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Environmental and genetic variation in the post-harvest quality of raspberries in subtropical areas in Brazil

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ABSTRACT. Raspberry is an economically important berry crop that contains numerous phenolic compounds with potential health benefits. It is known that the chemistry content is affected by processing factors, but limited information is available on the influence of cultural factors or genotype. To clarify this issue, this work aimed to characterize the following raspberry cultivars Polana, Autumn Bliss, Heritage, Batum, Golden Bliss, hybrid Boysenberry and black raspberry from Mantiqueira Mountains (Campos do Jordão city, São Paulo State, Cwa climate, mesothermal with dry winter, commonly named tropical de altitude, according to Köppen classification) and Alto do Rio Grande (Lavras city, Minas Gerais State, Cwb climate, with dry winter and summer temperate), two areas subtropical in Brazil, and quality attributes. The fruits were used for the following analysis: mass, size, number of drupelets, color, total acidity, soluble solids, total soluble solids / titratable acidity (TSS / TA), moisture and ash. The results revealed strong influence of growing site on fruit quality as well as the existence of variation among cultivars. Fruits produced in Mantiqueira Mountains had larger and higher TSS / TA. On the other hand, the growing raspberries in Alto do Rio Grande provided greater color tone, increased acidity, and low ratio of total soluble solids and total acidity.

Keywords: *Rubus idaeus*, *Rubus niveus*, location of cultivation, post-harvest characterization.

Variação ambiental e genética na pós-colheita de framboesas em áreas subtropicais do Brasil

RESUMO. Framboesa é uma baga economicamente importante que contém compostos fenólicos com inúmeros potenciais benefícios à saúde. Sabe-se que a composição química é afetada por fatores de processamento, mas há limitada informação disponível sobre a influência dos fatores culturais e genéticos. Para esclarecer esta questão, este trabalho teve como objetivo caracterizar as cultivares de framboeseira Polana, Autumn Bliss, Heritage, Batum, Golden Bliss e o híbrido boysenberry e framboesa negra da Serra da Mantiqueira (cidade de Campos do Jordão, Estado de São Paulo, clima Cwa, mesotérmico com inverno seco, comumente chamado de tropical de altitude, de acordo com a classificação de Köppen) e Alto do Rio Grande (cidade de Lavras, Estado de Minas Gerais, Cwb climáticas, com inverno seco e temperado no verão). Os frutos foram utilizados para as seguintes análises: massa, tamanho, número de drupeletes, cor, acidez total, sólidos solúveis, acidez titulável / sólidos solúveis totais (AT / SST), umidade e cinzas. Os resultados revelaram forte influência do local de cultivo sobre a qualidade do fruto, bem como a existência de variação entre cultivares. Frutos produzidos na Serra da Mantiqueira apresentaram maiores dimensões e alta relação sólidos solúveis totais e acidez total. Por outro lado, framboesas do Alto do Rio Grande destacaram-se no quesito cor, elevada acidez e baixa relação de sólidos solúveis totais e acidez total.

Palavras-chave: *Rubus idaeus*, *Rubus niveus*, local de cultivo, caracterização pós-colheita.

Introduction

In the latest decades, temperate climate fruit growing has been characterized by a significant regional increase, no longer being practiced only in the highland areas of the south of the country, moving into non-traditional cultivation regions (BARBOSA et al., 2010). Because of that, many orchards are established in areas poorly investigated as to the climatic adaptation of the species and cultivars (BETTIOL NETO et al., 2011; CAMPAGNOLO; PIO, 2012; GUEDES et al., 2013).

Recent example in Brazil is the growing of raspberries on the Mantiqueira Mountains in São Paulo and Minas Gerais States, which showed a marked growth in the latest years, before the high value aggregated to its fruits (SOUZA et al., 2014b). Maro et al. (2012) and Silva et al. (2012)

demonstrated the potential of the region in the production of raspberries. The reason of which is due to raspberries being quite appreciated for their peculiar aroma and unmatched flavor. In addition to these attractive characteristics, the fruits contain bioactive compounds with a high free-radical scavenging capacity and contain a number of bioactive compounds with antioxidant capacity, which offer significant benefits to one's health (WANG; LIN, 2000). Os fruits constitute source of a number of plant chemicals significant benefits, mainly ellagic acid, antocyanins and phenolic compounds (BEEKWILDER et al., 2005).

The quality standards for the Brazilian consumer are acceptability limits sometimes hard to quantify, since the cultivation of this species is recent and there is no importation of raspberries due to perishability of them (HAFFNER et al., 2002). Such limitation is due to the high respiratory rate, firmness loss and deterioration by fungi such as *Botrytis cinerea* (ANTONIOLLI et al., 2011).

The external appearance, texture and the nutritive value are important quality attributes of fruits, the appearance of which includes the physical characteristics such as size and coloration, the attribute of greatest highlight. Another important factor in the quality of fruits is firmness, which confers to the fruit texture, a determinant characteristic in the purchasing of the product by the consumer, for its being associated to the cooking quality, freshness, extensive shelf-life, fruit resistance to the transportation and handling during collection and marketing (BAÑADOS et al., 2002).

The fruit quality of a cultivar may be affected by several factors, specially the environmental cultivation conditions. In the case of raspberries, the yield of fruits and their quality is varying among the cultivars (SØNSTEBY et al., 2009), variation in the fruit quality being able to occur due to the growing place, as Anttonen and Karjalainen (2005) demonstrated in fruits coming from distinct places of Northern Europe.

The objective of the present work was to evaluate environmental and genetic variation in the post-harvest quality of raspberries in subtropical area in Brazil.

Material and methods

Fruits of the cultivars of raspberry trees 'Polana', 'Autumn Bliss', 'Heritage' and 'Batum', bearers of red-colored fruits and 'Golden Bliss', which produces yellow fruits, both belonging to the species *Rubus idaeus*, in addition to the black raspberry (*R. niveus*) and the interspecies hybrid between black mulberry and red raspberry Boysenberry, the parents of which are *R. loganbaccus* and *R. baileyanus* were utilized for this study. Around 500 grams of fruits of the cultivars above reported were collected at the physiological maturity point in two different places, one being a commercial orchard situated on the Mantiqueira Mountains (Campos do Jordão town, São Paulo State, 1,628 meters of elevation, Cwa climate, mesothermal with dry winter, commonly named tropical de altitude (Cwb), according to Köppen classification) and another in Alto do Rio Grande (Lavras town, Minas Gerais State, 918 meters elevation, Cwb climate, with dry winter and summer temperate). Both the orchards were conducted by following judiciously the recommendations by Moura et al. (2012). The average maximum and minimum temperatures and the accumulated rainfall for the development period and fruit collation (October to December of 2011) in Campos do Jordão were of 22.5ºC; 8.0ºC and 157.5 mm, respectively. In Lavras, these conditions were of 27.1ºC; 15.1ºC and 72.6 mm.

The fruits were collected soon after dawn, when the environmental were relatively lower. They were carefully placed onto transparent polyethylene terephtalate trays, with a capacity for 125 grams, measuring 11 cm in length x 10.5 cm in breadth x 4.5 cm in height, in the lids of which there were small circular holes to make the circulation of gases easier and the interior of which was placed a moisture-absorbing paper. The trays were put into plastic foam boxes with ice and transported to the Biochemistry Laboratory of the Chemistry Department when the selection as to the color uniformity and absence of mechanical or physiological injuries.

The fruits were the submitted to the following analyses: a) mass through direct weighing in electron scale with precision of 0.01 g; b) length and equatorial diameter obtained with a digital pachymeter, the measures being performed at the medium third of the fruit; c) number of drupelets from the drupelets from the powdering of the fruits by hand as reported by Perkins et al. (1993); d) coloration determined through colorimeter Minolta CR-400 and expressed by luminosity (L*), chromaticity (chroma) and hue angle (^{o}hue), according to the methodology reported by McGuire (1992), the measures being measured at two opposed points in the equatorial zone; e) firmness obtained in texturometer TA-XT2 (Stable Micro Systems Ltd., Godalming, U.K) by utilizing operational parameters probe P/2N, perforation velocity of 2 mm s^{-1}, pre-test velocity,

1.5 mm s^{-1}; test velocity, 1.5 mm s^{-1}; post-test velocity, perforation distance was standardized at 5 mm; f) total titrable acidity determined by sample titration, ground in polytron with a solution of 0.01 N NaOH, previously standardized with potassium biftalate to pH 8.1; g) total soluble solids with the aid of a digital refractometer Atago model N1, with reading in the range of 0 to 32 ºBrix; h) total soluble sugars; i) moisture and ashes.

Sixty fruits were used of each cultivar for the accomplishment of the physical analyses while the other analyses were done in quadruplicate. The experimental design was the completely randomized in factorial scheme 2 (environment) x 7 (genotypes), with four replicates. The data were submitted to the variance analysis and the means compared by the Scott-Knott test at the level of 5% of probability with the aid of the SISVAR program (FERREIRA, 2011).

Results and discussion

There was an interaction among the factors studied for the physical characteristics of the colored raspberries, with the exception of firmness (Table 1).

Only for hybrid 'Boysenberry', of both places, no differences as to the dimensions and mass were found. Fruits produced on the Mantiqueira Mountains presented greater length, diameter and mass with the exception of 'Autumn Bliss' which showed better results when were produced in Alto do Rio Grande. The fact of the values obtained for the mass of 'Autumn Bliss' being larger than those reported by the literature, which lie in the range of 2.7 grams (MOURA et al., 2012), suggests that this cultivar may be more adapted to the conditions of mild winter and warm summers of Alto do Rio Grande.

Another important point for that cultivar was to the number of drupelets which did not differ as for the cultivation place (Table 1). Possibly, both the mass and dimensions of the drupelets in fruits grown in Alto do Rio Grande were larger, which influenced the largest size of the fruits of 'Autumn Bliss' cultivated in this place. Perkins et al. (1993) also found variation in the number in different black mulberry cultivars (*Rubus* spp.). The influence of the cultivation place upon the number of drupelets may be associated to pollination-inherent factors. The low mass of the black raspberries allows to infer about the reduction in the in the sizes of these drupelets. Black raspberries coming from the two cultivation places made up a group of means aside of the length, diameter and mass, demonstrating that the smaller size and mass of the fruits is due to the characteristics inherent to the species. Similar remark can be found for the hybrid Boysenberry which, in turn, presented dimension larger than the other fruits.

Raspberries for being delicate fruits possess poor durability in post-harvest conservation (HAFFNER et al., 2002; KRÜGER et al., 2011). So, the evaluation of firmness is an important characteristic to be evaluated for the fruit conservation aiming the *in nature* consumption. Bañados et al. (2002) observed that there is differences among the raspberry cultivars as to the firmness of their fruits and found 0.73 N of strength in fruits of the cultivar Heritage and only 0.24 N of strength in fruits of the cultivar 'Autumn Bliss', standing out that this was the softest of the 14 cultivars evaluated. The values found by the authors were higher as compared with the current work since they evaluated fruits at the stage of opaque red-pinkish coloration, that is, fruits which have not reached their maturity point, for they were destined to exportation. In the case of ripe fruits collected at the bright red hue angle, as in the present work, the fruits were expected to be softer, showing lower firmness values.

Through the analysis of variance, it was found that the fruit coloration ranged owing to the cultivation place, the interaction between these two factors being significant (Table 2).

Table 1. Length, diameter, mass, number of drupelets and firmness of fruits from different raspberry cultivars grown in the Mantiqueira Mountains (1) and Alto do Rio Grande (2). UFLA, Lavras, 2012.

Cultivars	Lenght (mm)		Diameter (mm)		Mass (g)		Number of drupelets		Firmness (N)^{ns}
	1	2	1	2	1	2	1	2	-
Autumn Bliss	15.4 Be	18.3 Ab	16.6 Bd	18.5Ab	2.3 Be	2.9 Ab	56 Ad	59 Aa	0.11
Batum	19.9 Ad	17.0 Bc	19.4 Ac	16.9 Bc	3.1 Ad	2.7 Bb	71 Ab	57 Ba	0.12
Boysenberry	23.8 Aa	23.5 Aa	21.6 Aa	21.5 Aa	5.9 Aa	5.7 Aa	50 Ae	51 Ab	0.29
Black raspberry	13.5 Af	10.5 Be	16.5 Ad	13.8 Be	1.8 Af	1.0 Bd	80 Aa	47 Bb	0.13
Golden Bliss	20.5 Ab	15.8 Bd	21.2 Aa	17.0 Bc	3.8 Ab	2.2 Bc	57 Ad	51 Bb	0.12
Heritage	19.6 Ac	17.1 Bc	20.7 Ab	17.1 Bc	3.5 Ac	2.8 Bb	56 Ad	59 Aa	0.12
Polana	20.5 Ab	16.0 Bd	20.7 Ab	16.3 Bd	3.8 Ab	2.3 Bc	61 Ac	51 Bb	0.12
CV (%)	9.63		7.78		20.29		19.37		22.22

*Means followed by same uppercase letter in the line and lowercase letter in the column do not differ by Scott-Knott test ($p \leq 0.05$).

Table 2. Luminosity (L*), chroma and hue angle (°hue) fruits from different raspberry cultivars grown in the Mantiqueira Mountains (1) and Alto do Rio Grande (2). UFLA, Lavras, 2012.

Cultivars	L*		Chroma		°hue	
	1	2	1	2	1	2
Autumn Bliss	29.92 Ac	29.94 Ac	28.71 Ab	34.20 Aa	17.85 Bb	32.54 Ab
Batum	26.74 Ad	26.59 Ad	30.84 Ab	32.56 Aa	10.29 Bc	17.35 Ac
Boysenberry	21.52 Ae	20.43 Ae	15.68 Ad	11.94 Bb	-2.82 Ad	-8.80 Ad
Black raspberry	35.38Ab	35.66 Ab	5.14 Ae	4.58 Ac	-16.11 Be	-6.22 Ad
Golden Bliss	59.45 Aa	49.94 Ba	24.98 Bc	34.73 Aa	85.75 Aa	82.81 Aa
Heritage	32.22 Ac	25.47 Bd	30.57 Bb	34.96 Aa	14.15 Ac	19.56 Ac
Polana	26.82 Ad	27.23 Ad	32.99 Aa	32.14 Aa	19.93 Ab	18.51 Ac
CV (%)	10.04		14.28		7.91	

*Means followed by same uppercase letter in the line and lowercase letter in the column do not differ by Scott-Knott test ($p \leq 0.05$).

As to luminosity, only the cultivars Golden Bliss and Heritage presented significant differences according to the cultivation place. The few variations maintained themselves among the cultivars, within each place, cultivar 'Golden Bliss' being the one which showed the brightest sheen in both the places. For chromaticity, when produced in Alto do Rio Grande, both 'Golden Bliss' and 'Heritage' tended to present increased value pointing to higher intensity of the predominant color. On the Mantiqueira Mountains, highlighting 'Boysenberry' which showed the coloration brighter than in Alto do Rio Grande. Among the cultivars, the highest values of luminosity were ascribed to cultivar Polana. The hue angle of the fruits took over higher values in Alto do Rio Grande for 'Autumn Bliss', 'Batum' and Black raspberry. In relation to the cultivars within each place, it is noticed that the high values found for cultivar Golden Bliss, in both places, is due to the yellow coloration typical of their fruits. Out of the red cultivars, the surface color was denoted by the low values of °hue. The cultivation of 'Autumn Bliss' and 'Batum' on the Mantiqueira Mountains promoted a significant increase of the red pigmentation. Both black raspberry and 'Boysenberry' presented negative values of hue angle owing to the darker coloration. It is believed that in regions of mild climate, great influence occurs in fruit coloration due to the greater thermal range. That can be proved by comparing the results obtained with the cultivar Heritage, where the fruits with brightest luminosity, color intensity and hue angle when grown in Alto do Rio Grande, town localized at 918 m altitude in subtropical climate, which possesses greater thermal range as compared with the mountainous regions of Turquia, where Çekiç and Özgen (2010) colleted fruits of the raspberry tree 'Heritage' and obtained poorer results for the coloration of the fruits as compared with the present work.

The variance analysis enabled the identification of individual significant effects for both place and cultivars, in addition to the place x cultivar interaction for total titratable acidity, total soluble solids, moisture and ashes of the raspberries (Table 3).

Raspberries produced in Alto do Rio Grande with the exception of the black raspberry, presented acidity, on average, about three times as high as those coming from the Mantiqueira Mountains. Several factors act jointly to the amount of organic acids in fruits. Light, in terms of the duration of the exposition, quality and intensity constitute one of the main factors which influence the organic acid contents of fruits. Only black raspberry presented no significant differences in the two places with average TA of 0.63 mg of citric acid 100 g^{-1}, this value being lower than those reported by Parmar and Kaushal (1982) and Jin et al. (1999) which was of 2.01 and 1.26, respectively. The cultivars presented differences among the acidity levels according to the cultivation place. In Alto do Rio Grande, 'Golden Bliss' and 'Heritage' obtained higher contents while on the Mantiqueira Mountains the highlight was for 'Golden Bliss' and 'Autumn Bliss'. Hassimoto et al. (2008) also found differences among the black mulberry cultivars as to acidity content.

Little variation was found for the total soluble solid content according to the cultivation place, however, only black raspberry and 'Golden Bliss' presented differences. On the Mantiqueira Mountains, the greatest values of TSSs were observed for cultivar Golden Bliss with 13.5 °Brix. On the other hand, the lowest values were found for 'Autumn Bliss' e 'Boysenberry', with average values of 9.50 and 8.37 °Brix, respectively. 'Batum', 'Heritage, 'Polana' and black raspberry) took over intermediary values. In Alto do Rio Grande, black raspberry stood out with 13.15 °Brix. Parmar and Kaushal (1982) reported values of 11.01 °Brix for black raspberries. In Alto do Rio Grande, the lowest value of TSSs was also detected for 'Boysenberry' (7,29 °Brix). Since 'Boysenberry' is a interspecific hybrid between black mulberry and red raspberry, the total soluble solid content found as lower, equally to the one found in black mulberries which, according to Hassimoto et al. (2008), lie between 6.19 (cultivar Brazos) and 9.23 °Brix (cultivar Guarani).

Table 3. Titratable acidity (TA), pH, total soluble solids (TSS), TSS / TA, total sugars (TS), moisture and ash in fruits fruits from different raspberry cultivars grown in the Mantiqueira Mountains (1) and Alto do Rio Grande (2). UFLA, Lavras, 2012.

Cultivars	1	2	1	2	1	2
	TA		TSS		TSS / TA	
Autumn Bliss	1.45 Ba	3.31 Ab	9.77 Ab	6.60 Ad	2.95 Bb	1.45 Ba
Batum	1.17 Bb	3.42 Ab	9.60 Ab	9.24 Ac	2.80 Bb	1.17 Bb
Boysenberry	0.62 Bc	2.04 Ac	7.29 Ac	13.58 Ab	3.57 Bb	0.62 Bc
Black raspberry	0.66 Ac	0.60 Ad	13.15 Aa	17.11 Ba	22.14 Aa	0.66 Ac
Golden Bliss	1.35 Ba	3.57 Aa	9.62 Bb	10.06 Ac	2.70 Bb	1.35 Ba
Heritage	0.98 Bb	3.59 Aa	9.20 Ab	10.40 Ac	2.57 Bb	0.98 Bb
Polana	1.05 Bb	3.32 Ab	9.77 Ab	9.53 Ac	2.95 Bb	1.05 Bb
CV (%)	5.85		9.23		15.20	
	TS		Moisture		Ash	
Autumn Bliss	3.80 Bb	8.55 Aa	89.24 Aa	90.11 Aa	0.26 Aa	0.31 Ab
Batum	3.44 Bb	9.24 Aa	91.01 Aa	88.12 Bb	0.27 Ba	0.63 Aa
Boysenberry	2.62 Ac	2.40 Ac	90.09 Aa	91.11 Aa	0.28 Ba	0.63 Aa
Black raspberry	4.40 Ab	3.36 Ac	86.41Ba	80.49 Ac	0.27 Ba	0.62 Aa
Golden Bliss	8.17 Aa	3.38 Bc	88.98 Aa	90.47Aa	0.31 Aa	0.29 Ab
Heritage	8.99 Aa	6.69 Bb	88.67 Aa	89.38 Aa	0.29 Aa	0.32 Ab
Polana	8.55 Aa	8.02 Aa	89.76 Aa	87.83 Bb	0.28 Aa	0.32 Ab
CV (%)	12.64		1.44		9.97	

*Means followed by same uppercase letter in the line and lowercase letter in the column do not differ by Scott-Knott test ($p \leq 0.05$).

Through these results, one realizes that, fruits of red and yellow raspberries when produced in regions of milder temperatures in summertime and broader thermal range owing to the elevated altitude; tend to present increased balance between total soluble solids and acidity. In contrast, the growing in regions with warmer summers supports the bearing of more acidic fruits.

For the variable – total sugars – significant effect was found for the factor cultivar and the interaction, while for the factor place, the effect was not significant. The total sugar content ranged according to the cultivar. On the Mantiqueira Mountains, 'Polana', 'Heritage' and 'Golden Bliss' presented the highest contents, on the average, 8.57 g 100 g^{-1}. 'Autumn Bliss', 'Batum' and black raspberry formed a group of intermediary means (3.88 g 100 g^{-1}) and 'Boysenberry' presented only 2.62 g 100 g^{-1}. In Alto do Rio Grande, the maximum contents were found for the red raspberries 'Polana', 'Batum' and 'Autumn Bliss', with a mean of 8.60 g 100 g^{-1}. On the other hand, 'Golden Bliss', black raspberry and 'Boysenberry' exhibited the lowest values (3.05 g 100 g^{-1}).

Through the results obtained for total sugars, it is found that the soluble solid content in raspberries does not constitute a good indicator to infer about the fruit sweetness. Cultivars which presented the highest contents of TSSs not necessarily were those in which highest contents of total sugars were found. This can be associated to the presence of other water-soluble substances which also composes the refractometric index as vitamins, phenolics, pectins and organic acids (PALIYATH; MURR, 2008).

As to moisture, there was only difference among the cultivation places for cultivars Batum, Polana and for black raspberry, which presented increased water content when the fruits were grown on the Mantiqueira Mountains. However, the cultivars only differed from one another when they were grown in Alto do Rio Grande, possibly due to the higher temperatures of this place. So, the high water content in raspberries is a characteristic inherent to the species.

The ash content of colored raspberries of both cultivation places ranged from 0.26 to 0.63 mg 100 g^{-1}. In considering the place, variations were found only in Alto do Rio Grande. Only the fruits of black raspberry, 'Boysenberry' and 'Batum' produced in Alto do Rio Grande, differed signficantly with the values lower than those of other cultivars. The greatest values of ashes obtained in this study for black raspberries, were confirmed by Parmar and Kaushal (1982) who found values close to 0.77 mg 100 g^{-1}. Still, according to Souza et al. (2014a) reports in drawing the nutritional profile of raspberries, the ash content lay close to 0.25 mg 100 g^{-1}.

Conclusion

The amount of the colored raspberries is strongly affected by the cultivation place; both the places studied enabled the production of attractive-looking fruits. The quality attributes range according to the cultivar which enables to meet the consumer's different requirements.

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