Journal of Food Process Engineering ISSN 1745-4530

CHARACTERISTIC PROCESS VARIABLES DURING THE OSMOTIC DEHYDRATION OF STONE FRUITS: EXPERIMENTAL VALUES AND CORRELATIONS BETWEEN COMPONENTS CONTENT

ANABEL RODRIGUEZ[1], MARIA MARCELA RODRIGUEZ[2] and RODOLFO HORACIO MASCHERONI[1,3,4]

[1]CIDCA (Centro de Investigación y Desarrollo en Criotecnología de Alimentos), (CONICET La Plata-UNLP), La Plata, Buenos Aires 1900, Argentina
[2]TECSE-UNICEN, Olavarría, Buenos Aires, Argentina
[3]MODIAL-Facultad de Ingeniería (UNLP), La Plata, Buenos Aires 1900, Argentina

[4]Corresponding author.
TEL: 54-221-4890741;
FAX: ••;
EMAIL: rhmasche@ing.unlp.edu.ar

Received for Publication May 19, 2014
Accepted for Publication October 23, 2014

doi:10.1111/jfpe.12171

ABSTRACT

Stone fruits (plums, peaches, nectarines, cherries and apricots) are widely consumed fresh or processed. Osmotic dehydration – immersion of food pieces in hypertonic solutions – is often used as a pretreatment to further conservation procedures for these fruits. Usually, it is characterized determining the variation with time of water loss and solution solids gain. Both variables depend on food size, shape, structure and process conditions, and there are no general correlations for their variation.

As an alternative, it is important to develop relations between water and soluble solids content independent of product characteristics and process conditions.

In this work, we developed experimental values of relevant variables for stone fruits dehydrated in glucose or sorbitol and included them in linear correlations between water content and soluble solids for different stone fruits dehydrated in sugar or polyalcohol solutions and in a general linear correlation that allows to characterize both properties with only one rapid determination (of any of both).

PRACTICAL APPLICATIONS

Linear correlations for the variation of soluble solids content as a function of water content during osmotic dehydration were generalized to a unique linear regression equation independent of type of fruit and/or solute and valid for any process condition, which allows to characterize both properties with only one rapid determination (of any of both). This correlation can be easily used under process conditions to monitor the advance of osmotic dehydration of fruits.

INTRODUCTION

Fruits are considered as "healthy foods" due to their natural origin and their content in vitamins, fibers and other nutrients. Many of them have attractive appearance and desirable flavor and taste, which favor their consumption. Each time new methods for fruit processing are developed to prolong their shelf life or for their use as snacks or for their inclusion as ingredients in ice creams, yogurts, breakfast mixtures, pastry, jams, etc.

In particular, stone fruits (plums, peaches, nectarines, cherries and apricots) are widely consumed fresh or processed due to their nutritional value and desirable taste. Shelf life of these fresh fruits – even under refrigeration – is limited; so many research deal with treatments to prolong it. Among these, combined preservation methods that include a stage – normally the first – of osmotic dehydration (OD) are of interest due to the advantages of OD as a partial dehydration method.

In OD, fruits or vegetables – whole, peeled or portioned – are immersed in sugar/sugar-salt/alcohol concentrated aqueous solutions, where both partial dehydration of the tissues and solids uptake occur. Sometimes meats and fishes are also pretreated in solutions containing salts and flavor components. The driving forces for the mass transfer are the differences in chemical potentials of water and solutes between the food tissue and the dehydrating solution (Agnelli *et al.* 2005). Water removal is carried out in the liquid phase – without phase change– and at almost ambient temperatures, which lowers energy use and the occurrence of most chemical or physical degradation processes normally involved in hot-air drying. During subsequent processing, energy requirements decrease due to the lower water content (WC) of the product.

This process is used to broaden the availability period of fruits and vegetables and – in some cases – to enhance the soluble solids content (SS) in the final product as a pretreatment prior to air or microwave drying, refrigeration, freezing, preparing of candies and jams or frying (Torregiani 1993). A further use is in the development of minimally processed products, helping to prolong their shelf life through a slight reduction in water activity and improving the microbiological stability, without changing considerably the quality characteristics of fresh fruit (Torres *et al.* 2008). The interest in OD prior to further processing is also due to the enhanced nutritional and sensory properties of the final products. OD, carried out at low or moderate temperatures, protects thermosensitive compounds such as flavors, pigments and vitamins. Furthermore, as it prevents food from getting in contact with air, oxidation reactions and loss of volatile compounds are limited (Raoult-Wack 1994).

Literature presents numberless papers on experimental data of OD of fruits and vegetables. This is due to the wide variety of raw food materials, with their different compositions and structures, sizes and shapes of pieces, and of operating conditions during OD (composition, temperature and agitation of dehydrating solution, contact time), continuous or batch processes, one-use or reused osmotic solutions, etc., that determined the need for extensive experimental work to characterize each case (food, piece, solution, operating conditions). Most of these papers compare their results against data from the literature for similar food systems, but normally processed under different operation conditions, and in no case general correlations are given for the variation of process variables during OD (Floury *et al.* 2008). In this regard, it is very important to try to develop general relations between those food variables relevant to the OD process (WC and SS, weight reduction [WR], water loss [WL] and soluble solids gain [SG]), independent of product characteristics and process conditions. These correlations would be valuable for process design and operation, allowing to obtain OD products with targeted compositions, which could be determined by rapid and simple physical control tests (like weight change or SS).

Numerous recent research on stone fruits studied the application of the OD process to plums (Tarhan 2007; Rodríguez *et al.* 2010), apricots (Riva *et al.* 2005; Ispir and Togrul 2009), nectarines (Araujo 2004; Rodríguez *et al.* 2013), cherries (Yu 1998; Konopacka *et al.* 2009) and peaches (Mota 2005; Singh Yadav *et al.* 2012), among many others; but none of them dealt with the determination of relations between WC and SS, not even with general ratios between WL, SG and process conditions. Most of the studies used sucrose as dehydrating solute and there is much less research on other sugars or polyalcohols as alternative dehydrating solutes.

Therefore, the objectives of this work were to:

(1) Gather all the available information about WL, WC, SG and SS for nectarines, peaches, plums, cherries and apricots dehydrated in sugar or polyalcohol solutions;

(2) Determine WL, WC, SG and SS for nectarines, peaches and plums, dehydrated in glucose or polyalcohol solutions;

(3) Try to develop general correlations between WL and SG and/or between WC and SS for nectarines, peaches, plums, cherries and apricots dehydrated in any type of osmotic solution, which are simple and useful for technological purposes.

MATERIALS AND METHODS

Osmotic Dehydration

As most of the literature data referred to dehydration of stone fruits in sucrose solutions, glucose was chosen as characteristic of low molecular weight sugars and sorbitol as a typical polyalcohol. It was intended to determine if the relations SS versus WC for the different solutes (glucose, sucrose and sorbitol) followed similar or diverse trends.

Nectarines cv. August Red, plums cv. Larry-Ann and peaches cv. O'Henry had been harvested from the Experimental Farm at the Facultad de Agronomía of UNICEN, located in the city of Azul, Buenos Aires (Argentina), and immediately refrigerated at 5C. Dehydrations were performed the next day after slicing the fruits to 2 mm samples. These very thin samples intended to have very large area/volume ratio so as to get final products with uniform composition that secure lower dispersion in experimental data. These samples were introduced in flasks with the osmotic solution (glucose at 60% or sorbitol at 60%) and shaken at constant temperature of 35C for the scheduled periods (0.5, 1, 2, 4, 6, 8 h) in a thermostatic bath FERCA, model TT 400 with linear stirring (100 cycles per minute). The ratio of product to solution was always less than 1/20. The tests were performed in triplicate.

WC of fresh and osmodehydrated samples was determined by drying in a vacuum oven (model OVA031 XX1.5, Gallenkamp, U.K.) at 70 ± 2C until a constant weight was reached. SS was measured in an Abbe refractometer (No. A77341, Bellingham & Stanley Ltd, U.K.) and read in °Brix. All the measurements were performed at 25C and in duplicate.

TABLE 1. EXPERIMENTAL DATA OF WC AND SS FOR NECTARINES, PEACHES AND PLUMS DEHYDRATED IN GLUCOSE OR SORBITOL SOLUTIONS DURING 480 MIN

Fruit	Nectarines				Peaches				Plums			
Solute	Glucose		Sorbitol		Glucose		Sorbitol		Glucose		Sorbitol	
Time (min)	WC (%)	SS (%)	WC (%)	SS (%)	WC (%)	SS (%)	WC (%)	SS (%)	WC (%)	SS (%)	WC (%)	SS (%)
0	87.66	10.13	87.66	10.13	85.16	13.10	85.16	13.10	86.21	10.83	86.21	10.83
30	79.45	20.47	70.59	27.70	79.63	19.15	73.43	21.87	80.33	15.90	66.89	30.63
60	71.51	25.23	62.45	31.23	74.26	28.40	68.85	28.70	72.68	17.60	56.87	36.10
120	65.82	27.70	54.32	37.63	71.01	27.97	53.90	39.33	71.49	20.03	50.71	47.73
240	61.24	35.17	46.21	45.27	63.67	30.30	44.17	42.57	59.66	30.97	41.38	52.97
360	54.96	41.83	41.66	52.80	52.35	36.80	42.43	51.67	57.57	35.67	38.97	57.15
480	51.18	46.03	40.64	56.67	46.95	40.30	42.19	56.50	47.16	45.90	38.68	58.80

SS, soluble solids content; WC, water content.

Prediction Equations

SS as a Function of WC. In recent works (Tocci and Mascheroni 2008; Rodríguez and Mascheroni 2012), linear relationships were determined between WC and SS for samples of diverse shapes and sizes of different fruits dehydrated in sucrose, glucose or sorbitol solutions of various concentrations and temperatures, suggesting that this relationship is inherent to the food and solute type and independent of the characteristics of food (shape, size) and process conditions (solution temperature, concentration, mixing).

Moreover, as variations induced by food or solute type were minor, they could include all the analyzed data in an only linear regression equation – independent of food and

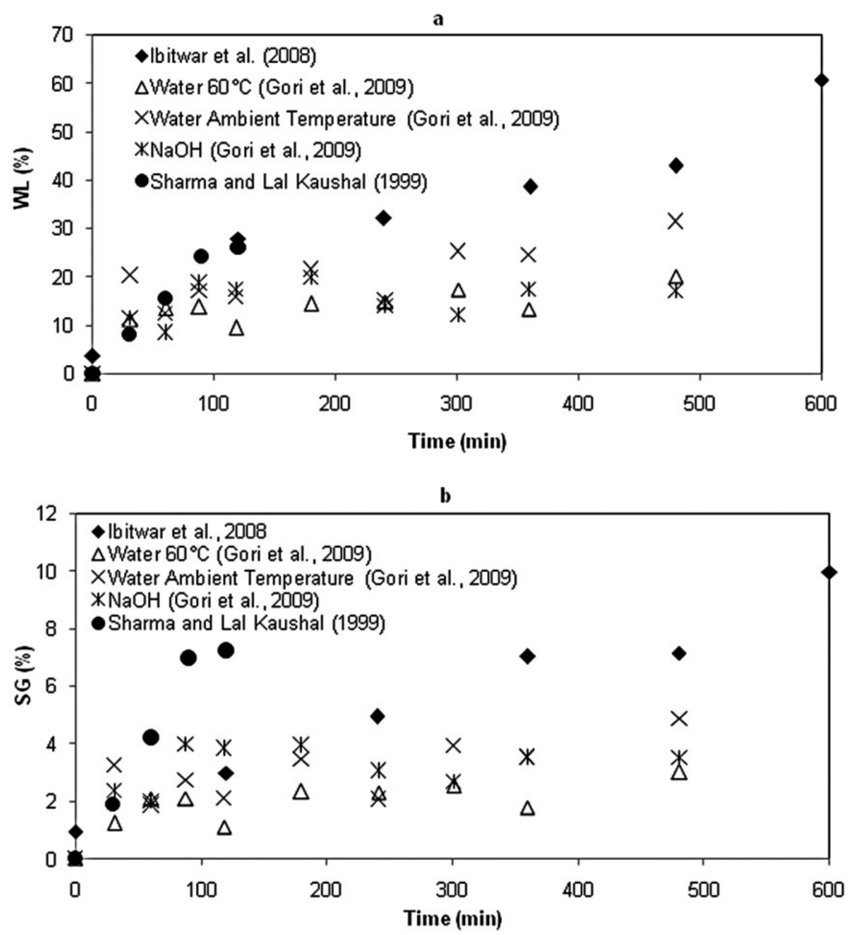

FIG. 1. LITERATURE DATA FOR: (A) WATER LOSS (WL) AND (B) SOLIDS GAIN (SG) OF PLUM PIECES DEHYDRATED IN SUCROSE SOLUTIONS UNDER DIFFERENT PROCESS CONDITIONS GIVEN IN TABLE 2

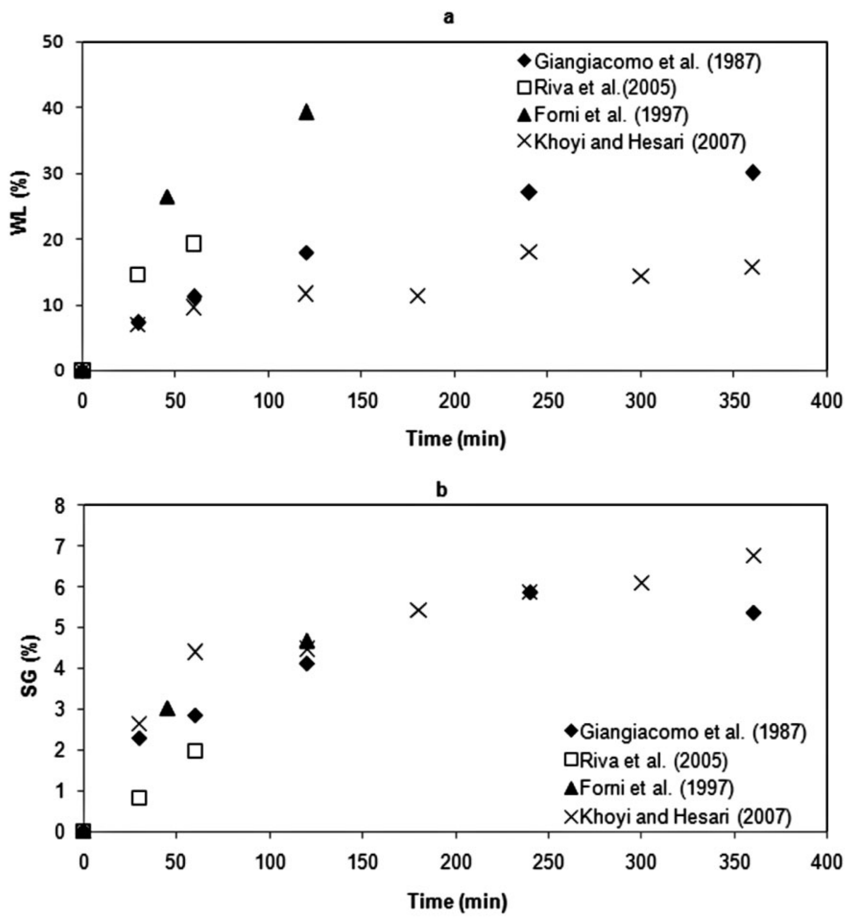

FIG. 2. LITERATURE DATA FOR: (A) WATER LOSS (WL) AND (B) SOLIDS GAIN (SG) OF APRICOT PIECES DEHYDRATED IN SUCROSE SOLUTIONS UNDER DIFFERENT PROCESS CONDITIONS GIVEN IN TABLE 3

solute type – with very high regression coefficient (Rodríguez and Mascheroni 2012).

RESULTS AND DISCUSSION

Experimental Data of SS versus WC

Table 1 presents the experimental data – obtained as described in Materials and Methods – of SS versus WC for nectarines, peaches and plums dehydrated in sorbitol or glucose solutions. Each datum is the average of three determinations. These data will be analyzed in the context of the following section.

Relations between Process Variables

Most of the published research on OD relates the variation of WL and SG (and sometimes their combined effect, WR) with time t through tables, figures or numerical calculations. Few other works deal with physical properties related to mass transfer (Sereno 2000; Rodríguez and Mascheroni 2012). Only one research could find a linear relationship between WL and SG at low and intermediate dehydration degrees, but no general correlation was developed (Floury *et al.* 2008).

In the case of numerical relations, two broad scopes are used:

(1) Simple regressions (linear, polynomial, logarithmic, potential, etc.) or partially theoretical simplified models like those of Magee, Azuara or Panagiotou (Magee *et al.* 1983; Panagiotou *et al.* 1998). All of them give results specific to the product (type of fruit, shape, size, pretreatments, peeling) and working conditions (type of solute, concentration, temperature and stirring of the osmotic solution) as both, WL and SG, are in fact surface- and time-integrated mass transfer rates that depend on all the cited characteristics. So, no general correlations can be arrived to. All the comparisons given in most research works are not valid, because even if belonging to same foods and solutes, as is later discussed in Figs. 1, 2 and 3, they correspond to different pretreatments, food shapes or sizes, solution concentrations or temperatures, diverse modes of stirring (or no stirring at all), etc. With what – statistically – data from diverse research correspond to different universes and cannot be compared.

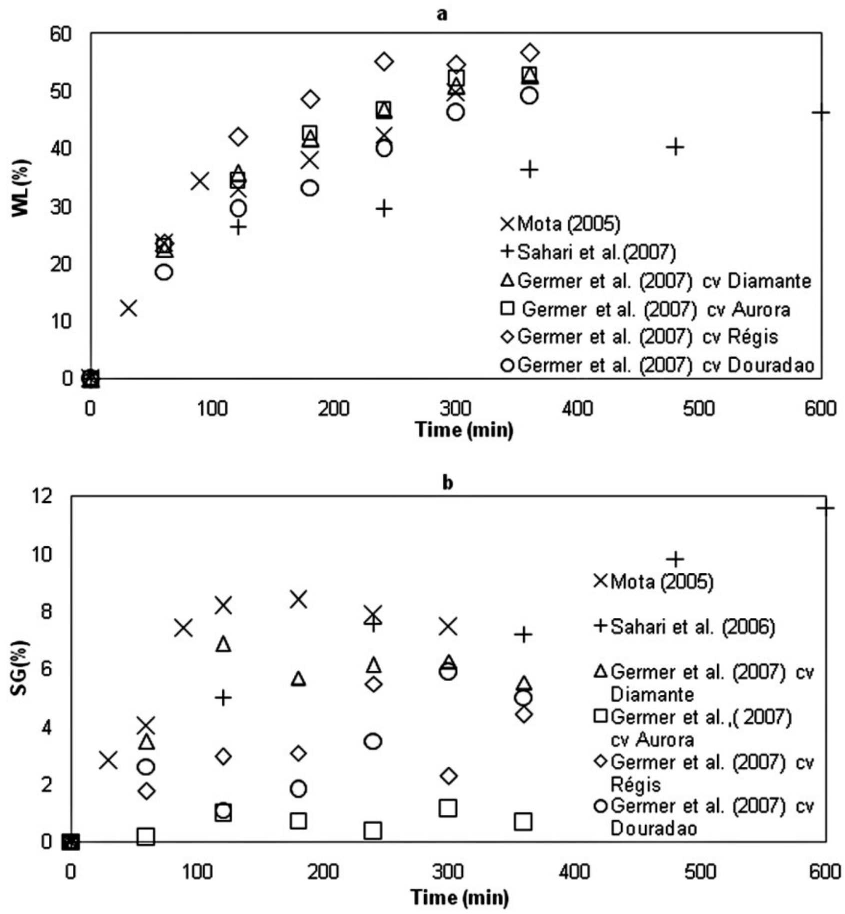

FIG. 3. LITERATURE DATA FOR: (A) WATER LOSS (WL) AND (B) SOLIDS GAIN (SG) OF PEACH PIECES DEHYDRATED IN SUCROSE SOLUTIONS UNDER DIFFERENT PROCESS CONDITIONS GIVEN IN TABLE 4

(2) Theoretically based transport phenomena models that range from simplified scopes that assume regular geometries and constant properties and parameters, arriving at the analytical solution of Crank's model, to more involved models that can consider – according to their particular development – the true geometry of the piece, shrinkage and/or variable diffusion coefficients and, sometimes, they account for certain influence of food tissues structure (Spiazzi and Mascheroni 1997; Rodríguez *et al.* 2013). These methods provide much more complete information, including predicted water and solutes concentration profiles. Variation of WL and SG with time can be easily derived. But, again, the results are specific to the process studied. The clear advantage of these methods is that – with the adequate input of product characteristics and properties and operation characteristics – they can simulate any dehydration test.

When choosing any of the cited prediction methods, the fact that WL and SG are food, solution and working conditions dependent prevents the possibility of generalizing their results. As a brief verification of this assertion, we present Tables 2, 3 and 4 and Figs. 1, 2 and 3. All of them refer to experimental data of WL and SG of stone fruits dehydrated in sucrose solutions. Table 2 and Fig. 1 relate to plums, Table 3 and Fig. 2 belong to apricots, and the last ones to peaches. Tables give details of the OD conditions and figure the related experimental results.

As can be seen from these figures, even with same fruits and solutes, but with possible differences in sample pretreatment, shape and/or size and solution temperature and/or concentration and/or stirring, experimental data are completely diverse. Results cannot be compared. No general prediction equation can be obtained.

Based on these limitations, we intended to widen the scope of this work searching in the literature for experimental data of SS versus WC in OD of stone fruits and included all of them, together with the data determined in this research, in individual linear regressions for each fruit and solute, individual general regressions for each fruit – including all dehydrating solutes tested for that fruit – and a general linear correlation using all the available data for stone fruits (305 experimental points).

In the case of nectarines, the additional data were taken also for glucose and sorbitol as solutes (Rodríguez *et al.*

TABLE 2. DATA FROM LITERATURE FOR THE OSMOTIC DEHYDRATION CONDITIONS OF PLUMS IN SUCROSE SOLUTIONS

Fruit characteristics	Pretreatment	Solution temperature	Solution concentration	Solution stirring	Reference
Whole (cv. Kala Amritsari)	NaOH	Ambient	Dry sugar	None	Ibitwar *et al.* (2008)
1/8 portions, unpeeled (cv. President)	NaOH	40C	40°Brix	None	Gori *et al.* (2009)
1/8 portions, unpeeled (cv. President)	Water (60C)	40C	40°Brix	None	Gori *et al.* (2009)
1/8 portions, unpeeled (cv. President)	Water (ambient temperature)	40C	40°Brix	None	Gori *et al.* (2009)
Whole, peeled	NaOH	50C	70°Brix	NA	Sharma and Lal Kaushal (1999)

NA, not applicable.

2010). For peaches, additional data were all for sucrose as dehydrating agent (Tocci and Mascheroni 1998; Mota 2005). For plums, data from literature were for plums cv. President dehydrated in sucrose or glucose solutions after different pretreatments (Rodríguez *et al.* 2010), dehydrated in sucrose solutions (Gori *et al.* 2009) and in sucrose or honey (Veloso *et al.* 2013). For apricots, experimental data belonged to dehydration with sucrose solution (Araujo 2004) or with sucrose or sorbitol solutions (Riva *et al.* 2005). For cherries, data were taken for nine cultivars of organic sweet cherries dehydrated in sucrose solution (Gobbi *et al.* 2006).

Figure 4a–e presents the experimental data for each fruit. For nectarines (a), peaches (b) and plums (c), different solutes were used. In these cases, the figure presents the linear regression for each solute and a general linear correlation for all data of the same fruit. For apricots (d), almost all data belonged to sucrose (only two points were for sorbitol), and in cherries (e) only sucrose was used as solute.

It can be seen that in all cases of individual solutes, high correlation coefficients were obtained, somewhat lower when using glucose, independent of the species of fruit or chemical composition of solution.

In particular, for fruits where data were obtained for more than one type of solute, the generalized linear regressions showed very high correlation coefficients R^2 (0.9856 for nectarines with two different solutes; 0.9415 for peaches with three solutes; and 0.9560 for plums also with three solutes) and of the same order of those of the individual solutes.

TABLE 3. DATA FROM LITERATURE FOR THE OSMOTIC DEHYDRATION CONDITIONS OF APRICOTS IN SUCROSE SOLUTIONS

Fruit characteristics	Pretreatment	Solution temperature	Solution concentration	Solution stirring	Reference
Slices, 1 cm (cv. Reale)	None	25C	70°Brix	Yes	Giangiacomo *et al.* (1987)
Cubes, 14 mm (cv. Tonda di Castigliole)	None	25C	60°Brix	Yes	Riva *et al.* (2005)
Cubes, 10 mm (cv. Tonda di Castigliole)	None	25C	65°Brix	Yes	Forni *et al.* (1997)
Slices, 1 cm (cv. Nasiry)	None	50C	50°Brix	NA	Khoyi and Hesari (2007)

NA, not applicable.

TABLE 4. DATA FROM LITERATURE FOR THE OSMOTIC DEHYDRATION CONDITIONS OF PEACHES IN SUCROSE SOLUTIONS

Fruit characteristics	Pretreatment	Solution temperature	Solution concentration	Solution stirring	Reference
Halves (cv. Biuti)	NaOH; blanched	45C	60°Brix	Yes	Mota (2005)
Slices, 1 cm (cv. Red Haven)	Water 60°C	22C	60°Brix	NA	Sahari *et al.* (2006)
1/6 longitudinal pieces (cv. Diamante, Aurora, Regis, Douradao)	NaOH; blanched	45C	65°Brix	Yes	Germer *et al.* (2007)

NA, not applicable.

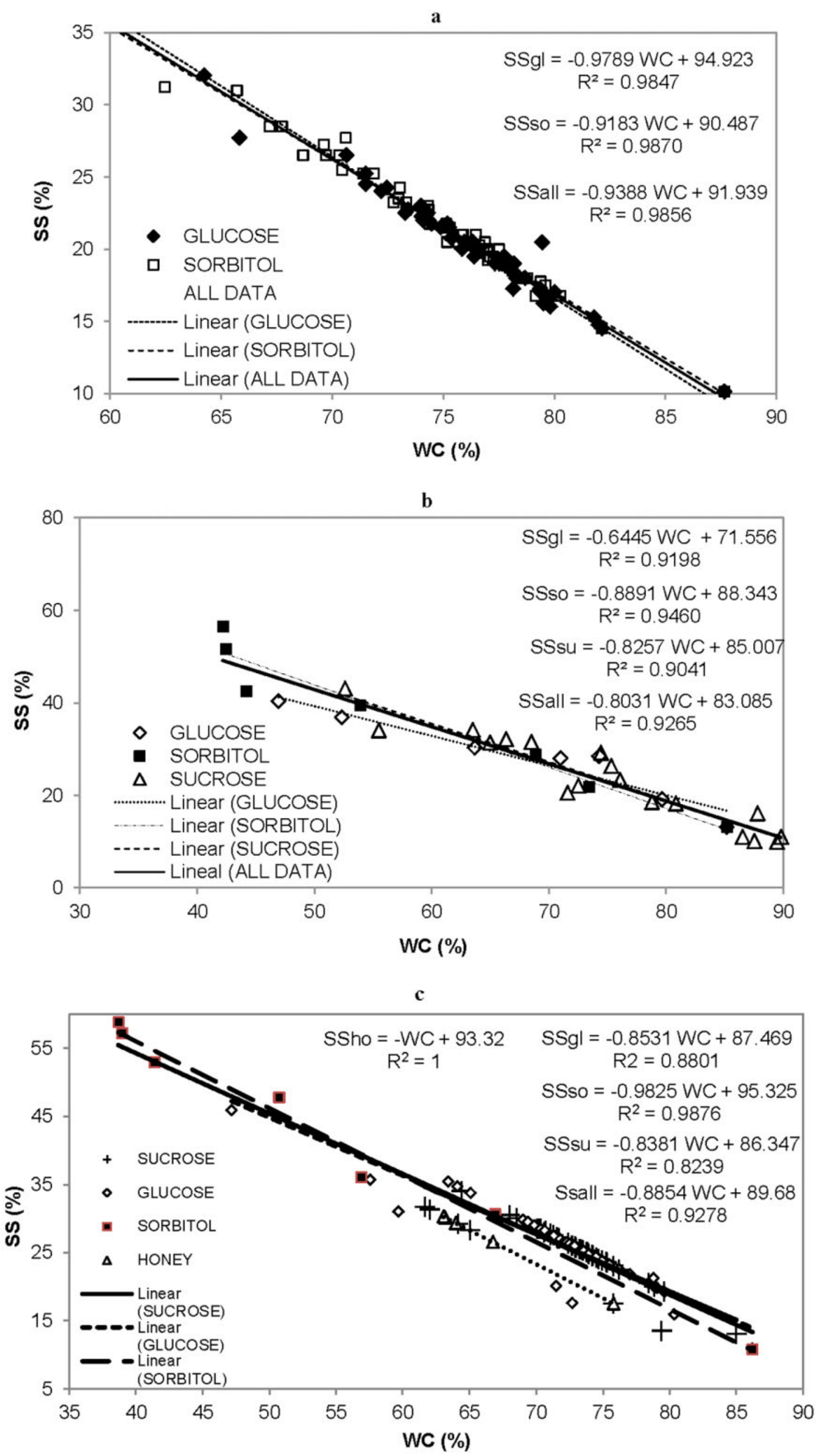

FIG. 4. EXPERIMENTAL DATA AND LINEAR REGRESSIONS FOR THE VARIATION OF SOLUBLE SOLIDS CONTENT (SS) VERSUS WATER CONTENT (WC) FOR: (1) INDIVIDUAL FRUIT SPECIES: (A) NECTARINES, (B) PEACHES, (C) PLUMS, (D) APRICOTS AND (E) CHERRIES; AND (2) FOR THE WHOLE DATA SET: (F)

Finally, Fig. 4f presents the generalized linear regression for the five stone fruits considered and all the solutes based on the whole data set with a total of 305 experimental points. The prediction equation obtained is

$$SS = -0.8865\,WC + 89.07$$

Its correlation coefficient R^2 is 0.9307, showing that all the data can be clearly included in an only one linear

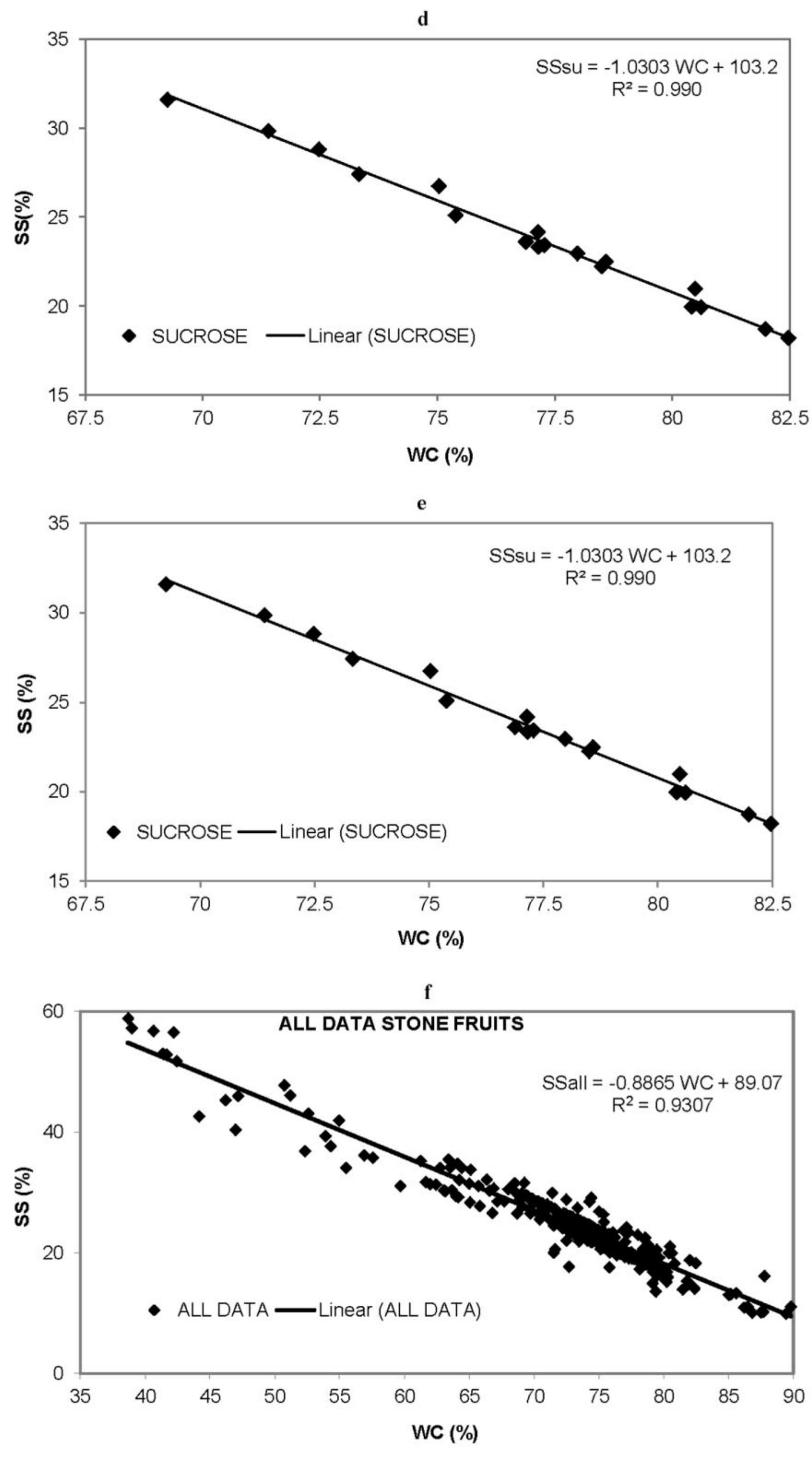

FIG. 4. CONTINUED

correlation, even considering several low-quality experimental data (as those whose amount of water plus SS was as low as 86.74% or as high as 103.52%). If these data are excluded (only eight pairs of "outsiders"), the new correlation that is given in Fig. 5 is

$$SS = -0.9221\,WC + 89.07 \quad R^2 = 0.9458$$

This by no way means that the fruit type (its structure and composition) and the solute type (molecular weight, molecule size and shape, and its interactions with water and

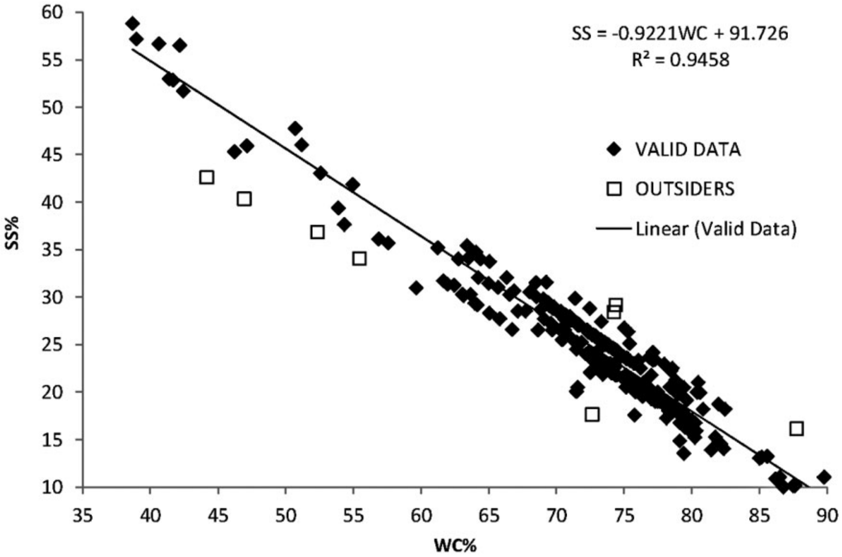

FIG. 5. EXPERIMENTAL DATA AND LINEAR REGRESSIONS FOR THE VARIATION OF SOLUBLE SOLIDS CONTENT (SS) VERSUS WATER CONTENT (WC) FOR THE WHOLE DATA SET, EXCLUDING EIGHT PAIRS OF DATA (AS MARKED IN THE FIGURE)

other solutes and with the fruit tissues) have no importance in the ratio between WL and SG, but that the existing differences are in the order of the total experimental errors, fundamentally of the accuracy of the determination of water and solute contents. When one works with different solutes for the same fruit as for nectarines, peaches and plums, slight differences can be determined for the linear regressions for each solute, as seen in Fig. 4, which is a proof of the differences in the SS versus WC ratio, induced by the diverse solutes.

CONCLUSIONS

No general predicting equations can be developed to relate weight loss or SG between them or with time during OD, even for a same type of fruit and dehydrating solute, but with different sample shapes, sizes or solute concentrations, temperatures or stirring.

On the contrary, linear correlations for the variation of SS as a function of WC can be obtained, which can be generalized to a unique linear regression equation independent of type of fruit and/or solute and valid for any process condition.

Consequently, WC and SS can be immediately related during any OD process by determining only one of both properties. This relationship has important practical implications because it can be used to monitor the advance of any OD process with a rapid test of SS (°Brix).

ACKNOWLEDGMENTS

The authors acknowledge the National Research Council of Argentina (CONICET) and the National University of La Plata (UNLP) for grants and fellowships that supported this work.

REFERENCES

AGNELLI, M.E., MARANI, C.M. and MASCHERONI, R.H. 2005. Modelling of heat and mass transfer during (osmo)dehydrofreezing of fruits. J. Food Eng. *69*, 415–424.

ARAUJO, E.A.F. 2004. *Estudo do Processo de Desidratação Osmótica e Secagem de Nectarina (Prunus Persica)*. Tese apresentada à Faculdade de Engenharia de Alimentos da Universidade Estadual de Campinas para obtenção do título de Doutor em Engenharia de Alimentos.

AZUARA, E., BERISTAIN, C. and GARCÍA, H. 1992. Development of a mathematical model to predict kinetics of osmotic dehydration. International J. Food Sci. Technol. *29*, 239–242.

BERTOLO, G., RONDO BROVETTO, B., de VECCHI, P., CARDONE, G., AVITABILE LEVA, A. and TORREGGIANI, D. 2001. Influence of temperature and extent of dehydration on texture and colour of apricot and strawberry ingredients. In *Proceedings of the Eight International Congress on Engineering & Food, ICEF 8,* Puebla México, April 9–13, 2000, Vol. *2* (J. Welti-Chanes, G.V. Barbosa-Canovas and J.M. Aguilera, eds.) pp. 1220–1224, Technomic Publishing Co Inc., Lancaster, PA.

FLOURY, J., LE BAIL, A. and PHAM, Q.T. 2008. Three-dimensional numerical simulation of the osmotic dehydration of mango and effect of freezing on the mass transfer rates. J. Food Eng. *85*, 1–11.

FORNI, E., SORMANI, A., SCALISE, S. and TORREGGIANI, D. 1997. The influence of sugar composition on the colour stability of osmodehydrofrozen intermediate moisture apricots. Food Res. Int. *30*, 87–94.

GERMER, S.P.M., QUEIROZ, M.R., AGUIRRE, J.M., BARBOSA, W., BARBARI, S.A.G.V. and SIGRIST, J.M.M. 2007. Aptidão de cultivares de pêssego do Estado de São Paulo para a produção de passas por processo combinado de secagem osmótica e secagem com ar quente. Braz. J. Food. Technol. *10*, 155–158.

GIANGIACOMO, R., TORREGIANI, D. and ABBO, E. 1987. Osmotic dehydration of fruit: Part 1. Sugars exchange between fruit and extracting syrups. J. Food Proc. Pres. *11*, 183–195.

GOBBI, S., BERTOLO, G., MAESTRELLI, A. and TORREGGIANI, D. 2006. High quality sweet organic cherry ingredients by osmotic dehydration before freezing: the primary importance of cultivar. In *Proceedings of the Joint Organic Congress*, May 30–31, 2006, Odense, Denmark (C.B. Andreasen, L. Elsgaard, S. Søndergaard and G. Hansen, eds.).

GORI, L.M., CROZZA, D.E. and PAGANO, A.M. 2009. Desarrollo de ingeniería de proceso para la deshidratación de frutas (ciruelas President). Parte 1: Estudio experimental del proceso combinado de ósmosis y secado por aire caliente. In *Acta del II Congreso Latinoamericano de Ingeniería y Ciencias Aplicadas "CLICAP 2009"*, March 18-2, 2009, San Rafael, Mendoza, Argentina (A. Ordónez Yapur, ed.) 7 pages.

IBITWAR, B.B., KAUR, B., ARORA, S. and PATHARE, P.B. 2008. Osmo-convective dehydration of plum (*Prunus salicina L.*). [11] Int. J. Food Eng. *4*, ••–••. Article 5.

ISPIR, A. and TOGRUL, I.T. 2009. Osmotic dehydration of apricot: Kinetics and the effect of process parameters. Chem. Eng. Res. Dev. *87*, 166–180.

KHOYI, M.R. and HESARI, J. 2007. Osmotic dehydration kinetics of apricot using sucrose solution. J. Food Eng. *78*, 1355–1360.

KONOPACKA, D., JESIONKOWSKA, K., KLEWICKI, R. and BONAZZI, C. 2009. The effect of different osmotic agents on the sensory perception of osmo-treated dried fruit. J. Hort. [12] Sci. Biotech. ••, 80–84. ISAFRUIT Special Issue.

[13] KOOCHEKI, A. and AZARPAZHOOH, E. 2010. Evaluation of mass exchange during osmotic dehydration of plum using response surface methodology. Int. J. Food Prop. *13*, 155–166.

MAGEE, T.R.A., MURPHY, W.R. and HASSABALLAH, A.A. 1983. Internal mass transfer during osmotic dehydration of apple slices in sugar solution. Irish J. Food Sci. Technol. *7*, 147–155.

MOTA, R.V. 2005. Avaliação da qualidade físico-química e aceitabilidade de passas de pêssego submetidas à desidratação osmótica. Ciênc. Tecnol. Aliment. *25*, 789–794.

PANAGIOTOU, N., KARATHANOS, V.T. and MAROULIS, Z.B. 1998. Mass transfer modeling of the osmotic dehydration of some fruits. Int. J. Food Sci. Technol. *33*, 267–284.

RAOULT-WACK, A.L. 1994. Recent advances in the osmotic dehydration of foods. Trends Food Sci. Technol. *5*, 255–260.

RIVA, M., CAMPOLONGO, S., LEVA, A.A., MAESTRELLI, A. and TORREGGIANI, D. 2005. Structure-property relationships in osmo-air-dehydrated apricot cubes. Food Res. Int. *38*, 533–542.

RODRÍGUEZ, A. and MASCHERONI, R.H. 2012. Generalized correlations for characteristic variables and thermophysical properties of osmotically dehydrated fruits. Drying Technol. *30*, 1323–1331.

RODRÍGUEZ, M.M., MASCHERONI, R.H. and PAGANO, A.M. 2010a. Dehydration of nectarines (*Prunus persica var. nectarine*) in concentrated osmotic agents in combination with hot air drying. In *IDS 2010, Vol. C, Section XI, Drying of Food and Agricultural Products, Proceedings of IDS 2010*, Oct. 3–6 2010, Magdeburg, Germany (E. Tsotsas, T. Metzger and M. Peglow, eds.) pp. 1415–1422. [14]

RODRÍGUEZ, M.M., GORI, L.M., MASCHERONI, R.H. and PAGANO, A.M. 2010b. Modeling of dehydration kinetics of European plum (*Prunus domestica L.*) by combined methods. In IDS 2010, Vol. A, *Section II, Fundamentals, Modeling, Simulation, Proceedings of IDS 2010*, Oct. 3–6, 2010, Magdeburg, Germany (E. Tsotsas, T. Metzger and M. Peglow, eds.) pp. 594–600.

RODRÍGUEZ, M.M., ARBALLO, J.R., CAMPAÑONE, L.A., COCCONI, M.B., PAGANO, A.M. and MASCHERONI, R.H. 2013. Osmotic dehydration of nectarines: Influence of process variables and determination of the effective diffusion coefficients. Food BioProcess Technol. *6*, 2708–2720.

SAHARI, M.A., SOUTI, M. and EMAM-JOMEH, Z. 2006. Improving the dehydration of dried peach by osmotic method. J. Food Technol. *4*, 189–193.

SERENO, A.M. 2000. Thermal properties and state diagrams of fruits and vegetables by DSC. In *Trends in Food Engineering* (•• ••, ed.) pp. 77–88, Technomic Pub. Co, ••. [15]

SHARMA, K.D. and LAL KAUSHAL, B.B. 1999. Mass transfer during osmotic dehydration and its influence on quality of canned plum. J. Sci. Ind. Res. *58*, 711–716.

SINGH YADAV, B., YADAV, R.B. and JATAIN, M. 2012. Optimization of osmotic dehydration conditions of peach slices in sucrose solution using response surface methodology. J. Food Sci.Technol. *49*, 547–555.

SPIAZZI, E.A. and MASCHERONI, R.H. 1997. Mass transfer model for osmotic dehydration of fruits and vegetables- I. Development of the simulation model. J. Food Eng. *34*, 387–410.

TARHAN, S. 2007. Selection of chemical and thermal pretreatment combination for plum drying at low and moderate drying air temperatures. J. Food Eng. *79*, 255–260.

TOCCI, A.M. and MASCHERONI, R.H. 1998. Determinación de capacidad calorífica. entalpía y densidad de melón, kiwi y durazno deshidratados osmóticamente. In *II Congreso Iberoamericano de Ingeniería de Alimentos, Tecnologías para el procesamiento y conservación de alimentos, paper II. 28*, March 24–27, 1998, Bahía Blanca, Argentina (Universidad Nacional del Sur, ed.).

TOCCI, A.M. and MASCHERONI, R.H. 2008. Some thermal properties of fresh and osmotically dehydrated kiwifruit above and below initial freezing temperature. J. Food Eng. *88*, 20–27.

TORREGIANI, D. 1993. Osmotic dehydration in fruit and vegetable processing. Food Res. Int. *26*, 59–68.

TORRES, J.D., CASTELLÓ, M.L., ESCRICHE, I. and CHIRALT, A. 2008. Quality characteristics, respiration rates, and microbial stability of osmotically treated mango tissue

(*Mangifera indica L.*) with or without calcium lactate. Food Sci. Technol. Int. *14*, 355–365.

[16] URFALINO, D.P. and QUIROGA, A. 2011. Desarrollo de técnicas combinadas de secado para la obtención de duraznos deshidratados con bajo contenido de sulfitos. RIA *37*, 165–171.

VELOSO, M., NUÑEZ, M., PÉREZ DE VILLARREAL, A. and PAGANO, A.M. 2013. Deshidratación osmótica combinada de ciruela europea (*Prunus domestica* L.) utilizando como agentes miel de abejas y sacarosa: Optimización múltiple del proceso. In *Actas del XIV Congreso Argentino de Ciencia y Tecnología de Alimentos*, Oct 23–25, 2013, Rosario, Argentina (Asociación Argentina de Tecnólogos Alimentarios, Buenos Aires, ed.).

YU, L. 1998. *Osmotic-air dehydration of cherries and blueberries*. Master in Science Thesis, University of Manitoba, Winnipeg, Manitoba.

AUTHOR QUERY FORM

Dear Author,

During the preparation of your manuscript for publication, the questions listed below have arisen. Please attend to these matters and return this form with your proof.

Many thanks for your assistance.

Query References	Query	Remarks
1	AUTHOR: Please provide fax number for the corresponding author.	
2	AUTHOR: Please check and confirm if all headings were set correctly.	
3	AUTHOR: Please specify whether Rodríguez *et al*. 2010 is 2010a or 2010b throughout the article.	
4	AUTHOR: Singh *et al*. 2012 has been changed to Singh Yadav *et al*. 2012 to match the Reference List. Please confirm that this is correct.	
5	AUTHOR: Please supply the town or city for Gallenkamp, U.K.	
6	AUTHOR: Please supply the town or city for Bellingham & Stanley Ltd, U.K.	
7	AUTHOR: Sereno 2004 has been changed to Sereno 2000 to match the reference list. Please confirm that this is correct.	
8	AUTHOR: Panagiotou 1998 has been changed to Panagiotou *et al*. 1998 to match the Reference List. Please confirm that this is correct.	
9	AUTHOR: Reference Azuara *et al*. 1992 has not been cited in the text. Please indicate where it should be cited; or delete from the Reference List.	
10	AUTHOR: Reference Bertolo *et al*. 2001 has not been cited in the text. Please indicate where it should be cited; or delete from the Reference List.	
11	AUTHOR: Please supply page range for Reference Ibitwar *et al*., 2008.	
12	AUTHOR: Please supply the volume number for Reference Konopacka *et al*., 2009.	
13	AUTHOR: Reference Koocheki and Azarpazhooh 2010 has not been cited in the text. Please indicate where it should be cited; or delete from the Reference List.	
14	AUTHOR: More than one reference shares the same author and year-of-publication details (Rodríguez *et al*. 2010). Please check that they have been correctly differentiated between using a and b after the year of publication.	
15	AUTHOR: Please supply the Editor name and the city location of publisher for Reference Sereno, 2000.	
16	AUTHOR: Reference Urfalino and Quiroga 2011 has not been cited in the text. Please indicate where it should be cited; or delete from the Reference List.	