Hibiscus-Ginger Wine: A Functional Beverage with Enhanced Bioactive compounds and Sensory Attributes

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***Abstract* —The juice from the dark red calyces of roselle (*Hibiscus sabdariffa*) was extracted by boiling them in water 80°C for 20 minutes. To increase the amount of sugar in the juice, sucrose was added. To start the fermentation process, a pure strain of wine yeast (*Saccharomyces cerevisiae*) was added to the juice. To give the resulting wine (9.20% v/v alcohol) time to develop its distinctive flavor and fragrance, it was aged for three months. The study of the wine revealed a change in total soluble solids, pH, alcohol content of the wine during fermentation. Regarding color, flavor, taste, and general acceptability, the aged roselle wine's sensory test revealed no discernible differences from commercial wine samples. Roselle calyx may yield an excellent and acceptable red table wine, according to the study's findings, and its industrial potential should be used. According to the results, the total soluble solids were 5.6°Brix and the titratable acidity was 0.74%. The pH of the wine was estimated to be 3.43 and the hibiscus wine was within the range of grape wines.**

Key Words*— Alcohol, fermentation, *Hibiscus sabdariffa, Saccharomyces cerevisiae, wine.

I.INTRODUCTION

In addition to being consumed fresh, fruits and vegetables are used extensively in the food business to make concentrated juice, jam, cans, and candies. Vegetables and fruits could be applied to the manufacture of wine as well. Some fruit juices are fortified with sugar in order to allow yeast to produce alcohol [1]. The demand for alcoholic beverages has grown in the last several years.

In addition to improving the effective use domestically grown fruits and vegetables to produce wine will inevitably raise the GDP of the country. Hibiscus is a locally available flower that is yet underutilized in India. The Malvaceae family includes the plant. A calyx extract from *H. sabdariffa* with hot water has been used to make non-alcoholic drinks. This extract is used to make an alcoholic beverage that is typically sweetened with sugar and flavored with ginger, pineapple, banana, vanilla, and strawberry [2]. The distinctive color of H. sabdariffa calyx extract ranges from red-to-red brown. Anthocyanins, the extract's pigment, have therapeutic properties [3]. According to [4], anthocyanins can reduce oxidative stress by absorbing free radicals from the body. Additionally, according to [5], anthocyanins have anti-inflammatory, anti-hepatotoxic, antibacterial, antiviral, antithrombic, and antiallergenic properties. Given the therapeutic benefits of anthocyanins, making red wine from *H. sabdariffa* may have two uses for humans. The current study, which aims to evaluate the physio-chemical and sensory properties of rosella calyx as a viable raw material substitution for wine production, is justified by the potential of an underutilized crop.

I.1. Hibiscus (*Hibiscus sabdariffa)*

Hibiscus sabdariffa, commonly referred to as "roselle," is a member of the Malvaceae family of plants. With more than three hundred species found in tropical and subtropical climates worldwide, a native plant of West Africa and from there it was carried to other parts of the world such as Asia and America, it is a nationally recognized medicinal plant. Roselle grows well in hotter climate of the sub-tropical in a range of soil types. It is found to be abundant in Citric, malic and tartaric are among the several organic acids. The plant's beta-carotene, vitamin C, protein, and total sugar content are also well-known. Roselle is widely known for its nutritional and therapeutic qualities and contains several photochemical substances that are essential to medicine.

I.2. Varieties of *Hibiscus sabdariffa*

There are many different varieties of Hibiscus, but the two most common and well-introduced are *Hibiscus* *altissima* and *Hibiscus sabdariffa*. Although *Hibiscus altissima* is not used for food, its high fiber content makes it more economically significant than Hibiscus sabdariffa. It is a branchless shrub with yellow flowers and red or green calyxes. The other unique type, *Hibiscus sabdariffa*, also known as "Roselle," grows in a bush with many branches; the flowers of Roselle are axillary or in terminal racemes, and the petals are white with a reddish center at the base of the stamina column.

I.3. Composition of *Hibiscus sabdariffa*

The three types of calyces that roselle produces—green, crimson, and dark red—are the primary reason it is grown. The most widely used red calyxes are distinguished by their anthocyanin content. The two main anthocyanins are delphinidin 3-Sambubioside and cyanidin 3-Sambubioside. Depending on the kind and region, roselle also contains varying amounts of organic acids, minerals, amino acids, carotene, vitamin C, and total sugar in its calyx, leaves, and seeds [6]. Manita-mishra [7] claims that other chemicals, such as flavonoids, anthocyanidins, triterpenoids, steroids, and alkaloids, have also been identified and extracted from Roselle. Table 1 clearly lists the nutrient contents of the various parts of the *Hibiscus sabdariffa*.

Table 1. Nutritional composition [18]

NUTRIENTS	CALYXES	SEEDS	LEAVES
Protein[g]	2	28.9	3.5
Carbohydrates [g]	10.2	25.5	8.7
Fat[g]	0.1	21.4	0.3
Vitamin A [I.E.]	-	-	1000
Thiamine [mg]	0.05	0.1	0.2
Riboflavin [mg]	0.07	0.15	0.4
Niacin [mg]	0.06	1.5	1.4
VitaminC [mg]	17	9	2.3
Calcium [mg]	150	350	240
Irom [mg]	3	9	5

I.4. Nutritional and Medicinal benefits of *Hibiscus sabdariffa*

Roselle, a safe medicinal plant [8], is well-known for its nutritional and therapeutic qualities[9] as well as its delicate taste. It contains a variety of medically significant substances known as phytochemicals. The use of the plant to treat a variety of illnesses, such as cancer, inflammatory conditions, and various cardiovascular issues, has been thoroughly studied by various researchers in various contexts [10].

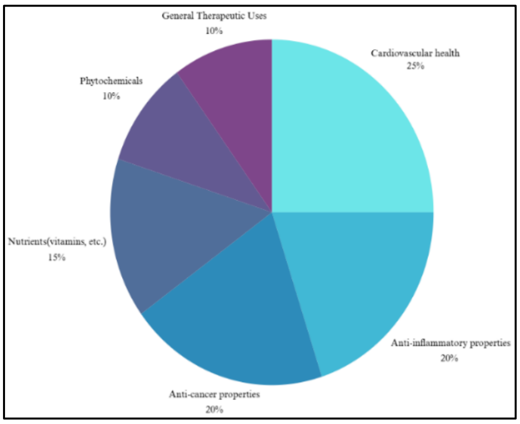

Fig. 1. Nutritional properties of hibiscus [19]

I.5. Ginger: History and Properties

As a member of the Zingiberaceae family, ginger (Z. officinale Roscoe) has long been used as a spice in cooking due to its strong, energizing scent. Despite ginger's lengthy history of human use, little is known about its past. Documents indicate that ginger has been grown for many years throughout tropical Asia, most likely in southern India and China. Greeks were familiar with and frequently used ginger, which they wrapped in bread to avoid nausea.

I.6. Anti-oxidant and Anti-Inflammatory properties of ginger

Since ancient times, ginger has been utilized in Chinese and Ayurvedic medicine because of its anti-inflammatory and antioxidant qualities. These characteristics are ascribed to the bioactive substances shogaol, parasol, zingerone, and primarily gingerol (or [6] -gingerol, which are the principal contributors to the beneficial effects of fresh ginger and are present in high concentrations.

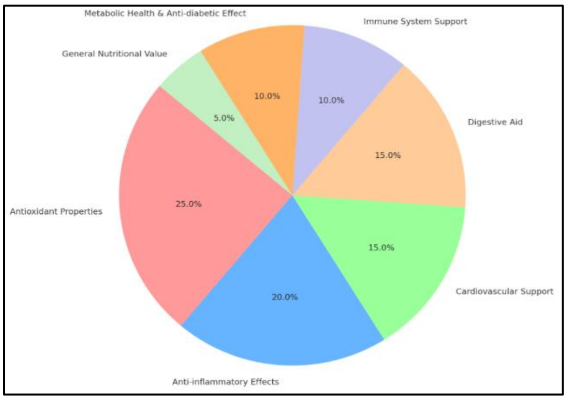

Fig. 2. Anti-oxidant and Anti-inflammatory properties of ginger [20].

II.MATERIALS AND METHODS

I. PROCUREMENT OF RAW MATERIALS

Hibiscus flowers (*Hibiscus sabdariffa*), water, ginger, sugar, yeast, lemon were sourced from the local market.

II.PREPARATION OF HIBISCUS WINE

Collection of good quality hibiscus flower from the local market. The hibiscus was manually washed in cold water to remove dirt. The petals of the hibiscus flower removed gently. About 15 g of the hibiscus were boiled in 1 L water for 10 min to bring out the color and flavor of petals. Then they were strained using sterile muslin cloth. After boiling the hibiscus flower it is been kept in the room temperature for cooling. Sugar(250g), Citric acid (0.3g), Yeast (2.5g), Spices (cinnamon and clove 0.7g), Ginger extract (1ml) are added one by one. For the preparation of ginger extract take about 2g of fresh ginger wash and peel. Grind the ginger into a fine slurry using a motor and pestle. Filter the extract using a clean muslin cloth. Then the prepared 2.5g yeast is added to the extract and the wine was subjected to primary fermentation at 25 ± 2°C for 30 days to produce wine. The young wine was racked into a sterile aspirator jar fitted with air lock. After the fermentation process, the sediment particle is been filtered using muslin cloth. To develop the flavor, aroma, and stability aging process is carried out for 4 weeks. For the storage and transportation of hibiscus wine the preserved wine is bottled in the glass jar.

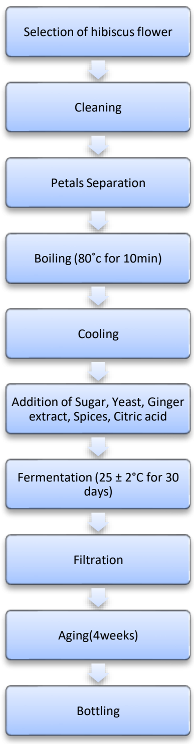

Fig.3. Flowchart

III. OPTIMIZATION OF WINE

INGREIENTS	QUANTITY TAKEN(g)
Hibiscus petals	15g
Water	1L
Sugar	250g
Yeast	3g
Citric acid (lemon juice)	0.3g
Ginger Extract	1ml
Spices (cloves, cinnamon)	0.14g

Table 2. Optimization of Wine

IV. DETERMINATION OF PHYSIO-CHEMICAL PROPERTIES

The physio-chemical properties such as pH, total soluble solids (°Brix), titratable acidity (TAA) and alcohol content were determined. In order to assess the degree of fermentation, the alcohol content was measured. Measurements of Total Soluble Solids (°Brix) were made to track the amount of sugar consumed during fermentation. To determine the organic acid content—which influences the wine's flavour, preservation, and microbiological stability—Titratable Acidity (TAA) was examined. These variables are crucial for comprehending the fermentation process and guaranteeing the Caliber of the final output.

V. DETERMINATION OF MICROBIAL ANALYSIS

The microbial analysis such as total plate count, yeast count and mold count were determined. This was done in order to assess the safety and microbiological quality of the wine and to evaluate the entire bacterial load present during fermentation.

III. RESULTS AND DISCUSSION

Significant physio-chemical alterations, microbiological shifts, and progressive enhancements in sensory quality were all brought about by the fermentation of Roselle wine. Titratable Acidity (TAA) increased from 0.60% to 0.73%, which is consistent with normal wine fermentation dynamics, while pH decreased from 3.72 to 3.44, indicating increasing acidity. The rapid drop in soluble solids (°Brix) from 21.00 to 5.60 indicated that active sugar conversion to alcohol had occurred. By Day 14, the alcohol content had risen gradually to 9.2% [w/v], indicating effective yeast activity and a successful fermentation.

According to microbial studies, active fermentation caused the Total Plate Count (TPC) to rise initially, but as alcohol levels climbed and microbial growth was inhibited, TPC subsequently decreased. The wine's low pH and increasing alcohol content probably contributed to the yeast count peaking and stabilizing in the second week while Mold development remained low.

After 30 days of storage, sensory analysis showed steady or enhanced customer acceptability. By Day 21, appearance and colour scores were flawless and stayed that way. Taste and texture continued to receive a satisfactory rating of 4, and flavour steadily increased until it reached its best grade on Day 30. These results suggest a product that is appealing to consumers and has a respectable shelf life.

At ₹25.27 for the entire manufacturing cost, the wine preparation turned out to be economical. The largest contributor to the expense was sugar, which was followed by yeast and spices. With a high yield of 90%, the procedure is appropriate for small-scale or experimental wine production, even with slight losses from sedimentation and filtration.

I. EFFECT OF FERMENTATION ON QUALITY ATTRIBUTES

Changes in physio-chemical qualities of the Roselle wine during fermentation are shown in Table 2. Roselle wine's physicochemical properties changed significantly during the fermentation process. The Total Soluble Solids (TSS) changed the most, going from 21.00 °B to 5.60 °B during the course of 30 days. This decline marks the wine's passage through the primary and secondary fermentation stages and illustrates the consistent uptake of fermentable sugars by yeast cells, which turns them into alcohol. The high sugar concentration in the early stages (primary fermentation) encouraged vigorous yeast activity, whereas the slowing fermentation rate in the later stages (secondary fermentation) was correlated with a gradual decrease in TSS because of the rising alcohol concentration, which can inhibit yeast metabolism. As a result of the must's increased generation of organic acid, which enhances the stability and shelf life of the wine, the pH decreased from 3.72 to 3.44. Indicating the buildup of organic acids during fermentation, titratable acidity (TAA), which is measured as a percentage of citric acid, rose from 0.60% to 0.74%. In addition to serving as a microbial stabilizer, this acidity enhances the flavour of the wine. Moreover, the alcohol concentration increased steadily from 0.00% to 9.20% w/v by Day 30, indicating that the yeast was fermenting and metabolically active under the experimental conditions. These physicochemical characteristics support the reproducibility and dependability of the fermentation process by matching values reported in related investigations. Similar fermentation trends were seen in Trials 1 and 2, confirming reproducibility and consistency.

II. TRIAL 1 and TRIAL 2

Days	TSS (°B)	pH	TAA (%)	Alcohol (% [w/v])
0	21.00 ± 0.02	3.72 ± 0.01	0.60 ± 0.06	0.00
2	19.40 ± 0.12	3.68 ± 0.13	0.60 ± 0.08	1.20 ± 0.15
4	17.80 ± 0.11	3.67 ± 0.09	0.61 ± 0.05	2.20 ± 0.11
6	15.50 ± 0.05	3.66 ± 0.16	0.61 ± 0.12	3.00 ± 0.06
8	13.10 ± 0.08	3.65 ± 0.14	0.62 ± 0.14	4.30 ± 0.08
10	12.20 ± 0.09	3.62 ± 0.04	0.63 ± 0.08	5.80 ± 0.12
12	11.60 ± 0.13	3.61 ± 0.17	0.65 ± 0.12	6.30 ± 0.16
14	10.10 ± 0.06	3.58 ± 0.15	0.67 ± 0.14	7.50 ± 0.09
16	8.60 ± 0.13	3.56 ± 0.12	0.67 ± 0.10	8.60 ± 0.02
18	8.10 ± 0.06	3.55 ± 0.08	0.68 ± 0.14	8.80 ± 0.06
20	7.60 ± 0.11	3.53 ± 0.16	0.69 ± 0.11	9.00 ± 0.04
22	7.20 ± 0.07	3.50 ± 0.05	0.71 ± 0.04	9.10 ± 0.12
24	6.80 ± 0.10	3.47 ± 0.09	0.72 ± 0.06	9.20 ± 0.08
26	5.70 ± 0.08	3.45 ± 0.05	0.72 ± 0.13	9.20 ± 0.06
28	5.62 ± 0.14	3.45 ± 0.16	0.73 ± 0.05	9.20 ± 0.04
30	5.60 ± 0.14	3.44 ± 0.16	0.73 ± 0.05	9.20 ± 0.04

Table.4. Changes in physio-chemical attributes during fermentation.

Days	TSS (°B)	pH	TAA (%)	Alcohol (% w/v)
0	21.00 ± 0.01	3.71 ± 0.02	0.61 ± 0.05	0.00
2	19.30 ± 0.10	3.67 ± 0.10	0.61 ± 0.07	1.10 ± 0.13
4	17.50 ± 0.09	3.65 ± 0.07	0.62 ± 0.06	2.10 ± 0.10
6	15.20 ± 0.04	3.64 ± 0.13	0.63 ± 0.11	2.90 ± 0.07
8	12.90 ± 0.07	3.63 ± 0.12	0.64 ± 0.13	4.20 ± 0.09
10	12.00 ± 0.08	3.61 ± 0.03	0.65 ± 0.07	5.70 ± 0.11
12	11.40 ± 0.12	3.60 ± 0.15	0.66 ± 0.11	6.20 ± 0.14
14	10.00 ± 0.05	3.56 ± 0.14	0.68 ± 0.13	7.40 ± 0.08
16	8.50 ± 0.12	3.54 ± 0.10	0.68 ± 0.09	8.50 ± 0.02
18	8.00 ± 0.05	3.52 ± 0.07	0.69 ± 0.13	8.80 ± 0.06
20	7.60 ± 0.10	3.50 ± 0.14	0.70 ± 0.10	9.00 ± 0.05
22	7.10 ± 0.06	3.48 ± 0.04	0.71 ± 0.03	9.10 ± 0.11
24	6.70 ± 0.09	3.45 ± 0.08	0.73 ± 0.05	9.20 ± 0.07
26	5.80 ± 0.07	3.44 ± 0.04	0.73 ± 0.12	9.20 ± 0.06
28	5.70 ± 0.13	3.43 ± 0.15	0.74 ± 0.04	9.20 ± 0.04
30	5.60 ± 0.13	3.43 ± 0.15	0.74 ± 0.04	9.20 ± 0.04

Table.5. Changes in physio-chemical attributes during fermentation.

PHYSIO-CHEMICAL PROPERTIES

The physicochemical content of newly made Roselle wine obtained is reported in Table 3. The Alcohol %, pH, brix, and total acidity all agreed with earlier research published by [15] and [16]. Because the wine has a volatile acidity of 0.33 g of acetic acid per 100 ml, its safety for human consumption is guaranteed. Titratable acidity and wine pH are directly correlated; that is, the higher the titratable acidity, the lower the pH, and vice versa. The wine would therefore continue to have good shelf stability [17].

Analysis	Roselle wine
TSS (°B)	5.60 ± 0.13
pH	3.43 ± 0.15
TAA (%)	0.74 ± 0.04
Alcohol (% [w/v])	9.20 ± 0.04

Table 6. Physicochemical composition of Roselle wine.

MICROBIAL ANALYSIS

Changes in associated physicochemical parameters throughout fermentation clearly showed microbial activity such as total plate count, yeast, and Mold levels, were explicitly examined. A high number of active yeast cells efficiently turning carbohydrates into ethanol is indicated by the quick drop in TSS during the first few days of fermentation. This is consistent with the primary fermentation phase, which is when yeast metabolism peaks. The rate of yeast activity and sugar conversion decreased as fermentation went on and alcohol levels rose, signalling the start of the secondary fermentation stage, where the increasing ethanol concentration naturally inhibits microbial activity. A further indirect indicator of microbial metabolic by products, specifically organic acids is the observed rise in titratable acidity. The final volatile acidity of wine is permissible safety limits and guarantees that the product is edible. This figure also implies that there is no unwanted microbial contamination present, which would raise the quantities of volatile acid. The chemical composition of the wine was largely impacted by the microbiological processes that took place during fermentation, which also helped to ensure its stability, safety, and sensory appeal.

Time Interval	Total Plate Count (CFU/ml)	Yeast Count (CFU/ml)	Mold Count (CFU/ml)
Day 0	1.2×10^3	2.0×10^3	Nil
Day 7	2.5×10^3	3.8×10^3	1.0×10^2
Day 14	3.0×10^3	4.2×10^3	2.5×10^2
Day 21	2.8×10^3	3.5×10^3	2.0×10^2
Day 30	2.0×10^3	3.0×10^3	1.5×10^2

Table 7. Microbial Analysis

- Due to fermentation activity, the TPC rises; however, when alcohol concentration rises, microbial growth is inhibited and the TPC falls.
- During the second week of active fermentation, the yeast count rises and then stabilizes.
- After a week, Mold begins to grow in little amounts, but it stays low because of the acidic and alcoholic environment.

SENSORY ANALYSIS

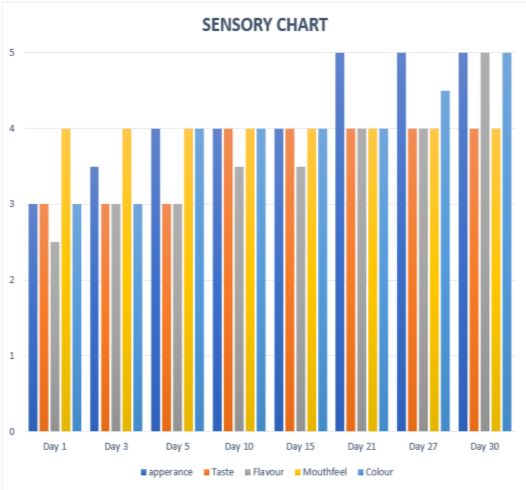

Fig. 4. Sensory analysis

Over the course of a 30-day storage period, the product's five sensory attributes—appearance, taste, flavour, mouthfeel, and colour—change, as shown in the sensory evaluation chart. On Days 1, 3, 5, 10, 15, 21, 27, and 30, sensory scores were recorded using a 5-point hedonic scale, with 5 being the maximum level of approval.

- Over time, scores for appearance and colour increased steadily, peaking at a perfect five by Day 21 and staying there.
- Throughout the storage time, the taste and mouthfeel were similar, achieving a score of 4, which indicates sustained consumer approval.
- After a lower starting score, flavour gradually improved, reaching a score of 5 by Day 30.

Overall, the product's sensory qualities either got better or stayed the same over time, indicating that it has a decent 30-day shelf life and is acceptable.

ESTIMATED YIELD CALCULATION

$$\text{Yield \%} = \frac{\text{Final weight of the product obtained} * 100}{\text{Initial weight of the raw materials}}$$

$$= \frac{900 * 100}{1000}$$

$$= 90\%$$

It was estimated that the prepared hibiscus wine had a yield percentage of about 90%. A percentage of the volume is lost during fermentation as a result of sedimentation, gas release (CO_2), and filtering of solid leftovers such yeast sediment and hibiscus petals. A significant amount of liquid is kept after processing, leading to a high yield, even with these little losses. Thus, for small-scale or experimental wine production, the total process shows good efficiency in terms of product recovery.

IV. CONCLUSION

The successful creation of hibiscus wine with ginger extract was made with natural materials like sugar, yeast, hibiscus flowers, and a few chosen spices. Ginger extract was added to improve the wine's sensory and functional qualities. Because ginger has anti-inflammatory and antioxidant qualities, its infusion enhanced the beverage's flavour profile while also adding possible health advantages.

A yield of 90% indicates that the fermentation process went well, resulting in little loss during processing and good recovery of the finished product. Favourable ratings were obtained from sensory examination in terms of appearance, taste, flavour, texture, and colour; as the wine aged, there was a discernible improvement.

With its appealing taste, aesthetic value, and potential market acceptability, the hibiscus-ginger wine formulation as a healthy, non-grape alternative wine with added medicinal value is a promising functional beverage that can be further investigated for shelf-life studies and commercialization.

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