Quality Function Deployment: Identification of Key Parameters in Grape Growing and Wine Making

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ABSTRACT

Background: The study conducted benchmarking research, assessed and identified suitable factors for the efficient benchmarking of Karnataka wines. As the Grape Processing Industry Board is being formed by the Wine Board of Karnataka (Wine Policy '2007'), which may have control of grape quality, standards formulation, label approval and market promotion, the study focused on recommending strategies for quality grape-growing, wine-making for label approvals.

Methods: The study adopted the Quality Function Deployment (QFD) tool to build the House of Quality to benchmark Karnataka wines with the new world wines.

Result: The findings demonstrate that the informative label was given high importance by customers during wine purchases. The wine industry to meet this requirement should focus more, on the factor-crushing method of grapes. Karnataka wineries are inferior to wine from other New World regions when it comes to other aspects such as flavour, colour, brand name, grape variety, meal pairings, alcohol content, wine label designand label information.

Key words: Benchmarking wines, House of quality, Indian wines, Karnataka wines, Quality function deployment.

INTRODUCTION

As India's food and beverage business expands at a rapid rate, all segments of the industry must keep up to satisfy its consumers (Gangwani *et al.*, 2020). India is part of the New-World wine region. Wines from other nations are sold all over the world, but in India, the market is significantly less. The study aimed to benchmark Indian wines in the worldwide marketand it focuses on Karnataka, India's southernmost state, which has 15 wineries. The wine policy of Karnataka in 2007 has opened a range of new opportunities for wineries and grape-growing farmers. According to Mr Manjunath VG, Vice President of Grover Zampa vineyards located in Bengaluru, Karnataka, presently produces 2.9 lakh metric tons of grapes in 16000 hectares. Karnataka's climatic conditions are apt for wine making as it has warm days and cool nights which help in the production of wine grapes. Though climatic conditions favour vine growing and winemaking, wine is the least consumed beverage according to the preliminary study. Therefore, the study aimed to gather information from all wineries, grape producers and wine consumers to understand the parameters followed and the needs of the consumers and accordingly develop strategies to match the needs of the consumers and benchmark Indian wines in the global market.

Enhancing quality of wine

It is considered that obtaining goods and services that can satisfy customers' wants and aspirations equates to quality (Fukey and Issac, 2014). The grape industry and wine manufacturers create goods that appeal to consumers (Jianying *et al.,* 2014). The grape harvest, varietal, soil and grower's experience were factors that affected wine quality (Smith and Bentzen, 2011).

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pH value, phenolic compounds and maceration

The pH scale is used to measure acidity; a higher pH value indicates a lower amount of acidityand a lower pH value indicates a higher degree of acidity. According to Ghatak, *et al*. (2014) Winemakers prefer a pH of 3.0 to 3.5 since the lowest pH promotes wine stability and affects intrinsic characteristics including flavour, colourand taste. Maceration is the initial stage of extracting the phenolic components from the grapes. The amount of alcohol in wine grows during the soaking process and would only marginally decrease if the wines were macerated for more than 14 to 30 days. Additionally, the quantity of esters grew as the wine's skin contact increased from the seventh to the fourteenth day of maceration (Petropulos *et al*., 2014).

Fermentation

Higher amounts of the chemicals responsible for the fresh and fruity aroma were discovered at 15°C. At 28°C, the

amount of floral-related scent components was higher (Molina *et al.,* 2007). A good balance between fruitiness and greenness is achieved in the white wine by using a low temperature during fermentation. The ideal temperature range for white wine production was 10 to 15°C, which balanced the notes of herbs and tropical fruits (Deed *et al.,* 2017). According to (Jagadeesh *et al.,* 2022) the fermentation period impacts the level of alcohol content and pH value in wines.

Ageing

White wine maturing in steel tanks contributed to an increase in alcohol, estersand other fragrant compounds (Meng *et al*., 2011). The oldest and most established traditional method, oak barrel ageing has been utilised extensively because it consistently yields high-quality wines (Tao *et al*., 2014). The characteristics of wood were transmitted to wineand the wood used for the process of maturation determines how much of the former is produced (Hernández *et al*., 2007). The pH and alcohol concentration of wine demonstrated an increasing tendency as it aged (Kiribhaga *et al*., 2022).

Grape varietal

Vitis vinifera grape cultivars had higher flavanol content than non-Vitis vinifera grape varieties (Li *et al*., 2017). The longest time with a neutral posture and appropriate wrist movement occurred with the VSP system (Kato *et al*., 2006). Phenolic compounds are abundant in grapes (*Vitis vinifera*), a plant in the Vitaceae family, especially in the skin and seeds (Krithika *et al*., 2015).

Late harvest

When key flavour and aroma constituents reached their peak in the later stages of ripening, there was a noticeable variation among the grapes (Cramer *et al*., 2014). When compared to early-harvest grapes, the late-harvest grapes contributed a more favourable sensory profile to the wines (Casassa *et al.,* 2013a). According to (Vool *et al*., 2015) The amount of soluble solids varied with temperature; it was lower in colder weather. For 'Vitis Vinifera' grape varietals, a Brix value of 20 to 23° Brix is advised.

Quality function deployment

QFD is a management strategy that helps teams stay focused on the customer's requirements throughout the whole manufacturing process of a process or product by employing a visual connective process (Bouchereau and Rowlands, 1991). QFD was a defined process to make sure that new products either matched or exceeded consumer demands (Cristiano *et al*., 2001).

The research questions addressed were:

1. What is the present winemaking standards followed in Karnataka and how does it affect the quality of wine?
2. What is the impact of quality wine grapes, customer's wine preferences and wine regulations on bench marking Indian wines?

Aim and objective

To conduct benchmarking studies and analyse data to determine suitable parameters for efficient wine benchmarking in the Karnataka region.

MATERIALS AND METHODS

The data was collected from all the stakeholders, namely, winery, customers and grape-growing farmers and further, the results were analysed statistically by using statistical tools like Pearson's Correlation and Cronbach's Alpha. Further, House of Quality was developed using the Quality Function Deployment (QFD) tool.

The study used 3 different questionnaires to collect surveys from consumers, wineries and farmers. Customers included (416 wine-consumers) of all ages who live in Karnataka and have consumed wines of both the New World and Karnataka. Karnataka is wine-producing state and it has 15 wineries. The product-related data was collected from 13 wineries (from the winemakers/owners) as the other 2 wineries denied permission. Thirty-two grape producers from around Karnataka answered the viticulture questionnaire. The Cronbach's alpha of the questionnaires is as follows: Customer's Questionnaire 0.8, Winery Questionnaire -0.7 and Grape Grower's Questionnaire - 0.8. This research work was carried out in the time frame of 2022-2023 at Ramaiah University of Applied Sciences, Bengaluru, India.

RESULTS AND DISCUSSION

Quality function deployment (QFD)

QFD deals with 3 components namely, the voice of the customer, areas of improvement and evaluation of the activities. This helps us to know what the customers demand and how the business evaluates its activities to fulfil that consumer needs. It also enables the business to know what improvements and innovations can be made to fill in the gaps. This is done using a House of Quality in QFD. House of Quality is a recognized specific tool within the QFD. It is a logical process and is created sequentially in a step-by-step procedure.

The house of quality is made up of numerous important parts (Fig 1), which are as follows:

Step 1: Customer requirements- Defines what customers want.

Step 2: Engineering requirements- Define how customer needs can be fulfilled by the business.

Step 3: Relationship matrix- It defines the correlation between customer and engineering requirements (What and How).

Step 4: Roof of the house- Defines the correlation between the engineering requirements (How).

Step 5: Competitive assessment- It shows how the company is performing in comparison with its competitors and defines the position in the market.

Step 6: Basement- Evaluate the engineering requirements (How) and define how the target can be fulfilled.

Benchmarking wines of india (Fig 2)

The study aimed to conduct benchmarking studies and analyse data to determine the apt parameters for evaluating wines in the Karnataka environment. The step-by-step House of Quality analysis (Fig 2) is explained below in detail.

Customer requirements

The results of the analysis (Fig 2) indicate that the informative labels rank highest among the following: grape variety, wine quality, wine taste, complementary food, price, wine label design, wine brand name, alcoholic content, health benefits of wineand wine colour. These elements would feature in the House of Quality's "Customer Requirement" column. On a scale of 1 to 10, the average importance rating provided by 416 customers is displayed in the next column labelled "Importance."

Engineering requirements (Relationship Matrix)

Wineries and vineyards would be better able to meet consumer expectations if the criteria related to winery management were followed in the order of priority indicated in Fig 4 and 5. This includes the efforts made by wineries and grape growers to meet the needs (How's). This segment lists all the parameters required by the winery

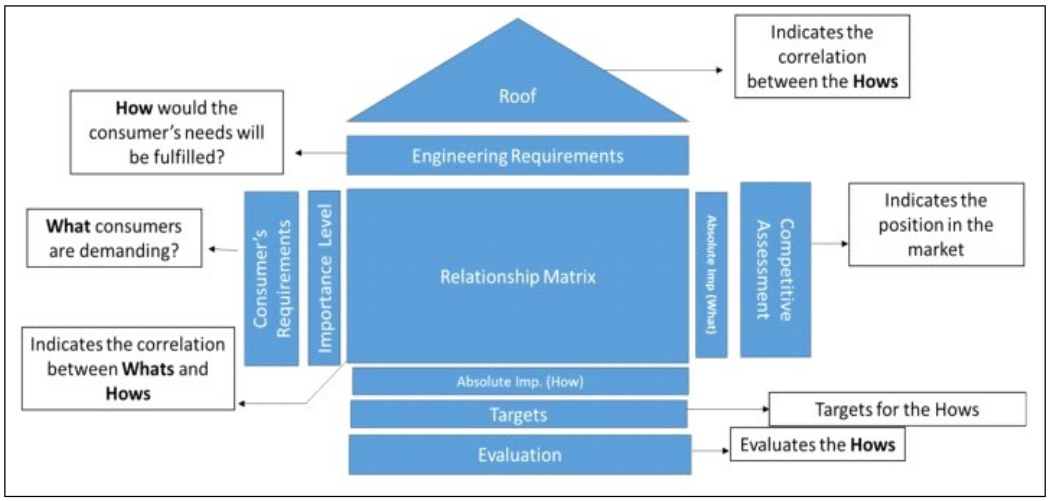

Fig 1: House of quality.

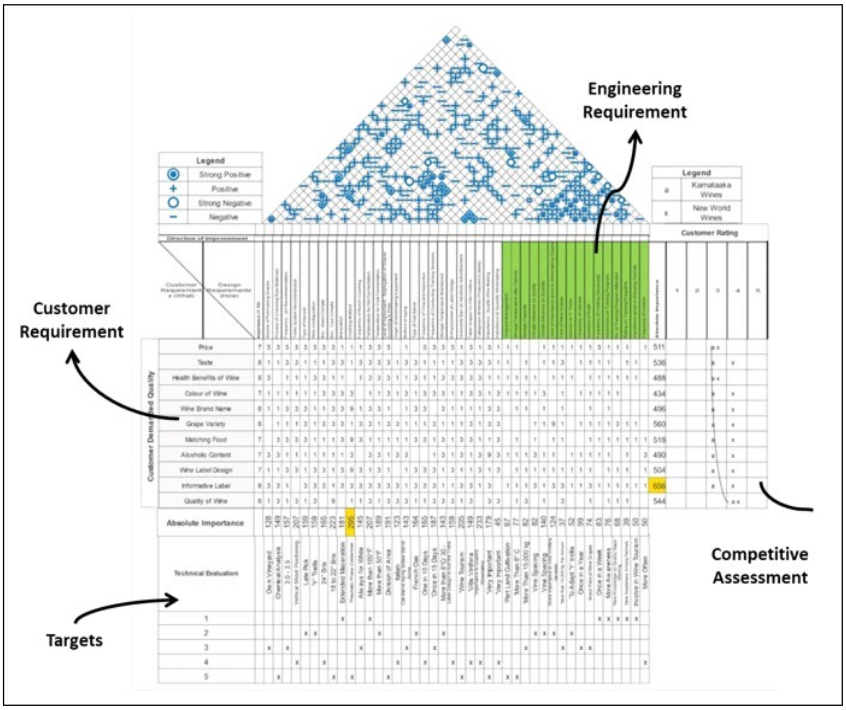

Fig 2: Identification of winemaking and grape growing parameters using house of quality.

and vineyard to produce a quality wine. The orders of importance of consumer requirements are shown in Fig 6 which would help wineries to fulfil the customer requirements. The correlation between the engineering requirements and customer needs yielded the numbers, which were then ranked as 9, 3, or 1 depending on how strong, medium, or weak the correlation was. The scores are mentioned in the 'Relationship Box' of House of Quality (Fig 3).

Relationship matrix - Calculation of values: (Fig 2)

Engineering requirement

This is obtained by correlation analysis (Pearson's) between each customer requirement factor and the parameter of winemaking (Table 1 and 2) or grape growing (Table No. 3 and 4) which is presently followed by the wine industry and done to identify the order of importance of parameters.

E.g. The price and source of grape purchases have a medium correlation.

Hence, a score of 3 is given. Likewise, the scores are given for each correlation in the relationship box. Therefore,

Absolute importance of price=Sum (Importance of Price) × Each Correlation Score. (in a horizontal manner).

This indicates the order of importance of engineering requirements.

Customer requirement

This calculation is done to find out the order of importance given by consumers while purchasing a wine.

Importance rating for Price (given by consumers) = 7. This is used to arrange the factors in the order of greater to

Strength of correlation	Score
Strong	9
Medium	3
Low	1

Fig 3: Scores given based on correlation strength.

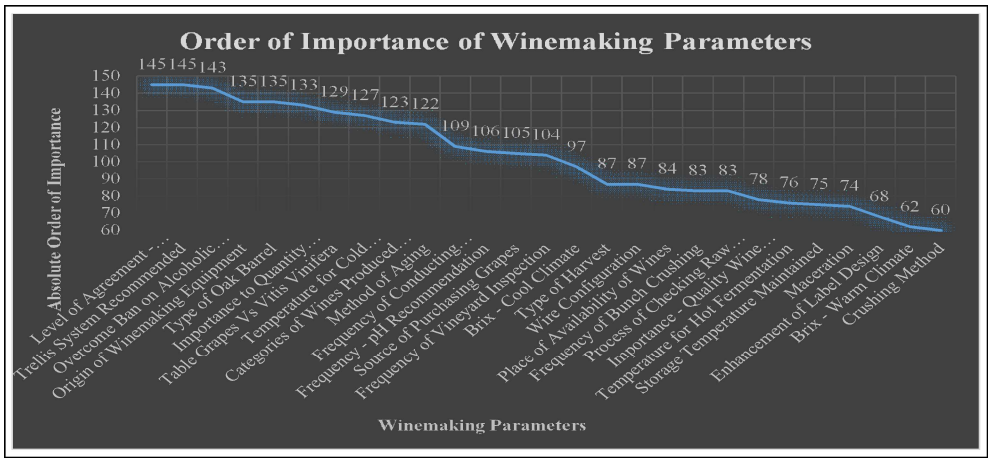

Fig 4: Winemaking parameters and Its order of importance based on house of quality analysis.

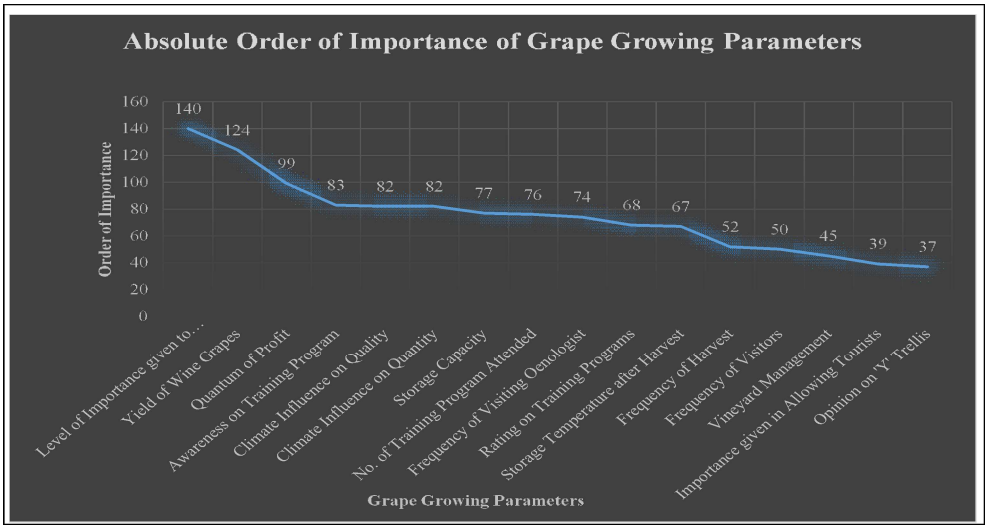

Fig 5: Grape growing parameters and its order of importance based on house of quality analysis.

Table 1: Correlation between customer requirements and winery related factors.

Correlation table of importance level of consumer requirements and winery related factors													
	Source of purchasing grapes	Process checking raw materials	Frequency of pH recomm--endation	Trellis system	Harvest type	Wire config--uration on	Brix-Warm climate	Brix-cool climate	Temp hot	Temp-cold ferment	Level of agreement segregating grapes according to plots it is grown	Origin of wine making equip	Frequency of vineyard inspection
Price	-0.3	-0.3	-0.4	0.4	-0.4	0.6	0.3	-0.3	0.5	0.3	0.5		-0.4
Taste	-0.1	-0.1	-0.6	0.3	-0.2	0.2	0.1	0.3	0.3	0.4	0.5	-0.2	-0.2
Health benefits	-0.3		0.2	-0.2	0.1	-0.4	-0.5	-0.1	0.4	-0.4	-0.3	-0.2	-0.2
Colour	-0.1	-0.1	-0.1	0.1	-0.1	-0.1	0.3	-0.3	0.1	0.2	0.5	0.1	-0.3
Brand	0.1	0.2	-0.5	0.6	0.3	-0.1	0.1	-0.3	0.3	-0.3	0.1		0.4
Grape Variety matching food		-0.1	0.2	0.1	-0.3	0.1	0.6	-0.3	-0.4	0.2	0.3	0.5	0.1
		0.3	-0.3	0.7	0.4	-0.2	0.1	-0.2	0.2	-0.1	0.2	0.2	0.5
Alcoholic content	-0.4	-0.3	0.1	0.1	-0.1	-0.2	-1	-0.2	-0.5	-0.4	-0.2	0.6	
Wine label Design	-0.1	-0.2	-0.3	0.4	0	-0.3	-0.3	-0.1	-0.1	-0.3	-0.2		0.5
Comprehensive Label	-0.5	0.1		-0.4	0.5	0.5	-0.1	-0.3	0.4	0.5	0.6	-0.5	-0.3
Quality	0.2	0.4	0.2	-0.3	0.1	-0.3		0.8	0.3	0.2	-0.3	-0.5	0.1

Source: Primary data.

lesser and thus the order of importance of customer requirements are analyzed.

Therefore,

Absolute Importance of Price = Sum (Importance of each Customer Requirement × Correlation Score of Source of Purchasing Grapes (in a vertical manner).

This is used to arrange the factors in the order of greater to lesser and thus the order of importance of engineering (vineyard and winery) requirements are analyzed. The same as been mentioned in Table 5, Fig 4 and 5.

Competitive assessment

This component, known as the competitive assessment, shows where Karnataka wines are concerning their competitors based on consumer requirements that have been defined (Fig 7). This was obtained from the customer questionnaire where the wine customers were requested to assess the Indian wines in comparison to other New World wines based on their wine consumption experience. This was done to understand where Karnataka wines stand in the competitive assessment column of the House of Quality. As a part of the questionnaire, the customers were asked to rate Karnataka wines and other New World Wines that are available in Karnataka on a scale of 1 to 5, with 1 being the lowest and 5 being the highest. This section of House of Quality analysis shows where Karnataka wines stand with its competitors based on customer criteria. In terms of other factors namely, taste, colour, brand name, grape variety, matching food, alcoholic content, wine label design and informative wine label Karnataka wineries lag behind in comparison to other New World Wines.

Basement (Targets)

House of Quality's basement (evaluation tab) displays the targets that specify how engineering requirements can be improved to satisfy customer needs and outline the potential for business improvement. Wineries and grape producers were given questions about various engineering needs to assess their present circumstances and identify areas for improvement.

Fig 8 and 9 demonstrate the goals defined for each parameter, which are winemaking and grape growth. The parameters were analyzed on a scale of 1 to 4 in the order of significance indicated by this study in Fig 8 and 9, there is potential for improvement.

In summary, the study identified multiple wine-making (27 criteria) and grape growing (16 parameters) requirements that must be addressed for high-quality winemaking while taking into account the global benchmark (Table 4 and 5). The most crucial factors that wineries and grape growers should use to compete with other New World wines in the global market were also determined by comparing the parameters to the standards adhered to in Karnataka (Step 5).

Table 2: Correlation between customer requirements and Winery-related factors (Contd.)

Correlation table of importance level of consumer requirements and winery related factors

	Freq of training sessions	Storage temp. maintained	Label design balancing	Table Vs vitis Vinefera	Imp-Qlty wine making	Macer-ation	Crushing method	Freq-bunch crushing	Method of aging	Type of Oak barrel	Ban on alco ad	Table Vs VV	Categories of wines produced (labels)	Imp-qty wine making
Price	-0.6	-0.4	-0.3	0.5	-0.5	0.1	0.1	-0.2	-0.1		0.2		0.2	-0.1
Taste	-0.1	0.1	-0.2			0.3	-0.1	-0.5	0.5	0.3	0.3	0.4	0.4	-0.4
Health benefits	0.2	-0.3	-0.4		-0.1	-0.2		-0.1	-0.1	-0.3	-0.5	-0.4	-0.5	-0.1
Colour	-0.4	-0.4	-0.1		-0.1	0.4	-0.3		0.3	0.2	0.2	0.3	0.3	-0.5
Brand		0.5	0.1		-0.3	-0.5	0.7	0.2	-0.1		0.2	0.2	0.1	-0.4
Grape variety	-0.4	-0.2	0.2	0.3	0.4	0.4	-0.1	0.6	-0.1	0.1	0.2		0.2	-0.4
Matching food	0.2	0.4	0.1		-0.1	-0.5	0.7	0.4	0.1	0.3	0.3	0.3	0.2	-0.5
Alcoholic content	-0.2	0.4	0.1	-0.2	0.8	-0.1	0.3		-0.5		-0.4		-0.4	-0.3
Wine label Design	0.4	0.2	0.6		0.1	-0.3	0.7	0.5	-0.2	-0.4	-0.1	-0.2	-0.3	-0.3
Comprehensive Label	0.6	-0.1	-0.1		0.3	0.6	-0.5	-0.4	-0.2	0.2	0.3	0.5	0.2	-
Quality	0.6	0.3	-0.3	-0.3	-0.3		-0.1	-0.2	0.5		-0.2			0.5

Original contributions

The focus of this research project was an analysis of the difficulties Karnataka vineyards encounter while trying to enter foreign markets. Consequently, the study's main objective is to benchmark Karnataka wines to those of other New World regions.

- Determined the parameters for grape growing and wine making that would improve wine quality and advance the growth of the winemaking sector, allowing wines to be benchmarked in the New World wine market.
- Determination of factors supporting global outreach regarding winemaking and grape cultivation.
- Quality enhancement of wines and benchmarking regional wines.

The present contribution pertains to the analysis of the state's current winemaking standards and their influence on the benchmarking of Indian wines. It was derived from the QFD analysis conducted during the bench marking study.

The study determined the various wine making (27 parameters) and grape growing parameters (16 parameters), (Table 5) that have to be followed for quality winemaking, keeping in mind the international benchmark. As per the findings after the analysis, the 'informative label' gets the highest level of importance for a customer during a wine purchase. The other customer requirements are as follows as per the order of importance; grape variety, quality of wine, taste of wine, matching food, price, wine label design, wine brand name, alcoholic content,

Table 3: Correlation between customer requirements and vineyard-related factors.

	Correlation table of importance level of consumer requirements and vineyard related factors								
	Storage temp after harvest	Yield of wine grapes	Freq of visiting oenologist	No. of training program	Rating on training program attended	Part land cultivation	Climate influence on quality	Climate influence on quality	Level of imp given to wine making grapes
Price	0.2	-0.2	0.3	-0.2	-0.2	-0.1		-0.1	0.1
Taste			0.1		-0.2	-0.1		-0.1	0.1
Health benefits	0.2	-0.1	-0.1	-0.1	-0.2	0.1	-0.1		-0.1
Colour	0.1		0.1	0.1		0.1	0.1	0.3	
Brand	-0.1							-0.1	
Grape variety			0.1	-0.3	-0.2		-0.1	-0.1	1
Matching food	-0.2		0.1	0.1	0.2		0.1		0.1
Alcoholic content	0.1		-0.2		0.1	0.2	-0.3	-0.2	-0.2
Wine label design	0.1			0.1	0.1		0.2	0.2	0.2
Comprehensive label	-0.2		0.2	0.1	0.1	-0.2	0.3	0.2	0.3
Quality	-0.1			0.1	0.2			0.1	

Source: Primary data.

Table 4: Correlation between customer requirements and vineyard-related factors.

	Correlation table of importance level of consumer requirements and vineyard related factors								
	Opinion Y" trellis	Freq of harvest	Quantum of profit	Awareness on training prog	Imp given in allowing tourists	Freq of visitors	Storage capacaity	Yield of wine grapes	Level of imp wine making grapes
Price	0.1	0.1		-0.2		-0.1			
Taste		0.1	0.2	-0.1	0.1		-0.2	-0.3	0.2
Health benefits	-0.1		-0.2	-0.2	-0.1		-0.1		-0.2
Colour			0.2	0.1			0.2	0.2	0.2
Brand			0.1	-0.1			0.2	0.1	0.1
Grape variety		-0.1	-0.2	-0.2	-0.2			-0.2	-0.2
Matching food			0.2	0.2	0.1	-0.1		-0.1	0.2
Alcoholic content	-0.2	-0.2		-0.1		0.4	0.2		
Wine label design	0.1	0.1	0.1	0.2		-0.1	0.1	0.2	0.1
Comprehensive label	0.2	0.2		0.2	0.2	-0.2	0.2	0.3	
Quality			-0.1	0.2			-0.3	-0.3	-0.1

Source: Primary data.

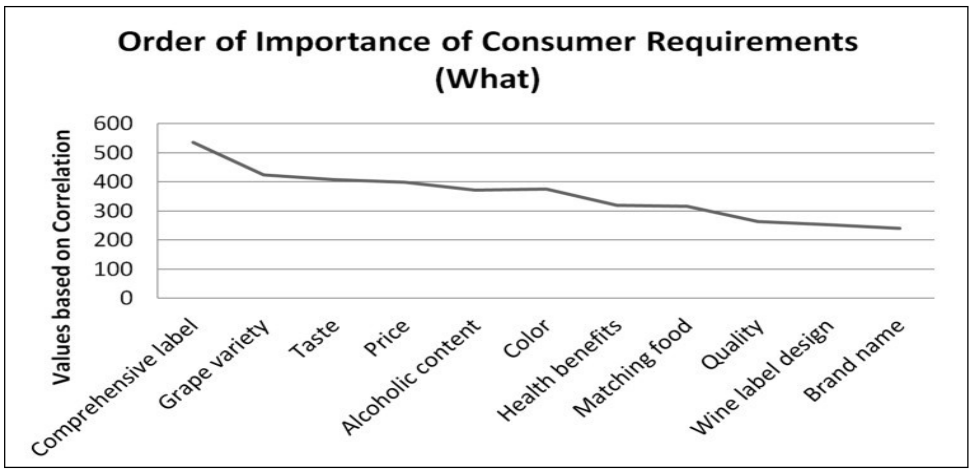

Fig 6: Order of importance of consumer requirements.

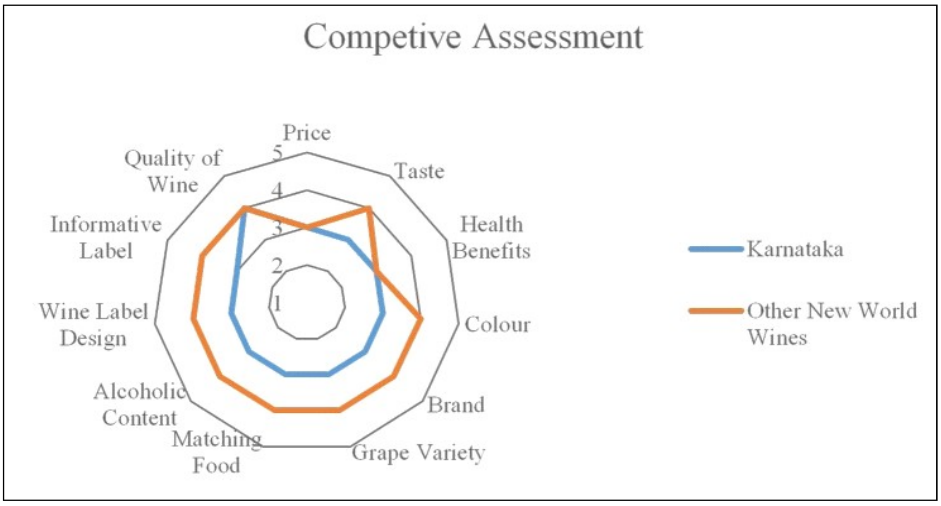

Fig 7: Comparison of Karnataka wines and other new world wines based on the customer rating.

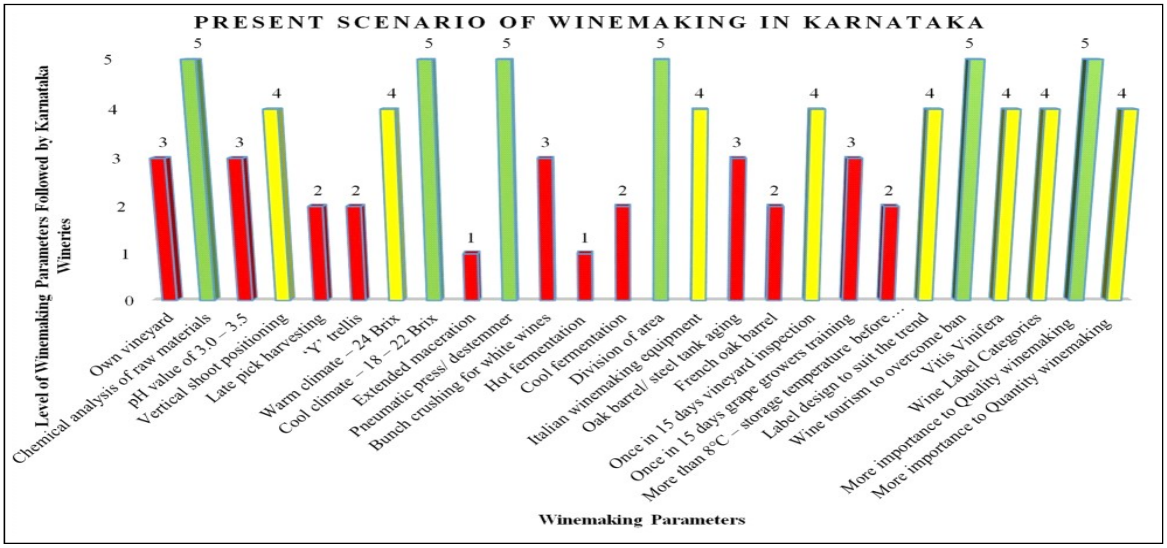

Fig 8: Evaluation of winemaking parameters followed by karnataka wineries and the scope of improvement.

As per the absolute importance of the engineering requirement of the study, that is, the techniques to be followed by the wineries and vineyard to produce quality wine are as follows according to the order of importance. These techniques if followed will match the customer requirements.

Based on the findings for House of Quality, study recommends wineries to use pneumatic press/de-stemmer

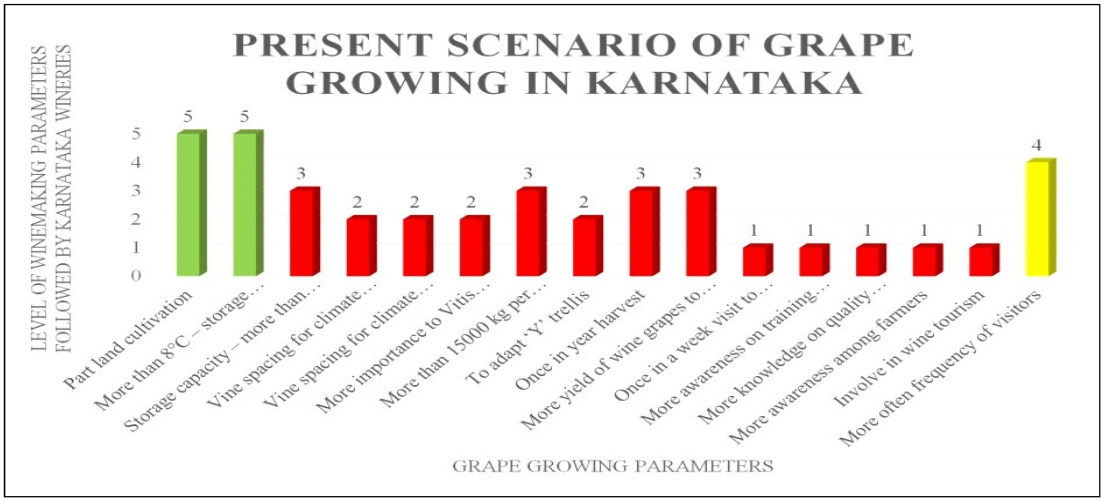

Fig 9: Evaluation of grape growing parameters followed by Karnataka vineyards and the scope of improvement.

Table 5: Order of absolute importance of winemaking requirements recommended to karnataka wineries.

Order of importance	Absolute importance of winemaking requirements	Score that decides the order
1	Level of Agreement - Segregation of Grapes According to Plots	145
2	Trellis System Recommended	145
3	Overcome Ban on Alcoholic Advertisement	143
4	Origin of Winemaking Equipment	135
5	Type of Oak Barrel	135
6	Importance to Quantity Winemaking	133
7	Table Grapes Vs Vitis Vinifera	129
8	Temperature for Cold Fermentation	127
9	Categories of Wines Produced (Labels)	123
10	Method of Aging	122
11	Frequency of Conducting Training Sessions	109
12	Frequency - pH Recommendation	106
13	Source of Purchasing Grapes	105
14	Frequency of Vineyard Inspection	104
15	Brix - Cool Climate	97
16	Type of Harvest	87
17	Wire Configuration	87
18	Place of Availability of Wines	84
19	Frequency of bunch-crushing	83
20	Process of Checking Raw Materials	83
21	Importance - Quality Wine Making	78
22	Temperature for Hot Fermentation	76
23	Storage Temperature Maintained	75
24	Maceration	74
25	Enhancement of Label Design	68
26	Brix - Warm Climate	62
27	Crushing Method	60

health benefits of wine and colour of wine. These are factors customers emphasise while purchasing a wine to match these customer requirements. for crushing grapes and always follows 'bunch crushing' for winemaking which will help keep the flavours of the grape intact. To maintain a brix value of 18° to 22° Brix in cool climate and 24° Brix in warm climate. 15°C to 30°C is the ideal temperature range for hot fermentationand 10°C to 15°C is ideal for cold fermentation. All wineries are suggested to use only the Vitis Vinifera grape varietal for winemaking and segregate grapes according to the plots. The table grapes are grown to be physically appealing, larger, seedless and thicker pulp. Vitis vinifera is a grape with thicker skin and higher juice content and is cultivated to create the sweetest and most potent grapes. When storing grapes for winemaking, they should be kept between -1 and 5°C and undergo a lengthy maceration. The storage temperature of Vitis vinifera grape varietal is -1 to 0.5°C (30 - 31°F) at 90 - 95% humidity. The wine in the maceration period (extended maceration) of 10 days was found to be higher in anthocyanin content, saturation and red colour when compared to wine which was in the maceration period of 30 days as it developed higher astringency, lighter colour and vegetal aromas. Regarding ageing, red wines should be aged in French oak barrels and steel casks. Both quality and quantity wine making are to be considered very important and frequently conducted training programs to get updated and frequently visit oenologists. The vineyard inspection is to be conducted frequently to make sure the vineyards follow the prescribed rules. It is advised that all vineyards incorporate wine tourism into their operations to get around the prohibition on alcohol-related advertising and connect with customers. In addition, the wineries enhance the wine label to suit the latest trend.

The vineyards are suggested to follow late harvest, as it increases the sugar level in the grapes. The study suggests the following part land cultivation, Vertical Shoot Positioning and 'Y' trellis system. The study recommends vine spacing in the vineyard to be more than 4 feet which would enable an equal proportion of sunlight to the vines. The pH level recommended is 3.0-3.5 and follow a chemical analysis for checking the raw materials. The wineries are suggested to have their vineyard which might help in maintaining the quality.

Conclusion

A study was conducted to benchmark Indian wines with other New World Wines in Karnataka to determine the necessary parameters for quality winemaking. The study identified 27 winemaking and 16 grape growing parameters that need to be followed for quality winemaking. The study also determined that an informative label is the most important factor for customers when purchasing wine, followed by grape variety, quality of wine, taste of wineand other factors. To compete with other New World wines in the international market, Karnataka wineries and grape growers should implement these parameters. The study suggests that wineries in India should adhere to established quality standards in order to improve the quality of their wine. Currently, only a small number of wineries follow these standards, leading to a reliance on table grapes and a lack of bunch crushing. Adhering to quality requirements could improve the reputation of Indian wines in the global market and increase competitiveness. The study's limitation is that it only included wines from seven New World wine regions to prevent bias because wines from other wine regions were either unavailable in Karnataka or were just slightly available. In addition to the limitation, there are 15 wineries in the state, out of which 13 wineries gave the information, 2 wineries were not ready to share information and 1 winery is in the transition period (change of ownership). The study focused only on the wineries of Karnataka leaving out the other 2 wine-producing regions of the country, namely, Maharashtra and Himachal Pradesh.

Conflict of Interest

The authors have no conflict of interests related to this publication.

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