A Study on the Fermentation and Quality Characteristics of Butterfly Pea Flower Wine

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***Abstract*—Butterfly pea flower (Clitoria ternatea) is a rich source of anthocyanins and natural antioxidants, making it a promising substrate for the development of value-added fermented beverages. The present study aimed to develop and evaluate a novel butterfly pea flower wine with desirable physicochemical, sensory, and storage characteristics. Fresh butterfly pea flowers were extracted using hot water treatment, followed by formulation of the must with sugar, acid adjustment, and inoculation with Saccharomyces cerevisiae. Fermentation was carried out under controlled conditions through primary and secondary fermentation stages, followed by clarification, aging, and bottling. The developed wine exhibited an attractive blue-to-purple coloration due to the pH-sensitive anthocyanin pigments present in butterfly pea flowers. Physicochemical parameters such as pH, total soluble solids (TSS), alcohol content, and color stability were monitored during fermentation and storage. The final product showed an alcohol content of approximately 8–12% with a stable pH range of 3.2–3.8 and a pleasant floral aroma with mild sweet-tart taste. Sensory evaluation using a 9-point hedonic scale indicated good consumer acceptability in terms of color, aroma, taste, mouthfeel, and overall quality. The study further highlights the potential of butterfly pea flower wine as a functional alcoholic beverage owing to its natural antioxidant properties and unique visual appeal. The developed product demonstrates significant scope for commercialization and further innovation in the fermented beverage industry.**

***Index Terms*—Butterfly pea flower; Clitoria ternatea; Wine fermentation; Anthocyanins; Functional beverage; Fermented beverage; Sensory evaluation.**

I. INTRODUCTION

The development of novel fermented beverages from natural plant sources has gained considerable attention in recent years due to increasing consumer demand for functional foods with health-promoting properties. Among these, fruit and flower-based wines have emerged as attractive alternatives to conventional grape wines because of their unique sensory characteristics, nutritional value, and therapeutic potential [1]. Fermentation technology not only enhances the shelf life and flavor profile of beverages but also contributes to the formation of bioactive compounds that may offer additional health benefits. In this context, the utilization of medicinal and edible flowers for alcoholic beverage production has become an important area of research in food technology and fermentation science [2].

Butterfly pea flower (Clitoria ternatea), a perennial flowering plant belonging to the Fabaceae family, is widely recognized for its vibrant blue color and rich phytochemical composition. The flower is traditionally used in herbal drinks, natural food coloring, traditional medicine, and culinary applications across many Asian countries. The characteristic blue-purple coloration of butterfly pea flowers is mainly attributed to anthocyanins, particularly ternatins, which are water-soluble pigments possessing strong antioxidant activity [3]. One of the unique properties of butterfly pea anthocyanins is their pH-sensitive color transformation, where the extract changes from blue under neutral conditions to purple or pink under acidic conditions. This property provides significant potential for the development of visually appealing and innovative food and beverage products [4].

In recent years, there has been increasing interest in replacing synthetic food colorants with natural alternatives because of consumer preference for clean-label and health-oriented products. Butterfly pea flower serves as an excellent natural colorant with additional functional benefits such as antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and

neuroprotective properties reported in several studies [5]. These bioactive characteristics make butterfly pea flower a promising ingredient for the formulation of value-added functional beverages.

Wine production through fermentation is one of the oldest biotechnological processes employed for beverage preservation and flavor enhancement. Traditionally, wines are produced from grapes; however, the fermentation of non-grape substrates such as fruits, herbs, flowers, and plant extracts has gained momentum owing to their availability, cost-effectiveness, and novel sensory profiles. The use of Saccharomyces cerevisiae in alcoholic fermentation plays a critical role in converting fermentable sugars into ethanol and carbon dioxide while simultaneously contributing to aroma and flavor development [6]. Parameters such as pH, temperature, sugar concentration, yeast activity, and fermentation duration significantly influence the quality and stability of the final wine product.

The incorporation of butterfly pea flower into wine production presents an opportunity to develop a naturally colored fermented beverage with enhanced functional and sensory properties. The anthocyanin-rich extract not only imparts a unique appearance but may also improve antioxidant potential and consumer acceptability. Furthermore, the acidic conditions developed during fermentation can influence pigment stability and produce attractive color variations, thereby increasing the product's marketability [7]. Despite the growing popularity of butterfly pea flower in herbal teas and beverages, limited scientific studies have focused on its application in wine production and evaluation of fermentation characteristics.

Therefore, the present study aims to develop and characterize butterfly pea flower wine using controlled fermentation techniques. The study focuses on evaluating important physicochemical parameters such as pH, total soluble solids, alcohol content, and color stability along with sensory quality attributes and storage stability. The research also seeks to explore the feasibility of utilizing butterfly pea flower as a functional ingredient in fermented beverage production and to establish its potential for commercial application in the food and beverage industry.

II. MATERIALS AND METHODS

2.1 Materials

Fresh butterfly pea flowers (Clitoria ternatea) were collected from local sources and used as the primary raw material for wine preparation. Commercial food-grade sugar was used as the fermentable carbohydrate source. Active dry wine yeast (Saccharomyces cerevisiae) was employed for alcoholic fermentation. Lemon juice/citric acid was used for acidity adjustment, while distilled water was utilized throughout the study. Optional additives such as yeast nutrient and potassium metabisulfite were used to improve fermentation efficiency and storage stability. All chemicals and reagents used for physicochemical analyses were of analytical grade.

2.2 Preparation of Butterfly Pea Flower Extract

Fresh butterfly pea flowers were thoroughly washed under running water to remove dirt and foreign materials. Damaged and discolored flowers were discarded. Approximately 250–300 g of flowers were added to 2 L of boiling water and heated at low temperature for 10–15 min to facilitate pigment extraction. The extract was cooled to room temperature and filtered using a sterile muslin cloth to obtain a clear deep blue-colored extract [3].

2.3 Preparation of Must

The filtered butterfly pea extract was used for must preparation. Sugar (1.2–1.5 kg) was dissolved separately in warm water and mixed with the extract. Additional water was added to adjust the final volume to 5 L. Acidity was adjusted using lemon juice or citric acid to maintain the pH between 3.2 and 3.8. The total soluble solids (TSS) of the must were adjusted to 20–24 °Brix using a hand refractometer to ensure suitable conditions for wine fermentation [5].

2.4 Pasteurization of Must

The prepared must was pasteurized at 65–70°C for 15 min to minimize microbial contamination and improve fermentation control. After pasteurization, the must was rapidly cooled to room temperature before yeast inoculation.

2.5 Yeast Activation and Inoculation

Active dry wine yeast (Saccharomyces cerevisiae) was activated by suspending 5 g of yeast in lukewarm

water maintained at 35–40°C for approximately 10 min. The activated yeast suspension was then added aseptically to the cooled must under sterile conditions.

2.6 Fermentation Process

2.6.1 Primary Fermentation

The inoculated must was transferred into sterile fermentation vessels and filled up to 75% of the container volume to allow space for foam and carbon dioxide production. The vessels were fitted with airlocks to maintain anaerobic conditions. Fermentation was carried out at 22–28°C for 5–7 days. During fermentation, yeast converted fermentable sugars into ethanol and carbon dioxide according to the following reaction:

$\text{Glucose} \rightarrow \text{Ethanol} + CO_2$

The progress of fermentation was monitored by observing CO_2 evolution, reduction in TSS, and changes in pH.

2.6.2 Secondary Fermentation

After completion of primary fermentation, the wine was siphoned carefully into another sterile container to separate sediments and yeast lees. Secondary fermentation was allowed to continue for 15–30 days under controlled conditions to improve clarity, flavor, and aroma.

2.7 Clarification and Aging

Clarification of wine was carried out either by natural cold settling or by using clarifying agents such as bentonite, gelatin, or egg white. The clarified wine was transferred into airtight sterile bottles and aged for 1–3 months in a cool and dark environment to enhance flavor development, aroma, and overall stability.

2.8 Bottling and Storage

Sterilized glass bottles were used for final packaging of the wine. The bottles were filled, sealed properly, and stored under refrigerated and ambient conditions for storage stability studies. Shelf-life observations were carried out periodically based on physicochemical and sensory changes.

2.9 Physicochemical Analysis

The prepared butterfly pea flower wine was analyzed for various physicochemical parameters including pH, total soluble solids (°Brix), alcohol content, color characteristics, and storage stability. The pH was measured using a digital pH meter, while TSS was determined using a refractometer. Alcohol content was estimated using standard fermentation analysis methods [5].

2.10 Sensory Evaluation

Sensory evaluation of the developed wine was conducted using a 9-point hedonic scale by a semi-trained panel. Parameters including color, aroma, taste, mouthfeel, and overall acceptability were evaluated. The scores obtained were statistically analyzed to determine consumer acceptability of the product.

2.11 Statistical Analysis

All experiments were conducted in triplicate and the obtained results were expressed as mean ± standard deviation. Statistical analysis was performed using standard analytical methods to evaluate the significance of variations observed during fermentation and storage studies.

III. RESULTS AND DISCUSSION

3.1 Fermentation Characteristics of Butterfly Pea Flower Wine

The fermentation of butterfly pea flower must use Saccharomyces cerevisiae was successfully completed under controlled conditions. Active fermentation was observed within 24 h of yeast inoculation, indicated by continuous carbon dioxide evolution and foam formation. The reduction in total soluble solids (TSS) during fermentation confirmed the utilization of fermentable sugars by yeast for ethanol production. Simultaneously, gradual decreases in pH and increases in alcohol concentration were observed throughout the fermentation period [8].

The initial TSS of the must was adjusted to 20–24 °Brix, which decreased significantly after primary and secondary fermentation due to sugar conversion into ethanol and carbon dioxide. The final alcohol content of the wine was found to be within the acceptable range of 8–12%, indicating efficient fermentation performance of the yeast culture.

3.2 Physicochemical Properties

The developed butterfly pea flower wine exhibited desirable physicochemical characteristics with acceptable acidity and stability. The pH of the wine

remained within the range of 3.2–3.8, which is considered suitable for wine preservation and microbial safety. Acidification using lemon juice/citric acid contributed to improved color stability and flavor balance [9].

The wine showed a visually attractive blue-to-purple coloration attributed to anthocyanin pigments present in butterfly pea flowers. The color intensity varied slightly during fermentation and storage due to changes in acidity and anthocyanin stability. Under acidic conditions, the wine exhibited a purple hue, whereas neutral conditions maintained a bluish appearance. This pH-dependent color transformation represents a unique functional and commercial feature of the product.

3.3 Anthocyanin Stability and Functional Properties

Butterfly pea flower is rich in anthocyanins, particularly ternatins, which possess antioxidant properties. The fermentation process retained a considerable amount of pigment stability, although slight degradation was observed during prolonged storage. Refrigerated storage conditions showed better preservation of color and antioxidant properties compared to ambient storage [10].

The presence of natural bioactive compounds may enhance the functional value of the wine by contributing antioxidant activity. Such characteristics increase the potential application of butterfly pea flower wine as a value-added functional fermented beverage.

3.4 Sensory Evaluation

Sensory analysis using a 9-point hedonic scale revealed favorable consumer acceptability of the developed wine. The product received good scores for color, aroma, taste, mouthfeel, and overall acceptability. The floral aroma imparted by butterfly pea flowers combined with the mild sweet-tart taste produced a distinctive sensory profile.

Among all evaluated parameters, color obtained the highest sensory score due to the unique natural pigmentation of the beverage. Aging further improved flavor smoothness and aroma complexity, resulting in enhanced overall acceptability [11].

3.5 Storage Stability

Storage studies demonstrated that the wine remained stable for up to 6 months under refrigerated conditions and approximately 3–4 months at room temperature. Minimal changes in pH, aroma, and color were observed during refrigerated storage. However, slight pigment fading and sediment formation occurred during extended ambient storage [12].

Proper sterilization, airtight bottling, and controlled storage conditions significantly contributed to maintaining product quality and shelf stability.

3.6 Overall Significance of the Study

The present study demonstrated the feasibility of producing a novel fermented alcoholic beverage from butterfly pea flowers with desirable physicochemical and sensory characteristics. The developed wine exhibited attractive natural coloration, acceptable alcohol content, pleasant flavor, and potential functional benefits due to anthocyanin-rich bioactive compounds [13]. The findings suggest that butterfly pea flower can serve as a promising raw material for innovative fermented beverage development and may possess significant commercial potential in the functional food and beverage sector.

IV. CONCLUSION

The present study successfully demonstrated the development of a novel butterfly pea flower wine using controlled fermentation with Saccharomyces cerevisiae. The prepared wine exhibited desirable physicochemical properties, including acceptable pH, stable color characteristics, and alcohol content within the standard range for fermented beverages. The anthocyanin-rich butterfly pea flower extract imparted a unique blue-to-purple coloration and contributed potential antioxidant benefits, enhancing the functional value of the product.

The fermentation and aging processes significantly improved the sensory quality of the wine by enhancing aroma, flavor, clarity, and overall acceptability. Sensory evaluation indicated favorable consumer preference, particularly for the attractive natural color and floral characteristics of the beverage. Storage studies further revealed that refrigerated conditions effectively maintained product stability and quality for an extended period.

Overall, butterfly pea flower demonstrated strong potential as a natural colorant and functional ingredient for fermented beverage production. The study highlights the feasibility of utilizing Clitoria

ternate in the development of innovative value-added alcoholic beverages with commercial significance. Further research may focus on optimization of fermentation parameters, enhancement of anthocyanin stability, evaluation of antioxidant activity, and development of diversified products such as sparkling or low-alcohol butterfly pea wines.

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