Preparation of Wine from Cactus Fruit in Adigrat Rural Areas

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***Abstract* - Six cactus cultivars which are commonly found in the Adigrat region were selected for the study. Optimization of fermentation conditions (like yeast strain, pH and temperature) and production of higher alcohols and other volatile compounds during wine fermentation were investigated. To prepare wine, the fruits were peeled and juice (must) was extracted immediately after crushing (control). The second fermented bottle lebelled by 'F2-J2' gave the highest juice yield (600 ml/kg) followed by F1-J1' (570 ml/kg). The sugar content of must ranged from 15 to 18% (w/v). The recovered juice was fermented at 15 and 20^{0}C and the ethanol concentration of cactus wine ranged from 6.3 to 8.5 per cent. Fermentation efficacy of three yeast strains, viz. Saccharomyces cerevisiae CFTRI 101, Palm Wine Isolate and Baker's Yeast was done and highest score was obtained for 'F2' wines with yeast strain S. cerevisiae CFTRI 101 followed by 'F3'. Total volatile composition of mango wine was evaluated using GCMS and identified 33 compounds having fruity aroma characters. More volatiles were observed in wine produced from 'F2'(320 mg/l).**

***Keywords* - Cactus juice, *Opuntias species*, GCMS analysis, Wine production, Volatile composition, Sensory evaluation**

I. INTRODUCTION

The food industry is always looking to find ways to add value to food, known as value added processing. Value added processing is simply the processing of an item resulting in a finished product having a value exceeding the cost of processing. The perish ability of fresh fruits makes it a good candidate for processing, especially for processing methods that extend its shelf life. Wine is an alcoholic beverage produced through the partial or total fermentation of wine producing fruits. Wine making was probably first discovered by accident when early men experienced the pleasures of alcohol that had been fermented by natural yeast from badly stored fruits and *V. Vinifera*. Historians believe that wine was being made in Caucasus and Mesopotamia as early as 6000 BC [Robinson K, The Oxford Companion to Wine, Oxford University Press, London, 1994.] Today Wine is a popular drink being enjoyed all over the world. Rig-Veda amply testifies that the wine is perhaps the oldest fermented product known to man. Wine has been made in India for as many as 5,000 years. It was the early European travelers to the courts of the Mughal emperors Akbar, Jehangir and Shah Jahan in the sixteenth and seventeenth centuries who reported tasting wines from the royal vineyards. In general, grapes are the main fruit that has been used for wine production. Though, the suitability of fruits other than grapes has been investigated all over the world the amount of wine produced from non-grape fruits is insignificant. For instance, beetroot, pineapple, sugar beet etc. [Joshi VK and Devender A, Panorama of research and development of wines in India, J Sci Indus Res, 2005, 64, 9-18.] Wine consists of flavoring, sugar, acid, tannin and yeast but above all water. It is the fermented product of the fruit of several species of *Vitis*, mainly *V. Vinifera*. The cactus pear fruit *(Opuntias ficus indica)* is associated with the semi-arid zones of the world; it is one of the few crops that can be cultivated in areas which offer very little growth possibility for common fruits and vegetables (Han & Felker, 1997). Commonly eaten fresh, it is known in some areas of the world as the 'bridge of life' because, during periods of little rain, it is one of the only crops that can be used as both human food and cattle feed.

Cactus pear is indigenous of the semi arid basins and valleys of South America (Mexico) 20, 000 years ago and later spread to the entire American continent and after it spread to the rest of the world. Cactus pear adapted well in the Southern Africa. Cactus pears were first introduced to South Africa more than 300 years ago. Carried by settlers to arid and semi-arid parts of the sub-continent thereafter, the plants gradually reverted to their spiny forms over a period of approximately 150 years. This contributed to the plant's invasive properties, which often resulted in dense, impenetrable thickets. More than two million hectares were invaded during the early part of the 20th century, severely affecting agriculture – although in cooler parts of the country, cactus was less aggressive and farmers utilized it more extensively. Similar invasions occurred in Ethiopia, Eritrea, Yemen, Saudi Arabia and Madagascar. To solve the problem of uncontrollable invasions, South Africa relied on biological control: pests such as the Cactus Moth (Cactoblastis cactorum) and the Cochineal (Dactylopius opuntiae). As predicted, however, these same insects also began to attack cultivated cactus. [Directorate Agricultural Information Services, PRETORIA 0001] .In Ethiopia especially in northern part of the country there is high potential production of pear cactus. Tigray covers about 80, 000 square km and is estimated to have about 360 000 ha of cactus pear, of which about two thirds consists of spiny plants. About half of the existing area of opuntias was planted; the remainder has been invaded by the naturalized cactus. Despite the great extent and importance of cactus pear in Ethiopia, there is a singular lack of awareness or mention of it in the literature on cactus pear, including the recent authoritative review by Barbera et al. (1995).

Several research studies have been carried out on the chemical composition of cactus pear fruit and production of juices, marmalades, gels, liquid sweeteners, dehydrated foods and other products other than wine. (Sawaya et al., 1983a;SaH enz, 1990; Cacioppo,1992; Ewaidah & Hassan, 1992; SaH enz et al., 1995c; (2000 Academic Press & Felker, 1997. In view of this, a research programme was initiated to investigate the suitability of cactus fruit for wine production, and also to characterize the wine produced. It had three specific Objectives, namely: Determine some characteristics of wine (taste, alcoholic content, Specific gravity, color, and flavor), Study sensory analysis and Study techno-economic feasibility analysis (by comparing the material cost and product cost). The laboratory production process of wine from cactus fruit begins at the vineyard/winery, where wine cactus using special techniques for cultivating and maintaining the crop, depending upon the species of cactus fruit and type of wine associated. Thereafter, the cactus fruits are harvested/collected, upon which they are then extracted of their juices, called the must, in a process called crushing either mechanically or by treading, the traditional method of basically cleaning by using leaves of tree remove the spiny and unwanted matters of the flesh of the cactus fruit. Cactus wines, as described in this project, are produced by fermented the raw cactus juice, from which the alcohol that is produced during the fermenting process will begin to give acceptable wine characterize. Fermentation commences by mixing the juices, sugar and citric acid and yeast together which then produces alcohol and carbon dioxide. Henceforth, the wine is then introduced into a series of processes called clarifying where the yeasts and other debris are filtered, fined and kept at constant temperature. Wine must then be aged for some time, in a process named aging, and thereafter bottled and transported to the end user. The whole process can take considerable time, from several weeks, months to years depending upon the degree of quality to be achieved.

II. OBJECTIVES OF THE PROJECT

General objective

The general objective of the project is production and characterization of wine from cactus fruit

Specific objective

– Determine some characteristics of wine (taste, alcoholic content, Specific gravity, color, and flavor).
– Study sensory analysis (taste, color, flavor and over all acceptance) using panelists.

***Opuntias species* description**

A number of authors have described Opuntias (Bravo, 1978; Pimienta, 1990; Sudzuki, Muñoz and Berger, 1993; Sudzuki, 1999; Scheinvar, 1999; Barbera, Inglese and Pimienta, 1999; Nobel and Bobich, 2002). That said, a brief description of the plant is useful as a reminder of the different parts used, the industrial processing required and the resulting end products. *Opuntias* are creeping or upright shrubs that can grow to 3.5–5 meters high. The root system is extensive, densely branched and with many fine shallow absorbing roots highly suited to arid zones. The length of the roots is closely related to the prevailing agro-environmental conditions and to crop management practices – particularly the use and application of irrigation and fertilizers (Sudzuki, Muñoz and Berger, 1993; Sudzuki, 1999; Villegas and de Gante, 1997).The succulent and jointed cladodes (stems) have an oval or elongated racquet shape that can grow up to 60–70 cm long depending on the amount of water and nutrients available (Sudzuki, Muñoz and Berger, 1993). When the cladodes are around 10–12 cm long they are tender and can be eaten as a vegetable. Cladodes continue to grow in size for about 90 days. The buds (called areoles) can be found on both sides of the cladodes. These are capable of developing new cladodes, flowers or roots depending on environmental conditions (Sudzuki, Muñoz and Berger, 1993). The areoles have two types of spine in their cavity: small and large. The small ones, grouped in large numbers, are called 'glochids' (aguates in Mexico) and the large ones are modified leaves according to some authorities (Granados and Castañeda, 1996). When people come into contact with the plant, spines are released that may penetrate the skin, and this can be a serious impediment when harvesting, processing and eating the fruit. The pads later lignifies and become woody stems that crack and turn white to grey in color. The flowers, which are sessile, hermaphrodite and solitary, normally develop on the upper edge of the leaves. Color is variable and includes red, yellow and white. In most parts of the world the plants flower once a year, although in Chile, under certain environmental conditions and with water supplied during summer, there is a second flowering in autumn (March), which explains the origin of the name inverniza for this fruit (Sudzuki, Muñoz and Berger, 1993).

Fig. Several types of *oputinia* plants

General characteristics of the species

Opuntias species has, simultaneously, both common and diverse characteristics. A capacity to resist high temperatures and long periods of drought make Opuntias highly suitable for production in arid and semi-arid zones. Some species are widely used for fruit production because of their high quality. This is the case with *Opuntias ficus-indica*, *Opuntias hyptiacantha*, *Opuntias megacantha* and *Opuntias streptacantha*. Some species produce colored fruit, which is an additional attraction for consumers. Other species are more suitable for the production of fleshy leaves as a vegetable (nopalitos), such as *Opuntia robusta*, *Opuntias leucotricha* and *Opuntia ficus-indica*. A large number of species are used to pro-duce forage, including *Opuntia robusta*, *Opuntias leucotricha* and *Opuntia ficus-indica*. Other species are used for cochineal breeding. The fruit is probably the most interesting part of the plant given its differing size, low acidity and useful sugar content. The characteristics of *Opuntias xoconostle* are different and attractive. These are described below different parts of the plant: chemical composition at various physiological states: In order to utilize the plant industrially it is essential to ascertain the chemical composition of its different parts. This helps in determining the most appropriate processing technologies and the conditions required to achieve safe, nutritious and high quality products. The fruits and cladodes are widely used for food, but the flowers are considered as a vegetable and can be eaten as such (Villegas and de Gante, 1997).Changes in the pH and the soluble solids and fiber content occur during ripening and must be taken into account when processing fruit or clad-odes to produce the best possible products.

III. Materials And Methods

Description of the study Area

The study was conducted between December and June, 2015, in Adigrat University, which is located in an estimate of 898 km away from Addis Ababa, capital city of Ethiopia to the north.

According to Central Statistical Agency of Tigray Region (2005), Adigrat town is located in the Eastern Tigray, at longitude and latitude 14°16’N of the Equator and 39°27’E of the meridian on the map of the world with an elevation of 2457 meters above sea level.

Sample collection and storage

Mature and healthy Cactus fruits were obtained from a farm in Fatsi, Edaga Hamus, Erob and Ganta Afeshum rural areas which were found in Eastern zone of Tigray around Adigrat. The sample was taken for the study using cylindrical plastic container and transported to Adigrat University, Chemistry Laboratory so as to become ready for the sample preparation step. The general and physiochemical characteristic was done at Addis pharmaceutical industry, Mekelle chemistry laboratory and Adigrat University, Chemistry Laboratory. During the sample preparation the cactus fruit was cleaned to remove any other foreign matter that comes along with it, the cactus fruit was sorted and visually inspected in order to remove any physically damaged from it. Therefore, the cactus fruit stored with in a cylindrical container at room temperature.

Cactus fruit wine production process

Raw material selection

Cactus fruit wine was made from following essential ingredients (water, cactus fruit, sugar, yeast, soybean and citric acid).

1. **Water**:-the water must be pure, with no trace bacteria.
2. **Cactus fruit**: - Cactus fruit is an edible fruit. It has a high nutritional value, as it is an excellent source of carbohydrates, proteins, and dietary fibers. It is rich in essential minerals such as iron and calcium, as well as other vital nutrients like folic acid and antioxidants.
3. **Yeast: -** It's quite simply the *Saccharomyces cerevisiae* (baker’s yeast) that convert the sugars in your fruit juice (called the must) to alcohol and carbon dioxide. Yeasts are tiny organisms that are floating around in the air and if you just leave a cup of cactus fruit juice on the side in the kitchen, within hours it will have some yeast in there. Unfortunately there are many types of yeast and wild yeasts are more likely to produce vinegar than wine. That's why you buy your yeast for wine making. Wine yeasts have been developed to withstand a high level of alcohol over the years and you can just buy all-purpose wine yeast.
4. **Citric acid: -** it is important to give the wines a lively flavor and also used to control growth of micro organisms during the production of root beet wine.
5. **Sugar: -** Ordinary household sugar will suffice (enough). The larger amount of sugar used, the more alcohol will be formed, within reason, but the yeast will not tolerate too much sugar. When the yeast has converted as much of the sugar as possible into alcohol, the fermentation will stop.

The overall production process starts from cleaning of the collected sample this is used to remove un wanted materials then next after cleaning slicing becomes this in order to increase the surface area it can help easily extract the juice from the fruit after slicing juice was extract using juice extractor equipment next the extracted juice cooked until boil it (at 100^0C) in this stage some amount of water was added after cooked the juice cool for few minutes and filter the cooked juice using sieve filter then next mixing of sugar, citric acid, water, yeast with the juice was carried out. After mixing fermentation process were proceed, during this process time and type of fermentation was different which mean that fermentation of the mixed juice were takes place at different time interval and fermentation type were both aerobic and anaerobic type these were to determine the quality of the product. Then next after fermentation clarification of some residues and yeasts were done using cloth filter finally aging was carried out in order to make the product flavored.

Experimental procedure

Fig: partially laboratory Instruments and equipments

Instrument	Equipment	chemicals
Refractometer	Fermenters	Cactus fruit
Viscometer	Oven	Citric acid
Conductivity meter	knife	Sugar
Picknometer	Dishtype container	Water
polarometer	weight balance	*Saccharomyces cerevisiae* yeast
PH meter	Sieve filter	
Stirrer and funnel	Storages	
Muffle furnace	Measuring cylinders	

Wine production Procedure

- 2.5 kg of cactus fruit was cleaned or washed thoroughly and was sliced thinly using knife after the fresh cactus.
- The sliced one was placed in juice extractor to be extracted the juice from the cactus fruit.
- The PH of the juice was measured.
- Brought to boil covered, cooked at 100°c water for about 60 minutes and 0.75L water was added.
- Removed from the heat and strained the liquid (juice) using sieves filter into container.
- 15ml citric acid was added then 0.25kg white sugar, and 1.5Lwater to the juice container.
- It was stirred well to dissolve the sugar and allowed cooling.
- Put for several days for fermentation to be carried out.

Fermentation types for the conversion of sugar found in the cactus fruit to ethanol.

a) **Fermentation type one -** 0.25kg Sugar, 15ml of citric acid (to enhance distinct aroma/flavor), 2.25L of water, 1.25 L of cactus fruit juice and0.00017kg yeast was added and mixed together and then fermented with anaerobic fermentation type for 7 days.
b) **Fermentation types two -** 0.25kg Sugar, 15ml of citric acid (to enhance distinct aroma/flavor), 2.25L of water, 1.25 L of cactus fruit juice and0.00017kg yeast was added and mixed together and then fermented with anaerobic fermentation type for 10 days.
c) **Fermentation types three -** 10ml citric acid was added, 2L water and 0.0017kg yeast to the 1L cactus fruit juice and it was fermented in anaerobic fermentation type for 14 days.
d) **Fermentation types four -** 10ml citric acid was added, 2Lwater and 0.0017kg yeast to the 1L cactus fruit juice and it is **aerobic** fermentation type for 14days. And then the result of these four fermentation type were recorded individually and they are found in the result and discussion part.

Mass determination

2.5kg cactus fruit bought and mass of single seed was determined by weighting on mass balance so as to measure the mass of sample used for the analysis.

Bulk Density determination of single seed cactus fruit

First the seed was measured using weight balance and next put water in the measuring cylinder with specified volume. The seed cactus fruit was immersed to the cylinder then the water was dispersed and increased its volume. So to be determined the bulk density of the single cactus fruit seed. The mass of single seed cactus fruit was measured by weight balance divided to the change in volume.

PH Determination

The pH meter was standardized with buffer solution to be determined the acidity as well as basicity of the prepared wine in the following method:

- The buffer solution with pH buffer solution of pH 4.00 at 25°C dissolved in 250ml distilled water was prepared.
- The electrode of the pH meter was in a glass beaker containing the sample was immersed.
- -The readings from the photo-detector of the pH meter obtained.

Alcohol content determination

Using hydro meter; measuring the specific gravity (SG) of the juice and wine determining the alcohol content.

$$Alcohol\ content = \frac{(SG_{start} - SG_{final})}{7.36}$$

- 100ml of the sample (must i.e., before fermentation) in the cylinder of the hydrometer and the value (original gravity) of the cactus fruit juice read on the hydro meter was placed.

- Also, after fermentation, 100ml of the sample in the cylinder was applied and immersed the hydrometer to the sample and read the specific gravity from the hydro meter table.

Chemical analysis

- The titrable acidity, pH and specific gravity of the cactus fruit juice were extracted and the standardized must were determined by the method of AOAC (2000).
- Alcohol percent of the fermenting must were determined every 24h for the first 8 days and every48h for the subsequent 6 days. These parameters were also determined for the produced wine and the imported wine.
- The titratable acidity was determined according to the method of Zoecklein *et al*; (1990) and reported as tartaric acid (% w/w).
- The soluble solids was determined using Abbe's refractometer at 20^0C, while the alcohol concentration was determined using the alcohol distillation and specific gravity method (Egan*et al*;1987) and conversion table (Amerine, *et al*; 1980).
- The concentration of reducing sugars was estimated by Shaffer & Somogyi11 method. Total dissolved solids were measured by estimating specific gravity of water soluble portion of the juice obtained by the centrifugation at 10,000 × g for 15min. The specific gravity was determined at 20°C with densitometer. With the aid of approximate tables the results were converted to grams of dissolved solids per 100 ml and expressed as grams of sucrose. Total acidity was determined by titration with 0.1 N NaOH expressed in tartaric acid and volatile acidity within the distillate samples expressed in acetic acid mg/100ml.
- Ethanol and other metabolites (glycerol, methanol and total esters) were determined with the help of Gas Chromatography.

Sensory evaluation

The bottled wine samples were evaluated for colour, taste and general acceptability rating by a expert panelists of 15 randomly selected men and women of between 18-40 years of age, who are familiar with testing wines. Each assessor was presented with chilled (15±2^0C) coded samples of wine in a clear glass tumbler and asked to taste the samples and rate their impression on a 9-point hedonic scale from excellent (9) to extremely bad (1).
One fully fermented imported red wine (free cell) was used as comparative references samples. The coded developed wine samples were also separately presented to the respective assessors to indicate if they would buy the wine if it were presented for sale.

IV. RESULT AND DISCUSSION

Results of the physico- chemical tests

The results of juice yield, physical and chemical composition is presented in Table 3.1. The juice of different fermented wines varies in sugar concentrations and other physico-chemical characteristics.

Table 3.1physico chemical composition of wine from cactus fruit juice

Fermented wines	**Juice (ml/kg)**	**Reducing sugars (% w/v)**	**Titrable acidity (%)**	***p*H**	**TSS* %**
F_1–J_1	570±10	16.3±1.32	0.33	4.1±0.53	16.0±1.2
F_2 - J_2	600±13	15.5±2.21	0.43	3.9±0.86	14.2±1.8
F_3-J_3	550±17	18.5±1.24	0.32	4.0±0.6	20.5±0.79
F_4-J_4	500±22	16.0±1.0	0.31	4.2±1.0	16.5±1.2

F1-J1=Before fermentation during juice time one similarly for the rest

As it shown above Fermented (F_2 - J_2) gave highest juice yield (600ml/ kg) followed by 'F_1–J_1', F_3-J_3 and F_4-J_4. The main prerequisite character of juice for fermentation is sugar content. The total soluble solids (TSS) of the cactus fruit must range from 14.2 to 20.5 per cent. The high TSS was from 'F_3-J_3' (20.5%) followed by 'F_4-$J_4$and F_1–J_1 lastly F_2 - J_2' (16.5%, and 14.2% respectively).
The sugar content of must range from 15 to 18% (w/v) while titrable acidity as tartaric acid range from 0.310 to 0.43% (w/v). The pH of the musts was 3.8 to 4.2. The low *p*H (3.9) was recorded in F_2 - J_2 variety that tasted acidic.

Physico-chemical characteristics of Cactus wine

The physical and chemical characters of Cactus wines fermented by the specified model tank are shown in Table 4.2.

Table 3.2 physico-chemical characteristics of cactus wine

Fermented wines	**Ethanol (%w/v)**	**T.A (% v/v)**	**V.A (%V/V)**	***p*H**	Residual sugers	Higher alcohols(mg/l)	**Total esters(mg/l)**	**Tannins(%w/v)**	**Color OD @590nm**
F_1	7.5	0.65	0.1	3.8	2.1	300	25	0.011	0.22
F_2	7	0.735	0.21	3.8	2.4	200	29	0.072	0.18
F_3	8.5	0.6	0.181	3.7	2.0	343	35	0.012	0.23
F_4	7	0.622	0.121	4	2.0	320	20	0.012	0.17

T.A = Titrable acidity **V.A= volatile acidity**

The concentration of higher alcohols differed with cactus fermented wines (200 to 343 mg/l) (Table 3.2) and highest content was in the wine produced from 'F3' and lowest in 'F2'.
Preparation of fruit cactus fruit influenced the synthesis of higher alcohols during fermentation.
Their concentration in Semillon wine tends to be lower in wine made from later harvested grape [Cole VC, 1995]. Our results also confirmed the previous reports [Millicevic B, 2002]. Higher alcohols may influence certain sensory characteristics although they constitute a relatively lesser quantity of the total Substances. Fermentation changed the aroma of fruit juice, because of the production of yeast volatiles and the metabolism of original fruit volatiles.
The concentration of esters in wine varied from 20 to 35mg/l (Table 2) and it was affected by many factors like variety of fruit, clarification and fermentation conditions. The results obtained confirmed the previous published reports [Zulian MF, 2002]. The concentration of total polyphenols was different in wine from cultivar to cultivar of cactus fruit. The highest concentration was detected in wine produced from 'F_2' followed the quantity of phenolic compounds present in cactus wine is comparable with commercial white wines. In all the cases the phenolic concentration increased after the fermentation. Phenolic compounds are among most important compounds in determining the quality of the wine, because they greatly influence colour, bitterness, astringency and chemical stability of the wine [Amerine, M.A, 1980].

Characterization of cactus wine by GCMS

The composition of wine prepared from 'F2' is shown in Table 3.3. The three major compounds (alcohols, esters and organic acids) were present in different concentration. The isoamyl alcohol (125mg/l) was higher in quantity as compared to all the compounds detected by GCMS, followed by isobutyl alcohol (102mg/l), n-propanol (54.11mg/l) ethyl acetate (35.15 mg/l) and phenyl ethanol (24.15mg/l) (Table 5). Ethyl hexanoate, ethyl decanoate and ethyl octanoate are produced in higher quantities (1.150 and 2.34g/l, respectively) in 'F2' (data not presented).
The volatile acids present in cactus wine are acetic acid, propanoic acid, benzoic acid. It is clear from this study that higher alcohols and esters were the main constituents in wine produced from Cactus fruits. Wine made from 'F2' showed good number of aroma components. Therefore, it is important to know the potential differences in volatile production by various yeast strains and fruit varieties in order to select the best one to produce desirable wine.

Table 3.3 different alcohols

S.no	Retention time(RT)	Name of the compound	F2(mg/l)
1	1.271	Ethanol %	8.5
2	1.35	Ethyl ether	Solvent
3	1.492	1-propanol	54.11
4	1.729	Isobutyl alcohol	102.40
5	2.581	Isoamyl alcohol	125.23
6	2.85	Pentane-2one	1.43
7	4.823	2-furan methanol	0.123
8	6.535	Hexane-1-ol	1.42
9	12.90	Phenethyl alcohol	22.15
10	19.414	Cyclohexane methanol	1.13
11	42.58	n-pentanedecanol	0.610
12	1.665	ethyl acetate	35.15
13	6.876	Ethyl hexanoate	0.942
14	15.92	Ethyl octanoate	1.15
15	20.124	Ethyl decanoate	2.34
16	19.67	Dimethyl strene	1.11

Sensory evaluation

After the chemical analyses, the beverage was subjected to sensory analysis to assess its acceptance among the consumers.
Table 3 presents notes attributed to the beverage by 15 trained tasters, designated in the Hedonic scale of nine points (1 = dislike extremely; 9 = like extremely). The average values were recorded for the four evaluated attributes of which the aroma is the one with a slightly higher value, followed by the taste, appearance, and overall acceptance with the respective questions.
The tests indicated some improvement in aroma and taste of the wines produced by using cells immobilized on cactus peels, particularly at low temperatures, when compared to wines produced by free cells (Table 3.4).
This can be attributed to the reduction of amyl alcohols, which are off-flavour compounds, at lower temperatures and therefore to an increase in the proportion of other aroma compounds in total volatiles. Mallouchos *et al*. (2003b) reported that wines produced by cells immobilized on grape skins have a better fruity aroma. Similar results were also reported by García-Romero *et al*. (1999) who found a considerable improvement in the wine sensory profile when fermentations were carried out in contact with the skins of Airen white wine grapes because of the transfer of the precursors of volatile compounds like esters, aldehydes, and alcohols into the wine. The wines produced by immobilized yeast biocatalyst showed fine clarity at the end of fermentation with low free cell concentrations as well as characteristic pleasant soft aroma and fruity taste.

Table 3.4. Effect of the use of immobilized yeast on sensory characteristics

Attribute	Wine from free yeast cells	Wine from immobilized yeast on cactus fruit
Appearance (color)	5.6±0.82	7.6±0.54(p<0.0243)
Aroma	6.1±0.25	7.9±0.73(p<0.0156)
Taste	6.7±0.67	7.7±0.24(p<0.1763)
General acceptance	6.7±0.67	7.5±0.61(p<0.2009)

V. CONCLUSIONS

The biocatalyst is economical, food grade, and does not need special pretreatment before use. Cactus peels, which otherwise may pollute the environment; can be beneficially used as an alternative cell immobilization support.
It can be concluded that F_2, F_1 and F_3' cactus fruits are most suitable for quality cactus wine production. The sensory evaluation has indicated that the wine possesses novel characteristics in aroma and taste and good acceptability. 'F2' wine fermented with yeast strain was most acceptable followed by 'F2' and 'F4'. Information on an adequate process for both juice and wine production from cactus and other tropical fruits and the findings regarding pectinase treatment, formation of major volatile compounds, GCMS characterization and sensory evaluation can be valuable references to the wine industry. This first study on the use of cactus peel as an immobilization support for yeast during wine making showed the potentialities of this process. The results obtained open the possibilities of applying this process also to other fermented beverages.

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