

Effect of Délestage with Partial Seed Deportation on Merlot and Cabernet Sauvignon

Wines

Bruce W. Zoecklein^{1*}, Lisa M. Pélanne, and Sandy S. Birkenmaier

¹Professor and Head, Wine/Enology-Grape Chemistry Group, Department of Food Science and Technology (0418), Virginia Tech, Blacksburg, VA 24061.

*Corresponding author [Fax: 540-231-9293; email bzoeckle@vt.edu]

This study compared délestage (rack and return) involving partial seed deportation, with merlot produced by manual cap punching for three seasons, and cabernet sauvignon produced by mechanical punch-down (pigeage) systems for one season. Fermentation reduced the percentage of color from monomeric pigments and increased the percentage of color from polymeric pigments for all treatments. Délestage wines generally had a higher percentage of color derived from large polymeric pigments than manual cap-punched or pigeage wines. Total glycosides increased during cold soak and fermentation, and were in greater concentration in the manual cap-punched merlot wines, and similar among the cabernet sauvignon treatments. Discrimination testing (triangle difference analysis) demonstrated merlot wines differed in aroma and/or flavor in two of three vintages. Cabernet sauvignon wines were perceived to differ in both aroma and flavor.

Key words: délestage, rack and return, polymeric pigments, glycosides, seed removal, volatile compounds

Introduction

The color, structure and aftertaste of red wines are mainly derived from the varied and complex impact of phenolic compounds. It is estimated that 50% or less of the total phenolic compounds present in the skins, seeds and flesh of grapes can be extracted during conventional winemaking (Somers and Vérette, 1998; Haslam, 1998). This transfer depends on various factors, including fruit maturity, duration of skin contact, temperature, ethanol concentration (Ramey *et al.*, 1986) and vinification practices, including cap management techniques (Singleton, 1982; Revilla *et al.*, 1997; Fischer *et al.*, 2000; Mattivi *et al.*, 2002). Therefore, understanding the quantitative and qualitative influences processing has on grape and wine phenolic compounds is important in premium wine production.

Monomeric and polymeric flavan-3-ols comprise the majority of the phenolic constituents in red wines (Singleton and Noble, 1976), being extracted from the skins and outer seed coat during fermentation (Thorngate and Singleton, 1994). Polymeric flavan-3-ols, referred to as proanthocyanidins or condensed tannins, arise either by addition of intermediates from flavan-3,4-diols to flavan-3-ol monomers, or by acetaldehyde-induced polymerization (Fulcrand *et al.*, 1996). Grape seeds differ from skins in that seed proanthocyanidins contain higher levels of monomeric flavan-3-ols, and those esterified to gallic acid (Cheynier *et al.*, 1997; Ricardo-da-Silva, 1997; Singleton, 1992). Additionally, seed proanthocyanidins generally have a lower dp (degree of polymerization) than those found in skins, and no trihydroxylation of the B-ring (Gawel, 1998). Proanthocyanidins are reactive molecules that may form complex species thought to impact wine sensory features. Monomeric and polymeric flavan-3-ols induce both astringent and bitter mouth sensations. Vidal *et al.* (2003) demonstrated that overall astringency increased

with increases in dp. Additionally, they reported that galloylation increased tannin coarseness, while trihydroxylation of the B-ring decreased coarseness.

Tannins in the skins and seeds can combine with anthocyanidin glycosides (anthocyanins) to form polymeric pigments (Somers, 1968). These pigments are believed to be formed by condensation products of malvidin-3-glucoside and various procyanidins created through acetyl bridges (Gawel, 1998). Additionally, anthocyanin-tannin complexes can be produced by binding between the C-4 of the flavylum salt and the C-8 of catechin (Santos-Buelga *et al.*, 1995; Remy *et al.*, 2000).

Adams *et al.* (2001) reported extractable seed tannins in syrah grapes declined by about half from véraison to harvest, and were about three times greater than skin tannin concentrations. Grape skin phenols are more easily extracted during fermentation than those of seeds and stems (Meyer and Hernandez, 1970). Although skins contain a lower concentration of total and polymeric phenols than seeds (Kantz and Singleton, 1990), they may be the primary source of polymeric phenols in wine (Kantz and Singleton, 1991). For the first five to seven days of the fermentation, phenolic compounds are extracted mainly from the skins, followed by extraction from the seeds (Ribéreau-Gayon and Glories, 1986). Several reports have suggested that seeds contribute significant concentrations of proanthocyanidins to wines (Kovac *et al.*, 1995; Singleton and Draper, 1964), while others have reported the seed contribution to be limited (Cheynier *et al.*, 1989; Ricardo-da-Silva *et al.*, 1993). These contradictory observations may be the result of differences in cultivar, fruit maturity, and winemaking. For example, duration of maceration primarily influences the extraction of phenolic compounds from the seeds (Vrhovsek *et al.*, 2002), while fermentation temperature appears to be a primary factor influencing the extraction from the skins (Ribéreau-Gayon and Glories, 1986).

Délestage, or rack and return, is a maceration technique designed to help optimize the exchange between the liquid and solid phase by emptying the fermentation vessel of liquid while airing the juice. Following several hours of cap draining, the liquid is gently pumped over, or returned, to the pomace. This procedure is designed to help oxygenate while minimizing mechanical grinding of the pomace (Dominique Delteil, personal communication, 2003). This study evaluated délestage in conjunction with partial seed deportation, to determine the impact on merlot wine composition for three seasons and on cabernet sauvignon for one season.

Materials and Methods

Merlot. Merlot fruit (approximately 8500 kg), grown in central Virginia was hand harvested each of three seasons at a minimum of 21.0 Brix (a common soluble solids concentration for central Virginia-grown merlot). Fruit was immediately destemmed, crushed and divided into six equal-weight (1416 kg) replicates. Must fermentable nitrogen levels were measured (Gump *et al.*, 2002) and adjusted to 250 mg/L using either Fermaid K™ (Scott Laboratories, Petaluma, CA, USA) or Superfood™ (The Wine Lab, Napa, CA, USA). Sulfur dioxide (30 mg/L) was added at crush to each lot. Musts were given a cold maceration (cold soak) period of 24 hours at 10°C, prior to fermentation. D-254™ yeast (Scott Laboratories, Petaluma, CA, USA) was hydrated as directed by the manufacturer, microscopically examined for budding, viability and purity, cooled to within 3°C of the must temperature, and added to each lot at a rate of 24 g dry yeast/100 L.

The six equal-weight lots were randomly assigned to treatments consisting of 1) control, conventional fermentation, with cap hand-punched two times per day, or 2) délestage, consisting

of a rack and return procedure with seed deportation conducted once per day until dryness, as follows. Following cap rise, fermenting juice was deported from a bottom valve through an external cylindrical dejuicing sleeve (2.39 mm holes) into a stainless steel vat. Seeds were retained within the sleeve. The deported juice was pumped to a separate tank while the dejuiced cap was allowed to drain freely for two hours. Juice was then returned to the top of the cap via a tank cap irrigator, using deflection plates to minimize skin breakage. The deported seeds were drained free of liquid, weighed and discarded.

Treatment and control vessels averaged filled height-to-diameter ratios of 0.64 and 0.75 for the délestage and conventional fermentations, respectively. Fermentations were conducted at an average liquid temperature of 28°C (range 26-35°C) and an average cap temperature of 30°C (range 28-37°C) in 1000 L capacity vessels. Pressing was performed at dryness (2.0 g/L reducing sugar) using a standard tank press (Willmes 10,000 L, Bensheim, Hessen, Germany) to 1 bar. Free-run and press-run wines were combined.

Cabernet sauvignon. Cabernet sauvignon fruit (18,144 kg) grown in northern Virginia was hand harvested at 23 Brix (typical for the region), and immediately destemmed, crushed, sulfur dioxide (30 mg/L) added, fermentable nitrogen levels were measured and adjusted and divided into treatment lots as described above. Musts were given a cold maceration (cold soak) period of 48 hours at 10°C prior to fermentation, and yeasted as described above. Treatment consisted of 1) control, fermentation using 10,000 L mechanical pigeage (Rieger, Röttestrasse, Bietigheim-Bissingen, Germany), or 2) délestage conducted in similar size and shape conventional stainless steel fermentation tanks (fill height to diameter ratio, 1:1). The pigeage was programmed to punch three times daily, 10 min per punch, with punching consisting of cycles of one min down and 30 sec up. Délestage was conducted daily as described above with

the following exception. Liquid was deported onto a flat tray (0.75 x 1.2 m) with a screen containing holes 2.39 mm in diameter. Fermentations were conducted at an average liquid temperature of 27°C (range 26-33°C) and an average cap temperature of 30°C (range 28-34°C). The mechanical punching and délestage were conducted for seven days. Pressing was performed post-dryness (2.0 g/L reducing sugar), 22 days following the beginning of fermentation using an EHP 5000™ (EuroMachine, Inc., Culpeper, VA, USA) 5000-L tank press, by allowing free drainage for one hr, followed by pressing to one bar. Free-run and press-run wines were not combined.

Chemical analysis. Fruit at harvest, and must collected during cold soak, fermentation, and postfermentation, was frozen and stored at -20°C for subsequent analysis. Two must samples (100 mL) were collected daily from a racking ferrule and frozen. Frozen fruit, must and wine samples were allowed to thaw to 20°C prior to analysis of grape glycosides and phenolic components. Fruit Brix, TA and pH were determined on fresh fruit and fermenting wine. Soluble solids were estimated using Brix hydrometers and an American Optical Model 10419™ temperature-compensating refractometer (Warner-Lambert Technologies, Keene, NH, USA), and pH by an Accumet Model 20™ pH meter (Fisher Scientific, Pittsburgh, PA, USA). Fermentable nitrogen was determined by Formol titration as described by Gump *et al.* (2002). Titratable acidity was determined by titration with NaOH to an endpoint of pH 8.2, and reducing sugar by Rebelein, as described by Zoecklein *et al.* (1999). Tartaric, malic and lactic acids were determined by HPLC, using an isocratic system Model 1100™ (Hewlett-Packard, Palo Alto, CA, USA) at 230 nm and a 100 mm x 7.8 mm Fast Acid™ column (Bio-Rad, Hercules, CA, USA). Spectrophotometric estimations of the total phenols by absorbance at 280 nm, total anthocyanins ($A^{20} - A^{SO_2}$) and absorbance of 420+520nm and 420/520 nm was determined as described by

Somers and Evans (1977) using a Genesys 5™, Spectronic Instruments Inc. (Rochester, NY, USA). HPLC analysis was conducted 18 months post-fermentation on selected phenols in finished aged wines produced from this study. The analysis was performed using a Hewlett-Packard 1050 series HPLC with a model 1040 series II diode array detector, and gradient elution as described by Price *et al.* (1995).

Total tannins (catechin equivalents), and the percentage of color from monomeric pigments, small polymeric pigments, and large polymeric pigments was estimated on thawed samples using the procedures of Hagerman and Butler (1978), as modified by Adams and Harbertson (1999) and Harbertson *et al.* (2003). The concentration of total glycosides was estimated by the analysis of glycosyl-glucose on thawed samples as described by Williams *et al.* (1995), modified by Iland *et al.* (1996), and further modified by Whiton and Zoecklein (2002). Analysis of phenol-free glycosides was conducted as described by Zoecklein *et al.* (2000).

Sensory analysis. Discrimination testing was performed on pooled wine replicates of both merlot and cabernet sauvignon, using triangle difference comparison sensory analysis as described by Amerine and Roessler (1976) and Meilgaard *et al.* (1991). The wines were evaluated six to eight months postfermentation in the sensory laboratory of the Department of Food Science and Technology at Virginia Tech, under controlled conditions that included red lighting to help eliminate color bias. Twenty-five mL of wine at 20°C was presented in standard ISO glasses to a panel of wine consumers with no previous formal wine evaluation experience. The number of panelists ranged from 24 to 53. Panel membership required regular wine consumption (at least one glass per week) and attendance at two informational sessions where the methodology of evaluation was described. Each evaluation session lasted approximately 20 minutes. No more than two sessions of three-three wine sets were completed each day per

panelist. Evaluation was done based on olfactory (aroma) and retronasal aroma and mouthfeel, hereinafter referred to as flavor. Evaluations for aroma and flavor occurred at different times.

Descriptive analysis was performed nine months post-fermentation on non-pooled cabernet sauvignon wine treatment replicates, using 11 trained panelists (9 female and 2 male) as described by Meilgaard *et al.* (1991). Twenty-five mL of wine at 20°C was presented in standard ISO glasses under standard conditions to panel members who evaluated three replications of the two products (pigeage versus délestage) six times. Panelists had one to ten years experience in descriptive or consensus sensory analysis. A list of descriptors was developed from three pre-evaluation training sessions. Assigned descriptors were alcohol, pungent, sour/acid/tart, sweet, astringent, bitter, burnt/hot, musty, grape, oak, honey, nutty, vanilla, smoky, black licorice, black current, bell pepper, grape, musty, astringent, bitter raspberry, and black cherry. Standards used for training were reported by Zoecklein *et al.* (1999). At the start of the testing, panelists received a reference sample for calibration purposes. Six samples were served each session with 24 hours between sessions. Intensity of attributes was recorded on a 10 cm unstructured line anchored at each end.

Statistical analysis. All data were statistically analyzed using SAS (SAS Institute, Cary, NC, USA). Statistical methods employed were ANOVA, multivariate analysis, and Student's t-test.

Results

Merlot. The average fruit Brix, pH, TA, berry weight, seeds per berry, and percentage of color derived from monomeric (MP), small polymeric (SPP) and large polymeric pigments

(LPP) are given in Table 1. Berries averaged 1.18 g, with 2.4 seeds, for the three seasons of this study. In seasons 2 and 3, merlot fruit monomeric pigments were responsible for an average of 70.5%, SPP 19.7%, and LPP 9.8% of the total color.

Seed weight removed at four stages of fermentation for merlot délestage, typical of this study, is seen in Table 2. By the completion of délestage-treated fermentations, an average of 25% of seeds had been deported each season. Fermentation rates were similar among treatments. Total phenols, estimated by the absorbance at 280 nm, increased lineally from crush until dejuicing for both délestage and control wines (Fig. 1). At day six (dryness), control lots had a total phenol concentration slightly greater (7.7%) than the délestage, typical of this study.

The percentage of color derived from the monomeric pigments was greater in the fruit than the wines, while the percentage of color from polymeric pigment forms showed the opposite trend (Table 1 and Fig. 2). Merlot délestage and control wines showed slight differences in the percentage of color from the different pigment sources. Délestage wines produced over three seasons averaged 4.8% lower color derived from monomeric pigments, 1.4% higher from SPP and 4.5% higher color from LPP, compared to control wines.

Following fermentation, control and délestage-produced merlot wines did not differ in alcohol percent (v/v), TA, tartaric, malic, and lactic acids, or pH (Table 3). The total tannin concentration was greater in the control wines at the completion of fermentation each season. The total phenol estimations demonstrated a higher concentration in control wines in two of the three seasons. Total anthocyanins were higher in the control wines in the two seasons measured, while absorbance at 420 nm plus 540 nm, and 420nm/520nm, did not demonstrate consistent patterns between délestage and control wines. Table 4 provides the concentration of selected phenolic compounds on aged merlot determined by HPLC analysis. Significant differences

among treatments were not observed. Catechin and epicatechin concentrations averaged 37 and 26 mg/L for the control and délestage-produced wines, respectively.

Merlot total glycosides increased by day two, the first day of fermentation (Table 5). By the completion of fermentation (dejuicing), the total glycoside concentration had increased by an average of 388% and 296% for the control and délestage wines, respectively. At dejuicing, the total glycoside concentration was greater in the control wines. Phenol-free glycosides increased by day two. They generally declined by the end of fermentation, and were in greater concentration in the délestage-produced wines at dejuicing.

The results of discrimination sensory analysis suggested that merlot wines were perceived to differ in aroma and/or flavor in two of three seasons (Table 6).

Cabernet sauvignon. Cabernet sauvignon underwent cold maceration for 48 hours, prior to yeast addition. The effect of fermentation on reducing sugar concentration and percent alcohol (v/v) at various sampling periods was determined by comparing one fermentation vessel each of délestage-and pigeage-produced cabernet sauvignon (Fig. 3). While the fermentation rates were generally similar between treatments, some differences in the wines were noted. There were no differences in alcohol percent (v/v), TA, pH, or tartaric, malic, or lactic acids, between pigeage and délestage-produced wines postfermentation (Table 7). Total tannin, total phenols and total anthocyanins were greater in pigeage-produced wines. Differences in absorbance at 420nm plus 520 nm, and 420nm/520nm, were noted between délestage and pigeage. Table 4 provides the concentration of selected phenol compounds on aged cabernet sauvignon. Significant differences among treatments were not observed.

Tannin concentrations remained stable until active fermentation, then increased and were higher in pigeage-produced wines at most sample periods (Fig. 4). Total phenols (AU 280)

increased for both treatments during pre-fermentation maceration, and significantly during fermentation (Fig. 5). At dejuicing, the total phenol concentration in the press wines averaged 14.5% and 9.8% higher than free run for the délestage and pigeage wines, respectively (data not shown). At the completion of fermentation, free-run pigeage-produced wines had higher absorbance at 420 nm plus 520 nm, and lower 420nm/520 nm absorbance than délestage (Table 7).

During the cold soak period, the percentage of color from monomeric anthocyanins declined dramatically in the juice, then declined or remained constant for the first three days of fermentation (Figure 6). By sampling day 10, the completion of alcoholic fermentation, the percentage of monomeric pigments had declined for both treatments. At dejuicing, day 22, the percentage of color from monomeric pigments in the pigeage free-run wine averaged 33% higher than the délestage. Press wines showed a similar trend (data not shown). The percentage of color from small polymeric pigments increased during the cold soak period, remained or declined during the first five days of fermentation for both treatments, then increased slightly (Fig. 7). The percentage of color from large polymeric pigments increased during cold soak and fermentation for both pigeage and délestage treatments, and was slightly higher in the délestage wines at dejuicing (Fig. 8). Postfermentation free-run cabernet sauvignon délestage versus pigeage wines demonstrated 34.6% versus 43.5% color from monomeric pigments, 53.8% versus 49.6% color from SPP, and 11.6% versus 6.9% color from LPP (Table 7), respectively.

Following cold soak, total glycoside concentration was higher in the pigeage than délestage tanks by an average of 49% (Table 8). Total glycosides increased during fermentation (cold soak to day 10) for both treatments. By the completion of fermentation (day 10) and at dejuicing, total glycoside concentrations were similar in the pigeage and délestage wines.

Phenol-free glycosides were in higher concentrations in the pigeage wines post-cold soak and at dejuicing.

Discrimination sensory analysis of cabernet sauvignon délestage and pigeage-produced wines indicated differences in aroma and flavor (Table 6). The principal component analysis for aroma indicated variation among treatment replicates that accounted for 59% of the variance (Fig. 9). The first and second principal component analysis of flavor accounted for 63% of the variance (Fig. 10).

Discussion

A relatively high concentration of extractable seed tannins has been shown to negatively impact wine quality in this and other wine-producing regions. The study was conducted using commercial-size lots, and seed deportation in conjunction with délestage, to help improve red wine mouthfeel. Due to logistical limitations, including the necessity for replications, wines were not produced by délestage alone, without seed removal.

The majority of the seeds deported (average 25%) were removed in the first few days of fermentation, possibly contributing to the lower total tannin concentration frequently observed in the délestage-produced wines. Tannin levels generally remained stable in the must until active fermentation, then increased significantly. Singleton and Draper (1964) demonstrated that fermentation for 90 hours resulted in the extraction of 65% of the available seed tannins, while 180 hours resulted in the extraction of 70%. Seed tannins comprise approximately 60% of the total phenols in conventionally-produced red wines (Singleton and Draper, 1964), with nearly half of the extractable catechins and oligomeric proanthocyanidins in grape seeds transferred into

wines (Sun *et al.*, 1999). Kovac *et al.* (1995) added seeds during fermentation (6% of the weight of the fruit) and noted a doubling in the concentration of catechins and proanthocyanins in the fermented wine. For the merlot wines, about 1.1% of the weight of the fruit was deported as seeds during délestage. Bosso *et al.* (2001) compared pump-over with délestage, using montepulciano d'abruzzo, and found that pump-over produced wines higher in anthocyanins, polymeric pigments and tannins. In the current study, wines produced by délestage contained a lower tannin concentration than controls (manual cap punching or pigeage), possibly due to limited extraction and seed deportation in the délestage treatments. However, HPLC analysis of aged wines did not demonstrate statistical differences in selected phenols, including those associated with seeds, such as catechin and epicatechin. The extent of phenol extraction from the seeds is dependent, in part, on the degree of seed oxidation or maturity (Gawel, 1998). Délestage can allow fermenting juice to percolate through the cap, providing an exchange that may minimize particulate extraction from the cap (Dominique Delteil, 2003, personal communication). Although not measured in this study, it is possible that délestage reduced the concentration of non-soluble solids, thereby aiding in the reduction of total phenols, including skin tannins. Total anthocyanins were frequently in higher concentrations in the conventionally- and pigeage-produced wines, versus délestage, possibly suggesting greater extraction. The higher concentration of total glycosides noted in the manual cap-punched merlot wines may also indicate increased extraction, although there were no differences in total glycosides in the cabernet sauvignon produced by pigeage and délestage.

Formation of polymeric pigments is important due to their contribution to color stability. It has been demonstrated that after only a few years of aging, the vast majority of color is due to polymeric pigments, with a small concentration of monomeric anthocyanins remaining (Somers,

1968). Analysis of the fruit demonstrated a relatively high percentage of color from monomeric pigments compared to LPP, consistent with Adams *et al.* (2001) and Harbertson *et al.* (2003). In years 2 and 3, the merlot fruit LPP averaged 9.8% of the color, while the corresponding wines averaged 18.5% color from LPP. The increase in percentage of wine color from LPP, compared to the fruit, appeared to parallel a decrease in the percentage of color from monomeric anthocyanins in the wine. It is generally assumed that the formation of polymeric pigments is the result of relatively slow, post-fermentation reactions (Somers, 1971). Eglinton *et al.* (2004) however, demonstrated that fermenting yeast cells and their metabolites are actively involved in condensation reactions with tannins and anthocyanins, suggesting polymeric pigment formation during fermentation. In this study, it must be noted that the analyses of the percentage of color from MP, SPP and LPP are estimations. For example, while not impacted by the phenolic matrix (Harbertson *et al.*, 2003), monomeric anthocyanins at the pH of the assay are largely in the leuco- or colorless form.

The percentage of cabernet sauvignon color from monomeric pigments declined during fermentation for both treatments, by an average of 25%. Zimman and Waterhouse (2004) demonstrated that a significant percentage of the loss of monomeric pigments could be due to association with grape solids. Therefore, it is possible that a cap management technique that impacts the non-soluble solids level could impact monomeric anthocyanins. The higher percentage of color from monomeric pigments in the pigeage wines at the end of fermentation may reflect increased fruit extraction. Cabernet sauvignon color from SPP increased during cold soak, and appeared to increase only slightly from the beginning of fermentation to dejuicing (average 7.8%). The percentage of color from LPP increased during fermentation by approximately 150%.

The cabernet sauvignon LPP-to-SPP ratio, as percent of color, ranged from 0.11 during cold soak to 0.37 at dejuicing. The SPP would be expected to contain pigment dimers and trimers formed by acetaldehyde crosslinking of anthocyanin and flavan-3-ols (Saucier *et al.*, 1997). The LPP fraction likely contains anthocyanins that have reacted directly with polymeric flavan-3-ols, or by acetaldehyde crosslinks, to form polymeric pigments large enough to precipitate with BSA in the assay.

Phenol-free glycosides were in higher concentration in the merlot, but not cabernet sauvignon, délestage-produced wines. The analysis of phenol-free glycosides includes all but shikimic acid metabolites. This analysis may be a better approximation of the glycosidically-derived aroma/flavor pool than is the total glycosides assay.

Discrimination sensory analysis on pooled treatment replications indicated differences in aroma and flavor among merlot and cabernet sauvignon délestage and control wines. PCA analysis of cabernet sauvignon treatment replications demonstrated differences between délestage and pigeage wines, and among replications of the same treatment. It is evident that délestage 1 and pigeage 3 have similar aroma and flavor profiles. While treatments were dejuiced each day at the same Brix, individual replication variation occurred, possibly as a result of the degree of seed deportation, pomace drain time, and/or oxygen exposure. With the exception of replication 1, délestage wines were characterized by pungent black pepper aromas and pungent raspberry flavors.

Conclusion

An important industry goal is to be able to customize maceration methods, predicated on

fruit composition and desired outcome. This study evaluated the impact of a cap management technique in conjunction with seed removal. Given the large variability in fruit composition, the response to a particular maceration technique may be variable. Délestage with partial seed removal appeared to slightly modify the percentage of color derived from monomeric and large polymeric pigments. The result of discriminatory sensory analysis generally suggested differences in aroma and flavor between délestage and control wines. These differences were charted for the cabernet sauvignon, and were variable among replications. These differences may or may not justify the additional effort involved in the utilization of délestage with seed deportation as a cap management strategy.

References

ADAMS, D.O. and HARBERTSON, J.F. (1999) Use of alkaline phosphatase for analysis of tannins in grapes and red wines, *American Journal of Enology and Viticulture*, 50, 247-252.

ADAMS, D.O., HARBERTSON, J.F., PICCIOTTO, E.A. and WENTE, K.D. (2001) Tannin and polymeric pigment development in syrah berries during ripening, in: SMITH, R.J. (ed) *Syrah Symposium Proceedings, San Diego, California*, Davis, California: American Society for Enology and Viticulture, 23-26.

AMERINE, M.A. and ROESSLER, E.B. (1976) *Wines: Their Sensory Evaluation*, San Francisco: W.H. Freeman and Co.

BOSSO, A., PANERO, L., GUAITA, M. and MARULLI, C. (2001) La tecnica del délestage nella vinificazione del Montepulciano d'Abruzzo, *L'Enologo*, 37, 87-96.

CHEYNIER, V., RIGAUD, J., SOUQUET, S.M., BARILLÈRE, J.M. and MOUTOUNET, M. (1989) Effect of pomace contact and hyperoxidation on the phenolic composition and quality of grenache and chardonnay wines, *American Journal of Enology and Viticulture*, 40, 36-42.

CHEYNIER, V., PRIEUR, C., GUYOT, S., RIGAUD, J. and MOUTOUNET, M. (1997) The structures of tannins in grapes and wines and their interactions with proteins, in: WATKINS, T.R. (ed) *Wine: Nutritional and Therapeutic Benefits*, American Chemical Society Symposium Series 661, Washington, D.C.: American Chemical Society, 81-93.

EGLINTON, J., GRIESSER, M., HENSCHKE, P., KWIATKOWSKI, M., PARKER, M. and HERDERICH, M. (2004) Yeast-mediated formation of pigmented polymers in red wine, in: WATERHOUSE, A.L. and KENNEDY, J.A. (eds) *Red Wine Color – Revealing the Mysteries*, American Chemical Society Symposium Series 886, Washington, D.C.: American Chemical Society, 7-21.

FISCHER, U., STRASSER, M. and GUTZLER, K. (2000) Impact of fermentation technology on the phenolic and volatile composition of German red wines, *International Journal of Food Science and Technology*, 35, 81-94.

FULCRAND, H., ES-SAFI, N., DOCO, T., CHEYNIER, V. and MOUTOUNET, M. (1996) LC-MS study of acetaldehyde-induced polymerisation of flavan-3-ols, *Polyphenols Communications*, 96, 203-204.

GAWEL, R. (1998) Red wine astringency: a review, *Australian Journal of Grape and Wine Research*, 4, 74-95.

GUMP, B.H., ZOECKLEIN, B.W., FUGELSANG, K.C. and WHITON, R.S. (2002) Comparison of analytical methods for prediction of pre-fermentation nutritional status of grape juice, *American Journal of Enology and Viticulture*, 53, 325-329.

HAGERMAN, A.E. and BUTLER, L.G. (1978) Protein precipitation method for the quantitative determination of tannins, *Journal of Agricultural and Food Chemistry*, 26, 809-812.

HARBERTSON, J.F., PICCIOTTO, E.A. and ADAMS, D.O. (2003) Measurement of polymeric pigments in grape berry extracts and wines using a protein precipitation assay combined with bisulfite bleaching, *American Journal of Enology and Viticulture*, 54, 301-306.

HASLAM, E. (1998) *Practical Polyphenolics – from Structure to Molecular Recognition and Physiological Action*, Cambridge: Cambridge University Press.

ILAND, P.G., CYNKAR, W., FRANCIS, I.L., WILLIAMS, P.J. and COOMBE, B.G. (1996) Optimisation of methods for the determination of total and red-free glycosyl glucose in black grape berries of *Vitis vinifera*, *Australian Journal of Grape and Wine Research*, 2, 171-178.

KANTZ, K. and SINGLETON, V.L. (1990) Isolation and differentiation of polymeric polyphenols using Sephadex LH-20 and analysis of grape tissue extracts, *American Journal of Enology and Viticulture*, 41, 223-228.

KANTZ, K. and SINGLETON, V.L. (1991) Isolation and determination of polymeric polyphenols in wines using Sephadex LH-20, *American Journal of Enology and Viticulture*, 42, 309-315.

KOVAC, V., ALONSO, E. and REVILLA, E. (1995) The effect of adding supplementary quantities of seeds during fermentation on the phenolic composition of wines, *American Journal of Enology and Viticulture*, 46, 363-367.

MATTIVI, F., ZULIAN, C., NICOLINI, G. and VALENTI, L. (2002) Wine, biodiversity, technology and antioxidants, *Annals of the New York Academy of Science*, 957, 27-57.

MEILGAARD, M., CIVILLE, G.V. and CARR, B.T. (1991) *Sensory Evaluation Techniques*, 2nd Edition, Boston: CRC Press, Inc.

MEYER, J. and HERNANDEZ, R. (1970) Seed tannin extraction in cabernet sauvignon, *American Journal of Enology and Viticulture*, 21, 184-188.

PRICE, S.F., BREEN, P.J., VALLADAO, M. and WATSON, B.T. (1995) Cluster sun exposure and quercetin in pinot noir grapes and wine, *American Journal of Enology and Viticulture*, 46, 187-194.

RAMEY, D., BERTRAND, A., OUGH, C.S., SINGLETON, V.L. and SANDERS, E. (1986) Effects of skin contact temperature on chardonnay must and wine composition, *American Journal of Enology and Viticulture*, 37, 99-106.

REMY, S., FULCRAND, H., LABARBE, B., CHEYNIER, V. and MOUTOUNET, M. (2000) First confirmation in red wine of products resulting from direct anthocyanin-tannin reactions, *Journal of the Science of Food and Agriculture*, 80, 745-751.

REVILLA, E., ALONSO, E. and KOVAC, V. (1997) The content of catechins and procyanidins in grapes and wines as affected by agroecological factors and technological practices, in: WATKINS, T.R. (ed) *Wine – Nutritional and Therapeutic Benefits*, American Chemical Society Symposium Series 661, Washington, D.C.: American Chemical Society, 69-79.

RIBÉREAU-GAYON, P. and GLORIES, Y. (1986) Phenolics in grapes and wine, in: LEE, T.H. (ed) *Proceedings of the Sixth Australian Wine Industry Technical Conference*, Adelaide, South Australia: Australian Industrial Publishers, 247-256.

RICARDO-DA-SILVA, J.M., CHEYNIER, V., SAMSOM, A. and BOURZEIX, M. (1993) Effect of pomace contact, carbonic maceration, and hyperoxidation on the procyanidin composition of grenache blanc wines, *American Journal of Enology and Viticulture*, 44, 168-172.

RICARDO-DA-SILVA, J.M. (1997) Anthocyanins and proanthocyanidins in grapes and wines. Their primordial role in enology, in: *Proceedings of the First Symposium "In Vino Analytica Scientia"*, Bordeaux, France, 12-14 June 1997, pp. 101-113.

SANTOS-BUELGA, C., BRAVO-HARO, S. and RIVAS-GONZALO, J.C. (1995) Interactions between catechin and malvidin-3-monoglucoside in model solutions, *Zeitschrift für Lebensmittel-Untersuchung und -Forschung*, 201, 269-274.

SAUCIER, C., LITTLE, D. and GLORIES, Y. (1997) First evidence of acetaldehyde-flavanol condensation products in red wine, *American Journal of Enology and Viticulture*, 48, 370-373.

SINGLETON, V.L. and DRAPER, D.E. (1964) The transfer of polyphenolic compounds from grape seeds into wines, *American Journal of Enology and Viticulture*, 15, 34-40.

SINGLETON, V.L. and NOBLE, A.C. (1976) Wine flavor and phenolic substances, in: CHARALAMBOUS, G. and KATZ, I. (eds) *Phenolic, Sulfur, and Nitrogen Compounds in Food*

Flavors, American Chemical Society Symposium Series 26, Washington, D.C.: American Chemical Society, 47-70.

SINGLETON, V.L. (1982) Grape and wine phenolics: background and prospects, in: SINGLETON, V.L. (ed) *Proceedings of Symposium: Grape and Wine Centennial*, U.C. Davis, Berkeley, California: University of California Press, 215-227.

SINGLETON, V.L. (1992) Tannins and the qualities of wines, in: *Plant Polyphenols Synthesis, Properties, Significance*, HEMINGWAY, R.W. and LAKS, P.E. (eds), New York: Plenum Press, 859-880.

SOMERS, T.C. (1968) Pigment profiles of grapes and of wines, *Vitis*, 7, 303-320.

SOMERS, T.C. (1971) The polymeric nature of wine pigments, *Phytochemistry*, 10, 2175-2186.

SOMERS, T.C. and EVANS, M.E. (1977) Spectral evaluation of young red wines: Anthocyanin equilibria, total phenolics, free and molecular SO₂, "chemical age," *Journal of the Science of Food and Agriculture*, 28, 279-287.

SOMERS, T.C. and VÉRETTE, E. (1998) Phenolic composition of natural wine types, in: LINSKENS, H.F. and JACKSON, J.F. (eds) *Wine Analysis*, Berlin: Springer-Verlag, 219-257.

SUN, B.S., PINTO, T., LEANDRO, M.C., RICARDO-DA-SILVA, J.M. and SPRANGER, M.I. (1999) Transfer of catechins and proanthocyanidins from solid parts of the grape cluster into wine, *American Journal of Enology and Viticulture*, 50, 179-184.

THORNGATE, J.H. and SINGLETON, V.L. (1994) Localization of procyanidins in grape seeds, *American Journal of Enology and Viticulture*, 45, 259-262.

VIDAL, S., LEIGH, F., GUYOT, S., MARNET, N., KWIATKOWSKI, M., GAWEL, R., CHEYNIER, V. and WATERS, E.J. (2003) The mouthfeel properties of grape and apple proanthocyanidins in wine-like medium, *Journal of the Science of Food and Agriculture*, 83, 564-573.

VRHOVSEK, U., VANZO, A. and NEMANIC, J. (2002) Effect of red wine maceration techniques on oligomeric and polymeric proanthocyanidins in wine, cv. blaufraenkisch, *Vitis*, 41, 47-51.

WHITON, R.S. and ZOECKLEIN, B.W. (2002) Evaluation of glycosyl-glucose analytical methods for various glycosides, *American Journal of Enology and Viticulture*, 53, 315-317.

WILLIAMS, P.J., CYNKAR, W., FRANCIS, I.L., GRAY, J.P., ILAND, P.G. and COOMBE, B.G. (1995) Quantification of glycosides in grapes, juices, and wines through a determination of glycosyl-glucose, *Journal of Agricultural and Food Chemistry*, 43, 121-128.

ZIMMAN, A. and WATERHOUSE, A.L. (2004) Incorporation of malvidin-3-glucoside into high molecular weight polyphenols during fermentation and aging, *American Journal of Enology and Viticulture*, 55, 139-146.

ZOECKLEIN, B.W., FUGELSANG, K.C., GUMP, B.H. and NURY, F.S. (1999) *Wine Analysis and Production*, New York: Kluwer Academic Publishers.

ZOECKLEIN, B.W., DOUGLAS, L.S. and JASINSKI, Y.W. (2000) Evaluation of the phenol-free glycosyl-glucose determination, *American Journal of Enology and Viticulture*, 51, 420-423.

Table 1 Merlot fruit Brix, pH, TA, berry weight, seed number, and percentage of color from monomeric pigments (MP), small polymeric pigments (SPP), and large polymeric pigments (LPP) for three seasons.

	Season 1	Season 2	Season 3
Brix	22.5 ^a	21.2	21.0
pH	3.70	3.73	3.69
TA (g/L)	5.51	6.15	5.20
Berry Weight (g)	1.10	1.20	1.23
Seed Number per Berry	2.1	2.7	2.5
Color from MP (%)	n.d.	72.0	69.0
Color from SPP (%)	n.d.	16.6	22.8
Color from LPP (%)	n.d.	11.4	8.2

^an=3

n.d.=not determined

Table 2 Average degrees Brix and average weight of seeds removed from 2121 kg of merlot fruit during délestage in one season.

	Brix	Seed weight removed (kg)
Day 1	21.2 ^a	10.4
Day 2	20.3	6.8
Day 3	9.5	2.4
Day 4	2.8	3.2

^an=3

Table 3 Effect of manual cap punching (control) and délestage on merlot wine chemistry for three seasons.

	Season 1		Season 2		Season 3	
	Control	Délestage	Control	Délestage	Control	Délestage
Alcohol % (v/v)	12.8a ^a	12.7a	11.5a	11.7a	13.1a	13.1a
TA (g/L)	6.57a	6.70a	6.20a	6.38a	4.85a	4.88a
Tartaric Acid (g/L)	2.21a	1.97a	3.06a	3.41a	1.50a	1.74a
Malic Acid (g/L)	trace	trace	trace	trace	trace	trace
Lactic Acid (g/L)	3.15a	2.23a	3.35a	4.07a	3.87a	2.44a
pH	3.60a	3.66a	3.65a	3.66a	3.87a	3.91a
Total Tannin (mg CE/L)	191.6a	173.0b	177a	150b	197.5a	171.1b
Total Phenol (AU ²⁸⁰)	59.8a	58.3a	43.1a	37.6b	40.1a	37.0b
Total Anthocyanin (AU ²⁰ -AU ^{SO₂})	ND	ND	3.89a	3.04b	2.37a	2.21b
AU ⁴²⁰⁺⁵²⁰	8.23a	6.92b	8.21a	7.82a	8.87a	7.64a
AU ^{420/520}	0.793a	0.780a	0.794a	0.789b	0.575b	0.585a

^aDifferent letters within rows and years denote significant difference ($p \leq 0.05$) of treatment means;

^bND=not determined; n = 3.

Table 4 Mean values of HPLC phenolic profiles of aged merlot wines for three seasons, and cabernet sauvignon wine produced one season. Significant differences were not observed at $p \leq 0.05$.

	Merlot		Cabernet Sauvignon	
	Control	Délestage	Pigeage	Délestage
Gallic Acid (mg/L)	22 ^a	21	55	37
Catechin (mg/L)	23	17	49	39
Epicatechin (mg/L)	14	9	29	16
Caftaric Acid (mg/L)	11	11	<1	6
Caffeic Acid (mg/L)	14	12	16	20
Quercetin (mg/L)	8	4	3	3
Malvidin Glucoside (mg/L)	30	13	20	21
Polymeric Anthocyanins (mg/L)	34	36	36	41
Total Anthocyanins (mg/L)	100	83	71	61
Monomeric Anthocyanins (mg/L)	50	28	25	30

^an=3

Table 5 Effect of manual cap punch (control) and délestage on total (TGG) and phenol-free (PFGG) merlot glycosides for two seasons.

Sample		TGG (μM)		PFGG (μM)	
		Control	Délestage	Control	Délestage
Season 2	Post Cold Soak	386b ^a	435a	157b	191a
	Day 2	1513a	1156b	180b	264a
	Dejuice	2068a	1866b	135b	194a
Season 3	Post Cold Soak	360b	394a	144a	152a
	Day 2	1260a	1279a	141a	127a
	Dejuice	1583a	1433b	120b	134a

^aDifferent letters within rows indicate significant difference ($p \leq 0.05$) of treatment means; n=3.

Table 6 Results of triangle difference testing of merlot manual cap punch and délestage wines produced in three seasons, and cabernet sauvignon pigeage and délestage produced in one season.

Variety	Aroma	Significance	Flavor	Significance
Merlot season 1	26/36 ^a	0.001	28/36	0.001
Merlot season 2	19/40	ns	22/40	0.100
Merlot season 3	5/24	ns	7/24	ns
Cabernet sauvignon	39/53	0.001	42/53	0.001

^aNumbers denote correct responses vs. total responses.

Table 7 Effect of pigeage and délestage on cabernet sauvignon wine chemistry and average percentage of color derived from monomeric pigments (MP), small polymeric pigments (SPP), and large polymeric pigments (LPP).

	Pigeage	Délestage
% Alcohol (v/v)	12.4a ^a	12.5a
TA (g/L)	5.19a	5.01a
Tartaric Acid (g/L)	1.36a	1.32a
Malic Acid (g/L)	0.52a	0.52a
Lactic Acid (g/L)	4.12a	3.72a
pH	3.96a	4.01a
Total Tannin (mg CE/L)	337.8a	294.5b
Total Phenols (AU ²⁸⁰)	65.2a	58.0b
Total Anthocyanin (AU ²⁰ -AU ^{SO₂})	2.65a	1.67b
AU ⁴²⁰⁺⁵²⁰	0.616a	0.608b
AU ^{420/520}	0.77b	0.81a
Monomeric Pigment (%)	43.5	34.6
Small Polymeric Pigment (%)	49.6	53.8
Large Polymeric Pigment (%)	6.9	11.6

^aDifferent letters within rows denote significant difference ($p \leq 0.05$) of treatment means; n = 3.

Table 8 Effect of mechanical pigeage and délestage on total (TGG) and phenol-free (PFGG) cabernet sauvignon glycosides.

Sample	TGG (μM)		PFGG (μM)	
	Pigeage	Délestage	Pigeage	Délestage
Post Cold Soak	986a ^a	662b	189a	98b
Day 10	1441a	1505a	139b	154a
Dejuice	1470a	1470a	113a	94b

^aDifferent letters within rows and assays indicate significant difference ($p \leq 0.05$) of treatment means; n=3.

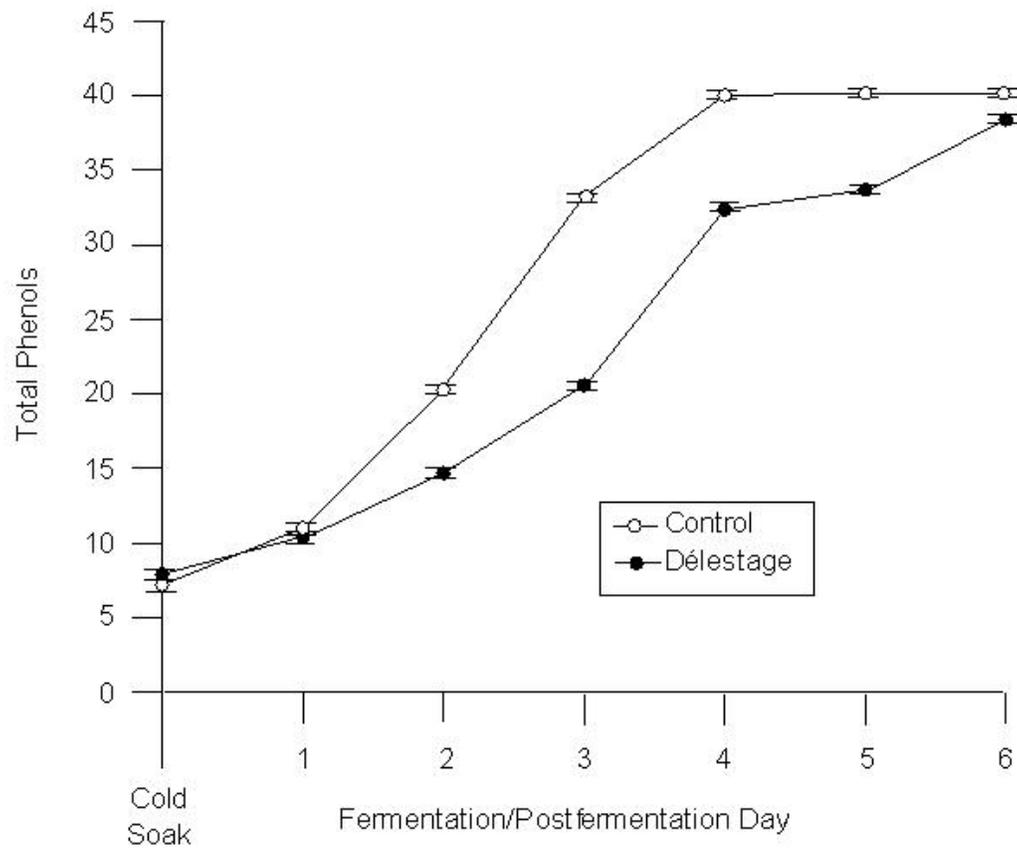


Figure 1.

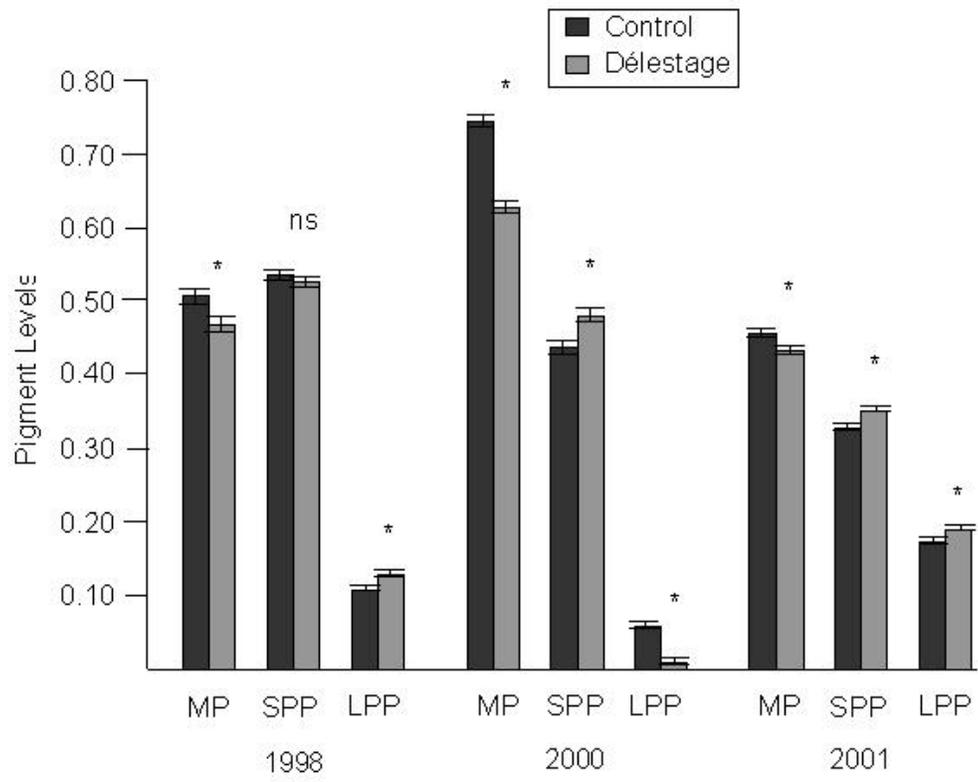


Figure 2.

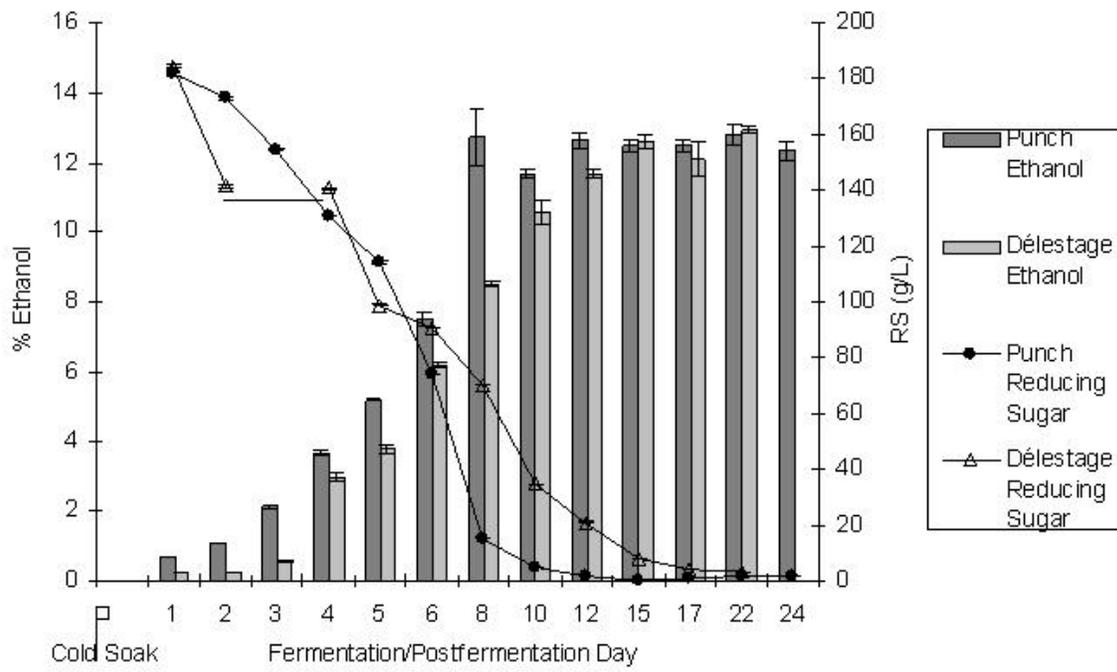


Figure 3.

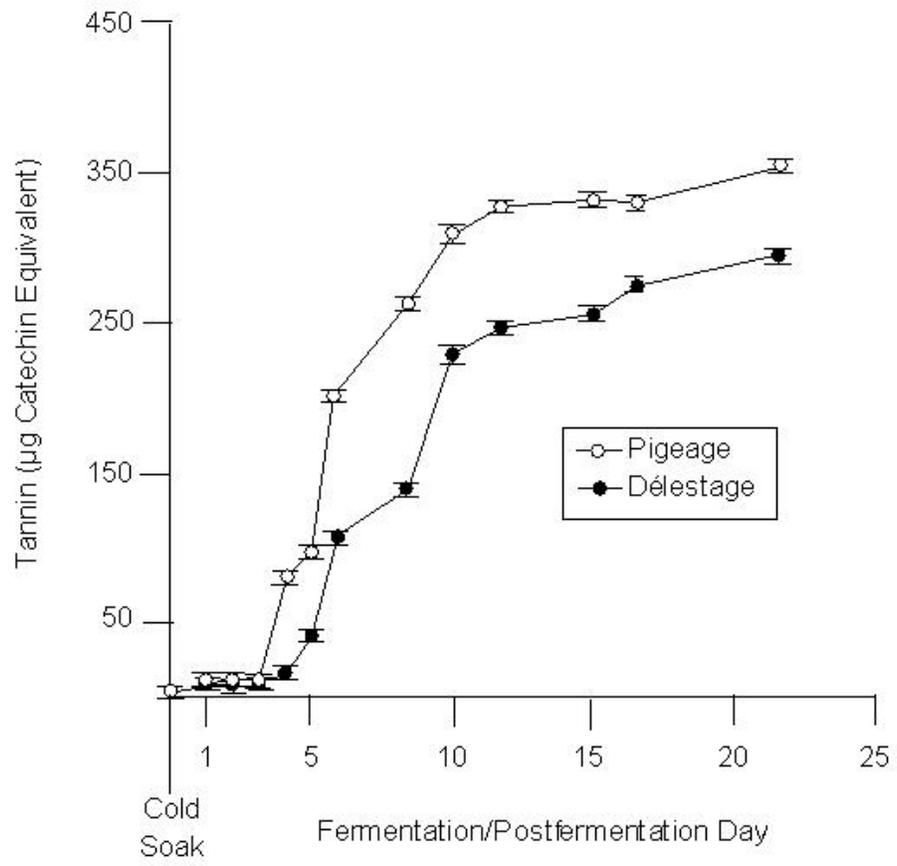


Figure 4.

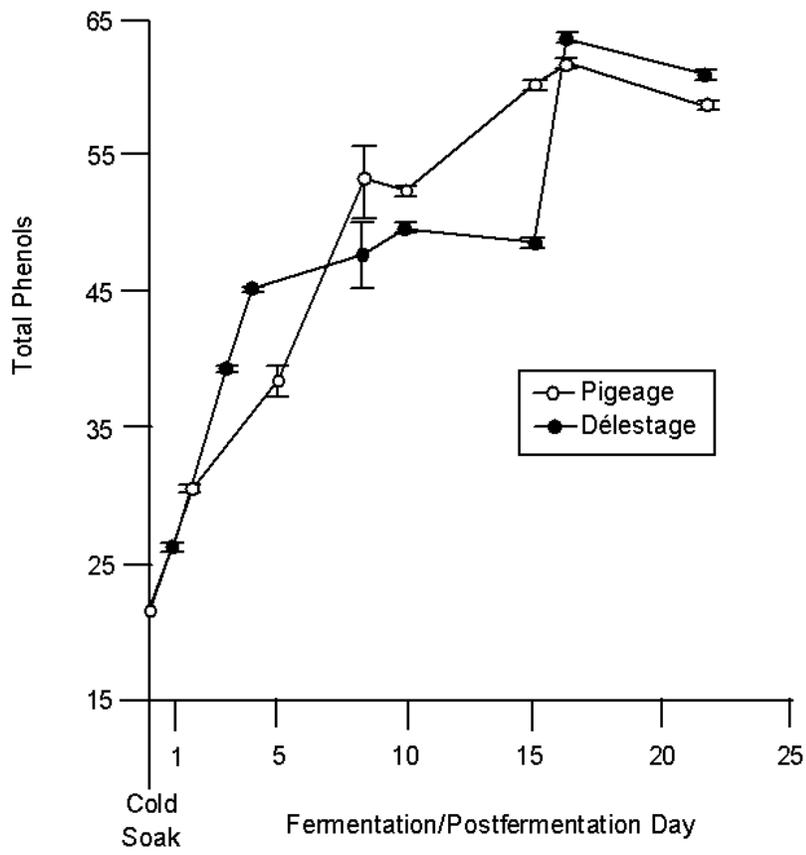


Figure 5.

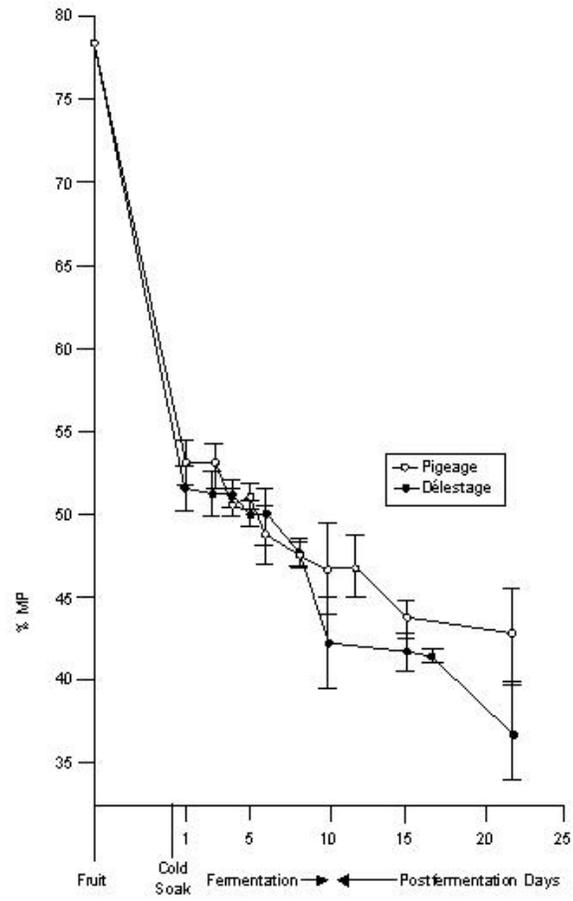


Figure 6.

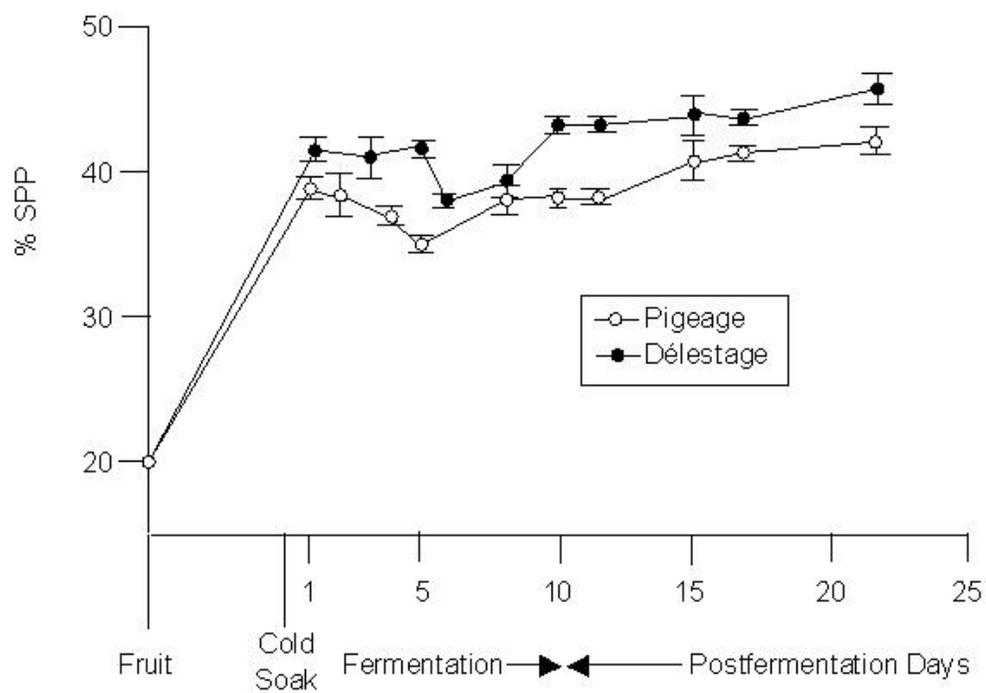


Figure 7.

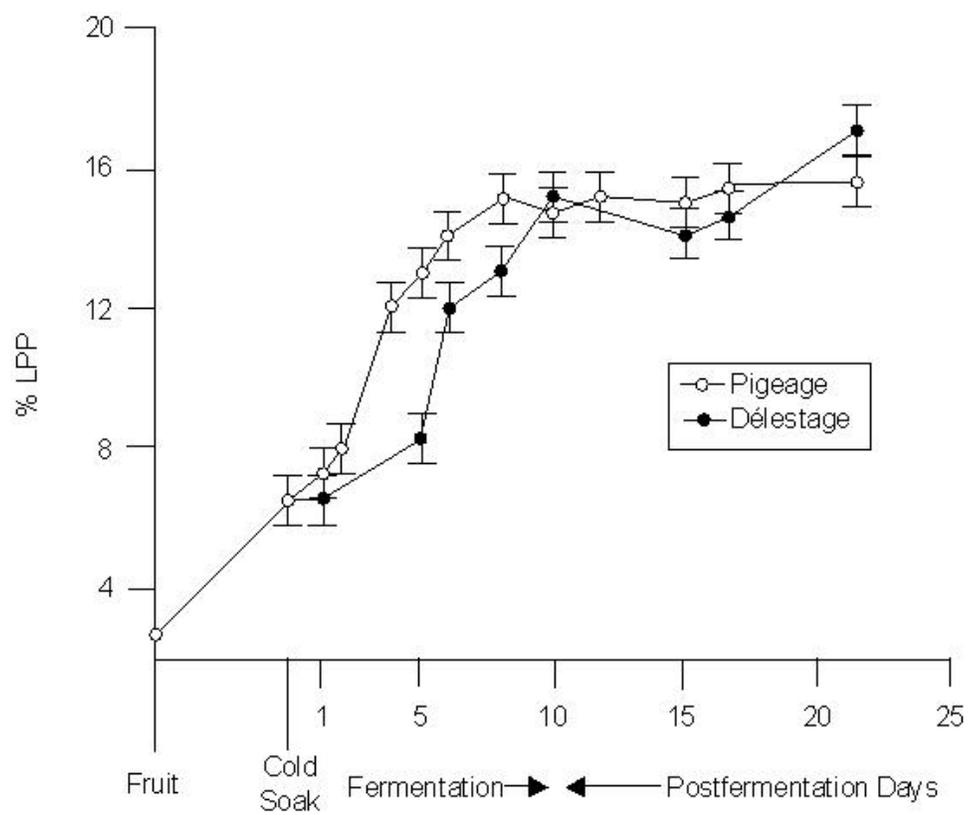


Figure 8.

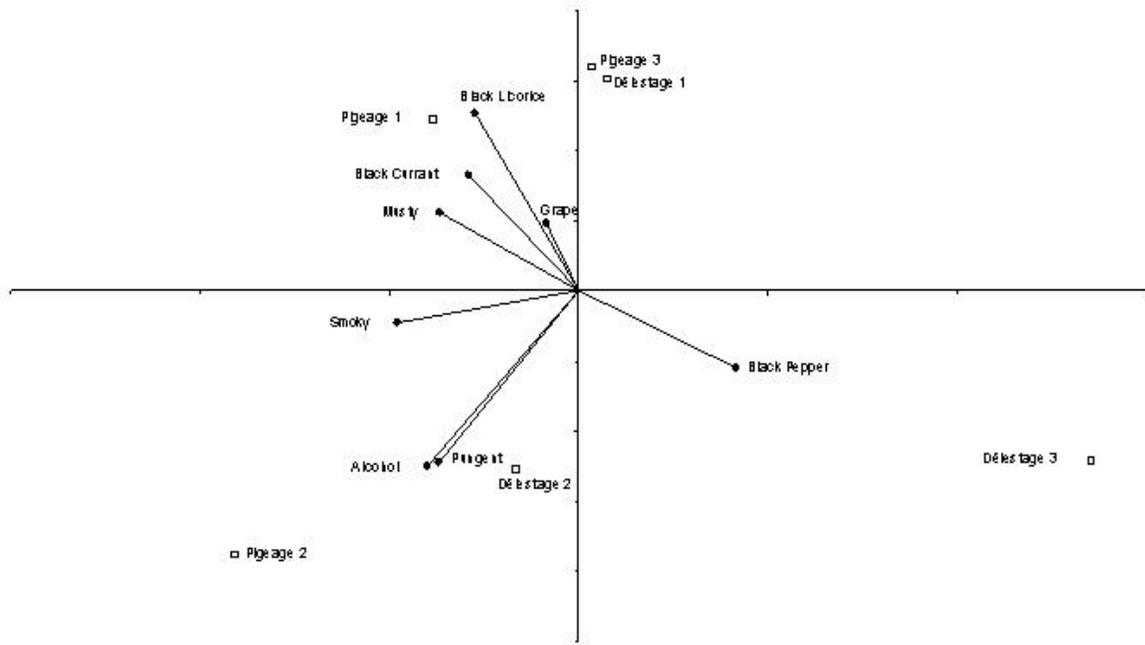


Figure 9.

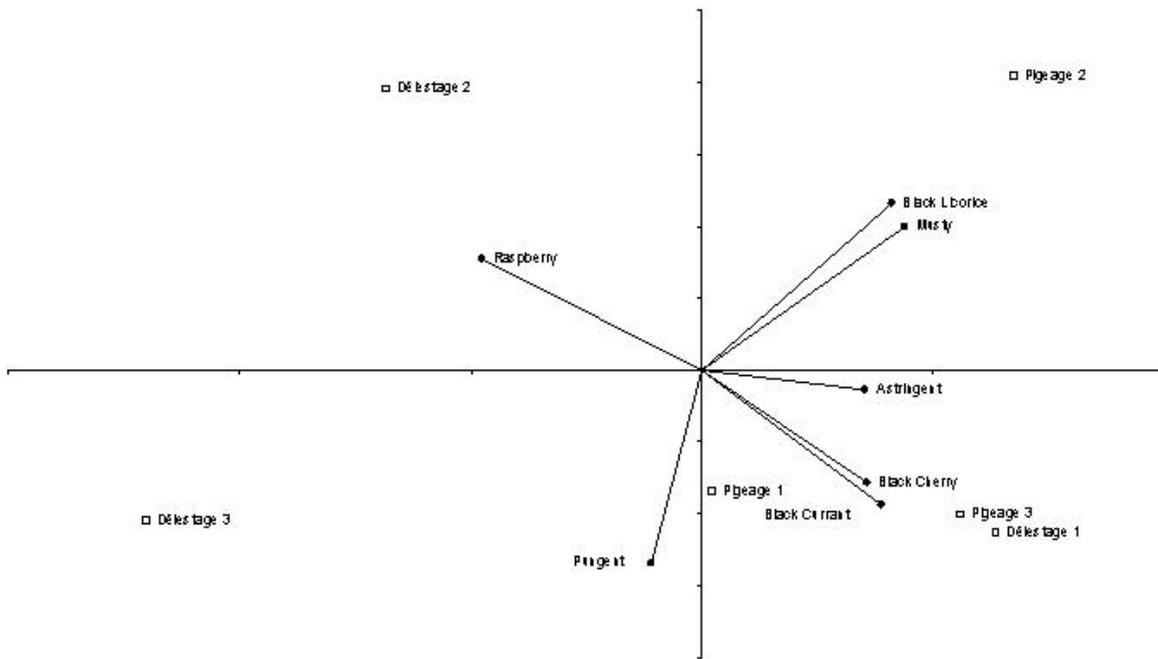


Figure 10.