

DETERMINATION OF ORGANIC ACIDS IN WHITE WINES BY RP – HPLC

N.D. MIRON, I.D. NISTOR, A.M. DOSPINESCU, A. GRADINARU

Universitatea din Bacău, Calea Mărășești, nr.157, Bacau

Abstract: The optimized RP-HPLC method (mobile phase: $c(\text{H}_3\text{PO}_4) = 6 \cdot 10^3 \text{ mol/L}$, $\text{pH} = 2,1$, flow rate $1,0 \text{ mL/min}$) was validated. Calibration curves were linear for all three acids in the concentration range tested; r^2 was better than 0,999. RSD's for tartaric and malic acids were within 2 %, and for citric acid 10,4 %. The average relative error for tartaric acid was 3,2 %, for malic acid 2,5 % and for citric acid 6,0 %. Ethanol caused an insignificant negative response at $t_R = 5,69 \text{ min}$, whereas glucose and fructose eluted in the void volume. According to the validation results, and from analysis of wine samples, the described HPLC method was found adequate for routine determination of tartaric and malic acids in dry, semi-dry, semi-sweet and sweet white wines.

Keywords: organic acids, RP-HPLC analysis, white wine

1. INTRODUCTION

The most widely used HPLC methods for their determination are ion exchange, (2,3) and ion exclusion (4) HPLC techniques. Today, the reversed phase HPLC methods are very popular in general (5), but not for organic acids determination in wine and must samples.

Our aim was to introduce LiChrosorb RP-18 as a stationary phase for routine and inexpensive HPLC determination of tartaric and malic acids in wines. These two acids are present in grapes in much higher concentrations than other acids. Their ratio is also an indicator of vintage quality (6). We found that with RP-HPLC on LiChrosorb RP-18 six organic acids (*i.e.* galacturonic, tartaric, malic, lactic, succinic and citric acids) can be separated. The chromatographic conditions for the optimal separation of the organic acids were established, and the method was validated. The results of selectivity, linearity, precision and accuracy are presented here. Due to some interferences, the RP-HPLC method described was found adequate only for the routine determination of tartaric and malic acids and to some extent also of citric acid in dry, semi-dry, semi-sweet and sweet white wines. The method was used to determine tartaric and malic acid concentrations in 15 white wine samples (vintage 1995) from three major wine-producing regions in Romania. Wine samples were of different quality and also varied in ethanol and sugar contents.

2. MATERIALS AND METHODS

2.1. Chemicals

All acids and reagents used were of analytical grade. Organic acids (p.a.) were from Merck.

2.2. Solvent

In preparation of wine samples and standard solutions a mixture of 96% ethanol and double distilled water (volume ratio 10/90) was used, which is referred to as the solvent. Prior to use, the solvent was sonicated for 5 minutes in an ultrasonic bath to remove air bubbles.

2.3. Standard solutions of organic acids

All organic acids used for standards were dissolved in the solvent to simulate the matrix effect of wine samples. The concentrations of organic acids varied from 0,5 to 10,0 g/L for tartaric acid; 0,2 to 15,0 g/L for malic acid; 0,1 to 5,4 g/L for lactic acid, and 0,05 to 1,0 g/L for citric acid. The prepared standard solutions of organic acids were stored at 4 °C.

2.4. Standard solutions of sugars

Two standard sugar solutions were prepared. The first one contained $y(\text{glucose}) = 100 \text{ g/L}$, and the second one ($\text{fructose}) = 100 \text{ g/L}$ of the solvent.

2.5. Wine samples

The samples were provided from local wineries. Samples of 15 Romanian white wines (see Table 4) were tested. They differed in quality, sugar concentration and provenience. Ethanol volume fraction varied from 10,1 to 12,6 %, according to the producers. An aliquot of wine sample was diluted (volume ratio 1/1) with solvent and 20 L of the obtained solution were injected. Before injection, all standards and sample solutions were filtered through Sartorius RC15 membrane filter units.

2.6. Spiked wine samples

For precision and accuracy validation, wine samples were spiked with organic acids to such an amount that the final concentration of the added acid varied from 1 to 3 g/L for tartaric and malic acids, and from 0,09 to 0,27 g/L for citric acid. Organic acid standards were accurately weighed in 50 mL volumetric flasks and dissolved in about 10 mL of the solvent. Then 25,0 mL of wine sample was added and the solution obtained was further diluted to 50 mL with the solvent.

2.7. HPLC system

This comprised an X-act 4-channel degassing unit, (Jour Research, Sweden), a Maxi Star, K1000 HPLC pump, a Marathon-XT autosampler, a UV/VIS detector, a K-2301 RI detector and a ValueChrom data acquisition system.

2.8. Chromatographic conditions for determination of organic acids

A LiChrosorb RP-18 column (10 m, 25 cm x 4,0 mm), with an injection volume of 20 L, wavelength 210 nm, and a mobile phase as below, flow rate 1,0 mL/min was employed.

For optimization of the separation of organic acids, aqueous solutions of H_3PO_4 in three different concentrations were tested: mobile phase 1 = $3,0 \cdot 10^{-4} \text{ mol/L}$ (pH = 3,0), mobile phase 2 = $1,5 \cdot 10^3 \text{ mol/L}$ (pH = 2,5), mobile phase 3 = $6 \cdot 10^3 \text{ mol/L}$ (pH = 2,1).

2.9. Chromatographic conditions for glucose and fructose determination

Before determination of organic acids, glucose and fructose were determined on a Bio-Rad Aminex HPX – 87C (30 cm x 7,8 mm) column at 80°C using an RI detector. Double distilled water was used as the mobile phase, with an injection volume of 20 L, and a flow rate of 0,6 mL/min (7).

3. Results

3.1. Influence of pH of the mobile phase

Separation of the organic acids on an HPLC LiChrosorb RP-18 (10 m, 25 cm x 4,0 mm) column was tested with three H_3PO_4 solutions. Mobile phase $c(\text{H}_3\text{PO}_4) = 6 \cdot 10^{-3}$ mol/L was the best mobile phase for HPLC separation of the organic acids tested as shown for 4 of them in Fig. 1. Although the pH of the mobile phase was 2,1, no column deterioration was observed even after prolonged use.

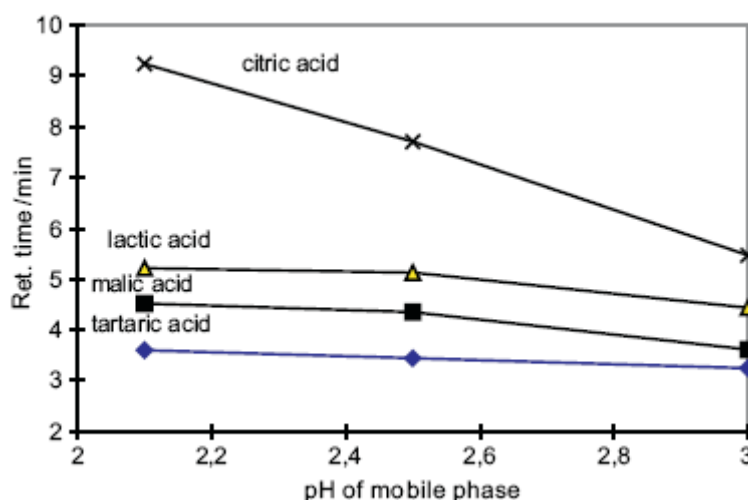


Fig.1 Influence of the mobile phase pH on the separation of organic acids, LiChrosorb RP – 18 column (10 m, 25 cm x 4,0 mm), UV detection at 210 nm

3.2. Selectivity of the method

Under the conditions described galacturonic, tartaric, malic, lactic, succinic and citric acids could be separated on a LiChrosorb RP-18 (10 m, 25 cm x 4,0 mm) column (Fig. 2). The peaks of all acids were symmetrical and well separated, but the chromatogram in Fig. 2 shows 7 peaks. It was found that two peaks ($t_R = 9,35$ and $10,63$ min) belong to succinic acid. We cannot explain the reason for such behavior. Succinic acid has $\text{pK}_1 = 4,16$ and $\text{pK}_2 = 5,61$ in aqueous solution, but these do not explain the occurrence of two peaks in a mobile phase with $\text{pH} = 2,1$. It is unclear why two peaks appear only in the case of succinic and not in the case of any other polycarboxylic acid. When the same standard solution of succinic acid was injected on a Bio-Rad Aminex HPX-87H column, only one peak was observed (unpublished results).(8)

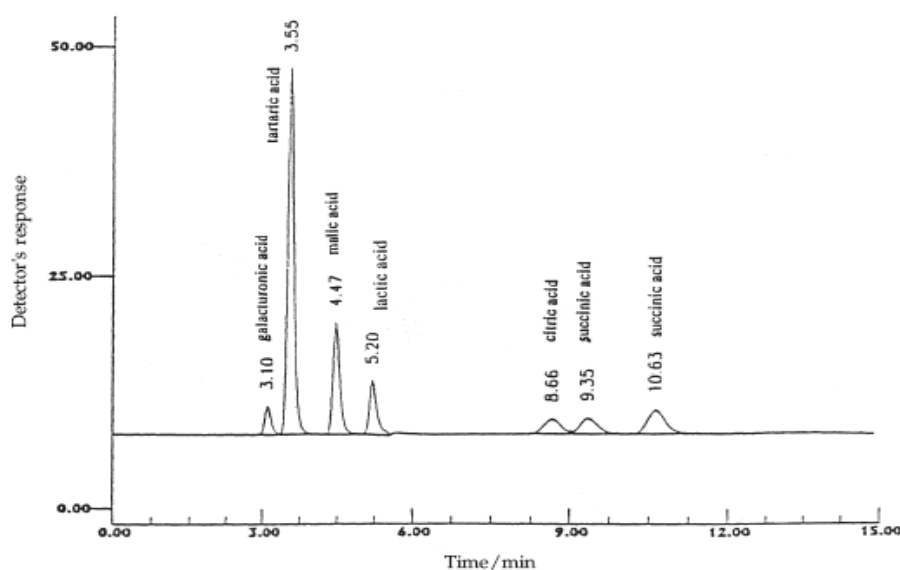


Fig. 2 HPLC separation of galacturonic, tartaric, malic, lactic, succinic and citric acids on LiChrosorb RP – 18 (10 m, 25 cm x 4,0 mm) with $c(\text{H}_3\text{PO}_4) = 6 \cdot 10^{-3}$ mol/L ($\text{pH} = 2,1$), UV detection at 210nm

With the optimal mobile phase we were able to separate 6 organic acids (Fig. 2), but when validating the method, we found it suitable only for the 3 most representative (tartaric, malic and citric) acids in white wines.

Possible interference of ethanol, glucose and fructose on the determination of the acids was checked by separate injection of 20 L of ethanol, glucose and fructose standard solutions.(9) Both sugars were dissolved in ethanol. Ethanol did not interfere with the determination of organic acids. Its elution at 5,69 min caused a very small, but negative response under the chromatographic conditions described. Glucose and fructose eluted in the void volume with $t_R = 3,10$ min.

The influence of shikimic and acetic acids on the determination of the main organic acids in wine was checked too. When a mixture of shikimic, lactic and acetic acids was injected, the separation of shikimic acid from lactic acid was poor (Fig. 3). The resolution between shikimic and lactic acid was only 0,5, and the resolution between lactic and acetic acid was 1,3. Shikimic acid eluted at 5,05 min under the chromatographic conditions used. Usually, the concentration of shikimic acid in wines is low, but this acid has a much higher extinction coefficient (10) than the other organic acids present in wine. Therefore, this RP-HPLC method is not selective for the determination of lactic acid.

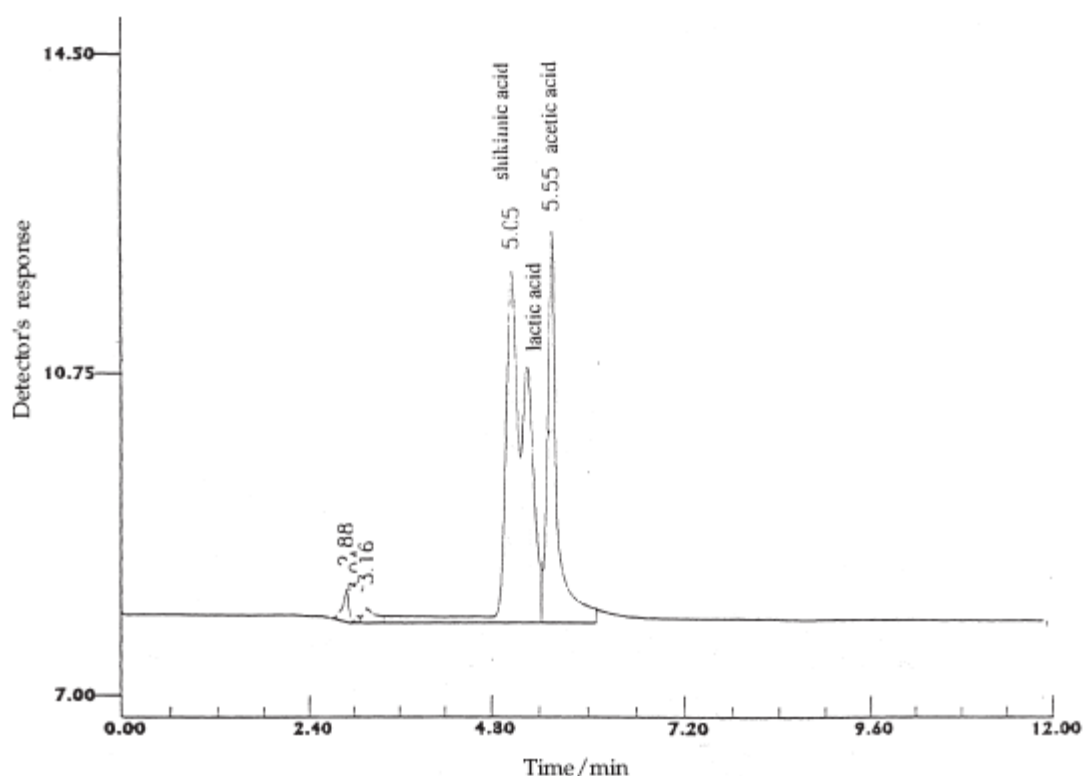


Fig. 3 Separation of shikimic, lactic and acetic acids on RP – HPLC column under the same conditions as in fig. 2

3.3. Linearity of the method

The linearity of the method was validated at six to eight concentrations of each acid (tartaric, malic and citric acids). The concentrations of the standard solutions of organic acids were chosen in such a way that the whole expected concentration range of each acid in the samples was covered. A calibration curve for each organic acid was constructed by linear regression of the observed average peak area versus concentration. The coefficients of the regression curves (the slope and the intercept on the y axis) and the squares of the correlation coefficients (r^2) were calculated by the least squares method. Calibration curves were linear for all the organic acids investigated (Table 1).

Table 1. Coefficients of the regression curve and the square of the correlation coefficient for each organic acid;

HPLC analysis: LiChrosorb RP-18 column (10 m, 25 cm x 4,0 mm), mobile phase $c(\text{H}_3\text{PO}_4) = 6 \cdot 10^{-3}$ mol/L, UV detection at 210 nm

| Organic acid | $\gamma(\text{acid})$ range/g/L | Slope | Intercept | r^2 |
|--------------|---------------------------------|--------|-----------|--------|
| Tartaric | 0,500 – 7508 | 236,35 | 14074 | 0,9998 |
| Malic | 0,200 – 15000 | 128,62 | 4621 | 0,9998 |
| Citric | 0,049 – 0,987 | 1685,6 | -3124 | 10000 |

3.4. Precision of the method

The precision of the method was determined by consecutive injections of blank wine samples and wine samples spiked with different concentrations of tartaric, malic and citric acids. (11) For each concentration, the average area of the detector response, the standard deviation and the relative standard deviation (RSD) were calculated (Table 2).

Table 2. Precision of tartaric, malic and citric acid determination in wine samples on LiChrosorb RP – 18 column; chromatographic conditions as in table 1

| Tartaric acid | | |
|------------------------------------|-----------------------------------|------------|
| $\gamma(\text{spiked})/\text{g/L}$ | $\gamma(\text{total})/\text{g/L}$ | RSD(N=6)/% |
| 0 | 1,9 | 1,04 |
| 1,0 | 2,9 | 0,41 |
| 2,0 | 3,9 | 0,33 |
| 3,0 | 4,9 | 0,25 |
| | average | 0,51 |
| Malic acid | | |
| $\gamma(\text{spiked})/\text{g/L}$ | $\gamma(\text{total})/\text{g/L}$ | RSD(N=6)/% |
| 0 | 2,9 | 2,16 |
| 1,0 | 3,9 | 1,25 |
| 2,0 | 4,9 | 0,36 |
| 3,0 | 5,9 | 0,37 |
| | average | 1,03 |
| Citric acid | | |
| $\gamma(\text{spiked})/\text{g/L}$ | $\gamma(\text{total})/\text{g/L}$ | RSD(N=6)/% |
| 0 | 0,24 | 15,04 |
| 0,09 | 0,33 | 12,91 |
| 0,18 | 0,42 | 7,30 |
| 0,27 | 0,51 | 6,41 |
| | average | 10,41 |

The precision validation indicated that this HPLC method is suitable for tartaric and malic acid determination in white wines under the chromatographic conditions described (Table 2). The precision of the citric acid determination, on the contrary, shows that this method is not suitable for its quantitative determination in white wines. The main reason for such low precision of the citric acid determination is the low concentration of this acid in wines. Citric acid in wine can be quantified by this RP-HPLC method with a precision of only about 10 %.

Table 3. Accuracy of tartaric, malic and citric acid determination in wine samples on LiChrosorb RP – 18 column; chromatographic conditions as in table 1

| Accuracy of tartaric acid determination | | |
|--|--|-------------------------|
| $\gamma(\text{added})$ (true value) g/L | $\gamma(\text{found})$ (measured value) g/L | Average RE (N = 6) % |
| 1,017 | 0,966 | -5,0 |
| 2,012 | 1,961 | -2,6 |
| 3,019 | 2,954 | -2,1 |
| | average RE for tartaric acid (%) | -3,2 |
| Accuracy of malic acid determination | | |
| $\gamma(\text{added})$ (true value) g/L | $\gamma(\text{found})$ (measured value) g/L | Average RE (N = 6) % |
| 1,009 | 0,988 | -2,1 |
| 2,013 | 1,967 | -2,3 |
| 3,022 | 2,930 | -3,0 |
| | average RE for malic acid (%) | -2,5 |

| Accuracy of citric acid determination | | |
|---------------------------------------|--|-------------------------|
| γ (added) (true value) g/L | γ (found) (measured value) g/L | Average RE (N = 6) % |
| 0,093 | 0,088 | -5,4 |
| 0,185 | 0,182 | -1,6 |
| 0,275 | 0,245 | -10,9 |
| | average RE for citric acid (%) | -6,0 |

Table 4. Mass concentration of glucose, fructose, tartaric acid and malic acid in white wines (1995 vintage, different wine-producing regions in Romania); chromatographic conditions as in Table 1

| Wine sample | Wine-producing region | f(glucose) g/L | f(fructose) g/L | f(tartaric acid) g/L | f(malic acid) g/L |
|-------------------|-----------------------|-------------------|--------------------|-------------------------|----------------------|
| Feteasca albă | Cotnari | 0,6 | 0,6 | 2,58 | 3,68 |
| Francusa | Hârlău | 0,3 | 4,2 | 1,67 | 2,88 |
| Grasă de Cotnari | Hârlău | n.d. | n.d. | 0,95 | 6,07 |
| Tămăioasă | Hârlău | 1,0 | 1,1 | 1,04 | 2,99 |
| Fetească albă | Hârlău | 0,2 | 1,3 | 1,89 | 2,88 |
| Francusa | Cotnari | <0,1 | 0,5 | 1,41 | 1,77 |
| Pinot gris | Cotnari | 3,9 | 4,2 | 1,22 | 4,06 |
| Sauvignon | Cotnari | 1,2 | 12,4 | 1,10 | 3,59 |
| Tămăioasă | Cotnari | <0,1 | 2,3 | 1,54 | 3,04 |
| Fetească albă | Huși | 3,9 | 4,3 | 0,95 | 5,52 |
| Busuioaca Bohotin | Huși | 2,8 | 14,1 | 1,43 | 2,72 |
| Zghihara | Huși | 10,4 | 10,3 | 0,95 | 5,68 |
| Sauvignon | Huși | 8,5 | 9,0 | 1,57 | 3,81 |
| Muscat Ottonel | Huși | 5,8 | 6,1 | 1,61 | 3,15 |
| Fetească regală | Vaslui | 6,4 | 6,4 | 1,39 | 3,27 |

3.5. Accuracy of the method

The accuracy of the method was measured as the agreement between the measured and the true value (found concentration and added concentration). Since for wine samples, the true value was not known, an approximation was obtained based on spiking a wine sample with known amounts of tartaric, malic and citric acids. A wine sample was spiked with three different concentrations of tartaric, malic and citric acids (added concentrations). The found concentration, γ (g/L), (measured value) of each acid at each concentration was calculated by the method of external standards as follows:

$$\gamma = (A_{\text{spiked}} - A_{\text{blank}}) \cdot \gamma_{\text{std}} / A_{\text{std}}$$

A_{spiked} - detector's response of spiked sample

A_{blank} - detector's response of blank sample

γ_{std} ~ concentration of standard solution, g/L

A_{std} - detector's response of standard

By comparing the found concentrations to the added concentrations, the relative error (RE, %) was calculated for the determination of each acid (Table 3).

Similarly as in the case of precision, the best accuracy was found for tartaric and malic acids, the average relative errors being 3,2 % and 2,5 %, respectively, while the average relative error in the determination of citric acid was 6,0 %.

3.6. Wine analysis

The described HPLC method was finally used on 15 white wines (Fig. 4) from different wine-producing regions in Romania (different sugar contents). The results of the glucose and fructose determinations (analyses were

performed as described under Materials and Methods), as well as those of tartaric and malic acid determinations are presented in Table 4.

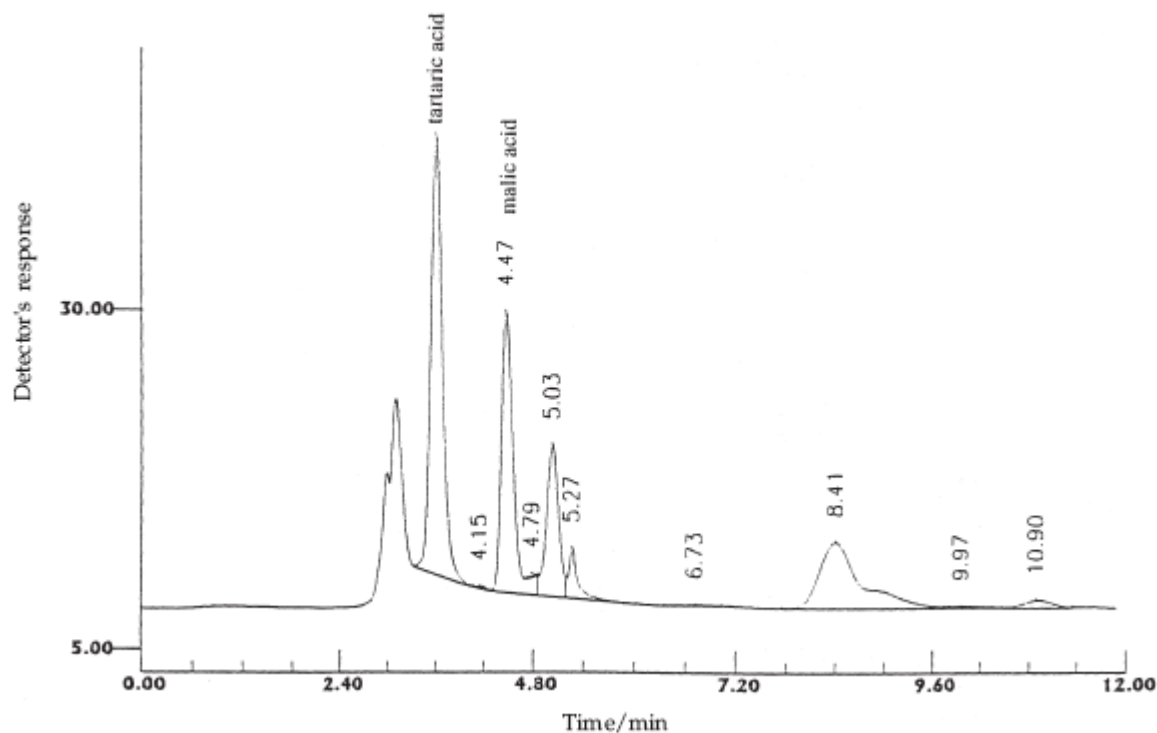


Fig. 4 Separation of organic acids in a samples of sweet wine on LiChrosorb RP – 18 under the same conditions as in fig. 2

4. CONCLUSIONS

The described RP-HPLC method using LiChrosorb RP-18 (10 m, 25 cm x 4,0 mm) with $c(\text{H}_3\text{PO}_4) = 6 \cdot 10^3$ mol/L (pH=2,1) as mobile phase and UV detection at 210 nm is fast, all acids eluting in less than 9 min. When analyzing different types of white wine no additional unknown interference appeared. According to the validation results and from the analysis of different wine samples, the HPLC method described was found adequate for routine determination of tartaric and malic acids in dry, semi-dry, semi-sweet and sweet white wines. To a limited extent the method can also be considered adequate for routine determination of citric acid in various white wines.

The results of the validation were compared to the results of other authors (Table 5, 1, 2). The linearity of the HPLC methods compared is similar and adequate. Accuracy expressed as recovery shows that on LiChrosorb RP-18 a lower amount of the acids is determined, but the found values are still within the reliability interval of the methods to which our results are compared. The precision of our method for tartaric and malic acid determination is better or comparable to the precision of other HPLC method, while the precision for the citric acid is rather worse.

Table 5. Comparison of different HPLC methods

| Substance analysed | HPLC method used | Reference cited | Linearity r | Recovery % | Precision RSD/% |
|--------------------|--------------------|---------------------------|-------------|---------------|-----------------|
| tartaric acid | Cation exchange | Frayne, 1986 (2) | 1,00 | 101,3 – 103,7 | 1,1 |
| tartaric acid | HPLC Ion-exclusion | Lopez-Tamames <i>et</i> | 0,9999 | 101,4 1,3 | 2,64 |
| tartaric acid | HPLC RP-HPLC on | <i>ah</i> , 1996 (1) this | 0,9999 | 96,8 | 0,51 |
| malic acid | Cation exchange | Frayne, 1986 (2) | 1,00 | 100,5 – 101,4 | 0,7 |
| malic acid | HPLC Ion-exclusion | Lopez-Tamames | 0,9999 | 99,8 3,3 | 1,5 |
| malic acid | HPLC RP-HPLC on | <i>et ah</i> , 1996 this | 0,9999 | 97,5 | 0 |

| | | | | | |
|-------------|--------------------|---------------------------|--------|----------|-----|
| citric acid | Cation exchange | Frayne, 1986 (2) | 0,98 | | 1,5 |
| citric acid | HPLC Ion-exclusion | Lopez-Tamames <i>et</i> | 0,9996 | 99,8 5,8 | 2,8 |
| citric acid | HPLC RP-HPLC on | <i>ah</i> , 1996 (1) this | 1,0000 | 94,0 | 5 |

The main disadvantage of the method presented is the fact that not all organic acids of potential interest can be determined and that succinic acid has two peaks.

On the other hand, it offers good routine quantitative determination of the two most important organic acids in white wines, as well as fast and simple isocratic separation on an inexpensive stationary phase with an unsophisticated HPLC system.

REFERENCES

- [1] E. Lopez-Tamames, M. A. Puig-Deu, E. Teixeira, S. Buxaderas, *Am. J. Enol. Vitic.* 47 (1996) 193-197
- [2] R. F. Frayne, *Am. J. Enol. Vitic.* 37 (1986) 281-287
- [3] J. D. McCord, E. Trousdale, D. D. Y. Ryu, *Am. J. Enol. Vitic.* 35 (1984) 28-29
- [4] M. L. Morales, A. G. Gonzales, A. M. Troncoso, *J. Chromatogr. A*, 822 (1998) 45-51
- [5] A. Escobal, C. Iriondo, C. Laborra, E. Elejade, I. Gonzalez, *J. Chromatogr. A*, 823 (1998) 349-454
- [6] S. [ikovec: *Vinarstvo-od grozdja do vina*, C.ZD, Kme~ki glas, Ljubljana (1993)
- [7] *Guide to Aminex HPLC Columns for Food and Beverage Analysis*, Bio-Rad, Chemical Division, Richmond, CA, USA
- [8] P. Cane, *Enotecnico*, 26 (1990) 69-72
- [9] B. Rankine, Blending: A most important aspect of wine-making, *Aust. Grapegrow. Winemak.* 289 (1988) 17-18
- [10] R.B. Boulton, V.L. Singleton, L.F. Bisson, R.E. Kunkee: *Principles and Practices of Winemaking*, Chapman & Hall, New York, USA (1996)
- [11] S. Datta, S. Nakai, Computer-aided optimization of wine blending, *J. Food Sci.* 57 (1992) 178-182
- [12] F. Iacono, G. Nicolini, E. Alonzo, Wine blending techniques and examples of qualitative result definition (sensory properties), *Vigne Vin*, 26 (1999) 81-86
- [13] J.G. Ferrier, D.E. Block, Neural-network-assisted optimization of wine blending based on sensory analysis, *Am. J. Enol. Vitic.* 52 (2001) 386-395
- [14] R.M. Arnold, A.C. Noble, Bitterness and astringency of grape seed phenolics in a model wine solution, *Am. J. Enol. Vitic.* 29 (1978) 150-152
- [15] J.L. Robichaud, A.C. Noble, Astringency and bitterness of selected phenolic in wines, *J. Sci. Food Agric.* 53 (1990) 343-353
- [16] P. Ribéreau-Gayon, P. Pontallier, Y. Glories, Some interpretation of colour changes in young red wines during their conservation, *J. Sci. Food Agric.* 34 (1983) 505-516
- [17] C.F. Timberlake, P. Bridle, Interactions between anthocyanins, phenolic compounds, and acetaldehyde and their significance in red wines, *Am. J. Enol. Vitic.* 27 (1976) 97-105
- [18] P. Ribéreau-Gayon: The Anthocyanins of Grapes and Wines. In: *Anthocyanins as Food Colours*, P. Markakis (Ed.), Academic Press, New York, USA (1982) pp. 209-244
- [19] B.S. Sun, T. Pinto, M.C. Leandro, J.M. Ricardo da Silva, M.I. Spranger, Transfer of catechins and proanthocyanidins from solid parts of the grape cluster into wine, *Am. J. Enol. Vitic.* 50 (1999) 179-183
- [20] T.C. Somers, The phenolic nature of wine pigments, *Phytochemistry*, 10 (1971) 2175-2186
- [21] E. Haslam, *In vino veritas: Oligomeric procyanidins and the ageing of red wines*, *Phytochemistry*, 16 (1980) 1625-1670
- [22] H. Fulcrand, P.J. Cameira Dos Santos, P. Sarni-Manchado, V. Cheynier, J. Favre-Bonvin, *Structure of new anthocyanin-derived wine pigments*, *J. Chem. Soc. Perkin Trans. 1* (1996) 735-739
- [23] J. Bakker, C.F. Timberlake, *Isolation, identification and characterization of new colour-stable anthocyanins occurring in some red wines*, *J. Agric. Food Chem.* 45 (1997) 354 - 363
- [24] H. Fulcrand, V. Cheynier, J. Oszmianski, M. Moutounet, An oxidized tartaric acid residue as a new bridge potentially competing with acetaldehyde in flavan-3-ol condensation, *Phytochemistry*, 46 (1997) 223-227
- [25] C. Saucier, D. Little, Y. Glories, *First evidence of acetaldehyde-flavanol condensation products in red wine*, *Am. J. Enol. Vitic.* 48 (1997) 370-373
- [26] N. Mateus, A.M.S. Silva, C. Santos-Buelga, J.C. Rivas-Gonzalo, V. De Freitas, *Identification of anthocyanin-flavanol pigments in red wines by NMR and mass spectrometry*, *J. Agric. Food Chem.* 50 (2002) 2110-2116