

Full Length Research Paper

Partial dehydration of 'Niagara Rosada' GRAPES (*Vitis labrusca* L.) targeting increased concentration of phenolic compounds and soluble solids

Wesley Esdras Santiago, Rodolpho César Dos Reis Tinini, Rafael Augustos De Oliveira and Barbara Janet Teruel

Postgraduation Program, Phd Course of Agricultural Engineering. Av. Cândido Rondon, 501, CEP: 13.083-875 Barão Geraldo, Campinas, São Paulo, Brazil.

Accepted 24 September, 2013

The partial dehydration of grapes after harvest and aimed wine-making, has been shown to be a process that brings increased concentration of sugar and phenolic compounds in the must, which results in the quality of the wines produced. However, the works developed so far studied the process for temperatures up to a maximum of 25°C and air velocity less than 1 m.s⁻¹. This study aimed to analyze the physical and chemical changes (concentration of total soluble solids (TSS) and phenolic compounds (CPC)) after partial dehydration of 'Niagara Rosada' grapes at the temperature subjected to two treatments combining two temperatures and one air velocity ($T_1 = 22.9^\circ\text{C}/1.79 \text{ m.s}^{-1}$ and $T_2 = 37.1^\circ\text{C}/1.79 \text{ m.s}^{-1}$), and relative humidity of approximately 40%. The loss of water in the grapes was approximately 14% and the drying process lasted between 20 to 50 h for the treatments T_1 and T_2 , respectively. We experimentally and statistically verified that the treatments promoted significant increase in TSS and CPC; however, for CPC at the temperature of 37.1°C, the increase accounted for approximately 29%, whereas, for the temperature of 22.9°C, it was only 5%. For TSS, the increase was on average $14.4 \pm 3.9\%$ between both treatments.

Key words: Chaptalization, temperature, air velocity, winemaking.

INTRODUCTION

Besides facilitating the transport, storage and microbiological stability, the dehydration process of agricultural products causes physical, chemical and organoleptic changes; therefore, it must be performed in a controlled manner and meet the limits established to not affect the quality (Sampaio et al., 2006). The reduction of the moisture content in fruits for processing, whether for juice, pulp and/or concentrates, causes an increase in the concentration of soluble solids (Azeredo et al., 2006; Dionello et al., 2009). When the grapes are used for winemaking, it is desirable the highest possible concentration of soluble solids and phenolic compounds.

Phenolic compounds, as well as anthocyanins and flavonoids, provide the sensory characteristics of the wine, and they are indicated as beneficial in the prevention of cardiovascular diseases (Bradamante et al., 2004; Freitas et al., 2010; Lasa et al., 2011).

According to the study of Barnabé and Filho (2008), the concentration of soluble solids in the must is the key factor so that, during winemaking, a significant amount of alcohol is produced. When the concentration of soluble solids is low, it becomes difficult, or even impossible, to obtain table wines with alcohol levels according to the required by the Brazilian law, which must be between 8.6

at 14%, according to note published in the Official Gazette ((Diário Oficial da União, 2004).). Studies developed by Guerra et al. (2003) showed that the shriveling of grapes in the vineyards, caused by loss of water, contributed to significant changes in the concentration of total soluble solids (TSS), in addition to the increase in the concentration of phenolic compounds in the skin, also as direct effects of over-ripening caused by rising temperatures in vineyards of grapes at the end of the maturation cycle. Later studies on the application of partial dehydration at temperature below ambient began by using a cold chamber intended for this function, the dehydration process may take up to 45 days (Bellincontro et al., 2004). While in some countries with wine tradition the partial dehydration of grapes is an important methodology for achieving quality table wines (Curvelo et al., 2005), in Brazil it is common in many wineries the addition of sugar to the must, a process called chaptalization, seeking to improve the alcohol content; however, this process results in wines of low quality, lower market value and higher cost of production.

Results obtained from several studies have proven the positive effect on wine produced from grapes that have undergone partial dehydration, supported by the increased concentration of sugar, phenolic compounds and aromatic compounds (Constantini et al., 2006; Moreno et al., 2008; Barbanti et al., 2008; Serratososa et al., 2010). More studies recently on dehydration of grapes for winemaking has evaluated with temperatures below of 25°C and air velocity below 1.5 m.s⁻¹. In this work we have proposed as objectives the analysis of the physical and chemical changes (concentration of soluble solids and phenolic compounds) after partial dehydration of 'Niagara Rosada' grapes at the temperatures of 22.9 and 37.1°C in a forced air system with air velocity of 1.79 m.s⁻¹. With these thermal and fluidic conditions we seek to accelerate the loss of water process without affecting the quality of the fruit to improve the quality of the must.

MATERIALS AND METHODS

Raw material

'Niagara Rosada' grapes (*Vitis labrusca* L.), from the harvest of July to November, 2011, were collected in the city of Jales, northwest of the State of São Paulo, stored in cardboard boxes with a capacity of 7 kg and transported to the Laboratório de Termodinâmica e Energia da Faculdade de Engenharia Agrícola da Universidade de Campinas (Laboratory of Thermodynamics and Energy from the School of Agricultural Engineering, at the University of Campinas). After completion of the pre-cleaning of the grape clusters to remove stems and grapes damaged or compromised by the presence of fungi, we carried out the distribution of samples according to the heat treatment to be applied and the subsequent analyzes of the physicochemical characterization.

Partial dehydration of grapes

The fruits were stored in 50 x 30 x 25 cm plastic package, with 25%

of effective opening area, containing 25 grape clusters, longitudinally arranged. The package was placed inside a cooling system with forced air (air flow rate of 2,900 m³. h⁻¹), which is installed inside a refrigerated chamber (cooling capacity of 4,400 kcal.h⁻¹ at -10°C) (Figure 1a). With the air flow perpendicular to the position of the clusters, the rates of heat and mass transfer are increased, allowing the dehydration process to occur in a shorter period without forced air (Figure 1a). The system is instrumented with sensors for temperature, relative humidity and mass measurement (Figure 1b). The system instrumentation was already achieved in previous works (Santiago et al., 2012b; Silva et al., 2011).

The temperature sensors are of the Pt 100 type, (FM= 0 at 100°C; model TR106; 4 to 20 mA; accuracy = ±0.2%); the one to measure the relative humidity are of the RHT-WM type with compact electronic module and transmitter of values (FM= 0 at 100%UR; 4 to 20 mA; accuracy = ± 1.5%); and to measure mass, a weighing system comprising a load cell, model PW12C3 - IMB (50 N (50 kgf); sensibility of 2±0.1% mV.V⁻¹).

Experimental delimitation

The experimental design was completely randomized with two treatments; the effects of treatments were evaluated in pairs by comparing the values before and after treatment. The treatments were a combination of two temperatures (T₁ = 22.9°C and T₂ = 37.1°C) with an air speed of 1.79 m s⁻¹. These temperature values were defined based on subsidies obtained from previous works (Santiago et al., 2012a; Santiago et al., 2012c) in which a range of temperature between 20 and 50°C were studied, obtaining the best results for the concentration of soluble solids and phenolic compounds with greater weight loss for the temperature values of 22.9 and 37.1°C. The results obtained were submitted to analysis of variance, being the averages compared by the Tukey test at 95% confidence in the statistical software Sisvar 5.3.

Physical-chemical analyzes

To perform the physical-chemical analysis, we randomly took six grapes from each cluster, comprising the area of the base, middle and apex of the cluster, according to the procedure proposed by Araújo et al. (2009). Then, the selected grapes were macerated for the preparation of the must for the analysis. The characterization of the review was based on specific methodologies standardized by the Adolfo Lutz Institute (2005) for the analysis of TSS in °Brix. The moisture content, in dry basis, was determined by drying a sample (100 g) in an oven (model MA035/1, manufacturer Marconi) with forced air circulation at 60°C, until reaching the constant weight of the sample. Concentration of phenolic compounds (CPC) was quantified in mg of gallic acid per 100 g of must according to the methodology described by Vargas et al. (2008).

RESULTS AND DISCUSSION

The results of the physicochemical analyses of grapes, before and after treatment are shown in Table 1. Figure 2 shows the variation in response to partial dehydration treatments (%). The results show that it is possible, by modulating the psychometric and thermal parameters of the dehydration process, to adjust the loss of water of grapes, with the consequent increase in the concentration of soluble solids and polyphenols. The use of the forced air system provided considerable decrease in time

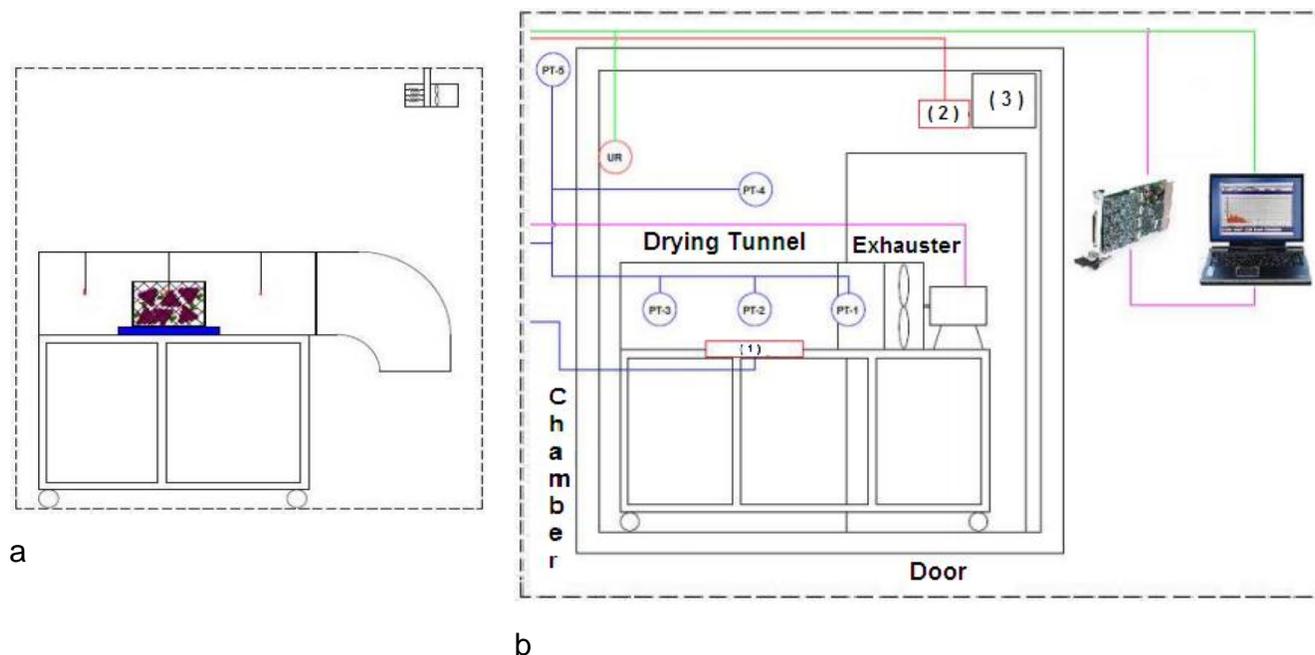


Figure 1. a, Schematic of the structure of forced-air drying; b, schematic of the system instrumentation. 1, Scale; 2, resistance; 3, evaporator.

Table 1. Physical-chemical characterization and analysis of variance for the concentration of total soluble solids (TSS) and concentration of phenolic compounds (CCF) in the must.

| Test ($^{\circ}\text{C}/\text{m}\cdot\text{s}^{-1}$) | TSS ($^{\circ}\text{Brix}$) | | CPC ($\text{mg gallic acid}\cdot 100\text{g}^{-1}$ must) | | Dbm | |
|--|-------------------------------|--------|---|----------|--------|-------|
| | Before | After | Before | After | Before | After |
| T_1 (22.9/1.79) | 17.57 | 20.07* | 927.33 | 974.00* | 3.54 | 3.04* |
| T_2 (37.1/1.79) | 17.23 | 20.60* | 772.00 | 1096.00* | 3.76 | 2.66* |
| Average | 17.40 | 20.34 | 849.67 | 1035.00 | 3.65 | 2.85 |

*Parameters with significant change at 95% confidence level compared to initial value.

to process the loss of water up to the level of control established which was 14%, lasting 20 h (T_1) and 50 h (T_2), with relative humidity of approximately 40%. Partial dehydration caused a significant increase in concentration of soluble solids and phenolic compounds. However, for CPC at the temperature of 37.1 $^{\circ}\text{C}$, the increase accounted for approximately 29%, whereas, for the temperature of 22.9 $^{\circ}\text{C}$, it was only 5%. For TSS, the increase was on average $14.4 \pm 3.9\%$ between both treatments.

The results indicate that partial dehydration of grapes for winemaking can bring satisfactory results in the parameters of soluble solids and polyphenols, not only for the temperature below room temperature but as well as above. In works carried out in Europe, dehydration has been performed only at temperatures between 10 and 25 $^{\circ}\text{C}$ (Bellincontro et al., 2004; Barbanti et al., 2008). According to Barbanti et al. (2008), usually the loss of

water in grapes at psychrometric ambient conditions and without control may last from 90 to 120 days to reach the optimum vinification, and the grapes may still lose up to 40% of mass, exceeding the 20% limit recommended by the International Code of Oenological Practices (2006).

In an experiment carried out by Bellincontro et al. (2009) maximum loss of water was 20%, at the temperature of 10 and 20 $^{\circ}\text{C}$ and air velocity of 1.5 $\text{m}\cdot\text{s}^{-1}$. Dehydration lasted 26 days (624 h) and 16 days (384 h), respectively. However, the increase of $^{\circ}\text{Brix}$ went from 21 to only 24. In the present study, the dehydration time was not more than two days, providing a loss of water of 14% and increased concentration TSS from 17 to 20 $^{\circ}\text{Brix}$, that is, for the same increase in TSS, which was 3 $^{\circ}\text{Brix}$ in both cases, there was a decrease of time of 14-22 days, which would improve the logistics and cost-effectiveness of the processes involved, as well as for the chain of wine production.

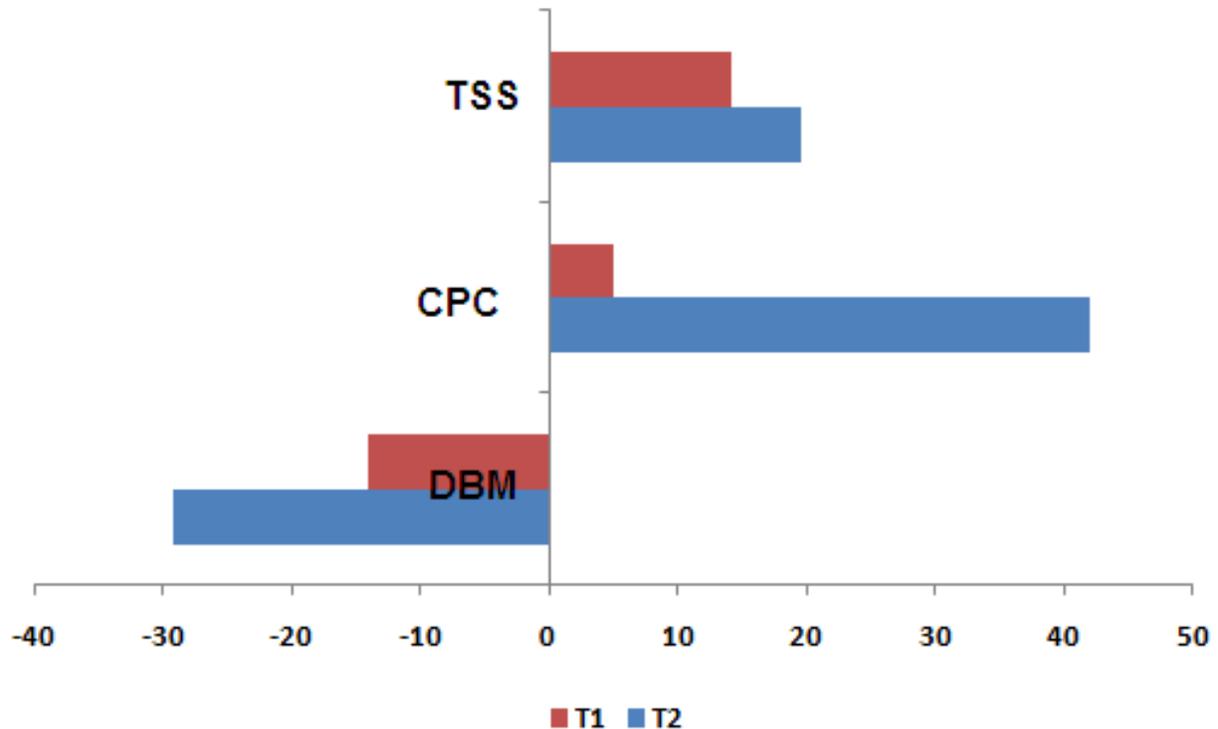


Figure 2. Variation of the physicochemical response to the treatments of dehydration. TSS, Concentration of total soluble solids; CPC, concentration of phenolic compounds; DBM, moisture in dry basis.

Concentration of total soluble solids (TSS)

The average values of TSS significantly varied in both treatments. Treatment “T₂” showed the greatest value of TSS (20.6 °Brix). Although it is just above the value of TSS obtained by treatment “T₁”, this result may be associated with the moisture content of the clusters, since according to Dionello et al. (2009) and Serratosa et al. (2010) the reduction of moisture of grape bundles results in musts with increased value of total soluble solids. By lowering the water content of the grapes, which was approximately 14%, there was a positive impact on the concentration of soluble solids and polyphenols. Studies developed by Moreno et al. (2008) and Bellincontro et al. (2009) indicate loss of water of the order of 14 to 20% with equal positive impact on the concentration of soluble solids. The concentration of total soluble solids, besides acting as an important indicator of the maturity and influencing the chemical and enzymatic modifications occurring in other components of the grapes, serves as the basis of calculation for obtaining the alcoholic potential of the must, since the fructose present in solid soluble is responsible for most of the fermentation.

Varieties of European grapes, such as Malvasia, Trebbiano and Sangiovese, were partially dehydrated, with an increase of up to 34% of total soluble solids in the must, but at the temperature of 21°C, air velocity from 1

to 1.5 m.s⁻¹ and humidity of 42% (Bellincontro et al., 2004). Between 10 and 25°C, Barbanti et al. (2008) observed a similar increase to the value of total soluble solids in the must.

The partial dehydration of grapes above room temperature accelerated the process of mass transfer, and as a consequence the loss of water, which was in total of 14%, still within the norms established. According to the International Code of Oenological Practices, (2006), in grapes for winemaking, the total loss of water in grapes during dehydration cannot be above 20%, as it can cause physiological damages to the product, compromising the quality of the winemaking process and the wine produced. The controlled loss of water in the grapes can be an alternative to produce wines with appropriate alcohol content, since the fruit does not always reach the desired ripeness, and the concentration of soluble solids in the must is essential for the production of alcohol. In Brazil, specifically, the legislation requires the alcohol content to be between 8.6 at 14%. When this content is not met, then it is allowed the addition of exogenous sugar to correct the alcohol content (chaptalization); however, the law limits this correction as a sufficient quantity to produce 3 degrees GL of alcohol, which in wines most often does not meet this limit imposed.

The amount of soluble solids obtained in the study demonstrates the high fermentation potential; even

though the 'Niagara Rosada' Grape cultivar is not used in Brazil to produce wines (Manfroi et al., 2006; Rizzon and Miele, 2004; Chavarria et al., 2008), this value of TSS equates to the value of TSS of the must of some European grape varieties (*V. vinifera* L.).

Concentration of phenolic compounds (CPC)

Treatment "T₁" showed no significant response to the polyphenol content and we believe that the significant effect obtained by the second treatment was due to the fact that, at the temperature of 37.1°C, there is the disintegration or breaking of the pectin molecules of the skin, allowing phenolic compounds present there to be released, as discussed by Vedana et al. (2008). The increase in the concentration of polyphenols obtained in this study also becomes promising when aiming practical application, as phenolic compounds are of great importance in Oenology, since they are directly or indirectly related to the quality of wine and are antioxidants beneficial to the human health.

Conclusions

The results obtained so far open a perspective of practical application of the technology of partial dehydration at the temperature of 37.1°C to the sector of Viticulture. With the combination of forced air and temperature of 37.1°C, it is possible to accelerate the process of loss of water of grapes, providing increased concentration of phenolic compounds and total soluble solids, thus reaching the alcohol content in must required for the manufacture of wines without the need for the chaptalization process.

The significant reduction in the time required to remove the amount of water recommended from the grapes before vinification, with the consequent increase in the chemical properties evaluated, could contribute to the cost-effectiveness of the processes involved in the production chain of Viticulture.

REFERENCES

- Araújo EG, Piedade SMS, Conceição MAF, Pereira JC (2009). Métodos de amostragem e tamanho de amostra para avaliar o estado de maturação da uva Niagara rosada. *Rev. Bras. Biom.*, São Paulo. 27(4): 501-518.
- Azeredo HMC, Jardine JG (2006). Desidratação osmótica de abacaxi aplicada à tecnologia de métodos combinados. *Rev. Bras. Prod. Agroind.*, Campina Grande. 8(2): 153-162.
- Barbanti D, Mora B, Ferrarini R, Torielli GB, Cipriani M (2008). Effect of various thermo-hygrometric conditions on the withering kinetics of grapes used for the production of "Amarone" and "Recioto" wines. *J. Food Eng.* 85(3):350-358.
- Barnabé D, Filho WGV (2008). Recuperação de etanol a partir do bagaço de uva. *Rev. Ener. Agric. Botucatu.* 23(4):1-12.
- Bellincontro A, De Santis D, Botondi R, Villa I, Mencarelli F (2004). Different postharvest dehydration rates affect quality characteristics and volatile compounds of Malvasia, Trebbiano and Sangiovese grapes for wine production. *J. Sci. Food Agric.* 84:1791-1800.
- Bellincontro A; Nicoletti I, Valentini M, Tomas A, Santis D, Corradini D, Mencarelli F (2009). Integration of Nondestructive Techniques with Destructive Analyses to Study Postharvest Water Stress of Winegrapes. *Am. J. Enol. Vitic.* 60(1):57-65.
- Bradamente S, Barenghi L, Villa A (2004). Cardiovascular Protective Effects of Resveratrol. *Cardiovasc. Drug. Rev.* 22:3.
- Chavarria G, Santos HP, Zanús MC, Zorzan C, Marodin GAB (2008). Caracterização físico-química do mosto e do vinho Moscato Giallo em videiras cultivadas sob cobertura de plástico. *Pesq. agropec. bras.*, Brasília, 43(7):911-916.
- Código Internacional De Práticas Enológicas (2011). O.I.V. Rue D'Aguesseau, Paris, 2006. Available in: <http://news.reseauconcept.net/images/oiv_it/Client/Code_Ed_2006_FR.pdf > Access in: Feb 09, 2011.
- Constantini V, Bellincontro A, De Santis D, Botondi R, Mencarelli F (2006). Metabolic changes of Malvasia grapes for wine production during postharvest drying. *J. Agr. Food Chem.* 54: 3334-3340.
- Curvelo-Garcia AS (2005). Práticas enológicas internacionalmente reconhecidas. *Ciênc. Téc. Vitiv.* v. 20, p.105-130.
- Diário Oficial Da União (2011). Law No. 10.970, of November 12, 2004. Available in: <http://www.receita.fazenda.gov.br/legislacao/Leis/2004/lei10970.htm> Access in: Oct 24, 2011.
- Dionello RG, Berbert PA, Molina MAB, Pereira RC, Viana AP, Carlesso VO (2009). Secagem de fatias de abacaxi in natura e pré-desidratadas por imersão-impregnação: cinética e avaliação de modelos. *Tecnol. Aliment.*, Campinas, 29(1):232-240.
- Freitas AA, Detoni AM, Clemente E, Oliveira CC (2010). Determinação de resveratrol e características químicas em sucos de uvas produzidas em sistemas orgânico e convencional. *Rev. Ceres, Viçosa*, v. 57(1):001-005.
- Guerra CC, Zanús MC (2003). Uvas viníferas para processamento em regiões de clima temperado. *EMBRAPA - Sistema de Produção*, 4, ISSN 1678-8761.
- Instituto Adolfo Lutz (2005). Normas analíticas do Instituto Adolfo Lutz: Métodos químicos e físicos para análises de alimentos. V. 1, 4 ed. Brasília. 1018 p.
- International Code of Oenological Practices (2006). Organización Internacional de La Viña Y El Vino. Rue D'Aguesseau, Paris.
- Iasa MJ, Churruga I, Simón E, Arias N, Milagro F, Martínez JA, Portillo MP (2011). The combination of resveratrol and CLA does not increase the delipidating effect of each molecule in 3T3-L1 adipocytes. *Nutr. Hosp.* 26:5 Madrid.
- Manfroi L, Miele A, Rizzon LA, Barradas CIN (2006). Composição química do mosto da uva Cabernet Franc conduzida no sistema lira aberta. *Ciênc. agropec.*, Lavras. 30(4):787-792.
- Moreno JB, Cerpa-Caldrón F, Cohen SD, Fang Y, Qian M, Kennedy JA (2008). Effect of postharvest dehydration on the composition of pinot noir grapes (*Vitis vinifera* L.) and wine. *Food Chem.* 109:755-762.
- Rizzon LA, Miele A (2004). Avaliação da cv. Tannat para elaboração de vinho tinto. *Ciênc. Tecnol. Aliment.*, Campinas, 24(2): 223-229.
- Sampaio SM, Queiroz MR (2006). Influência do processo de secagem na qualidade do cogumelo shiitake. *Eng. Agríc. Jaboticabal.* 26(2):570-577.
- Santiago WE, Silva JTR, Teruel BJ, Oliveira RA (2012a). Mudanças físico-químicas de uvas Niagara Rosada após secagem parcial. *Rev. Bras. Energ. Ren.* 1:239-252.
- Santiago WE, Silva JTR, Teruel BJ, Oliveira RA (2012b). Sistema de pesagem dinâmica para determinação da perda de massa de produtos hortícolas durante secagem. *Anais do X Congresso Latino Americano y del Caribe de Ingeniería Agrícola e XLI Congresso Brasileiro de Engenharia Agrícola (CLIA-CONBEA).*

- Santiago WE, Tinini RCR, Teruel BJ (2012c). Qualidade de uvas niágara rosada (*Vitis labrusca*) submetidas a desidratação em diferentes temperaturas. In: XXII Congresso Brasileiro de Fruticultura, 2012, Bento Gonçalves. Anais do XXII Congresso Brasileiro de Fruticultura.
- Serratos MP, Marquez A, Lopez-Toledano A, Merida J, Medina M (2010). Compostos fenólicos obtidos de uvas secas em câmara com temperatura controlada da casta Pedro Ximénez. Livro das Actas 30/04/2010. 17: 24. 8: 123-131. Simpósio de Vitivinicultura do Alentejo. Evento Alentejo das Gastronômias Mediterrânicas - Festival Internacional.
- Silva JCTR, Teruel BJM (2011). Control system for forced-air cooling of horticultural products. Eng. Agríc. (Impresso). 31:621-630.
- Vargas PN, Hoelzel SC, Rosa CS (2008). Determinação do teor de polifenóis totais e atividade antioxidante em sucos de uva comerciais. Alim. Nutr. Araraquara ISSN 0103-4235.19(1):11-15.
- Vedana MIS, Ziemer C, Miguel OG, Portella AC, Candido IMB (2008). Efeito do processamento na atividade antioxidante de uva. Alim. Nutr. Araraquara. 19(2):159-165.