



Literature Review : The Effect of Fermentation in Butterfly Pea Flower Processing to Increase Nutritional Value and Health Benefits

Uchik Yulianti, Arinka Hana Zhahira *

Department of Food Technology and Agricultural Products, Universitas Negeri Surabaya, Surabaya, Indonesia

*Corresponding Author : arinkahna@gmail.com

Article history:

Submitted 27 February 2026

Revised 18 March 2026

Accepted 3 April 2026

Keywords:

Bioactive compounds;

Butterfly pea flower;

Clitoria ternatea;

Fermentation;

Kombucha.

ABSTRACT

Clitoria ternatea, or butterfly pea flower, is a tropical plant rich in bioactive compounds with traditional health benefits. Given growing consumer interest in functional foods, fermentation is a powerful strategy for enhancing the nutritional and functional profile of butterfly pea flower. This review aims to synthesize current knowledge on how fermentation affects the bioactive compounds, nutritional value, and health benefits of butterfly pea flower. A literature review was conducted to examine microbial transformation mechanisms, changes in bioactive compounds, and improvements in nutritional aspects. Key findings indicate that fermentation significantly increases the stability and bioaccessibility of anthocyanins and phenolic compounds, leading to enhanced antioxidant capacity and potent antimicrobial effects. Fermented butterfly pea flower products, such as kombucha, also show potential in modulating gut microbiota and metabolic syndrome markers, in addition to overall nutritional enhancement. Fermentation is an effective biotechnological approach for creating innovative functional food products with superior nutritional quality and better health benefits. Further research, including human clinical trials, is needed to fully exploit its therapeutic potential.

INTRODUCTION

Clitoria ternatea L., commonly known as butterfly pea flower, is a leguminous plant widely found in tropical and subtropical regions. Traditionally, butterfly pea flower has been used as a natural dye in food products and herbal medicine due to its rich phytochemical content (Siregar et al., 2023). This flower is known to contain various bioactive compounds such as anthocyanins, flavonoids, phenols, saponins, triterpenoids, and alkaloids, which collectively provide broad pharmacological potential (Kushargina et al., 2023). Identified health benefits include antioxidant, anti-inflammatory, antidiabetic, anticancer, antibacterial, antihistamine, and immunomodulatory activities (Santosa, 2023). Several studies also indicate that butterfly pea flowers can ameliorate cardiovascular dysfunction and oxidative stress (Kushargina et al., 2023). In recent years, interest in functional foods and probiotic beverages has increased significantly, driven by consumer awareness of the importance of health and nutrition, especially after the pandemic (Yusufoğlu et al., 2025). Fermentation, as one of the oldest food processing methods, has proven to be an effective strategy for enhancing the nutritional value and functionality of plant-based foods (Abbaspour, 2024). The fermentation process involves chemical changes in organic compounds by enzymes produced by microorganisms, such as *Symbiotic Culture Of Bacteria and Yeast* in kombucha, which can produce organic acids, vitamins, and enzymes, as well as increase nutrient bioavailability (Kushargina et al., 2023).

Although the potential of butterfly pea flowers and the benefits of fermentation have been extensively explored separately, the integration of these two fields, namely how fermentation specifically modifies the composition and enhances the health benefits of butterfly pea flowers, still requires comprehensive review. Preliminary studies have shown that fermenting butterfly pea flowers, particularly in the form of kombucha, can increase antibacterial and antioxidant activity (Fadillah, et al., 2022). However, there are still gaps in our

understanding of the detailed mechanisms behind these changes, as well as their specific impact on the nutritional aspects and bioavailability of bioactive compounds.

Therefore, this scientific review article aims to synthesize the latest information on the effects of fermentation on butterfly pea flower processing technology to increase its nutritional value and health benefits. This review will focus exclusively on the use of butterfly pea flower fermentation in the fields of health and nutrition, covering fermentation mechanisms, resulting health benefits, nutritional improvements, and effective fermentation methods. This article is expected to provide a deeper understanding for students, lecturers, and researchers regarding the potential of fermented butterfly pea flowers as innovative functional foods that contribute to health and well-being.

FERMENTATION METHODS

The Most Effective Types of Fermentation for Blue Pea Flowers in the Context of Health and Nutrition

The selection of fermentation methods is a crucial factor that determines the profile of bioactive compounds, nutritional value, and ultimate health benefits of hibiscus flower products. Various types of fermentation can be applied to hibiscus flowers, each with its own characteristics and optimization potential.

Kombucha Fermentation

Kombucha fermentation is one of the most researched and applied methods for butterfly pea flowers (Rezaldi et al., 2022). This process involves the use of Symbiotic Culture Of Bacteria and Yeast to ferment a sweet tea solution, in this case, butterfly pea flower infusion and sugar (Wahyuningtias et al., 2023). Microorganisms in SCOBY, including acetic acid bacteria and yeast, work synergistically to convert sugar into organic acids (such as acetic acid, lactate, and gluconate), alcohol, gas, and other metabolites (Kushargina et al., 2023).

1. *Critical Parameters in Kombucha Fermentation Sugar Concentration*: The proportion of sugar greatly affects the chemical and organoleptic properties of butterfly pea flower kombucha (Siregar et al., 2023). Optimal sugar concentration can also increase antibacterial activity and affect anthocyanin stability (Kushargina et al., 2023).
2. *Fermentation Duration*: Fermentation duration has a significant impact on organoleptic properties and antioxidant activity (Wahyuningtias et al., 2023). Studies show that fermentation duration can affect the content of bioactive compounds (Kushargina et al., 2023).
3. *Fermentation Temperature*: Temperature is an important factor that affects the fermentation process and metabolite formation. Temperatures of 18, 25, and 30 degrees Celsius have been studied to determine their effect on organoleptic properties and antioxidant activity (Wahyuningtias et al., 2023).
4. *pH*: The decrease in pH that occurs during kombucha fermentation plays a role in stabilizing anthocyanins, maintaining the distinctive blue color of butterfly pea flowers, and ensuring product safety by inhibiting the growth of pathogenic microbes (Rezaldi et al., 2022). The ideal final pH for kombucha is generally around 4.2-4.5 (Kushargina et al., 2023).

Butterfly Pea Flower kombucha fermentation has been shown to produce a beverage with high antioxidant and antimicrobial activity (Kushargina et al., 2023). This is due to an increase in total phenolic compounds and flavonoids, as well as the formation of organic acids that contribute to health benefits (Rezaldi et al., 2022).

Lactic Acid Fermentation

Although less specific to butterfly pea flowers than kombucha, lactic acid fermentation with lactic acid bacteria is a promising fermentation method for plant-based materials. This process can enhance nutritional and functional properties by:

1. *Increased Bioavailability*: LAB can biotransform polyphenols into molecules with better bioavailability and bioactivity (Moloto et al., 2023). Probiotic enzymes can also release phenolic compounds from the food matrix, increasing their extractability and positively affecting their bioaccessibility and antioxidant properties (Méndez-Galarraga et al., 2025).
2. *Enhanced Antioxidant and Anti-inflammatory Properties*: Fruit and vegetable beverages fermented with LAB exhibit enhanced nutritional properties. In addition to abundant micronutrients and phytochemicals, these products benefit from BAL activity, which produces bacterial metabolites during fermentation, making them good candidates for functional foods with anti-inflammatory and antioxidant properties (Garcia, C., & Remize, 2022).

3. *Enhanced Bioactivity of Polyphenols*: Probiotic fermentation can enhance the bioactivity and bioaccessibility of polyphenols, as demonstrated in *Dendrobium officinale* in gastrointestinal digestion simulations and in vitro fecal fermentation (Li et al., 2022).

Lactic acid fermentation could be an alternative method for processing butterfly pea flowers, potentially yielding products with enhanced nutritional and health profiles, although specific research on butterfly pea flowers still needs to be expanded.

FERMENTATION MECHANISM

Changes in Bioactive Compounds and Nutrients in Butterfly Pea Flowers

Fermentation is a complex biochemical process involving the activity of microorganisms, such as bacteria and yeast, to convert substrates into end products through specific metabolic pathways (Padmalita et al., 2024). In the context of butterfly pea flower processing, fermentation, especially through the production of kombucha with *Symbiotic Culture Of Bacteria and Yeast*, significantly modifies the profile of bioactive compounds and nutrients, thereby increasing its health potential and nutritional value (Permatasari et al., 2022)

The Role of Microorganisms in Compound Transformation

Microorganism cultures in butterfly pea flower fermentation, particularly SCOBY, play a crucial role in degrading the substrate (sugar) into various beneficial metabolites. Yeast breaks down sugar into ethanol and carbon dioxide, while acetic acid bacteria convert ethanol into acetic acid and other organic acids (Padmalita et al., 2024). These organic acids, such as acetic acid, glucuronic acid, and gluconic acid, not only give the fermented product its sour taste but also act as antimicrobial and antioxidant agents (Chen et al., 2023).

Table 1. Comparison of kombucha fermentation and lactic acid fermentation

Features or Aspects	Kombucha Fermentation	Lactic Acid Fermentation
Fermentation Agent	SCOBY	Lactic Acid Bacteria
Main Product	Effervescent drinks (organic acids, low alcohol, probiotic vitamins) (Kushargina et al., 2023)	Plant-based dairy products (lactic acid, probiotics, bioactive metabolites) (Garcia & Remize, 2022)
Impact on Antocyanins	Stability increases due to decreased pH (Rezaldi et al., 2022)	Potential for increased bioaccessibility and bioactivity through biotransformation (Méndez- Galarraga et al., 2025)
Increase in Phenolic Compounds	Proven to increase total Phenols and flavonoids (Siregar et al., 2023)	Increase the release and bioavailability of phenolic compounds (Moloto et al., 2023)
Health Benefits	Antioxidant, antimicrobial (including anti- biofilm), potential modulation of metabolic syndrome (Yuanita et al., 2025)	Increased antioxidant, anti- inflammatory, improved nutritional profile (Garcia & Remize, 2022)
Potential Application of Butterfly pea flowers	Butterfly pea flower kombucha as a functional drink (Kushargina et al., 2023)	Butterfly pea flower-based probiotic drink, an additional ingredient in fermented food products (Garcia & Remize, 2022)
Crisis Parameters	Sugar fermentation, fermentation time and temperature, initial pH (Wahyuningtias et al., 2023)	BAL Strain, Substrate, environmental condition (pH, Temperature, Time) (Moloto et al., 2023)

BIOACTIVE COMPOUNDS, BIOAVAILABILITY AND NUTRITIONAL VALUE

Butterfly pea flowers are known to be rich in anthocyanins, blue-purple pigments that have high antioxidant activity (Kushargina et al., 2023). The fermentation process can affect the stability and bioavailability of anthocyanins. The decrease in pH during fermentation, induced by acid production by lactic acid bacteria, plays an important role in increasing anthocyanin stability (Rezaldi et al., 2022). The acidic environment protects the anthocyanin structure from degradation, although anthocyanins are susceptible to environmental factors such as temperature, light, and oxygen (Huang et al., 2023). Several studies have shown that microorganisms can also biotransform anthocyanins into new metabolites that may have different or improved biological activities, or enhance their bioaccessibility by releasing phenolic compounds from the food matrix (Méndez-Galarraga et al., 2025).

In addition to anthocyanins, butterfly pea flowers also contain flavonoids and other phenolic compounds

(Kushargina et al., 2023). Fermentation can increase the total phenol and flavonoid content (Siregar et al., 2023). Microorganisms in fermentation have the ability to degrade complex phenolic compounds into simpler forms, freeing them from glycoside bonds or fiber matrices, thereby increasing bioavailability and antioxidant activity (Méndez-Galarraga et al., 2025). This biotransformation process can produce new phenolic derivatives that are more biologically active (Lu et al., 2025).

Fermentation can also produce new secondary metabolites or modify existing ones, such as alkaloids and saponins (Padmalita et al., 2024). These compounds are known to have cellular mechanisms that inhibit the growth of bacteria, microbiomes, or fungi, contributing to the health benefits of fermented products (Padmalita et al., 2024). The chemical changes that occur during fermentation not only increase the activity of bioactive compounds, but can also increase overall nutritional value. Metabolites produced, such as B complex vitamins, riboflavin, and amino acids, can be formed or increased in concentration (Kushargina et al., 2023). Fermentation can also reduce antinutrient content and degrade complex macronutrients into more digestible forms, thereby improving digestibility and nutrient availability (Abbaspour, 2024). The acidic environment created during fermentation can also affect mineral absorption.

Overall, the fermentation mechanism in butterfly pea flowers involves profound microbial transformation, resulting in significant changes in their phytochemical composition and nutritional profile. This process increases anthocyanin stability, releases and modifies phenolic compounds, and produces new metabolites that enrich the functional and health potential of butterfly pea flowers.

THE HEALTH IMPACT OF BUTTERFLY PEA FLOWER FERMENTATION

Fermentation of Butterfly pea flowers not only alters their phytochemical and nutritional profiles but also significantly enhances various health benefits, including antioxidant, antimicrobial, anti-inflammatory activities, and potential to modulate metabolic syndrome. This increased functionality makes fermented butterfly pea flowers strong candidate for the development of functional foods.

Antioxidant Activity

Butterfly pea flowers (*Clitoria Ternatea*) are naturally rich in antioxidant compounds such as anthocyanin, flavonoids, and phenolic compounds (Kushargina et al., 2023). These compounds play crucial role in neutralizing free radicals, which are the primary triggers of oxidative stress and various degenerative diseases (Santosa, 2023). Fermentation has been shown to increase the antioxidant capacity of butterfly pea flowers (Wahyuningtias et al., 2023). The production of organic acids and the biotransformation of phenolic compounds by microorganisms during fermentation can enhance the availability and activity of antioxidants (Méndez-Galarraga et al., 2025). For example, butterfly pea flower kombucha has shown significant antioxidant activity, which is believed to originate from the synergy of bioactive compounds formed during the fermentation (Wahyuningtias et al., 2023). Research shows that fermentation can also produce new metabolites with stronger or more stable antioxidant properties (Yusufoğlu et al., 2025).

Antimicrobial Effects

Fermentation of butterfly pea flowers, especially in the form of kombucha, has strong shown strong antimicrobial activity. Acetic acid produced during the kombucha fermentation process plays an important role in inhibiting the growth of various pathogenic bacteria (Rezaldi et al., 2022). Studies show that butterfly pea flower kombucha is effective against gram-positive and gram-negative bacteria, including *Streptococcus mutans* and *Klebsiella pneumoniae*, which are common pathogens that cause infections (Rezaldi et al., 2022). In addition, Butterfly pea flower kombucha also has potential as an anti-biofilm agent against *Streptococcus Viridans*, a bacterium associated with oral health problems (Yuanita et al., 2025). The presence of secondary metabolites such as alkaloids, flavonoids, and saponins in butterfly pea flower kombucha also contributes to this antimicrobial mechanism (Padmalita et al. 2024). This mechanism demonstrates the potential of fermented butterfly pea flower as a natural agent for maintaining microbiological health.

Anti-inflammatory Potential

Bioactive compounds in butterfly pea flowers, such as anthocyanins and flavonoids, have intrinsic anti-inflammatory properties (Borse et al., 2025). The fermentation process can enhance these effects through the biotransformation of these compounds into more bioactive forms or through the production of new metabolites with anti-inflammatory properties. Although specific research on the anti-inflammatory effect of fermented butterfly pea flower is still on going, the increase in phenolic compounds and antioxidants after fermentation indirectly supports an increase in anti-inflammatory potential (Cheepchirasuk et al., 2025). Kombucha, in general, is known to have anti-inflammatory effects, and its application in butterfly pea flowers may produce similar benefits (Silvi et al., 2024).

Improved Nutritional Aspects

Fermentation of butterfly pea flowers can also enhance the nutritional value and bioavailability of nutrients. The fermentation process can

- **Increase Vitamin Content:** Fermentation microorganisms can synthesize certain vitamins, especially B complex vitamins, thereby improving the nutritional profile of the final product (Kushargina et al., 2023).
- **Reduce Antinutrients:** Some antinutrients naturally present in plants can be degraded during fermentation, which in turn improves the absorption of essential nutrients (Abbaspour, 2024).
- **Improve Bioavailability:** Biotransformation of complex compounds into simpler, more digestible forms can improve the absorption and utilization of nutrients and bioactive compounds by the body (Abbaspour, 2024). For example, anthocyanins and other phenolic compounds may have better bioaccessibility after fermentation due to the breakdown of the cellulose matrix or glycosidic bonds (Méndez-Galarraga et al., 2025).

Overall, butterfly pea flower fermentation has a significant positive impact on various aspects of health, ranging from protection against cell damage and pathogen inhibition to the potential treatment of metabolic conditions. These benefits are supported by complex changes in the biochemical profile that occur during the fermentation process, making it a promising field for research and development of functional food products. The selection of fermentation methods should be based on the end product objectives, the bioactive compound profile to be enhanced, and sensory preferences. Kombucha fermentation has shown promising results for butterfly pea flowers in terms of antioxidant and antimicrobial activity, while lactic acid fermentation offers great potential for improving nutrient bioavailability. Combining optimize the potential of butterfly pea flowers as a functional food ingredient.

CONCLUSIONS

Butterfly pea (*Clitoria ternatea* L.) is a natural resource rich in bioactive compounds, particularly anthocyanins, flavonoids, and phenolic compounds, which inherently have a variety of health benefits. The use of fermentation technology has proven to be a highly effective approach in optimizing the potential of butterfly pea, both in terms of nutrition and functional benefits. The fermentation process, particularly through the kombucha and lactic acid fermentation methods, significantly alters and enhances the phytochemical profile and nutritional value of butterfly pea flowers (Abbaspour, 2024).

The fermentation mechanism involves the activity of microorganisms that produce organic acids, such as acetic and lactic acids, as well as the biotransformation of bioactive compounds. The decrease in pH during kombucha fermentation, for example, plays a vital role in stabilizing anthocyanins and increasing total antioxidant activity (Wahyuningtias et al., 2023). Additionally, fermentation can break down complex phenolic compounds, increase their bioaccessibility, and even produce new metabolites with stronger biological activity (Méndez-Galarraga et al., 2025). These transformations contribute to increased nutritional value through the synthesis of B vitamins and the reduction of antinutrients, making nutrients more readily available for absorption (Abbaspour, 2024).

The positive health impacts of butterfly pea flower fermentation are diverse. The increased antioxidant capacity of fermented butterfly pea flower products, such as kombucha, provides better protection against oxidative stress and cell damage (Wahyuningtias et al., 2023). Fermentation also produces strong antimicrobial effects, effectively fighting pathogenic bacteria such as *Streptococcus mutans* and *Klebsiella pneumoniae*, and has potential as an anti-biofilm agent against *Streptococcus viridans* (Yuanita et al., 2025). Additionally, preliminary evidence suggests that butterfly pea flower fermentation may contribute to anti-inflammatory effects and has potential in modulating metabolic syndrome through its interaction with gut microbiota (Permatasari et al., 2022).

The kombucha fermentation method has been extensively explored with critical parameters such as sugar concentration, duration, and fermentation temperature proven to affect the final product quality (Siregar et al., 2023). Lactic acid fermentation also offers great potential in increasing the bioavailability of polyphenols and other functional properties (Moloto et al., 2023).

Thus, fermented butterfly pea flower represents a promising strategy for developing innovative functional food products with enhanced nutritional value and health benefits. However, further research, particularly clinical studies in humans and optimization of fermentation parameters for industrial scale, is still needed to fully realize the full potential of fermented butterfly pea flower as a sustainable health solution.

REFERENCES

- Abbaspour, N. (2024). Fermentation's pivotal role in shaping the future of plant-based foods: an integrative review of fermentation processes and their impact on sensory and health benefits. *Applied Food Research*, 4(2), 100468. <https://doi.org/10.1016/j.afres.2024.100468>
- Garcia, C., & Remize, F. (2022). Lactic acid fermentation of fruit and vegetable juices and smoothies: innovation and health aspects, 2111–2126. <https://doi.org/https://doi.org/10.1016/B978-0-323-89875-1.00008-0>
- Kushargina, R., Suryaalamshah, I. I., Rimbawan, R., Dewi, M., & Damayanthi, E. (2023). Effect of fermentation and adding sugar on organoleptic of butterfly pea kombucha (*Clitoria ternatea* L.). *Jurnal SAGO Gizi Dan Kesehatan*, 5(1), 44–52.
- Li, R., Wang, Z., Kong, K. W., Xiang, P., He, X., & Zhang, X. (2022). Probiotic fermentation improves the bioactivities and bioaccessibility of polyphenols in dendrobium officinale under in vitro simulated gastrointestinal digestion and fecal fermentation. *Frontiers in Nutrition*, 9-2022. <https://www.frontiersin.org/journals/nutrition/articles/10.3389/fnut.2022.1005912>
- Lu, C., Zhang, J., Zhao, X., Zi, Y., & Xiao, X. (2025). Biotransformation of phenolic acids in foods: pathways, key enzymes, and technological applications. *Foods*, 14(13). <https://doi.org/10.3390/foods14132187>
- Moloto, M. R., Akinola, S. A., Seke, F., Shoko, T., Sultanbawa, Y., Shai, J. L., Remize, F., & Sivakumar, D. (2023). Influence of fermentation on functional properties and bioactivities of different cowpea leaf smoothies during in vitro digestion. *Foods*, 12(8). <https://doi.org/10.3390/foods12081701>
- Padmalita, M. H., Permatasari, A. A., Destiana, T. A., Damayanti, R., & Ramadina, N. S. (2024). Pemanfaatan kombucha bunga telang sebagai produk bioteknologi farmasi. *MARAS: Jurnal Penelitian Multidisiplin*, 2(3), 1419–1426. <https://doi.org/10.60126/maras.v2i3.402>
- Permatasari, H. K., Nurkolis, F., Gunawan, W. Ben, Yusuf, V. M., Yusuf, M., Kusuma, R. J., Sabrina, N., Muharram, F. R., Taslim, N. A., Mayulu, N., Batubara, S. C., Samtiya, M., Hardinsyah, H., & Tsopmo, A. (2022). Modulation of gut microbiota and markers of metabolic syndrome in mice on cholesterol and fat enriched diet by butterfly pea flower kombucha. *Current Research in Food Science*, 5(June), 1251–1265. <https://doi.org/10.1016/j.crf.2022.08.005>
- Rezaldi, F., Hidayanto, F., Setyaji, D. Y., Fathurrohlim, M. F., & Kusumiyati. (2022). Biotechnology of kombucha telang flower (*Clitoria ternatea* L) as antibacteria *Streptococcus mutant* and *Klebsiella pneumoniae* based on different concentrations of sugar. *Farmagazine*, 9(2), 21–27.
- Santosa, D. F. (2023). Beneficial health effects of butterfly pea (*Clitoria ternatea*): a literature review. *Indonesia Journal of Biomedical Science*, 17(2), 244–247. <https://doi.org/10.15562/ijbs.v17i2.486>
- Siregar, R. N., Handarini, K., Sucahyo, B. S., & Hariyani, N. (2023). Pengaruh proporsi bunga telang (*Clitoria ternatea* L.) dan gula terhadap sifat kimia dan organoleptik minuman kombucha. *Pro-STek*, 5(2), 105. <https://doi.org/10.35194/prs.v5i2.3738>
- Wahyuningtias, D. S., Fitriana, A. S., & Desy Nawangsari. (2023). Pengaruh suhu dan lama waktu fermentasi terhadap sifat organoleptik dan aktivitas antioksidan teh kombucha bunga telang (*Clitoria ternatea* L.). *Pharmacy Genius*, 2(3), 198–207.
- Yuanita, T., Firmansyah, A. B., Ulfadi, B. T. P., Prasetyo, E. P., & Wahjuningrum, D. A. (2025). Effect of butterfly pea flower (*Clitoria ternatea* L.) kombucha against *Streptococcus viridans*. *Conservative Dentistry Journal*, 15(1), 14–17. <https://doi.org/10.20473/cdj.v15i1.2025.14-17>
- Yusufoğlu, B., Açar, Y., Kezer, G., Zargarchi, S., Mertoglu, K., & Esatbeyoglu, T. (2025). Exploring the potential of anthocyanin-infused fermented beverages for sustainable health solutions: a pathway to functional food development. *Future Foods*, 12(February). <https://doi.org/10.1016/j.fufo.2025.100708>