all formulations fall within the 'good' flowability category.[37] The study by Pratama *et al*. also reported similar angles of repose, ranging from 23.03 to 28.07 degrees, which are consistent with the results of this study.[33] Notably, the angle of repose is inversely proportional to the flow rate; as the flow rate increases, the angle of repose decreases, resulting in granules that flow freely through the hopper nozzle.[50]

Table 3: Physical Quality Tests Results of CLE Granules

Characteristic	Formula (Mean ± SD)			Standard
	F1	F2	F3	
Moisture content (%)	1.58 ± 0.16	1.41 ± 0.33	1.51 ± 0.17	1-5% [35]
Flow rate (g/s)	17.50 ± 0.40	12.70 ± 0.09	15.12 ± 0.29	10 g/s < [33]
Angle of repose (°)	32.09 ± 0.71	33.25 ± 1.58	32.53 ± 0.64	25-35° [37]
Compressibility Index (%)	21.51 ± 2.56	28.17 ± 1.43	23.99 ± 0.81	1-20% [37]

The compressibility test results, presented in Table 3, indicate that formulations F1 and F3 have compressibility index values of 21.51% and 23.99%, respectively, categorising them as having 'fair' flowability. This suggests that while the granules can flow, they do so less efficiently than those classified as having 'good' or 'excellent' flowability. Formulation F2, with a compressibility index of 28.17%, falls into the 'poor' flowability category, although it remains capable of flowing under vibration.[37] A compressibility index below 10% indicates excellent flow properties, while values exceeding 38% indicate very poor flowability.[34] The compressibility index values of the granules are influenced by the presence of irregularly shaped particles, which generate void spaces filled with air between the particles.[51] Excessively low moisture content can adversely affect the flowability of granules. Granules with very low moisture levels exhibit poor flow due to increased dustiness, higher interparticle friction, and a greater likelihood of electrostatic charging. In the absence of adequate moisture, the natural lubricating effect between particles diminishes, resulting in increased resistance to flow. Moreover, low moisture levels can render granules more brittle, forming fines and promoting particle segregation, further disrupting uniform and efficient flow.[37] Therefore, while moisture control is critical to prevent agglomeration, overly dry granules may compromise flowability. This is evident in the findings of this study, where formulation F2, which had the lowest moisture content (1.41%), demonstrated the poorest flow characteristics, indicated by the lowest flow rate, highest angle of repose, and highest compressibility

index among the three formulations.

Subsequent tests on the physical quality of the CLE tablets included organoleptic evaluation, weight uniformity, disintegration time, and friability over a 28-day storage period (days 0, 14, and 28) and tablet hardness testing only on day 28. The organoleptic test results for all formulas indicate a round shape with a diameter of 1.2 cm and a thickness of 0.4 cm, a characteristic extract aroma, and a bitter taste that is not adhesive. Tablet F1 is light brown with speckles, Tablet F2 is light brown without speckles, and Tablet F3 is light brown with some speckles. According to the study by Fadhilah & Saryanti,[52] brown speckles on tablets are attributed to using natural materials, which may cause speckling and result in a less attractive tablet colour. The speckles on the tablets may also be due to differences in colour between the active ingredient and excipients, leading to the migration of the active ingredient during the drying process.[53]

The weight uniformity test results indicate that all tablet formulas meet the weight uniformity requirements. For tablets with an average weight greater than 300 mg, the criteria are that no tablet deviates by more than 10% from the average weight and no more than 2 tablets deviate by more than 5% from the average weight.[39] Weight uniformity is related to dose accuracy; if tablets meet the weight uniformity criteria, patients are expected to receive the intended therapeutic effect.[54] The flow rate of granules in F2 was the slowest among the other formulations, which affected the amount of granule mass flowing for compression, ultimately leading to differences in tablet weight.[54,55]

The friability test results for the Cemcem leaf extract tablets, as shown in Table 4, indicate that F1 and F3 meet the friability criteria over 28 days of storage, with values ranging from 0.71% to 0.95%. Meanwhile, F2 meets the friability criteria (<1%) on day 0 with a value of 0.33% but does not meet the criteria on days 14 and 28, with values ranging from 1.20% to 1.26%. The increased friability is attributed to using a tablet press in the laboratory, which resulted in 'whiskering' at the tablet edges, and the pressure during storage (using airtight plastic) likely contributed to the higher friability percentage.

Table 4: Results of the CLE Tablet Friability Test

Formula	Friability (%)		
	Day 0	Day 14	Day 28
F1	0.71	0.91	0.92
F2	0.33	1.20	1.26
F3	0.75	0.93	0.95

The disintegration time test results for CLE tablets, as shown in Table 5, indicate that all formulas meet the disintegration time requirement of no more than 15 minutes over 28 days of storage.[41] The results of the disintegration time test also demonstrated that an increase in the concentration of Primojel® resulted in a reduction in the disintegration time of the granules. Primojel® functions as a super disintegrant by facilitating rapid absorption of water, which is then rapidly absorbed and swells in the tablet, thereby facilitating its disintegration when in contact with liquid media.[56] Increasing tablet compression pressure, related to tablet hardness, does not affect the disintegration time of tablets that use Primojel® as a disintegrant.[20] This is consistent with the study by Adriana,[57] which found that increasing the use of Explotab® accelerates the tablet disintegration time.

The tablet hardness test results for CLE tablets on day 28 showed that the average hardness for formula F1 was 8.58 kgF, for formula F2 was 3.63 kgF, and for formula F3 was 5.77 kgF, within the range of 3.63 kg to 8.58 kg. These results indicate that the average hardness of F3 meets the requirements, whereas F2 does not meet the criteria as it falls outside the 4-10 kg range.[38] The differences in hardness may be attributed to the properties of the compressed materials.[58]

Table 5: CLE Tablet Disintegration Time Test Results

Formula	Disintegration Time (second) (Mean ± SD)		
	Day 0	Day 14	Day 28
F1	222.00 ± 22.00	259.67 ± 40.72	277.67 ± 13.41
F2	187.00 ± 23.84	200.67 ± 23.79	247.33 ± 19.06
F3	169.50 ± 7.37	183.00 ± 13.64	185.33 ± 11.86

Although the punch force during compression was the same for all formulas because the tablet press was standardised, F2, produced from granules with the slowest flow rate among the formulations, resulted in tablets with higher porosity and minimal hardness. This is evident from the fact that while the thickness of all tablet formulas is the same, F2 has the lowest weight, indicating that it is more porous. The physical quality evaluation of the granules indicated that formulation F2 exhibited the poorest characteristics among the three. Granules with suboptimal properties typically produce tablets of inferior quality. Consequently, the CLE tablets from formulation F2 demonstrated the worst physical characteristics compared to the other two formulations. Based on the results of the physical quality tests, it can be concluded that the 6% Primojel® concentration in formula F3 produced tablets of Cemcem leaf (*Spondias pinnata* (L.f) Kurz) extract with the best physical quality and stability during 28 days of storage at room temperature. Subsequently, formula F3 was reformulated into formulas F4 and F5 with varying concentrations of Cemcem leaf extract as the active ingredient, specifically 2% and 5%, respectively. The results of the F4 and F5 CLE tablets can be seen in Figure 1. The CLE tablets with extract concentrations of 2% (F4) and 5% (F5) exhibit slight colour differences. The colour variation was attributed to the differing extract concentrations; the F4 tablets with a higher extract concentration were pale yellow, whereas the F5 tablets with a lower concentration had a yellowish-white colour. Both F4 and F5 tablets were of the same shape, being flat and round, and had a distinctive *Cemcem* leaf odour.

Figure 1: CLE Tablets Formulated with Extract Concentrations of 2% (a) and 5% (b)

The antioxidant capacity was analysed using the DPPH method. When the sample reacts with DPPH free radicals, a hydrogen atom transfer occurs, stabilising the DPPH.[59] A dark purple colour is exhibited by the free radical DPPH, which contains unstable nitrogen compounds, and this colour changes to yellow upon reduction by antioxidant compounds.[60] The advantages of the DPPH method are its simplicity, speed, sensitivity, and the minimal sample quantity required for analysis.[61,62] The AEAC (Ascorbic Acid Equivalent Antioxidant Capacity) expresses the antioxidant capacity test.[63] Vitamin C was used as a standard in measuring antioxidant capacity because it is a secondary antioxidant that can scavenge free radicals and prevent chain reactions.[64,65] The standard curve for vitamin C was generated by analysing the antioxidant activity of ascorbic acid using the same method applied to the sample, specifically the DPPH method. The linear

regression equation obtained from the vitamin C standard curve was y = -0.0196x + 0.9168, with an R^2 value of 0.9737. The antioxidant capacity tests, expressed in AEAC as vitamin C equivalents, showed different results for each tablet formulation. The antioxidant capacity of the F4 CLE tablet was 83.537±0.29 mg AEAC/100 g tablet. In other words, every 100 g of Cemcem leaf extract tablets has an antioxidant capacity equivalent to 83.537±0.29 mg of vitamin C. Meanwhile, the antioxidant capacity of the F5 CLE tablet was 170.782±5.71 mg AEAC/100 g tablet (Figure 2).

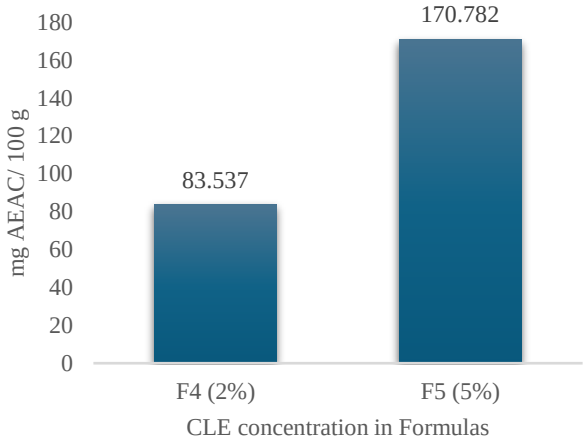

Figure 2: Antioxidant Capacity (mg AEAC / 100 g) of F4 and F5 CLE Tablets

The daily requirement for vitamin C ranges between 40 mg and 200 mg.[66] The need for vitamin C can increase 300% to 500% in cases of infections, neoplastic diseases, post-surgery or trauma, hyperthyroidism, pregnancy, lactation, and when used as an antioxidant.[66,67] The antioxidant capacity results were relatively low, expressed as vitamin C equivalents. Several factors, including the granulation process, tablet compression, and storage conditions, may influence this. According to the study by Najihudin *et al*.,[68], the IC_{50} value of Tahongai leaf extract was 37.339 ppm, categorising it as having strong antioxidant capacity. In contrast, the antioxidant activity of instant granules made from Tahongai leaf extract showed an IC_{50} value above 140-150 ppm, which falls into the moderate to weak category. Further, the antioxidant activity of the same formulation measured on day 28 showed an IC_{50} value above 170 ppm, classified as weak. This indicates a decrease in antioxidant activity when transitioning from extract to instant granule form. This study observed a similar trend in the ethanol extract tablets of *Cemcem* leaves. This reduction in antioxidant activity could be attributed to several factors, including the formulation process and drying process,[69] storage conditions,[70] and exposure of the active compounds to light.[71,72] Additionally, interactions between excipients and the extract as the active ingredient may affect its dissolution rate, and the relatively low extract concentrations of 2% and 5% in the CLE tablets are also suspected to influence their antioxidant capacity.

Conclusion

The study reveals that the F3 formulation produced CLE tablets with the best physical quality at a 6% Primojel® concentration. Additionally, an increase in extract concentration correlated with an increase in the antioxidant capacity of the CLE tablets. These findings lay the groundwork for future research focused on optimizing active and inactive components to improve therapeutic efficacy and stability. Further studies may include advanced formulation strategies, long-term stability testing, and in vivo evaluations to establish pharmacological potential and clinical relevance.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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