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EFFECT OF DIFFERENT SOURCES OF FERMENTATION ON FLAVOUR PROFILE OF APPLE WINES BY DESCRIPTIVE ANALYSIS

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Flavour profiling by descriptive analysis of apple wines fermented with different *Saccharomyces cerevisiae* strains and natural sources of fermentation with or without nitrogen source addition was carried out. Out of 45 attributes used, 38 were found significant and were employed for further evaluation. Generally, the intensities of many of the descriptors in the apple wines were low. Both the natural sources of fermentation (NSF) imparted different flavours notes like lactic, sharp, acetic and fruity to the wine. "W" strain of *Saccharomyces cerevisiae* gave wines with higher astringency and phenolic flavours, ethyl acetate like, acetaldehyde like flavour, UCD 505 and UCD 522 fermentated wines were peculiar for more ethanolic, sweety and bitter taste, whereas UCD 595 imparted more phenolic, astringent, sour, and ethanolic flavour notes to the wines. The addition of nitrogen source (irrespective of source of fermentation) reduced the development of some flavours considered undesirable (acetic, amyl alcoholic, fusel alcoholic, vegetative). Addition of nitrogen source enhanced the intensity of some other flavour attributes like ethanolic and phenolic in the wines. Due to the same vinification practices (except for the source of fermentation) some modifications in the flavour attributes of apple wines fermented by natural source of fermentation were recorded. The flavour profile of wines fermented by different sources of fermentation, was also reflected in the chemical characteristics examined. Besides higher fermentability, the addition of nitrogen source also affected the physico-chemical characteristics of the wines and consequently, their flavour profile. Application of Principal Component Analysis (PCA) to the means of flavour scores generated from flavour profiling, weakly separated and characterized the wines fermented by different sources of fermentation but did not differentiate the wines fermented with or without nitrogen source. It is concluded that the descriptors described here can characterize apple wine of different quality attributes. The list of descriptors, concentration of standards and details of the technique have also been described.

Keywords: alcoholic beverages, natural sources of fermentation, flavour profile, *Saccharomyces*, descriptive analysis, principal component analysis

Preparation of products like cider and wine of appealing qualities is essential for consumer acceptance. To maintain the quality, many factors such as fruit maturity, yeast strains, nitrogen source addition, use of enzymes and other postfermentation treatments

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and clarifying agents are optimized (AMERINE et al., 1980; WILLIAMS, 1982; EWART, 1986; JOSHI & BHUTANI, 1991). The quality of wine can be specified in terms of physical, chemical and sensory quality characteristics especially the flavour.

Wine flavour by palate is limited mainly to sweetness, sourness, bitterness, astringency, but may include metallic and pungency (PIGGOTT, 1988; SHANTI NARASHIMAHAN & RAJALAKSHMI, 1999). It has also been described as a multi-dimensional sensation and quantified using Descriptive Analysis (DA) technique by employing various discriptors and subjecting the data to multivariate analytical techniques such as Principal Component Analysis (PCA) for different alcoholic beverages; grape wine, beer, pear and apple essences (NOBLE et al., 1984; WILLIAMS, 1975; WILLIAMS et al., 1978; and WU et al., 1977). For cider also, flavour is an important quality characteristic and its production depends upon a variety of factors such as apple juice, variety/maturity of fruits, various ingredients, yeast strains, fermentor design and operation, secondary fermentation, maturation and processing factors alongwith the final product make up (JARVIS et al., 1995). A descriptive flavour profile wheel has also been developed and is used within the cider industry, to compare the ciders made under different conditions or that from different raw materials. However, as a routine analytical tool, only a few general descriptors are employed (JARVIS et al., 1995) though for research purposes the number of descriptors may range from 50 to 86 (NOBLE et al., 1984; WILLIAMS et al., 1978).

Apple wine or cider is still produced in some countries of the world by the spontaneous fermentation in contrast to the standard wine yeasts (AMERINE et al., 1980). How much the flavour of such a wine is different from that made by the standard wine yeast is not documented. Whether the flavour profile of apple wine fermented by different strains of *Saccharomyces cerevisiae* is different from that made from natural source of fermentation, is also not clear. Neither it is documented that how much addition of nitrogen source influences the flavour quality of apple wine. An attempt has been made here to answer some of these questions by developing suitable descriptors and determining their effectiveness in characterizing the apple wines using PCA.

Materials and methods

1.1. Materials

In all, 12 types of apple wines were prepared in the experiment using 4 standard wine yeasts viz. *Saccharomyces cerevisiae* var. *ellipsoideus* strains, W, 505, 522, 595 and two natural sources of fermentation, NSF_1 and NSF_2 (Table 1). The natural sources of fermentation were obtained from the tribal areas of Himachal Pradesh, consisting of solid residues from the indigenous fruit fermentations to prepare alcoholic beverages. NSF_1 and NSF_2 were two morphologically different materials, which were used in the study (JOSHI & SANDHU, 2000).

Table 1. Physico-chemical characteristics[a] of apple wine fermented with different sources of fermentation

Treatment No.	Source of fermentation/ yeast of strains	Ethanol (% v/v)	Total sugar (%)	Titratable acidity (%)	Total[b] soluble solids (°B)	pH	Tannin (mg l^{-1})	Esters (mg l^{-1})	Volatile acidity (%AA)	Methyl alcohol (µg l^{-1})	Amyl alcohol (µg l^{-1})
Saccharomyces cerevisiae (W)											
1	With nitrogen	11.0	0.30	0.48	7.0	3.74	152	79	0.02	50	264
2	Without nitrogen	10.5	0.83	0.49	7.2	3.94	207	68	0.05	63	352
Saccharomyces cerevisiae (UCD 505)											
3	With nitrogen	9.8	0.59	0.54	7.2	3.81	195	125	0.05	68	198
4	Without nitrogen	7.4	1.91	0.42	6.9	3.90	189	111	0.04	79	211
Saccharomyces cerevisiae (UCD 522)											
5	With nitrogen	10.9	0.55	0.42	7.4	3.90	168	83	0.02	49	279
6	Without nitrogen	8.6	1.07	0.32	6.2	4.11	184	43	0.05	70	282
Saccharomyces cerevisiae (UCD 595)											
7	With nitrogen	12.0	0.41	0.50	7.0	3.75	168	71	0.02	135	280
8	Without nitrogen	9.4	0.51	0.41	7.0	4.02	189	71	0.05	131	271
Natural source (NSF_1)											
9	With nitrogen	8.5	1.06	0.49	7.2	3.78	146	83	0.02	190	318
10	Without nitrogen	6.4	5.00	0.78	7.9	3.88	209	588	0.17	144	325
Natural source (NSF_2)											
11	With nitrogen	8.7	1.13	0.54	12.6	3.67	151	129	0.04	507	260
12	Without nitrogen	5.7	3.12	0.71	10.6	3.79	281	226	0.22	680	327
	CD (P>0.05)	0.13	0.25	0.53	1.81	0.08	27.9	10.7	0.007	–	–

[a] Composition prior to blending
[b] Direct refractometer reading
Nitrogen source = 0.1%

The apple must was prepared from apple juice concentrate diluted directly to total soluble solids (TSS) of 24 Brix (°B). The apple juice concentrate was manufactured by hpmc, Parwanoo, (H.P) having 72 °B and 1.7% acid (malic acid). Even number treatments were without nitrogen source, while the odd received 0.1% diammonium hydrogen phosphate (DAHP). To each set, 100 ppm SO_2 and 0.5% pectinol enzyme were also added.

The fermentation of apple must (4 litres each) with different sources of fermentation was carried out in duplicate at a temperature of 22±1 °C in the glass containers equipped with air locks in duplicate. The fermentation was initiated by 5% inoculum of respective source of fermentation prepared in the sterilized apple juice. When no more fall in °B took place, the wines were siphoned and filled in the containers. The wines were racked after every 15 days followed by one months' interval. The wines were matured for a period of one year at an ambient temperature (mean 15±8 °C). These were pasteurized at 62.5 °C for 20 min, after keeping a head-space of 2.5 cm, when matured.

1.2. Physico-chemical analysis

The wines were analysed for different physico-chemical characteristics viz. total sugars, ethanol, total soluble solids, pH, titratable acidity, volatile acidity, tannins, esters, methyl alcohol and amyl alcohol as per the standard methods (AMERINE et al., 1980; RANGANNA et al., 1986; CAPUTI et al., 1968). Total soluble solids (°B) were measured by hand refractometer, pH by digital pH meter, ethanol was measured colourimetrically by potassium dichromate method, while the colour was estimated by Lovibond tintometer and expressed as units of red and yellow colour. Tannins were also measured colourimetrically with tannic acid as a standard. All the estimations were carried out in triplicate. Methyl and amyl alcohol content, in the beverages were measured by GLC (Shimadzu make). For methanol estimation, nitrogen flow of 30 ml min^{-1} as a carrier, column and injection temperature of 130 and 222 °C respectively, in 'Porapack' column, were used. Amyl alcohol was measured by SE-30 column and injection temperature of 40 °C and 110 °C with nitrogen flow of 18 ml min^{-1}. Flame ionisation detector (FID) was used for both the estimations. Standards were also analysed similarly and were used to calculate the methyl alcohol and amyl alcohol contents in the samples, respectively. All other operational conditions were the same as prescribed by the manufacturer. Both methyl and amyl alcohol were expressed as $\mu l\ l^{-1}$.

1.3. Flavour profiling

One year matured wines were used for sensory analysis by descriptive analysis as detailed earlier (PIGGOTT, 1988). The judges were familiarized in the training session with different wines and the standards prior to flavour profiling session. The various descriptors used were the same as described by WILLIAMS (1975) for evaluation of cider and perry aroma constituents. Discussion was allowed only in the familiarizing session.

Five judges participated in the sensory evaluation session. The judges evaluated the wines in duplicate. No wine was presented to the judges in combination of more than once. In each session, 6 wines were served to the judges. The judges were asked to evaluate the wines for different terms called as ‘descriptors’ and to award scores (1–9), depending upon the intensity of flavour tested, in comparison to the standard whose intensity was rated to be the highest (9 score). Evaluations were carried out in the isolated booths at room temperature. During the session, the panelists used plain water to rinse their mouths in between the wine tasting session. The wines were served in tulip shaped wine glasses, covered with glass dishes. Judges evaluated each term as listed in Table 2, across all the samples before proceeding to the next sample.

1.4. Analyses of data

The data obtained from the of physico-chemical analyses of apple wine were analysed by analysis of variance using completely randomised design (CRD) and the means with critical differences (CD) are reported.

1.5. Principal component analysis

The data of flavour profiling were first assessed by the analysis of variance 3 factor randomised block design (RBD) for significance of differences between the treatments, performance of judges and the significance of attributes. Means of only significant terms were used for Principal Components Analysis (PCA). The statistical computer programme was run on a Personal Computer in the computer Centre of Dr YSPUHF, Nauni, Solan using PCA, BAS computer package (LUDWIG & REYNOLDS, 1988). Various descriptors, treatments and the scores constituted the data. The output was obtained in the form of Principal Components (first three) for the treatments (species) and attributes (sampling units), correlation coefficients matrix and eigenvectors. The analysis was performed without rotation. The three PC components were plotted in 3-D diagram for determining the respective positioning of the treatments in three dimensional space. The values for principal components (PC) for attributes as vectors and principal component values for the wines of different treatments obtained by fermentation by different sources of fermentation were plotted simultaneously. The interpretation of data from PCA was made accordingly. The means of different descriptors were plotted as spider web diagrams with respect to the source of fementation, with/without nitrogen source.

Table 2. Details of descriptors and summary of analysis of variance* of apple wines fermented by various fermentation sources

No.	Descriptor	Standard	Treatment	Judges	Replication	Judges	Wine
1	Sharp	Acetic acid (1%)	2.78*	0.59	0.07	3.03	2.60*
2	Vinegary	Vinegar (25 time diluted)	6.27*	8.26*	1.10	5.59	7.92*
3	Acetic	Acetic acid (15 µl/100 ml)	7.80*	36.32*	3.06	3.96	12.79*
4	Lactic	Sauerkraut liquid (few ml)	1.96*	2.31	0.35	1.59	3.31*
5	SO_2	KMS (0.5% soln)	5.77*	33.34*	0.04	3.95	3.02*
6	Acetaldehyde	Acetaldehyde (100 µl/100 ml)	1.83*	9.03*	0.09	1.29	1.35
7	Ethyl alcohol	Ethyl alcohol (8%)	13.92*	9.56*	5.63	6.45	12.95*
8	Amyl alcoholic	75 ml/100 ml of amyl alcohol	9.20*	65.55*	3.39	3.95	9.71*
9	Ethyl acetate	10 µl/100 ml of ethyl acetate	4.66*	26.94*	3.15	1.95	7.18*
10	Fusel alcoholic	10 µl/100 ml methyl propanol	8.48*	22.07*	2.12	6.99	9.50*
11	Black currant	Black currant jam	1.33*	4.50*	0.12	0.71	2.63*
12	Berry like	Strawberry essence	0.84	2.31	1.04	0.78	0.53
13	Plum like	Plum pulp	5.99*	13.80*	5.57*	4.35*	9.70*
14	Apple like	Apple juice concentrate diluted (1:6)	2.34*	23.55*	1.88	1.38	1.13
15	Grape like	A few fruits of grape	3.36*	13.03*	1.38	2.14	4.74*
16	Citrus like	A few pieces of orange peel	9.48*	85.31*	3.76	3.10	7.40*
17	Apricot like	Apricot flavour	4.73*	26.71*	2.75	2.53	5.54*
18	Green/unripe	Green grass/green olives	2.68*	6.15*	0.25	1.94	4.40*
19	Cucumber like	A piece of fresh cucumber	6.73*	2.81*	0.32	5.95	11.27*
20	Vegetable like	A few pieces of cabbage	1.48*	6.28*	0.07	1.08	1.32
21	Rose like	Petal of rose	4.54*	27.31*	7.04*	2.72	3.53*
22	Metallic	Sodium carbonate (1% soln)	4.16*	17.12*	2.76	2.69	5.31*
23	Musty	A wooden cork	2.81*	15.67*	0.26	1.77	2.28*
24	Earthy	0.5% Bentonite in 10 ml water	1.09	1.20	1.74	0.75	2.41*
25	Spicy (black pep)	Pieces of black pepper	2.37*	7.34*	0.37	1.87	2.71*
26	Allspicy	Mixture of spices (25 times dil.)	2.26*	5.03*	4.70*	1.89	2.77*
27	Spicy/clove	A few pieces of cloves	1.07	2.53*	1.26	0.68	2.10*
28	Synthetic	Vanilla flavour (25 times dil.)	2.59*	3.12*	0.94	1.60	6.32*
29	Caramel	Heated 65% sugar solution	8.34*	38.62*	0.07	5.26	9.60*
30	Sweety	Sugar solution (1%)	22.50*	132.70*	13.35*	10.50	30.41*
31	Burnt	Burnt sugar	5.09*	1.45	0.18	3.92	11.09*
32	Raisin	A few pieces of raisin	7.27*	11.17*	1.13	4.54	16.75*
33	Yeasty	Fermented must (1 g sediment)	3.51*	12.10*	0.22	2.50	4.44*
34	Lactic	Curd	2.10*	5.85*	0.01	1.37	3.65*
35	Mushroom	A few pieces of mushroom	4.52*	16.22*	2.56	3.79	3.02*
36	Sulphury	One hard boiled egg	1.14	1.97	0.15	1.05	1.25
37	Cabbage	A few pieces of cabbage	1.43*	6.74*	0.08	0.99	1.23
38	Rubbery	A rubber piece boiled in water	1.60*	4.49*	0.43	1.00	2.97*
39	Astringent	A few pieces of Aonla	7.90*	20.18*	3.31	6.55	8.82*
40	Phenolic	100 mg l^{-1} soln. of tannic acid	3.79*	21.09*	2.67	1.74	5.70*
41	Sour	0.8% Soln. of citric acid	8.67*	31.18*	6.03*	5.90	11.35*
42	Fatty	Fat (butter) oxidized	5.19*	10.20*	0.09	3.87	8.61*
43	Bitter	Tea leaves extract	11.32*	19.25*	3.76	8.31	20.56*
44	Salty	1% Common salt solution	2.22*	8.47*	0.18	1.43	3.08*
45	Soapy	5 g block of unperfumed soap	1.83*	7.50*	0.164	1.39	1.50

* = significant at 5% level of significance

2. Results and discussion

2.1. Selection of descriptors

The results of ANOVA (Table 2) show that overall there were no significant differences between the treatments for the terms berry like, earthy, spicy/clove and sulphury. The judges scored all the attributes significant except for the terms sharp, lactic, berry like, earthy, burnt and sulphury. Barring the terms; berry like, plum like, sweety and sour for other terms replications were non-significant. All the descriptors except for acetaldehyde, berry like, apple like, vegetable like, sulphury, cabbage and soapy were significant for wines of various treatments. The analysis of the flavour profiling data of different treatments by ANOVA showed it to be significant for 38 attributes out of 45 used in evaluation (Table 2). These attributes were thus, retained for Principal Component Analysis and were used to plot spider web diagram.

2.2. Flavour characterisation of apple wines

In general, the results (Fig. 1) showed that the flavour notes perceived from the apple wines of different treatments were low and mostly in the range of threshold to moderate except for a few whose intensities were quite high (acetic like, ethyl alcohol, amyl alcohol, ethyl acetate, fusel alcoholic, plum like, citrus like, rose like, metallic, caramel, sweety, raisin, sour, astringent and phenolic). The remaining flavour attributes had quite low intensity and all the sources were virtually comparable (Fig. 1). Wines made with natural sources of fermentation exhibited definite variations with respect to some flavour attributes. The trend for NSF1 was similar for all the attributes except for low ethanolic, higher ethyl acetate-like, lower black currant and higher raisin like. It is in contrast to the standard yeast fermented wines. Further, the wines fermented by second natural sources of fermentation (NSF2) imparted higher flavour notes of acetic, ethanolic, amyl alcoholic, ethyl acetate like, fusel alcoholic, plum like, synthetic, caramel like, sweety, astringent and bitter descriptors. In an earlier study, the primary characterization of cider has been described as spicy aromatic apple note as the dominating cider aroma, found in all the ciders, though to a variable extent (Jarvis et al., 1995). The wines fermented by standard wine yeasts generally had high intensity of ethyl alcohol, ethyl acetate, sweety, astringent, phenolic and sour taste. Figure 2 shows that the addition of nitrogen source reduced the intensity of several flavour attributes (lactic, yeasty, amyl alcohol, fusel alcoholic, green, cucumber, sweety, caramel, synthetic, burnt, raisin, cabbage and fatty) but enhanced the intensity of others like ethyl alcohol, rose like, black currant, lactic acid (by taste) rubbery, astringent phenolic, bitter and salty.

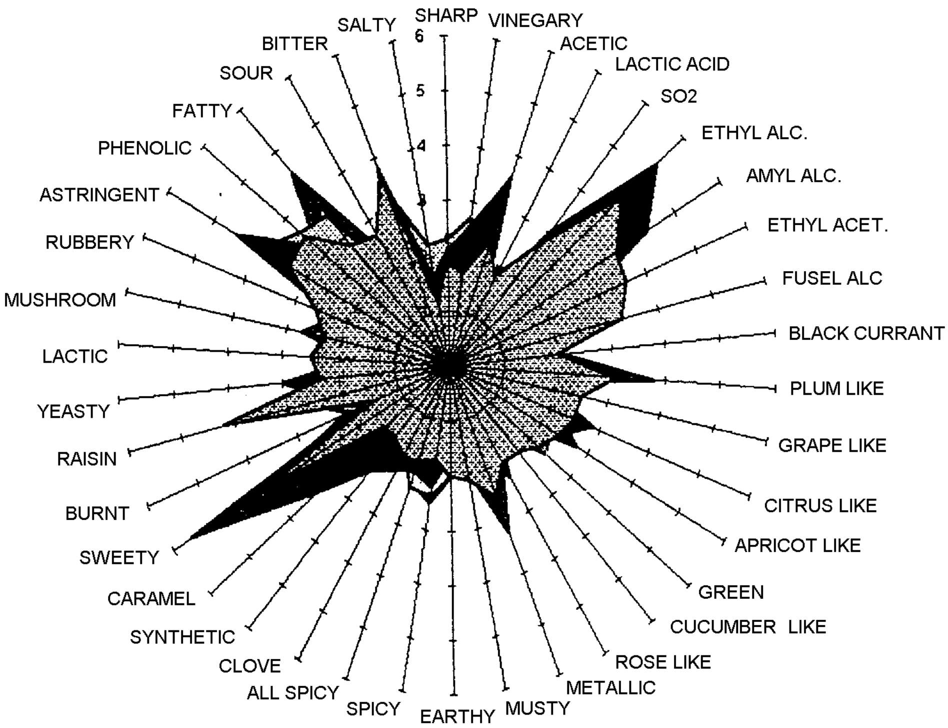

Fig. 1. Flavour profile of apple wines made by different sources of fermentation.
▒ Yeast W; ■ UCD 505; □ UCD 522; ▒ UCD 595; ■ NSF-2; ▒ NSF-2

However, only a small fraction of the flavour notes evaluated (sulphur dioxide, sour, apricot like) remained unaffected by it. The reduction in some of the flavours notes like amyl alcohol, fusel alcohol, sweet and raisin due to addition of nitrogen source might be the result of better fermentability of the musts due to increased availability of nitrogen in the medium. Decline in ethyl acetate or those attributes related to the fruity characters is probably, the result of high fermentability of the musts with nitrogen source which may have made the fermentation related compounds like ethanol, polyphenols and esters more dominating, thus decreasing the perceptions of other compounds and consequently, the related flavour attributes.

2.3. Principal component analysis

The means obtained for different attributes and analysed by PCA indicated that first 3 PCs accounted for 83.2 percent of total variance. However, the first 2 PCs were important as per the KAISER criterion as they have eigen-values of more than 1 (KAISER, 1960). The values of 3 PCs were also plotted as three-D figure with PC 1, PC

2 and PC 3 forming three axis (Fig. 3). It can be seen that the PCA has clustered though weakly all the standard wine yeasts against the NSF_1 and NSF_2 separately, especially the NSF_2 (Treatment No. 12), which is a clear outlier. However, NSF_1 treatment did have some similarity to the standard wine yeast as revealed by the position of the treatment in the figure.

For characterizing the wines, values of PC 1 were plotted against PC 3 (Fig. 4). The figure shows that the PCA separated to some extent the wines fermented by natural sources of fermentation from those fermented by the standard wine yeasts.

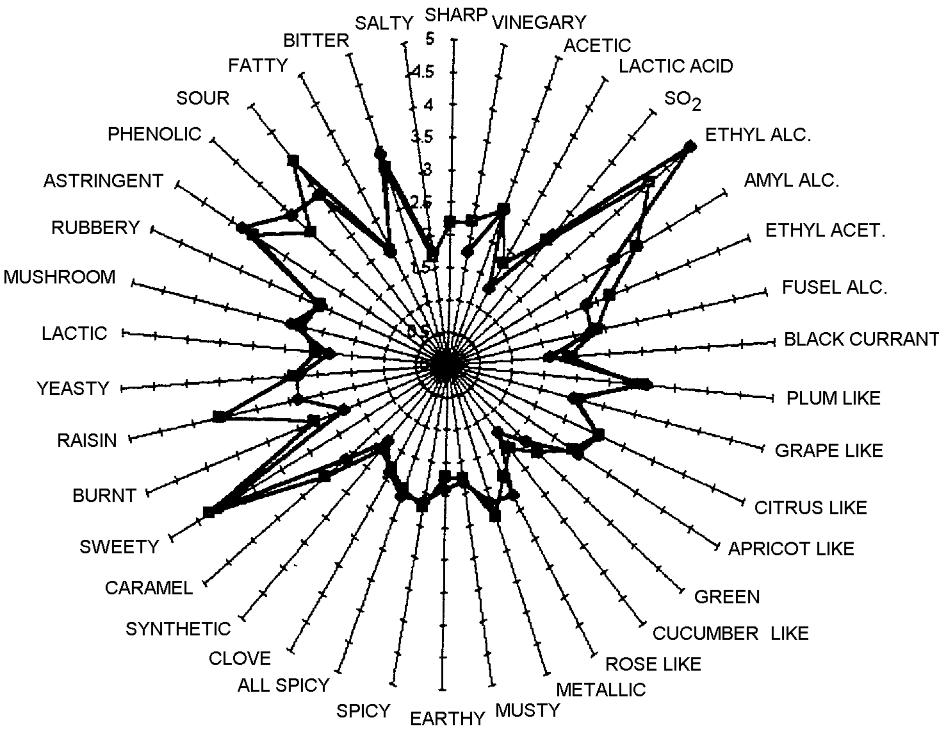

Fig. 2. Flavour profile of apple wines fermented with and without nitrogen sources.
–◆– With nitrogen; –■– without nitrogen

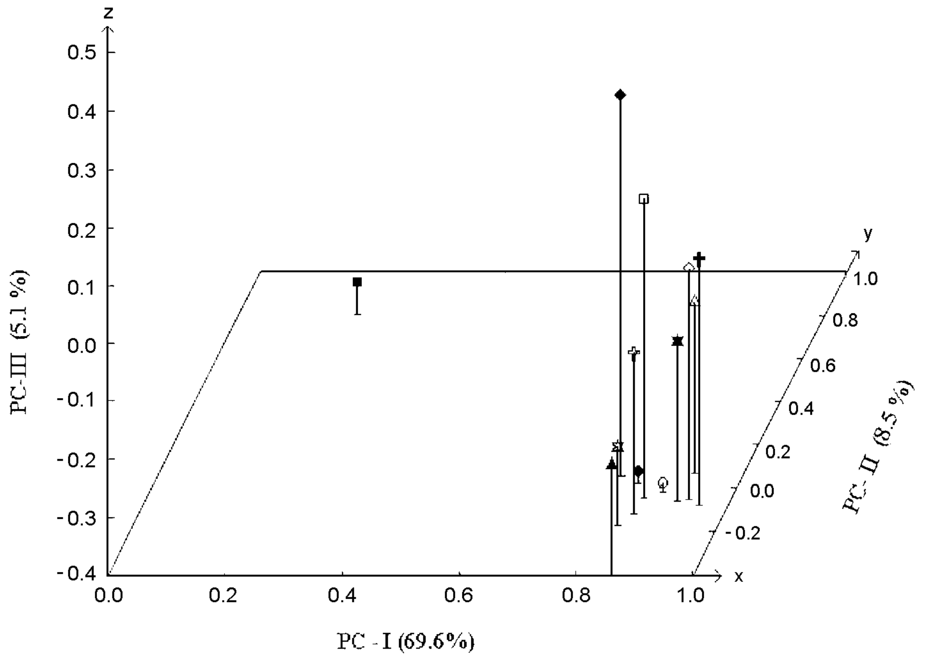

Fig. 3. Projection of flavour profiling data of apple wine fermented with or without nitrogen source in planes defined by principle component 1, 2 and 3. ●○: W; ▲△: UCD 595; ✶ ✡: UCD 505; ✝ ✞: UCD 522; ♦◊: NSF_1; ■□: NSF_2; open symbols: with nitrogen; closed symbols: without nitrogen

Exceptions were the treatment 9 (wine fermented by NSF_1), which had characters similar to the standard wine yeasts, while the treatment 8 (UCD 595 without nitrogen source) was strikingly different from the wines fermented by standard wine yeasts. The differences in the behaviour of commercial yeasts and the natural source of fermentation were found to be stronger than the addition of nitrogen source as no clear grouping or separation of wines with or without nitrogen sources took place (Figs. 4 & 5). Both the figures show similar trend except that the treatment with natural source of fermentation without N was a clear outlier, and other treatments were separated to a lesser extent. It is also clear from the figures that most of the separation took place along the PC 1 except for treatments numbers 12 and 8 which have been separated either by component 2 or 3 or both. In an earlier study, descriptive analysis of wines fermented by different malo-lactic bacteria showed significant differences in the aroma perception of the wines (McDaniel et al., 1987). It is also clear from the results (Figs. 4 & 5) that the Ist PC is defined mostly by raisin, fusel alcohol, citrus like, vegetable like, green/unripe, ethyl alcoholic, grape like, bitter, sweety, lactic, astringent, cabbage, spicy/phenolic and sour descriptors. The 3rd PC was found to be related to acetic, plum like, rose like, cucumber like, earthy, sharp and metallic descriptors.

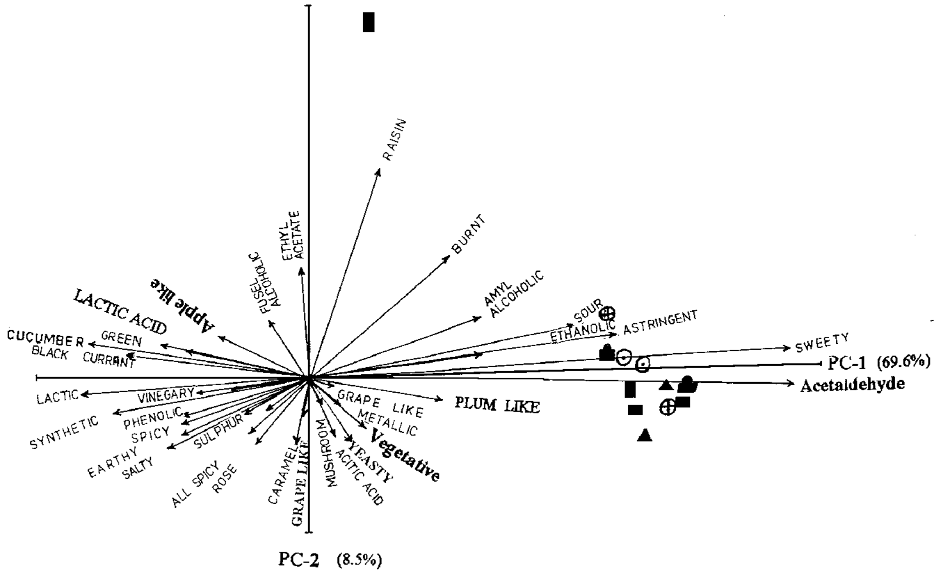

Fig. 4. Projection of flavour profiling data of apple wine fermented with different sources of fermentation in planes defined by principle component 1 and 2. ⊙: W; ▲: UCD-505; ⊕: UCD-595; ■: UCD-522; ☗: NSF-1; ▮: NSF-2

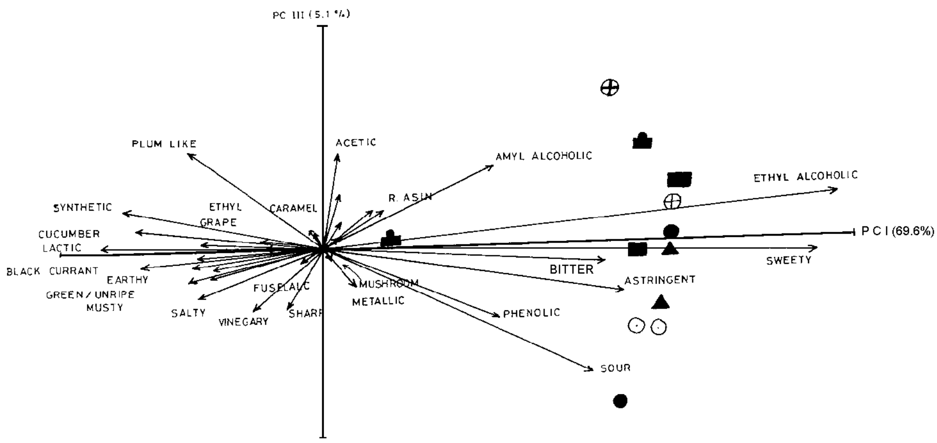

Fig. 5. Projection of flavour profiling data of apple wine fermented different sources of fermentation in planes defined by principle component 1 and 3. ⊙: W; ▲: UCD-505; ⊕: UCD-595; ■: UCD-522; ☗: NSF-1; ▮: NSF-2

Thus, the wines fermented by the yeasts or natural source of fermentation without nitrogen source were generally richer in sweety/raisin flavour tones than those with it. These wines were also richer in fruity flavour than those fermented by standard wine yeast. However, some of their flavour notes like acetic like and amyl alcoholic could be considered undesirable and correlative with faulty fermentations. The 'W' fermented wines possessed high astringency and phenol like, those by UCD 505 and UCD 522 had more ethanolic, sweety, bitter-taste, while UCD 595 was rich in phenolic, sour and ethanolic flavour notes. Wines fermented by natural sources of fermentation were distinct for raisin, amyl alcoholic and yeasty flavour tones. Vinification practices like delayed additions of SO_2 to the must have been reported to allow the growth of wild yeasts and bacteria consequently, the production of certain grassy flavours in the cider. It is presumably due to the activity of lipoxygenase present in the apple juice which must have oxidised fatty acids to give a more rounded flavour (JARVIS et al., 1995). Here in our study SO_2 was added uniformly to all the treatments, so the differences in the flavour profile could be attributed to the type of microflora employed to conduct the fermentation. In an earlier study, use of SO_2 might have allowed limited activity of wild microflora, thus modifying the flavour profile of wines. Besides, the differences in flavour profile of wines fermented with different yeasts found in our study could be their inherited characteristics as found earlier in wine from grape (HERRAIZ et al., 1990).

2.4. Chemical composition and flavour profiling

The differences obtained in the flavour profiling of wines made by different yeasts/source of fermentation could largely be correlated with the differences in their chemical characteristics. The wines fermented by natural source of fermentation were characterized by their higher residual sugar, more total esters, higher methanol content, higher alcohols concentration, low ethyl alcohol and more volatile acidity than the wines fermented by standard yeast as can be seen from the results (Table 1). The clear influence of addition of nitrogen source to the must was on the time taken for completion of fermentation (Fig. 6). Wines fermented with natural source of fermentation took more time with lower ethyl alcohol content than the standard wine yeasts. Some of the abnormal physico-chemical characteristics (Table 1) produced by the natural source of fermentation in the respective wine can be correlated with longer time taken by these fermentations to complete (Fig. 6).

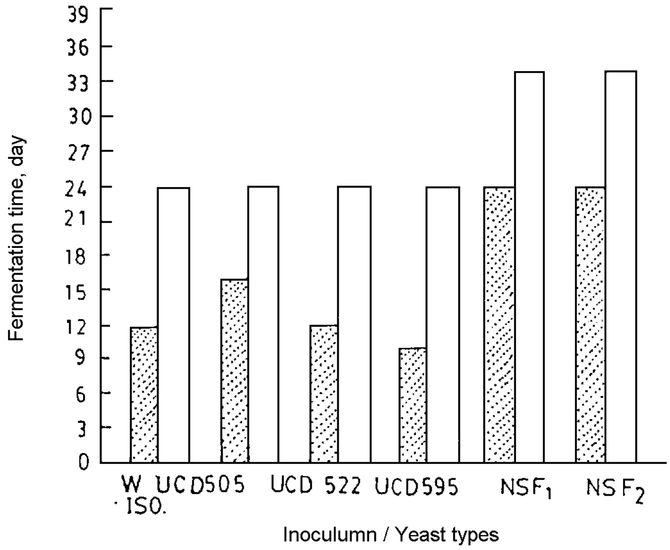

Fig. 6. Comparison of time of fermentation of apple musts with or without nitrogen source by different inoculum/yeast types. ▒: With nitrogen source; □ without nitrogen source

2.5. Discussion

An appraisal of the results on flavour profile discussed so far clearly show distinct differences in the flavour profile of wines fermented with different sources of fermentation. At the same time, some modifications in flavour attributes of wines have certainly taken place which could be due to the influence of same vinification practices followed in their preparation (i.e. the use of nitrogen source effecting the rate of fermentation, irrespective of source of fermentation, use of sulphur dioxide). During an earlier investigation on fermentation characteristics of several strains of yeast, significant differences were noted in the product flavours when a particular strain was grown in the pasteurized juice base compared to those grown in a base treated with SO_2 (JARVIS et al., 1995). Apparently, the residual sucrose gave the wine a sweeter flavour, similar to what happened in the wine fermented with natural source of fermentation (Table 1) in our study. Earlier also, profiles of cider and perry essences and their correlation with analytical data have been considered advantageous (WILLIAMS, 1975). Descriptive analysis has also been applied to characterize the beer, wine flavour (MEILGAARD et al., 1979; WILLIAMS, 1982), the wines from different regions or treatments, especially by the use of PCA and CVA technique (NOBLE et al., 1984; GUINARD & CLIFF, 1987; HEYMANN & NOBLE, 1987; 1989). However, the number of descriptors employed seem to be more, though certainly have lower number (range from 50 to 86) than used earlier (NOBLE et al., 1984; WILLIAMS, 1975; JARVIS et al., 1995).

In an overview, the flavour profiling of wines fermented by standard wine yeasts, points out their preference in apple wine fermentation in contrast to natural source of fermentation, yet contribution of non-*Saccharomyces* yeasts to the flavour quality of wines warrants more serious considerations, especially with a wine with more fruity flavour (high ester content) and low acetic acid (FLEET, 1990). In the future, these yeasts seem to have potential for their use in the multistage fermentation of fruits for better aroma profile in wine as is practiced in the case of lambic beer, where the specific microflora involved in various stages of fermentation is known to influence the flavour of finished beer (KEERSMAEKER, 1996). Although combination of wild yeasts and selected yeast culture produces desirable flavour, occasionally the risk of undesirable flavour arising in uncontrolled/natural fermentation is very high. Inoculation of mixed cultures of selected yeasts has reportedly been made under aseptic conditions to develop specific flavour attributes during fermentation. Similarly, deliberate inoculation of cider with a single or mixed strains of malo-lactic bacteria has shown that the most satisfactory flavour changes are associated with inoculation of mixed cultures at the end of primary fermentation (JARVIS et al., 1995). Such fermentations can be expected in future to produce wines of desired sensory quality characteristics.

3. Conclusions

1. The technique of descriptive analysis can successfully be applied for flavour profiling of cider or apple wine of variable flavour quality.

2. The good wines though can be characterized at wine-house testing by using a few descriptors yet to differentiate the wines with all possible flavours or those made from different raw materials or fermentation sources, the number of descriptors appears to be appropriate.

3. The flavour profiling of apple wines could throw quite a useful information on the quality of wine in itself and in conjunction with chemical characteristics.

4. The natural source of fermentation has affected the flavour profile of apple wine distinctly but the effect of standard wine yeast was smaller.

5. The vinification practices also influenced the flavour profile of wines fermented by different sources of fermentation.

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