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Enhancing Anthocyanin Butterfly Pea Stability using Encapsulation: A Scoping Review of Coating Materials and Techniques

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LITERATURE REVIEW

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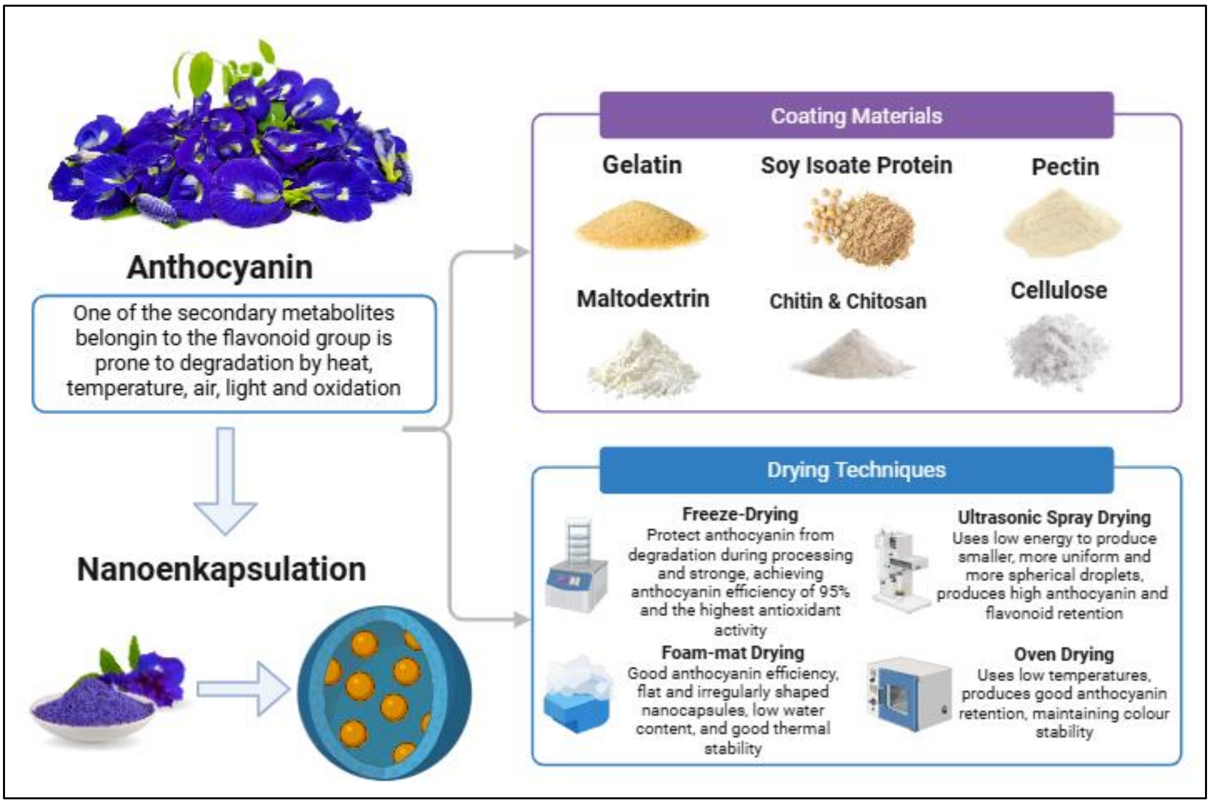
ABSTRACT

Butterfly pea flowers are rich in anthocyanin and have therapeutic benefits, particularly due to their antioxidant properties. However, their use in the food and pharmaceutical industries is still limited due to their low stability in environmental conditions, which causes degradation, decreased stability and bioavailability. Nanoencapsulation is a potential method for improving the stability and effectiveness of anthocyanin. This review aims to identify various coating materials and encapsulation techniques used to protect anthocyanin in butterfly pea flowers, as well as to evaluate their effects on the final product's stability, characteristics, and physicochemical properties. Literature search were conducted through PubMed, ScienceDirect, Scopus, and SpringerLink using structured keywords, following the inclusion criteria based on the Population, Concept, Context (PCC) framework and the PRISMA-ScR protocol. A total 7 published articles met the inclusion criteria. The results show that combination gelatin with coating materials such as pectin or maltodextrin was effective and commonly used. The use combination of gelatin+pectin or gelatin+maltodextrin with freeze drying is capable of forming a strong film, binding anthocyanin, stabilising colour, and proceting anthocyanin from degradation due to its low-temperature process, resulting in high encapsulation efficiency, high retention, and good morphology and particele size. In conclusion, no ideal coating material and encapsulation techniques. Further in vivo bioavailability studies are warranted to evaluate the most promising combinations, gelatin + pectin or gelatin + maltodextrin with freeze drying.

Key Messages:

- The selection of coating materials and drying techniques should consider stability, bioactivity, characteristics, and physicochemical properties of anthocyanin.
- The combination of gelatin with pectin or maltodextrin, using freeze drying, was the most reported approach because of high encapsulation efficiency, retention, and good morphology and particle size.

GRAPHICAL ABSTRACT



INTRODUCTION

Butterfly pea flower (*Clitoria ternatea*) is a well-known herbal plant due to its high anthocyanin content. These water-soluble flavonoid compounds, which have a diphenylpropane ($C_6C_3C_6$) structure, are responsible for their bright blue, purple, and red colours. More importantly, these compounds provide various therapeutic benefits, including anti-obesity, anti-diabetic, anti-cholesterol, anti-inflammatory, antioxidant, anti-convulsant, and memory improvement (1,2). The anthocyanin content in butterfly pea flowers, has been reported to prevent weight gain by reducing the expression of adipogenic genes and activating lipase hormones in preadipocyte cells incubated with 500-1,000 µg of butterfly pea flower for 24 hours (3). In addition, supplementation rich anthocyanins, cyaniding and delphinidin in rats fed a high-fat diet has been reported to reduce the adverse effects of obesity, dyslipidemia and insulin resistance through the inhibition of inflammation, oxidative stress, NF -κB/JNK activation, as well as inhibiting pancreatic lipase, lipid absorption, and modulating incretin for glucose and lipid balance (4). Due to this dual functionality as a natural dye and a bioactive compound, anthocyanins in butterfly pea flowers hold significant potential for applications in the functional food and pharmaceutical industries (5).

In general, anthocyanins are unstable. Their stability is highly degradable due to various factors, including chemical structure, pH, temperature, air, light, oxygen, solvents, co-pigments, metal ions, and enzymes (6). This vulnerability leads to rapid loss of anthocyanin content, colour, biological activity, and overall quality during storage and processing, resulting in low stability and bioavailability and limiting their effective utilization (7). A study encapsulated butterfly pea flower powder using maltodextrin at a low drying temperature of 70°C, which was able to maintain the anthocyanin content, with the highest anthocyanin content (47.36 mg/g) and maintain the colour stability of anthocyanin brightness (52) (8). address these challenges, encapsulation strategies, particularly nanoencapsulation, have emerged as a highly promising solution.

One approach that has been widely researched is nanoencapsulation. Nanoencapsulation is a process of coating solid, liquid, enzymes, microorganisms, and minerals into nanoparticles with a diameter of 1-100 nm. This technology aims to protect bioactive compounds from degradation, increase stability and

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solubility, reduce nutrient loss, extend shelf life, and improve organoleptic properties (9,10). For unstable and degradation-prone bioactive compounds such as anthocyanin, nanoencapsulation of anthocyanin using biopolymers such as maltodextrin, chitin, gelatin, chitosan, monoglycerides, and isolate whey protein using various encapsulation techniques such as freeze-drying, foam-mat drying, and ultrasonic spray drying have proven to be critical techniques for maintaining their integrity and functionality (7,11). Bioactive compounds such as anthocyanin is highly susceptible to degradation or oxidation during processing and storage, resulting in poor stability and bioavailability. Therefore, in recent years, the food industry has utilized several techniques to protect them; in this case, nanoencapsulation proved to be a promising alternative (7).

The effectiveness of nanoencapsulation depends on the choice of coating material and drying method used. Biopolymers such as maltodextrin, chitin, gelatin, cellulose, and pectin are often used as coating materials due to their ability to significantly increase the stability of phenolic compounds, one of which is anthocyanin (9). Polysaccharides are used as encapsulation coating materials because they can be degraded by gut microbiota, allowing for targeted release in the colon and potentially providing a prebiotic effect (12). In addition, the selection of the appropriate encapsulation method, such as freeze-drying, spray-drying, or oven drying critically affects the encapsulation efficiency, particle morphology, and colour stability and antioxidant activity of the final product (9).

Given the vast array of available coating materials and encapsulation techniques, there is an pressing need to identify the most optimal combinations specifically for anthocyanin in butterfly pea flowers. Therefore, this scoping review aims to systematically identify various coating materials and encapsulation techniques used to protect anthocyanins in butterfly pea flowers and evaluate their effect on the stability and physicochemical properties.

METHODS

Study Design

This scoping review systematically aims to identify various coating materials (maltodextrin, gelatin, cellulose, chitin, chitosan, pectin, and soy isolate protein) and encapsulation techniques (freeze drying, spray drying, foam drying, oven drying) used to protect anthocyanin in butterfly pea flowers and evaluate their effect on the stability, characteristics, and physicochemical properties of the final product. This study gathered information from previous research that provided a comprehensive overview of how various coating materials and encapsulation techniques affect the anthocyanin content, stability, characteristics, and physicochemical properties of anthocyanin in butterfly pea flowers. This scoping review uses the framework from Arksey and O'Malley (13). Reporting in this study was based on the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) protocol (Figure 1) (14).

The research question was based on the PCC (Population, Concept, Context) approach:

- P (Population): Anthocyanin in Butterfly Pea Flowers
- C (Concept): The use of coating materials (maltodextrin, gelatin, cellulose, chitin, chitosan, pectin, and soy isolate protein) and encapsulation techniques (freeze drying, spray drying, foam drying, oven drying).
- C (Context) : Protection of anthocyanin, stability, characteristics, and physicochemical properties (anthocyanin encapsulation efficiency, anthocyanin retention, particle size, and morphology) of encapsulated anthocyanin in butterfly pea flowers.

Search Strategy and Eligibility Criteria

Relevant articles were retrieved from several scientific databases, such as PubMed, Science Direct, Scopus, and Springer Link. The articles published within the last 5 years (2020-2025). This five-year period was selected to capture the most recent advances and innovations in encapsulation technology, particularly focusing on developments in coating materials and optimization of relevant drying techniques. The search strategy utilized Boolean operators (AND, OR) to combine keywords effectively (15). The keywords used included: (*Clitoria ternatea* OR butterfly pea flower) AND (anthocyanin OR delphinidin)

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AND (encapsulation OR nanoencapsulation) AND (maltodextrin OR gelatin OR chitosan OR soy protein isolate OR pectin OR cellulose OR chitin) AND (spray drying OR freeze drying OR foam mat drying OR oven drying).

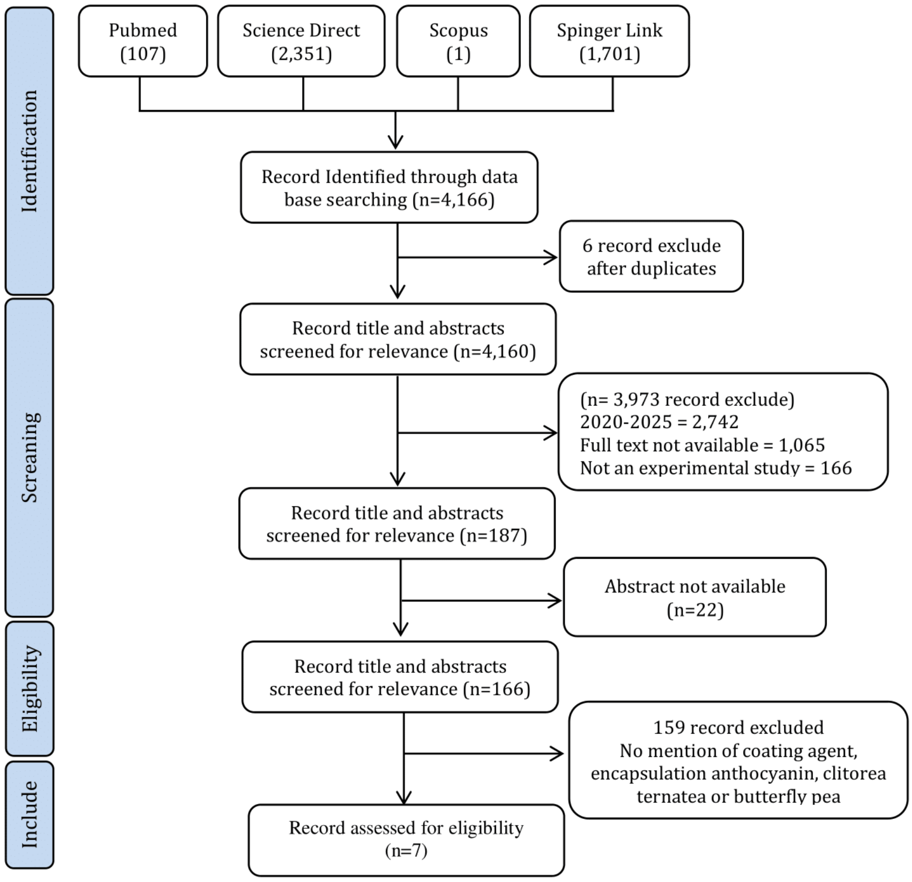

Figure 1. PRISMA-ScR diagram for study selection

All identified articles were imported into a reference manager (Mendeley) and duplicates were removed. The inclusion criteria were: a) original research articles; b) articles published within the last 5 years (2020-2025); c) articles written in Indonesian or English; d) full-text availability; e) studies investigating butterfly pea flower (*Clitoria ternatea*); f) studies utilizing one or more specified coating materials (maltodextrin, gelatin, chitosan, chitin, pectin, or soy protein isolate); g) studies employing one or more encapsulation techniques (spray drying, freeze drying, foam mat drying, or oven drying); h) studies reporting outcomes related to the content, stability, characteristics, or physicochemical properties of encapsulated anthocyanin. The exclusion criteria include: a) studies not specifically analyzing anthocyanin in butterfly pea flowers; b) studies not involving encapsulation processes with the specified coating materials and drying techniques; c) non-original research articles such as literature reviews, scoping reviews, book reviews, or conference proceedings.

Data Extraction and Analysis

Data extraction was carried out systematically using a standardized data extraction form. The information presented in the extraction table included: (a) author(s), year of publication, and country of study; (b) methods used (type of coating material and drying technique employed); (c) the role of the coating material in the encapsulation process and results; and (d) encapsulation or nanoencapsulation characteristics (encapsulation efficiency, anthocyanin content and retention, antioxidant capacity, anthocyanin stability during storage, particle size, particle morphology, and other physicochemical properties). The PRISMA-ScR flow diagram (Figure 1) illustrated the study selection process. The obtained

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data were synthesized and presented qualitatively in narrative and tabular forms to summarize key findings and identify patterns and inconsistencies across the included studies.

RESULTS

A total of 4,166 research articles were initially identified through database searches. After removing duplicates and screening titles and abstracts, 166 articles were selected for full-text review. Following the inclusion and exclusion criteria, 7 studies were included in the final analysis. The selected studies were published between 2020-2025 and investigated various coating materials used either individually or in combination, and drying techniques effective for protect and maintain the stability of anthocyanin, as well as their effects on the characteristics and physicochemical properties of anthocyanin in butterfly pea flowers.

Table 1. Summary of the Role of Various Coating Materials and Encapsulation Techniques on the Stability of Anthocyanin in Butterfly Pea Flowers

No	Authors/ Year/ Country	Method		Functional coating material	Encapsulation/ nanoparticle characterization
		Coating material	Drying method		
1	Maneeratanachot *et al.*, (2024) Thailand	Maltodextrin and Monoglycerides	Foam mat drying T 60°C. 70°C, 80°C	Maltodextrin stabilises the shape, helps protect and retain the anthocyanin. Monoglycerides: increase foam porosity, shorten foam base drying time, and improve preservative and storage properties.	Anthocyanin retention: 210 mg/100 grams Encapsulation efficiency of 98% Morphology: flat, irregular shape, relatively smooth surface Particle size: 50 x 10^4 nm Thermal stability: good thermal stability (temperature 70°C).
2	Narayanan *et al.,* (2023) India	film packaging made from gelatin/pectin with the addition of butterfly pea flower anthocyanin extract	Freeze drying T -80°C	Gelatin: the main film-forming component, forms a film, and supports the incorporation of anthocyanin. Pectin: helps increase the binding capacity of anthocyanin and improves shape stability.of the film	Anthocyanin retention: 198.3 mg/100 gram of extract Particle size: 50 x 10^4 nm Morphology: indicates chemical incorporation of anthocyanin into the film matrix → more stable and smoother, even distribution. Colour stability: stable blue colour Thermal stability: stable at low temperatures.
3	Liew *et al.,* (2020) Malaysia	Gelatin	1. Ultrasonic spray drying: Feed rate 3 mL/min, T 100 °C 2. oven konvenksi : 2 hours , T 80°C . 3. freeze drying : 24 jam, T -80 °C	Creating stable capsules with high efficiency, good morphological structure, and increased antioxidant and antimicrobial activity.	Anthocyanin retention: highest ultrasonic spray drying (1.58±0.14 mg/100 g), freeze drying (0.78±0.01 mg/100 g) Anthocyanin efficiency: Highest freeze-drying (efficiency value 95.75%). Morphology: Microencapsulation (freeze-drying) shows a fibrillar structure Particle size: Freeze-drying 0.2–0.7 × 10^6 nm) Colour stability: Stable blue

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No	Authors/ Year/ Country	Method		Functional coating material	Encapsulation/ nanoparticle characterization
		Coating material	Drying method		
4	Lyn *et al.,* (2024) Malaysia	Gelatin	4. Ultrasonic spray drying, T 50°C, 24 hours	The main film-forming ingredient creates a flexible and transparent film structure, helping to protect anthocyanins from oxidative and light degradation during processing and storage, maintains colour stability and preserves bioactive activity and physical structure.	Total phenolics: 100 mg GAE/100g. Colour stability: stable based on pH, stable at pH ±7, changes rapidly when acidic/alkaline. Thermal stability: thermal stability improves at low temperatures, below 40°C. Morphology: produces a thick and sturdy film.
5	Koshy *et al.,* (2022) India	packaging film of soy protein isolate and chitin nano wish (CNW)	5. Casting dan Oven konveksi T 55°C	Soy protein isolate is a strong barrier and film-forming agent with excellent film-forming properties. CNW helps control the film's hygroscopic properties and water vapour penetration, reducing cracks and improving mechanical stability.	Anthocyanin: 20.66 mg C3G-eq/100 gram; Particle size: 10–50 nm. Morphology: needle-like with a crystallinity index of 99.67%. Thermal stability: decreasing degradation → low-temperature drying (55°C). Anthocyanin retention: good, even distribution. Colour stability: stable at pH ±7; changes rapidly in acidic/alkaline conditions.
6	Hailu *et al.,* (2025) South Africa	Selulosa-kitosan	Oven 6. T 60°C, 1 hour	Cellulose-chitosan forms a stable, strong, and biodegradable film matrix, which can help protect anthocyanin from degradation.	Anthocyanin: butterfly pea flower 58.39 ± 11.81 mg/100 g. Colour stability: stable in cold and dark storage. Particle size: 10-50 nm. Morphology: smooth, dense, and homogeneous film surface, with even distribution of anthocyanin particles.
7	Punbusayakul *et al.,* (2025) Thailand	Gelatin	Oven konveksi, T 50°C, 48 hours	As a strong film former, stable capsule matrix, protects anthocyanins from degradation, controls film flexibility, maintains colour stability against pH changes. Gelatin forms a fragile film without the addition of plasticisers or other substances.	Colour stability: stable blue-green colour, transmission value exceeds 80%. Thermal stability: colour stable at low temperatures (48–100 °C), protein loss (250–300 °C). Solubility: decreases. Morphology: smooth and dense on the surface, without large pores.

Articles Characterization

A total of 7 research articles were included in this review, which examine suitable coating materials for wrapping anthocyanin in butterfly pea flowers. Seven related articles were published by Maneeratanachot *et al.*, (2024), Narayanan *et al.,* (2023), Lyn *et al.,* (2024), Koshy *et al.,* (2022), Hailu *et al.,* (2025), Liew *et al.,* (2020), and Punbusayakul *et al.,* (2025). The author found several studies from various countries based on research conducted in Thailand (n=2), India (n=2), Malaysia (n=2), and South Africa (n=1). All findings were conducted in Asia, but none have been made in Indonesia. Seven subjections were

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used to analyse the results: author, year, country, coating material, drying method, functional coating materials, and encapsulation or nanoparticle characterization.

The article shows the function and roles of various types of coating materials used either individually or in combinations to protect and maintain the stability of anthocyanin in butterfly pea flowers using using various methodologies such as freeze drying, foam mat drying, ultrasonic spray drying, and convection oven drying techniques. The study's findings indicate that there is no ideal coating material and drying technique for protecting and maintaining the stability and physicochemical properties of anthocyanins based on encapsulation efficiency, retention, morphology, and particle size Based on these findings, using gelatin coating combined with other coating materials, such as maltodextrin, using the freeze drying method is effective and commonly used. The findings are summarized and presented in detail in Table 1.

Various Coating Materials for the Characteristic of Anthocyanin in Butterfly Pea Flowers

Of the seven articles obtained, no coating material was identified as ideal for protecting and maintaining anthocyanin stability and physicochemical properties based on encapsulation efficiency, retention, morphology, and particle size. Therefore, a combination of coating materials is necessary to achieve optimal protection. Various coating materials reported in the literature show diverse results in term of the characteristics and physicochemical properties of the resulting capsules. Regarding encapsulation efficiency, the maltodextrin + monoglyceride combination produced an encapsulation efficiency of (98%) with good thermal stability at low temperatures (16). Gelatin produced an encapsulation efficiency of (≥95%), demonstrating excellent performance in effectively encapsulating the core material compared to other combinations (17). Regarding encapsulation efficiency, the combination of maltodextrin + monoglyceride is better than gelatin. Regarding anthocyanin retention, the gelatin + pectin combination showed high retention (198.3 mg) in a stable nano formulation (18). Meanwhile, the cellulose + chitosan combination produced anthocyanin retention (58.39 mg) (19). The SPI + chitin combination reported a retention value of (20.66 mg) (20). Conversely, the use of gelatin reported a lower retention value (0.78 mg) in a stable nano size (17), which could potentially provide a less practical option for maximising anthocyanin protection. Regarding anthocyanin retention, combination gelatin + pectin performed better than other coating materials, individually or in combination. Regarding morphology and particle size, using gelatin to encapsulate anthocyanins produced microcapsules with a fibrillar structure, smooth texture, dense without large pores, and sturdy (16, 17,18). Meanwhile, combinations such as soy protein isolate (SPI) and chitin, as well as gelatin and pectin, are more effective in forming nano-sized particles with a needle-like structure and a very high crystallinity index of 99.67% (20), indicating a highly ordered structure and potentially less porous nature that may affect release kinetics differently compared to the irregular particles from maltodextrin. Gelatin emerged as the most frequently used material of the eight coating materials identified. However, its tendency to form fragile structures highlights that its future application will likely depend on its use in hybrid systems. The selection of the optimal combination ultimately depends on the desired characteristics of the final product. Therefore, it must be combined with other coating materials to achieve more robust results (18). Using gelatin in combination with other coating materials, such as pectin or maltodextrin, effectively protects and maintains the stability and physicochemical properties of anthocyanins, as assessed by encapsulation efficiency, retention, morphology, and size of the encapsulated anthocyanin particles.

Drying Method and Its Effect on the Characteristics of Anthocyanin in Butterfly Pea Flowers Nano capsules

Of the seven articles obtained, no encapsulation technique was identified as ideal for protecting and maintaining anthocyanin stability and physicochemical properties based on encapsulation efficiency, retention, morphology, and particle size. Various encapsulation techniques reported in the literature show diverse results in terms of the characteristics and physicochemical properties of the resulting capsules. Foam mat drying produced an efficiency of 98% with retention of 210 mg/100 g, yielding flat and somewhat irregularly shaped nanocapsules with a relatively smooth surface, low moisture content, and

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good thermal stability, particularly at 70°C (16). Freeze drying at a temperature of -80°C for 24 hours resulted in an anthocyanin efficiency of 95.75%, with anthocyanin retention of 0.78±0.01 mg/100 g with micro particles formed a fibrillar structure, exhibiting a stable blue colour with brightness (17). The freeze-drying method also produces nano-sized particles that form a stable, smooth film structure with even distribution and anthocyanin retention of 198.3 mg (18). Drying using the ultrasonic spray drying method at a temperature of 50°C produces thicker biopolymers as the amount of butterfly pea flower increases, with mechanical strength also increasing. This process also results in colour changes, ranging from pink to blue to green, influenced by the storage temperature (21). Meanwhile, using a temperature of 100°C resulted in anthocyanin retention of 1.58±0.14 mg/100 g. Drying using a combination of casting and convection oven at 55°C produces nano-sized particles with a needle-like shape and a crystallinity index of 99.67%, resulting in good anthocyanin retention, uniform distribution, and reduced colour degradation compared to higher temperatures ≥70°C (20). Drying using an oven at a low temperature (50°C) for 48 hours also resulted in anthocyanin retention of 58.39 mg/L for butterfly pea flowers and 216.75 mg/L for red cabbage, in the form of nano-sized particles with a solid surface, appearing smooth without large pores. Oven drying produces a stable blue-green colour with consistent film thickness and increased tensile strength without cracking (19,22).

The degradation of anthocyanin content is also influenced by temperature. The degradation of anthocyanin content during storage occurs at high temperatures, which can cause the colour to turn brown (21). Low-temperature drying (55°C) can reduce colour degradation in anthocyanins compared to high temperatures. Low temperatures also result in good anthocyanin retention, efficiency, and even distribution (20). Of the five encapsulation techniques used, freeze drying is an effective and common drying method to protect and maintain the stability and physicochemical properties of anthocyanin-based encapsulates, including efficiency, retention, morphology, and particle size.

DISCUSSION

From the findings obtained, using gelatin combined with other coating materials, such as pectin or maltodextrin, with freeze drying is a effective and commonly used approach that results in encapsulation efficiency, high retention, and good particle morphology and size. Compared to other coating materials, gelatin as an encapsulant can maintain the stability of anthocyanins from degradation and produce anthocyanin efficiency ≥95%, resulting in stable physicochemical characteristics and properties with microcapsule and nanocapsule sizes (17,21,22). Gelatin is the most commonly used coating material to protect anthocyanins in butterfly pea flowers. Gelatin is a water-soluble protein produced from collagen hydrolysis (23). Gelatin is a promising biopolymer and is often used in the food, pharmaceutical, photography, and cosmetics industries due to its functional characteristics, such as its ability to bind water, form gels, act as a water vapour barrier, form films, form foams, and improve emulsions in encapsulation, so it is often used as a coating, carrier, and stabiliser in encapsulation techniques (24). The role of gelatin as an anthocyanin coating material in butterfly pea flower extract protects anthocyanins from degradation during processing and storage, maintaining their colour stability and activity, and increasing their bioavailability (17,21). In the context of stability and encapsulation characteristics, gelatin plays an important role in film formation, creating a stable, flexible, and transparent matrix (21).

The limitation of gelatin as a coating agent is that it forms a fragile and weak film without adding softeners or other ingredients, such as maltodextrin and pectin (21). Pectin enhances the ability to bind anthocyanins, thereby improving shape stability (18). Pectin is water-soluble, has good thermal stability, and is resistant to gastric pH and digestive enzyme action, reaching the intestine intact to be fermented by the microbiota. However, pectin has high hydrophilicity, causing it to absorb water and be stable at specific pH levels, so pectin is often combined with other natural polymers, which improve mechanical quality and film barrier properties (25,26). The gelatin-pectin combination shows high retention (198.3 mg) in a stable nano formulation (18). Meanwhile, maltodextrin stabilises the form and helps protect and preserve anthocyanin in butterfly pea flowers (16). Maltodextrin is a good coating material because it is easily soluble, safe, and can protect anthocyanins from oxidation or heat. This results in good encapsulation efficiency (27). Maltodextrin also undergoes rapid dispersion, can form a matrix, maintains colour stability

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from degradation, inhibits crystallisation, has strong binding capacity, and has low viscosity compared to starch. However, maltodextrin has a slow absorption time (8).

The butterfly pea flowers (*Clitorea ternatea*) is a flower plant that is rich in anthocyanin content. Anthocyanin is one of the secondary metabolites included in the flavonoid group and water-soluble pigments. However, anthocyanins are known to be susceptible to damage and have low stability. The stability of anthocyanins is influenced by several factors, one of which is temperature, which can cause anthocyanin degradation, thereby reducing their bioavailability and physical properties during processing and storage (28). The most frequently used drying method for anthocyanin encapsulation in butterfly pea flower extract is freeze drying. Freeze drying is a drying method used to protect bioactive compounds that are sensitive to heat, temperature, and pH of the environment, thereby producing high-quality products with both physical properties and minimal thermal damage to anthocyanin content at low temperatures and under vacuum conditions. Freeze drying is an effective method for encapsulation because it produces the highest encapsulation efficiency and antioxidant activity compared to other drying methods. Encapsulation using the freeze-drying method is more effective in maintaining anthocyanin stability against degradation, producing anthocyanin efficiency of ≥95%. The resulting microcapsules and nanocapsules exhibit smooth surfaces with no large pores, maintaining stable color brightness in a solid form (17,22).

The freeze-drying method is carried out using low temperatures, generally -80℃ (17). High temperatures can accelerate the oxidation process, which can cause anthocyanin degradation, thereby affecting the stability, bioavailability, and physical characteristics of anthocyanins. This is because an increase in high temperatures can alter the equilibrium reaction of anthocyanins, causing the flavylium cation form to transform into a chalcone, which then degrades to a brown compound. In addition, high temperatures can also trigger hydrolysis of the 3-glucose group, changing anthocyanins into less stable anthocyanidins (8). Although effective, freeze drying is expensive, and the process typically takes between 4 -12 hours (5).

CONCLUSION

Using coating materials and encapsulation techniques can impact the stability, characteristics, and physicochemical properties of anthocyanins. Various coating materials have been identified, including gelatin, maltodextrin, chitosan, pectin, monoglycerides, protein isolates, cellulose, and chitin, used individually or in combination. Various encapsulation techniques utilize low temperatures, including freeze drying, foam mat drying, ultrasonic spray drying, and oven drying. From the seven articles obtained, no ideal coating materials or encapsulation techniques were found to protect and maintain the stability, characteristics, and physicochemical properties of anthocyanins, based on encapsulation efficiency, retention, morphology, and particle size. From these findings, using gelatin combined with other coating materials such as pectin or maltodextrin using freeze-drying has proven effective and is commonly used. Further in vivo bioavailability studies are warranted to evaluate the most promising combinations, such as gelatin + pectin or gelatin + maltodextrin, with freeze-drying.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

1. Grzebieniarz W, Tkaczewska J, Juszczak L, Kawecka A, Krzyściak P, Nowak N, et al. The influence of aqueous butterfly pea (Clitoria ternatea) flower extract on active and intelligent properties of furcellaran Double-Layered films - in vitro and in vivo research. Food Chem [Internet]. 2023 Jul 1 [cited 2025 Jun 2];413:135612. Available from: https://www.sciencedirect.com/science/article/pii/S0308814623002285
2. Widowati W, Wargasetia TL, Zakaria TM, Marthania M, Gunadi MS, Halim N, et al. Antioxidant Activities of Ginger (Zingiber officinale Roscoe) and Telang Flower (Clitoria ternatea L.) Combination Tea. Maj Kedokt Bandung. 2022;54(3):154–60.
3. Chayaratanasin P, Allen C, Chturong S, Saenset S, Pasukampnset P, Suanpairintr N, et al. Clitoria ternatea Flower Petal Extract Inhibits Adipogenesis and Lipid Accumulation in 3T3-L1 Preadipocytes by Downregulating Adipogenic Gene Expression. Molecules. 2019;24:1894.
4. Daveri E, Cremonini E, Mastaloudis A, Hester SN, Wood SM, Waterhouse AL, et al. Cyanidin and delphinidin modulate inflammation and altered redox signaling improving insulin resistance in high fat-fed mice. Redox Biol. 2018;18(April):16–24.
5. Multisona RR, Shirodkar S, Arnold M, Gramza-Michalowska A. Clitoria ternatea Flower and Its Bioactive Compounds: Potential Use as Microencapsulated Ingredient for Functional Foods. Appl Sci 2023, Vol 13, Page 2134 [Internet]. 2023 Feb 7 [cited 2025 Jun 2];13(4):2134. Available from: https://www.mdpi.com/2076-3417/13/4/2134/htm
6. Vidana Gamage GC, Lim YY, Choo WS. Anthocyanins From Clitoria ternatea Flower: Biosynthesis, Extraction, Stability, Antioxidant Activity, and Applications. Front Plant Sci. 2021;12(December):1–17.
7. Gómez-Gaete C, Avendaño-Godoy J, Escobar-Avello D, Campos-Requena VH, Rogel-Castillo C, Estevinho LM, et al. Revolutionizing fruit juice: exploring encapsulation techniques for bioactive compounds and their impact on nutrition, flavour and shelf life. Food Prod Process Nutr [Internet]. 2024;6(1). Available from: https://doi.org/10.1186/s43014-023-00190-9
8. Yudiono K. Effect of Maltodextrin Concentrations and Drying Temperature on the Physico-chemical Characteristics and Color Measurements of Butterfly Pea Flowers (Clitoria ternatea L) Powder. Turkish J Agric - Food Sci Technol. 2024;12(4):657–65.
9. Alu'datt MH, Alrosan M, Gammoh S, Tranchant CC, Alhamad MN, Rababah T, et al. Encapsulation-based technologies for bioactive compounds and their application in the food industry: A roadmap for food-derived functional and health-promoting ingredients. Food Biosci [Internet]. 2022;50(PA):101971. Available from: https://doi.org/10.1016/j.fbio.2022.101971
10. Taouzinet L, Djaoudene O, Fatmi S, Bouiche C, Amrane-Abider M, Bougherra H, et al. Trends of Nanoencapsulation Strategy for Natural Compounds in the Food Industry. Processes. 2023;11(5):1–31.
11. Fuzetti CG, de Castilhos MBM, Nicoletti VR. Microencapsulation of natural blue dye from butterfly pea (Clitoria ternatea L.) flowers: The application of different carriers. J Food Process Preserv. 2022;46(4):1–12.
12. Andrade D, Maldonado-Bravo F, Alburquerque A, Pérez C, Gamboa A, Caro N, et al. Nanoencapsulation of Maqui (Aristotelia chilensis) Extract in Chitosan–Tripolyphosphate and Chenopodin-Based Systems. Antioxidants 2024, Vol 13, Page 273 [Internet]. 2024 Feb 23 [cited 2024 Sep 10];13(3):273. Available from: https://www.mdpi.com/2076-3921/13/3/273/htm
13. Westphaln KK, Regoeczi W, Masotya M, Vazquez-Westphaln B, Lounsbury K, McDavid L, et al. From Arksey and O'Malley and Beyond: Customizations to enhance a team-based, mixed approach to scoping review methodology. MethodsX [Internet]. 2021;8:101375. Available from: https://doi.org/10.1016/j.mex.2021.101375
14. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Ann Intern Med [Internet]. 2018 Oct 2 [cited 2025 Jun 17];169(7):467–73. Available from: /doi/pdf/10.7326/M18-0850?download=true
15. MacFarlane A, Russell-Rose T, Shokraneh F. Search strategy formulation for systematic reviews:

https://doi.org/10.56303/jhnresearch.v4i3.682

Issues, challenges and opportunities. Intell Syst with Appl [Internet]. 2022;15:200091. Available from: https://doi.org/10.1016/j.iswa.2022.200091

16. Maneeratanachot S, Chetpattananondh P, Kungsanant S. Encapsulation of anthocyanin from butterfly pea flowers (Clitoria ternatea L.) extract using foam-mat drying. Food Bioprod Process [Internet]. 2024 May 1 [cited 2025 Jun 11];145:105–15. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0960308524000622
17. Liew SY, Mohd Zin Z, Mohd Maidin NM, Mamat H, Zainol MK. Effect of the different encapsulation methods on the physicochemical and biological properties of clitoria ternatea flowers microencapsulated in gelatine. Food Res. 2020 Aug 1;4(4):1098–108.
18. Narayanan GP, Radhakrishnan P, Baiju P, S AM. Fabrication Of Butterfly Pea Flower Anthocyanin-Incorporated Colorimetric Indicator Film Based On Gelatin/Pectin For Monitoring Fish Freshness. Food Hydrocoll Heal [Internet]. 2023 Dec 15 [cited 2025 Jun 3];4. Available from: https://www.sciencedirect.com/science/article/pii/S2667025923000432
19. Hailu FW, Fanta SW, Tsige AA, Delele MA. Development of simple and biodegradable pH indicator films from cellulose and anthocyanin. Discov Sustain. 2025 Dec 1;6(1).
20. Koshy RR, Reghunadhan A, Mary SK, Pillai PS, Joseph S, Pothen LA. pH indicator films fabricated from soy protein isolate modified with chitin nanowhisker and Clitoria ternatea flower extract. Curr Res Food Sci [Internet]. 2022 Jan 1 [cited 2025 Jun 11];5:743–51. Available from: https://www.sciencedirect.com/science/article/pii/S2665927122000570
21. Lyn FH, Dini Batrisyia · J Nur, Adilah · A Nor, Hanani · Z A Nur. Gelatin/Butterfly Pea (Clitoria ternatea) Extract Film as Intelligent Packaging: Effects of Storage Temperature. J Packag Technol Res 2024 83 [Internet]. 2024 Nov 5 [cited 2025 Jun 17];8(3):217–28. Available from: https://link.springer.com/article/10.1007/s41783-024-00177-y
22. Punbusayakul N, Jaisan C, Kaewprachu P, Yarnpakdee S, Chakrabandhu Y. Improvement of the physicochemical and mechanical properties of intelligent gelatin/butterfly pea films using coconut milk residue. Appl Food Res [Internet]. 2025 Jun 1 [cited 2025 Jun 3];5(1). Available from: https://www.sciencedirect.com/science/article/pii/S2772502225001246
23. Tan Y, Zi Y, Peng J, Shi C, Zheng Y, Zhong J. Gelatin as a bioactive nanodelivery system for functional food applications. Food Chem. 2023 Oct 15;423:136265.
24. Lu Y, Luo Q, Chu Y, Tao N, Deng S, Wang L, et al. Application of Gelatin in Food Packaging: A Review. Polymers (Basel). 2022;14(3).
25. Cao Y, Song Z, Dong C, Zhang L, Yu Q, Han L. Potato oxidized hydroxypropyl starch/pectin-based indicator film with Clitoria ternatea anthocyanin and silver nanoparticles for monitoring chilled beef freshness. Int J Biol Macromol [Internet]. 2024;273(P2):133106. Available from: https://doi.org/10.1016/j.ijbiomac.2024.133106
26. Rosales TKO, Fabi JP. Pectin-based nanoencapsulation strategy to improve the bioavailability of bioactive compounds. Int J Biol Macromol. 2023;229(July 2022):11–21.
27. Sari DP, Aditiyarini D, Ariestanti CA, Ariestanti CA. Stabilitas Ekstrak Bunga Telang (Clitoria ternatea L .) Terenkapsulasi Maltodekstrin dan Gelatin dan Potensi Prebiotiknya. J Ilmiiah Ilmu-Ilmu Hayati. 2024;9(3):226–37.
28. Enaru B, Drețcanu G, Pop TD, Stănilă A, Diaconeasa Z. Anthocyanins: Factors Affecting Their Stability and Degradation. Antioxidants [Internet]. 2021 Dec 1 [cited 2025 Jun 13];10(12):1967. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC8750456/

https://doi.org/10.56303/jhnresearch.v4i3.682