

Berry Characterisation of cv Shiraz According to Position on the Rachis

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In this study, characterisation of the physical and compositional parameters of berries located in different positions on the rachis of Shiraz/R99 bunches was done. Berries were divided according to position on the rachis (apical, median and basal) and berry weight, resulting in four berry weight classes, averaging 0.86 g, 1.29 g, 1.74 g and 2.26 g and 0.74, 1.18, 1.59 and 2.09 cm³, respectively. The berries were analysed individually. The fresh weight of the berries comprised approximately 4% seeds, 20% skin and 76% flesh. Different percentage distributions were found for each class of berry weight and according to position on the rachis. From the top to the bottom rachis position, an increase in skin proportion value and a decrease in flesh and seed proportion value occurred. Skins decreased and flesh increased in proportion from the smallest to the largest berry size. The seed maintained a relatively stable proportion, irrespective of berry size. Larger berries had more flesh compared to skin than smaller berries. A higher level of soluble solids occurred in the shoulder to middle bunch area (28.7 °B and 28.6 °B, respectively) than in the bottom area (27.6 °B). It is extremely difficult to obtain uniform berry size and composition under field conditions. Continuous efforts are required to reduce variation and the potential negative impact on wine quality and consistency of wine style.

INTRODUCTION

The physical and chemical variation between berries from any given vineyard seems not to be considered seriously by many grape growers and winemakers. Although management practices generally aim to minimise variation in the vineyard, the existence of berry variation is often ignored entirely (Hunter *et al.*, 2010). Variation between and within bunches obviously affects sampling strategy (Di Lorenzo *et al.*, 2007; Tarter & Keuter, 2008; Barbagallo *et al.*, 2011), grape composition, and wine style (Sousa de Melo, 2011). Uneven berry development and its impact on wine quality are largely undocumented.

In the vineyard, different forms of variation in grape quality may occur: from vine to vine, from shoot to shoot, between bunches, and between berries. This variation may result from vineyard heterogeneity, including differences in soil characteristics, young vine establishment, graft combination, plant material quality, node number, shoot number, bunch number, bunch position, microclimate, etc. (Baker *et al.*, 1965; Hunter *et al.*, 2010). Variation

may be minimised by site selection (and most importantly by choosing a site that is well demarcated with limited variation in the soil), judicious pruning practices and canopy management (Hunter *et al.*, 2010).

The variables that may contribute to variation among bunches include inflorescence primordia size, flower number, fruit set, berry number, berry volume and, notably, bunch position (Shaulis, 1956; Smart, 1985, Carbonneau *et al.*, 1991; Pisciotta *et al.*, 2010, 2012). According to Smart (1985), variation among berries is poorly understood. Although the factor(s) leading to the occurrence of berry variation are not yet clearly identified, variation is manifested in berry size, berry composition, seed number, and seed size (Olmo, 1946; Kasimatis *et al.*, 1975; Di Lorenzo *et al.*, 1991; Ummarino & Di Stefano, 1996; Trought *et al.*, 1997; Pisciotta *et al.*, 2010; Barbagallo *et al.*, 2011; Pisciotta *et al.*, 2012). Factors that may contribute include the following: variation in bunch architecture; relationship between seed, pulp and skin development; cell division and expansion; role of vascular function in berry growth and development

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(Fernandez *et al.*, 2006; Gray, 2006); berry position on the rachis (Tarter & Keuter, 2005); sun exposure; pollination of individual flowers (Trought *et al.*, 1997); flower and inflorescence size; and progress of the setting and further development processes (Poni *et al.*, 2008). A typical berry follows a double-sigmoid growth curve during its post-flowering development (Coombe, 1987), but two berries in the same cluster may follow quite different paths (Matthews *et al.*, 1987; Pisciotta *et al.*, 2010, 2012). The divergence of the growth curves becomes apparent shortly after flowering and the timing of this divergence is responsible for the extent of the differences between berries at harvest (Pisciotta *et al.*, 2012).

The specification of grape quality would require physical (berry size, seed hardness, skin and pulp integrity, etc.), biological (incidence and severity of diseases) and chemical (sugar, acidity, pH, anthocyanins, phenolics, tannin, aroma precursors, flavour, etc.) aspects of the grape to be considered, but these are difficult to control from season to season (Greenspan, 2005) and would certainly further complicate the quest to limit variation, to produce the required wine quality, to identify different wine styles, and to produce consistent wine styles.

Although zonal/differential management and harvesting are appropriate techniques for managing the variation that occurs in the vineyard, neither the origin of variation nor the variation in grape composition and ripening are fully addressed; this may clearly occur over a multitude of scales.

The broad objective of this study was to determine whether the position of the berry on the rachis would affect the physical and compositional parameters of the berry. Different berry categories were also included.

MATERIALS AND METHODS

Vineyard

Grapes from a nine-year-old *Vitis vinifera* L. cv. Shiraz (clone SH1A) vineyard, grafted onto Richter 99 (*Vitis berlandieri* x *Vitis rupestris*) (clone RY2A), were used. The vineyard is located at the Experimental Farm of the ARC Infruitec-Nietvoorbij at Stellenbosch (Western Cape, South Africa). The area is within a Mediterranean climate. The vines are spaced 2.75 m x 1.5 m on a Glenrosa soil (Soil Classification Working Group, 1991) with a western aspect (26° slope) and trained onto a seven-wire (cordon wire and three sets of movable wires) lengthened Perold (vertical shoot positioned) trellising system (Zeeman, 1981). Rows were oriented North–South. Vines were micro-sprinkler irrigated at the pea size and véraison stages (12 hours at 32 L/h). The vines were pruned to two-bud spurs, with a spur spacing of approximately 15 cm in a double cordon. Rye was used as cover crop during the winter. Normal cultivation practices for the production of healthy grapes were used.

Measurements

One typical bunch per vine was selected from eight vines according to appearance, ampelography, similar exposure (diffused sunlight) conditions and being representative of the vineyard (Di Lorenzo *et al.*, 2007). These bunches contained a total of 911 berries, of which every single berry was analysed individually. Sampling was done on 13 March

2007 (full ripeness stage) and the berries were divided according to position on the rachis (apical, median and basal, by dividing the total rachis length into thirds). Berries on the wings were classified according to the length of the rachis axis (divided into thirds). Harvested grapes were cooled to the same temperature (20°C) before processing. Each one of the berries was analysed for must total soluble solids (Brix) (by means of a refractometer), mass (g), volume (cm³) (determined by graduate cylinder), skin mass (g), skin surface (cm²) (measured with a LICOR LI 3100 area meter), number of seeds per berry, and total seed mass (g). The percentage distribution of skin, pulp and seed (mass basis), the skin:pulp ratio, and berry skin surface (cm²):berry volume (cm³) ratio were calculated. The variation in the total number of berries per rachis position (a third) was calculated for all the parameters. After all the berries had been processed, four different berry classes were selected according to berry weight (g). The four berry classes were as follows: 1 (≤ 1.0 g); 2 (between 1.01 g and 1.50 g); 3 (between 1.51 g and 2.0 g) and 4 (> 2.0 g).

Statistics

A statistical data analysis was performed by ANOVA regression analysis, taking into account rachis position (top, middle, bottom) as category variables and berry weight classes (1, 2, 3, 4) as quantitative variables. Each berry was treated as an experimental unit. For each weight category and rachis position, the coefficient of variation of berry weight was also calculated. All statistical analyses were performed using SYSTAT 9®.

RESULTS AND DISCUSSION

The apical third of the rachis had the most berries (43%) of the total bunch, followed by the middle (37.8%) and bottom (19.2 %) parts.

This distribution reflected the bunch structure of Shiraz, with the wings having a role in determining the number of berries of a particular part of the bunch. Dividing the berries according to weight into four classes showed classes 2 and 3 being the best represented in the entire sample (38.1% and 37.9% respectively), whereas the smallest and largest berries (classes 1 and 4 respectively) were less well represented (7.2 % and 16.8 %, respectively; Table 1).

All four berry size categories were better represented in the top and middle part of the rachis. The average weight of the different berry classes was 0.86 g, 1.29 g, 1.74 g and 2.26 g respectively for classes 1, 2, 3 and 4, therefore differing by 0.43 to 0.50 g. Moreover, except for classes 3 and 4 (8 to 9%), the coefficient of variation was similar for all categories (from 10% to 16%; Table 2).

The fresh weight of the berries comprised of approximately 4% seeds, 20% skin and 76% flesh. A different percentage distribution was found for each category size and berry position along the rachis (Table 3).

From the top to the bottom rachis position there was an increase in skin proportion value and a decrease in flesh and seed proportion value. Different berry classes showed different proportions of skin, seed and flesh, with the skins decreasing and the flesh increasing in proportion from class 1 to class 4. The seeds maintained a relatively stable

TABLE 1

Berry percentage distribution for each category size and position. For each category size, the percentage of berry number (first column) is based on total berries (n = 911), whereas percentage of berries per class (second column) is based on total berries per single category size.

Size category	1		2		3		4		Total
Rachis position	% of berry number	% of berries per class	% of berry number	% of berries per class	% of berry number	% of berries per class	% of berry number	% of berries per class	%
Top	3.4	47.7	16.9	44.4	16.1	42.5	6.6	39.2	43.0
Middle	2.4	33.8	12.9	34.0	14.9	39.3	7.5	44.4	37.7
Bottom	1.4	18.5	8.3	21.6	6.9	18.2	2.7	16.4	19.3
Sum	7.2		38.1		37.9		16.8		100

TABLE 2

Berry weight and coefficient of variation for each category size and rachis position (n = 911).

Size category	1		2		3		4	
Rachis position	mean	c.v.	mean	c.v.	mean	c.v.	mean	c.v.
	g	%	g	%	g	%	g	%
Top	0.87	12	1.30	11	1.75	8	2.24	8
Middle	0.83	16	1.28	12	1.74	8	2.28	9
Bottom	0.87	10	1.30	11	1.74	8	2.26	9
Mean	0.86	13	1.29	11	1.74	8	2.26	8

TABLE 3

Relative proportion (%) of skin, seeds and flesh for each rachis position and berry size category (n = 911). The coefficient of variation is determined for each category size for skin, seeds and flesh.

Size category	1			2			3			4			Mean		
Rachis position	skin	seeds	flesh	skin	seeds	flesh	skin	seeds	flesh	skin	seeds	flesh	skin	seeds	flesh
	%			%			%			%			%		
Top	23.6	4.0	72.4	20.1	4.0	75.9	18.5	4.4	77.1	17.6	4.2	78.2	19.4	4.2	76.4
Middle	20.4	4.3	75.3	20.8	3.9	75.3	19.0	4.1	76.9	18.9	4.0	77.1	19.7	4.0	76.2
Bottom	22.3	4.6	73.1	21.8	3.7	74.5	20.1	3.9	76.0	19.1	4.4	76.5	20.8	3.9	75.2
Mean	22.3	4.2	73.5	20.7	3.9	75.4	19.0	4.2	76.8	18.5	4.1	77.4	19.8	4.1	76.1
± c.v.	27.0	40.1	9.1	20.9	41.6	6.4	15.3	30.1	4.1	14.2	23.2	3.5	19.8	34.5	5.6

proportion, irrespective of the weight category, but displayed a high coefficient of variation.

The regression analysis showed that rachis position had only a slight effect, and significant differences were obtained for only four of the thirteen variables analysed. In contrast to results found with Pinot noir (Trought *et al.*, 1997), berry position on the rachis affected the berry weight:berry volume ratio (Table 4), skin mass (Table 5), soluble solids (Kasimatis *et al.*, 1975; Tarter & Keuter, 2005) and skin area:berry volume ratio (Table 6).

Consequently, at our determined range of classes, berry weight, berry volume, berry pulp, skin mass and skin area varied with size category and are not discussed further because this result was as expected (Tables 4 and 5). Berry volume, berry weight:berry volume ratio (Table 4) and skin mass (Table 5) showed an interaction between rachis position and category size; rachis position effect on berry volume was not significant and it is interesting to note the distribution

per class along the rachis. Naturally, berry volume increased from the 1st to the 4th berry size category (0.74, 1.18, 1.59 and 2.09 cm³ respectively for classes 1, 2, 3 and 4). The smallest and the biggest berries in terms of volume were located in the middle part of the bunch (Fig. 1).

The higher berry weight:berry volume ratio for the smallest berries and for the middle part of the bunch indicates more concentrated berries (Fig. 2).

In agreement with many researchers, seed weight increased more than proportionally to berry weight, obviously due to the increase in seed number from the smallest to the largest berries (from 1.14 to 2.93; Table 7) (Olmo *et al.*, 1946; Cawthon & Morris, 1982; Di Lorenzo *et al.*, 1991; Boselli *et al.*, 1995; Ummarino & Di Stefano, 1996; Trought *et al.*, 1997; Glynn & Boulton, 2001; Roby & Matthews, 2004; Walker *et al.*, 2005; Barbagallo *et al.*, 2011).

In contrast to what was found by Ummarino and Di

TABLE 4

Results of regression analysis for the berry parameters (n = 911): berry weight, berry volume, berry weight:berry volume, pulp weight.

Variables	Berry weight		Berry volume		Berry weight:berry volume		Pulp weight	
	(g)		(cm ³)		(g/cm ³)		(g)	
Source	F ratio	p	F ratio	p	F ratio	p	F ratio	p
Rachis position (R.P.)	2.131	0.119	1.350	0.265	6.586	0.009	0.630	0.533
Size - category (linear)	5453	0.000	931	0.000	13.465	0.000	4424	0.000
R.P.*Size - category	1.957	0.142	2.571	0.018	3.844	0.003	0.655	0.520

TABLE 5

Results of regression analysis for the berry parameters measured (n = 911): seeds, single seed mass, skin mass, skin area.

Variables	Seeds per berry				Single seed mass		Skin mass		Skin area	
	(g)		(n)		(g)		(g)		(cm ²)	
Source	F ratio	p	F ratio	p	F ratio	p	F ratio	p	F ratio	p
Rachis position (R.P.)	0.576	0.562	0.441	0.644	0.113	0.893	3.805	0.023	0.254	0.775
Size - category (linear)	520	0.000	516	0.000	0.266	0.606	861	0.000	339	0.000
R.P.*Size - category	0.408	0.665	0.191	0.826	0.649	0.523	5.473	0.004	0.387	0.679

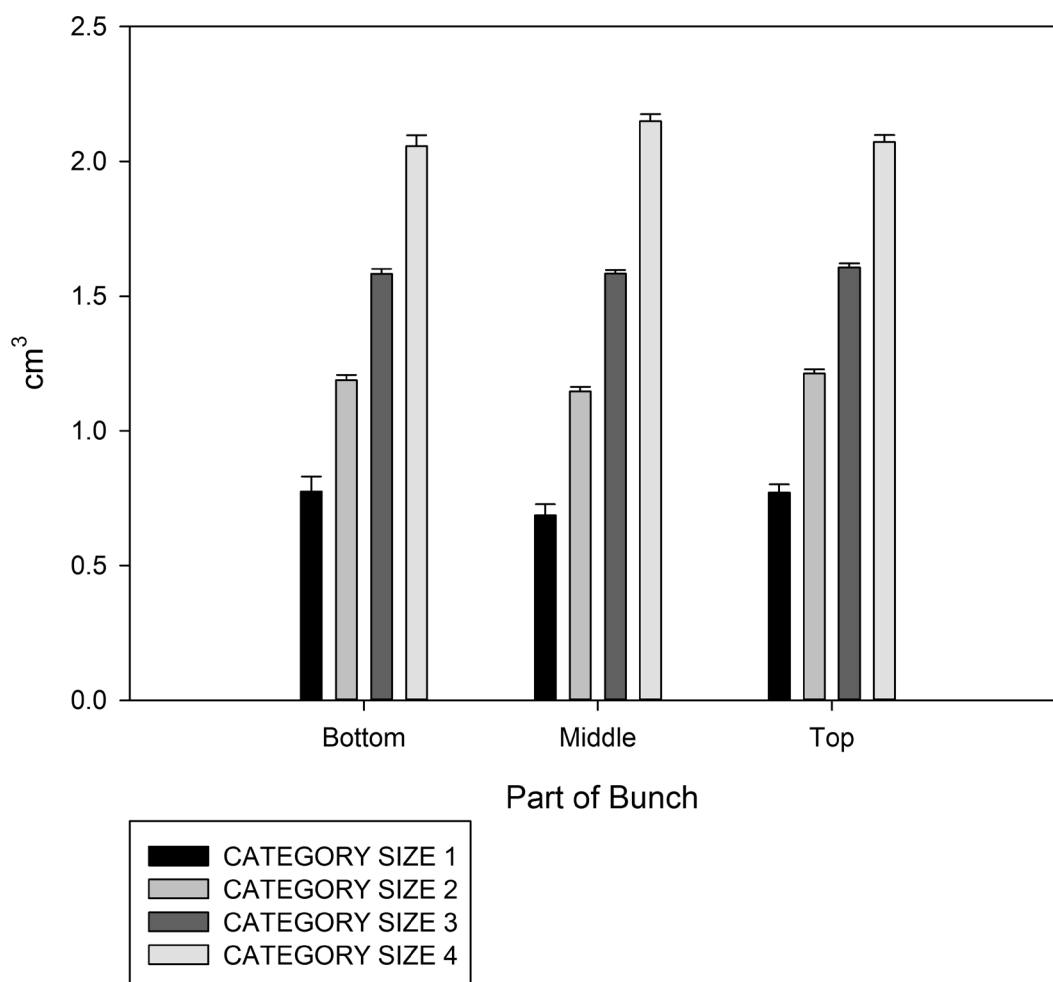


FIGURE 1

Average of berry volume in the four berry size categories as a function of the position on the rachis. Vertical lines represent standard errors.

Stefano (1996), single seed weight did not change significantly with berry size (Table 5). Differences in skin mass (g) were also found along the rachis, and berries from the bottom area of the bunch seemed to have the heaviest skin ($0.322 \text{ g}, \pm 0.01 \text{ s.e.}$) compared to berries from the middle ($0.318 \text{ g}, \pm 0.01 \text{ s.e.}$) and the top areas ($0.301 \text{ g}, \pm 0.01 \text{ s.e.}$). Even for this parameter, bottom and top positions showed a lower coefficient of variation (25.2% and 26.3%, respectively) than that of the middle position (29.5%). Different bunch exposure and berry development in the respective bunch areas may have contributed to these findings. Moreover, skin mass increased by 42% from class 1 to class 2, 22.2% from

class 2 to class 3, and 27.3 % from class 3 to class 4 (Fig. 3).

In accordance with what is generally observed, larger berries had more flesh compared to skin than smaller berries (Table 3) (Matthews & Nuzzo, 2007; Barbagallo *et al.*, 2011). Consequently, skin area was affected by berry weight, increasing from small to large berries and displaying larger differences between classes 1 and 2, in comparison with classes 3 and 4 (Table 7).

Skin mass:skin area ratio also appeared to increase from the top to the bottom bunch area (data not shown), and from the smallest to the largest berries (Table 7). Highest skin mass per unit of skin area was found in the largest berries

TABLE 6

Results of regression analysis for the berry parameters measured ($n = 911$): skin mass:skin area ratio, skin:pulp ratio, skin area:berry volume ratio and soluble solids.

Variables	Skin mass:skin area ratio (g:cm ²)		Skin:pulp ratio (g/g)		Skin area:berry volume (cm ² :cm ³)		Soluble solids (°Brix)	
Source	F ratio	p	F ratio	p	F ratio	p	F ratio	p
Rachis position (R.P.)	1.986	0.138	1.050	0.350	2.026	0.025	7.244	0.001
Size - category (linear)	81	0.000	58	0.000	288	0.000	220	0.000
R.P. *Size - category	2.668	0.070	1.850	0.158	1.397	0.124	2.943	0.053

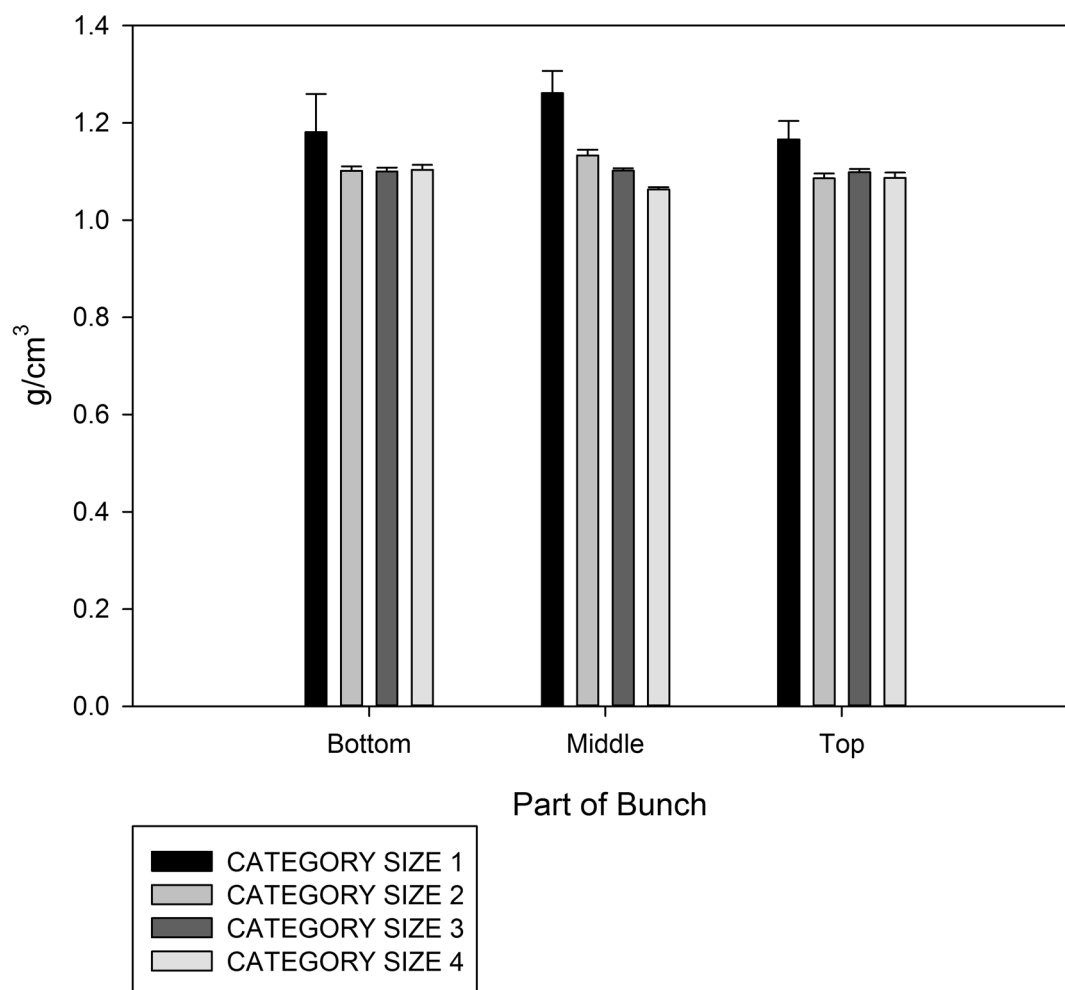


FIGURE 2

Average of berry weight (g):berry volume (cm³) ratio in the four berry size categories as a function of the position on the rachis. Vertical lines represent standard errors.

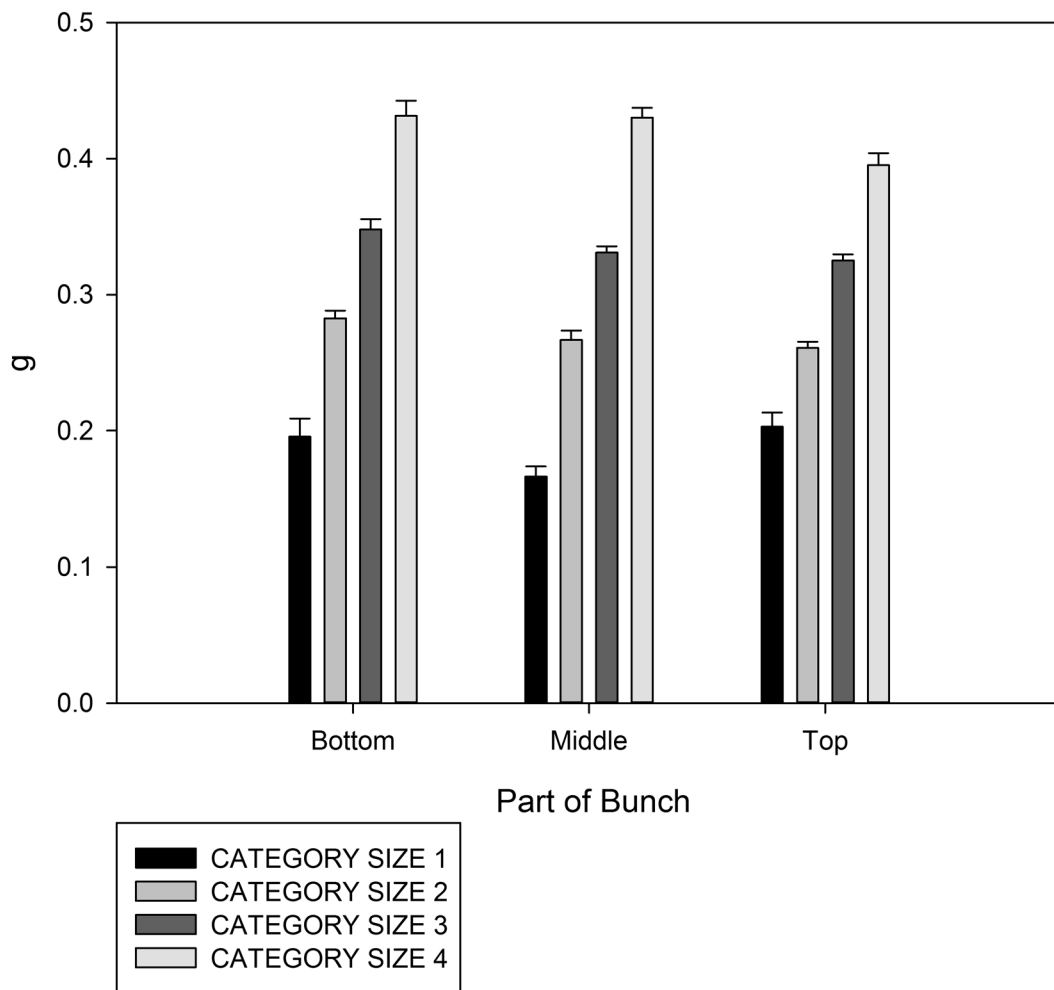


FIGURE 3

Average of skin weight of a single berry in the four berry size categories as a function of position on the rachis. Vertical lines represent standard errors.

TABLE 7

Berry parameters as a function of berry size.

Parameters	Seed weight		Seed number		Skin surface		Skin FW/S		Skin/pulp		Skin S/BV		Soluble Solids	
	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
Size category	g	±	n	±	cm ²	±	g/cm ²	±	g/g	±	cm ² /cm ³	±	Brix	±
1	0.03	0.00	1.14	0.05	3.74	0.12	0.05	0.00	0.31	0.01	5.25	0.21	30.54	0.27
2	0.05	0.00	1.55	0.04	4.70	0.05	0.06	0.00	0.28	0.00	3.97	0.06	29.16	0.13
3	0.07	0.00	2.23	0.04	5.36	0.05	0.06	0.00	0.25	0.00	3.41	0.04	27.94	0.11
4	0.09	0.00	2.93	0.06	5.90	0.07	0.07	0.00	0.24	0.00	2.82	0.03	26.83	0.10

FW = Fresh weight; S = Skin surface; BV = Berry volume

(class 4). Classes 2 and 3 did not differ significantly, while class 1 had the lowest value (Table 7). Moreover, relative skin mass (expressed as percentage of the whole berry) increased from the top part of the bunch to the bottom part (19.4 %, 19.7% and 20.8%, respectively) (Table 3).

Skin mass (g):berry pulp (g) ratio was negatively related to berry fresh weight (Table 7). The skin surface (cm²):berry volume (cm³) ratio (Table 7) would result in a higher impact of the skin for smaller berries during contact with the must during fermentation, creating a different and likely more

favourable medium for wine quality, depending on the condition of the grapes during harvest and on the volume of the juice (solvent) (Hunter *et al.*, 2004; Matthews & Nuzzo, 2007; Barbagallo *et al.*, 2011).

Berry position along the rachis affected the soluble solids content (Fig. 4). Several researchers (Nelson *et al.*, 1963; Nelson & Richardson, 1967) have found a wide distribution of soluble solid values within single bunches of “Thompson Seedless” table grapes, but they did not compare the variation for different cluster areas. Weaver and Ibrahim

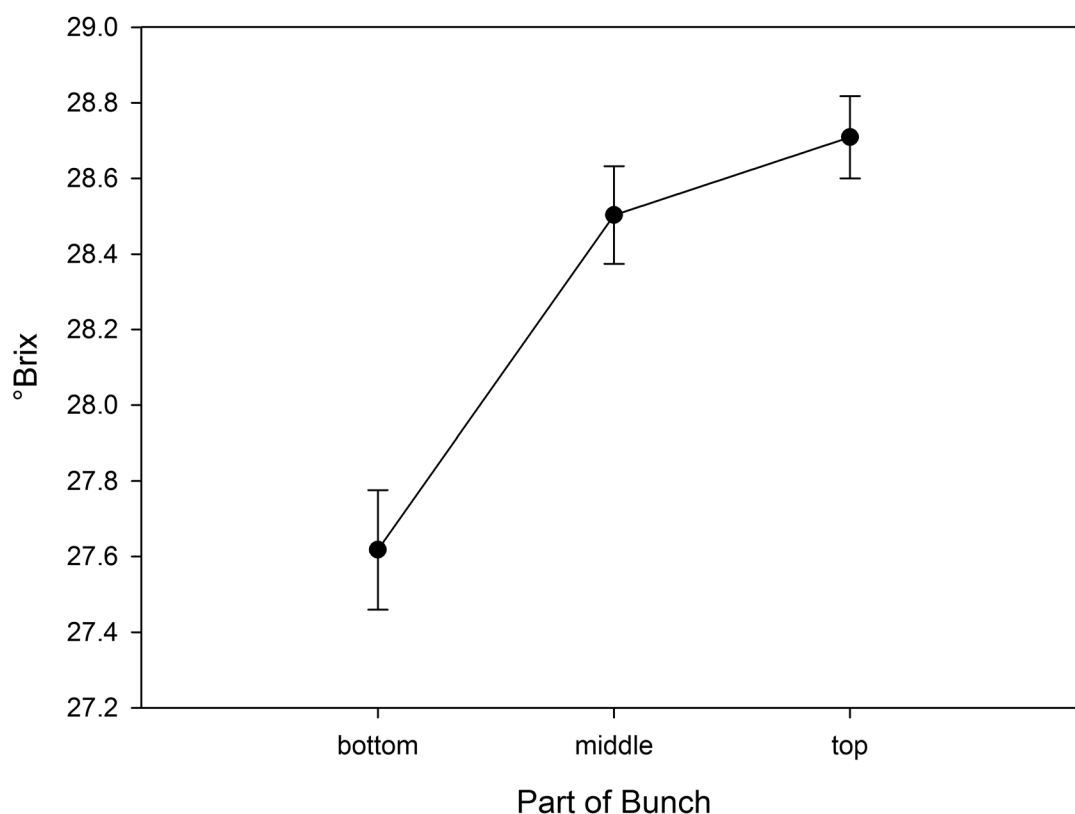


FIGURE 4

Soluble solids (°Brix) at different positions on the rachis. Vertical bars represent standard errors.

(1968) divided mature bunches of Thomson Seedless grapes into five equal parts from apex to base. They found that all the portions of the bunch had approximately the same percentage of soluble solids, with no significant differences between them. Trought *et al.* (1997) also found no significant difference in soluble solid content along the rachis of Pinot noir and Cabernet Sauvignon bunches. In contrast, Kasimatis *et al.* (1975) found a significantly lower °B in berries from the bottom area and a significantly higher °B in the apical area compared to that in the central area. Tarter and Keuter (2005) indicated that, with respect to percentage of soluble solids, significant differences among berries can exist regionally within a cluster of Cabernet Sauvignon. They suggested that sugar sampling is best confined to the top region of a bunch. In this study, Shiraz berries showed significant differences in terms of soluble solids along the rachis (Table 6), having a higher level in the shoulder to middle bunch area (28.7 °B and 28.6 °B respectively) than in the bottom area (27.6 °B). With reference to the average of total soluble solids, differences were -0.81, +0.12 and +0.28 respectively, for the bottom, middle and shoulder areas (Fig. 4), with similar coefficient of variation values (8.0%, 7.6% and 7.5% in the middle, bottom and shoulder areas respectively).

Sugar content per berry seemed proportional to size (Roby & Matthews, 2004; Barbagallo *et al.*, 2011), whereas the concentration was negatively related. The sugar concentration value decreased approximately 12% from smaller to larger berries (Table 7).

CONCLUSIONS

The position of the berry on the rachis had no consistent effect on berry size, but affected soluble solid concentration and skin mass. Higher soluble solid values were found in the top part of the bunch. After categorising the entire population of berries into four weight categories, only a small fraction of the total berry population was found in the smallest and largest weight categories. Most berries were in the 1.01 to 2.0 g range. Heterogeneity in ripeness level among berries may depend upon the variety. It is extremely difficult to obtain uniform berry size and composition under field conditions, even when all vineyard management practices are properly executed. Since berry variation may have a negative impact on wine quality and on the consistency of wine style, continuous efforts are required to reduce variation.

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