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Variation in Fruit Constituent Sugar Concentrations and their Stability during Processing of Selected Genotypes in *Prunus domestica*

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Abstract

The *Prunus domestica* breeding program at the University of California, Davis has several selections which produce fruit that many processors find difficult to dry, sort, rehydrate, and pit using current processing machinery. Unlike the commercial 'Improved French' cultivar, UC Davis breeding program germplasm selections have highly variable ratios of various sugar constituents. The goal of this project was to determine if the different ratios of soluble sugars and sorbitol correlate with difficulties in processing. Thus, the objectives of this research were to select cultivars with distinctly different sugar profiles and then determine what changes in sugar and sorbitol concentrations occur as the fresh fruit is dried and subsequently processed. This research could help determine what sugar ratios in plums are preferential for industrial processing. Based on previously published information, it was anticipated that sucrose would more readily hydrolyze during drying and processing than sorbitol and that higher concentrations of sorbitol would be more stable and potentially act as a preservative, inhibiting degradation of sucrose and reducing sugars. In 2010 and 2011, fruit of 17 and 10 prune genotypes, respectively, were analyzed for glucose, fructose, sucrose, and sorbitol concentrations before and after drying. In 2011, the dried fruit were also rehydrated and pitted using commercial machinery. As anticipated, sucrose concentrations generally decreased during drying and processing while glucose, fructose, and sorbitol concentrations remained relatively stable. There was no apparent concentration-related preservative effect of sorbitol on the other sugars, however the rate of change in fructose and glucose differed among cultivars. The change in sugar profiles from fresh to dried was much greater than the change from dried to processed. Additionally, sugar profiles of the ten genotypes dried in both years were consistent between years.

The *Prunus domestica* cultivar development program at the University of California, Davis, was established in 1985 with the support of the California Dried Plum Board. The program was initiated to develop new European plum cultivars which produce fruit with characteristics similar to the industry standard, 'Improved French'. Currently, California produces about 160,000 metric tons, 60% of the world market and 99% of the US market of dried plums, often called prunes (California Dried Plum Board, 2013). The California industry has over 24,000 hectares and is essentially composed of one cultivar, 'Improved French'. The industry's monocultural structure is a potential problem if catastrophes related to weather and/or disease were to occur.

Dried plum processing in California involves harvesting with mechanical trunk shakers and partially drying the fruit for 20 to 25 hours at 74 °C to change the moisture content from about 80% to approximately 20%. Processing includes rehydration of the dried fruit in steam for 12-20 minutes until it reaches ~32% moisture. After rehydrating, the fruit is pitted with a machine that uses a metal probe to punch out the pit and potassium sorbate is applied as a preservative. In some large processing facilities, the prunes are put through multiple machines for sizing, pitting, steaming and bagging.

In the past three decades, the UCD breeding program has produced several high qual-

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ity candidate prune selections for production in California, but most have had problems enduring commercial handling procedures. A current obstacle for the program is predicting which selections will be able to withstand commercial processing.

The four major soluble carbohydrates found in prune fruit and examined in this research are glucose, sucrose, fructose, and sorbitol. Different ratios of these three sugars and one sugar alcohol can greatly influence fruit taste. Fructose is three times sweeter than sorbitol, 2.3 times sweeter than glucose, and 1.7 times sweeter than sucrose (Genard et al., 2003). Additionally, these soluble carbohydrates vary in their susceptibility to degradation and caramelization upon heating. Sucrose can hydrolyze upon heating, producing glucose and fructose (Wilford et al., 1997). Thus, since drying involves heating, sucrose in fresh fruit can hydrolyze during dehydration and increase the concentrations of fructose and glucose which are the reducing sugars (Stacewicz-Sapuntzakis et al., 2001). These reducing sugars are the main ingredients in non-enzymatic browning, also called the Maillard Reaction or MR (Fayle and Gerrard, 2002). Reducing sugars in French 'd'Agen' prunes decrease less when the fruit is dried at 70 °C rather than 80 °C, suggesting that using lower temperatures during drying helps reduce sugar degradation and caramelization (Wilford et al., 1997). Sorbitol sugar alcohol is not a reactant molecule in the MR because it does not have the necessary carbonyl group. Thus, fruit with high sorbitol concentrations exhibit less browning during dehydration. However, upon drying, when water loss is ~ 60% and the temperature is high, sorbitol reportedly also undergoes some caramelization (Wilford et al., 1997).

Sorbitol is a sugar alcohol unique to the Rosaceae family, and sorbitol and sucrose are the major components involved in translocation of carbohydrates in the phloem as it moves from leaves to fruit (Seymour et al., 1993; Layne and Bassi, 2008). In *Prunus* sp. fruits, sorbitol moves into the fruit and is either stored or is metabolized to glucose and fructose by sorbitol oxidase and sorbitol dehydrogenase, respectively (Layne and Bassi, 2008; Kim et al. 2015). A review of sugar compositions of Rosaceae fruits from eight sources, indicates that *P. domestica* fruit contain much higher sorbitol concentrations than most other Rosaceae genera and fruits of other *Prunus* species (Richmond et al., 1981; Van Gorsel et al., 1992).

Sorbitol is a desirable consumer product because of its digestive benefits and low glycemic index (Stacewicz-Sapuntzakis et al., 2001). It is also non-cariogenic, meaning that it does not promote tooth decay (Dried Plum Board, 2013). High-sorbitol fruit provides consumers with a natural laxative and sweet flavor (Stacewicz-Sapuntzakis et al., 2001). Fruit with a low glycemic index are particularly attractive in diabetic-friendly diets. It is ironic that while plums have a uniquely beneficial sugar profile, "in general, plums have attracted the curiosity of biochemists to a remarkably small degree" (Seymour et al., 1993).

We suspect that sorbitol is an important factor in determining fruit process-ability and how the sugars react to heat. It is thought to act as a preservative, a humectant, and a preventative against excessive fruit browning (Cinquanta et al., 2002; Forni et al., 1992). Adding sorbitol before dehydration preserves functional protein properties in egg (Yoo and Lee, 1993). Forni et al. (1992) stressed that the sorbitol concentration in a plum should be a factor in determining suitability for drying and processing, because sorbitol does not degrade in the MR like glucose and fructose.

During this research, other questions arose concerning yearly variation in soluble solids content. Information from private prune processors suggested that differences in sugar concentrations of 'Improved French' occur from year to year (Steve Rasmussen, personal communication). Similarly, Brooks et al. (1993) reported a significant difference in total soluble solids between two different

years in *P. persica* (L.) Batch germplasm. However a different, three-year study found no significant differences in fructose and sorbitol concentrations in *P. persica* among years (Cantin et al., 2009). The same study noted that while environmental conditions often influence sugar concentrations, the sugar profile of sucrose, glucose, fructose and sorbitol are relatively constant across environments. One aspect of this study was to test if sugar profiles remained relatively constant when sugar concentrations changed by year.

The UCD plum breeding program relies on a very diverse germplasm to produce a wide array of fruit characteristics. Its selections produce fruit that are superior to 'Improved French' in traits such as flavor, fruit size, small pit size, strong pit, field heat tolerance, and fresh to dry fruit ratios (DeJong et al., 2011 and DeJong et al., 2012). However, many of the new selections produce fruit that does not remain intact during processing. Prune cultivars are known to vary in total sugar content and the relative proportions of the four major sugars (Wrolstad and Shallenberger, 1981; Forni et al., 1992; Seymour et al., 1993). Therefore, we suspected that there are substantial variations in constituent sugars among selections in the UCD breeding program, although the sugar ratios of fruit from the germplasm and active selections had not previously been tested. Preliminary sugar analyses showed that the superior-flavored genotypes had different sugar and sorbitol ratios than 'Improved French', and often also did not withstand processing well.

The overall goal of this project was to determine whether differences in sucrose, glucose, fructose, and sorbitol ratios were correlated with a fruit's ability to withstand processing. We first characterized the constituent sugars in fruit from multiple selections. Next, we determined how the different sugars reacted to heat during drying and processing. Finally, we determined if initial sugar concentration ratios were correlated with the amount of change that occurred in the sugar profile during drying, and the processing durability of the fruit. This project also determined what sugars degrade upon drying to 20% moisture and during subsequent partial rehydration to 30% moisture and processing, and whether high sorbitol concentrations influence the degradation of reducing sugars. We expected sucrose concentrations to decrease substantially during heating due to hydrolysis and that fructose and glucose concentrations would remain relatively stable or increase, since sucrose hydrolysis produces fructose and glucose. The loss of fructose or glucose would depend on the extent of their involvement in the MR or browning. Just as sorbitol can retain properties of proteins (Yoo and Lee, 1993), we anticipated that sorbitol might inhibit breakdown of reducing sugars. Thus, we hypothesized that plums with higher fresh sorbitol concentrations would lose less glucose, fructose, and sucrose than plums with lower sorbitol concentrations.

Materials and Methods

The experiments were conducted over two years (2010 and 2011). In 2010, we determined sugar concentrations in fresh and dried fruit from 17 plum genotypes. In 2011, we examined fresh, dried and processed fruit of ten genotypes: nine selected from among the original 17 and one additional genotype that was suspected of having an unusually high sorbitol concentration.

Fruit harvest and sampling. The trees used in this experiment were grown in one of two experimental plum blocks, one in Fresno County, CA, and the other in Solano County, CA. Both orchards were managed with semi-conventional farming methods, with foliar fertilization, winter pruning, irrigation, and pest control methods such as herbicide and dormant oil sprays. Fruit were harvested from trees that were five to eight years old. Trees were propagated by planting rootstocks, then top-grafting scions onto the base of each scaffold in the second or third year after planting the rootstocks. In both years, fruit was harvested when the average fruit

pressure was 3 to 4 PSI. In 2010, two boxes of fruit from one tree of each genotype were harvested: ~ 20 to 27 kg of fresh fruit. Ten fruit were randomly selected from the bulk sample for fresh sugar analysis. The remainder of the fruit was dried.

In 2011, fruit from nine genotypes were harvested from the same trees as in 2010, along with several other trees of the same genotypes located in the experimental blocks. Fruit from one additional genotype were also harvested. The genotypes harvested were chosen on the basis of the sugar profiles determined in 2010 and whether there would be enough fruit to send through commercial prune processing equipment. Twenty-seven to 46 kg fruit were harvested from each genotype. Fresh fruit sugar analysis was conducted on three randomly selected subsamples of ten fruit each from each of the ten genotypes. After the fruit were dried, three 10-fruit subsamples of each genotype were again randomly selected for dried sugar analysis and the rest were processed using commercial machinery. Three more 10-fruit subsamples of processed fruit from each variety were also analyzed for sugar contents.

Fresh Juice Preparation. The fresh fruit juice preparation in 2010 and 2011 was the same except for the numbers of subsamples and genotypes tested. From the 10-fruit sample or subsample, 10 fruit slices were blended in a standard food blender. The resultant juice was strained from the flesh using cheesecloth mesh and centrifuged at 4°C at 17,000 × g for 10 min. The clarified supernatant was removed and submitted to the UCD Analytical Lab for high-performance liquid chromatography (HPLC) sugar analysis as described by Richmond et al., (1981).

Dried Fruit Preparation. In 2010 and 2011, the remainder of the fresh fruit that was not used for fresh sugar analysis was dried in a Harvest Saver R-4 dehydrator (Commercial Dehydrator Systems, Inc., Eugene, OR). Fruit from each genotype was dried for 20 to 25 hr at 73.8 °C to ~ 20% moisture. The dried fruit was separated according to screen size according to industry practice. Screen sizing used screens with specific sized holes to sort dried fruit by size. The largest A screen designation separated fruit with a dried mass of 9.07 grams or larger.

Three 10-fruit subsamples from each genotype were selected from the A screen or larger for sugar analysis. In both years, fruit flesh and skin were removed from the pit and ground in liquid nitrogen to obtain a homogenous sample. The ground dried flesh was then submitted to the UCD Analytical Lab for sugar and sorbitol profiling. In 2011, when more than one tree was harvested per genotype, each tree was tested separately. Thus, if two trees were harvested for a specific genotype, six subsamples were taken for that genotype, three from each tree.

Analysis of Processed Fruit. In 2011, the dried fruit remaining after sampling for sugar analysis were combined to create one large dried fruit sample for each genotype. The bulk samples were then sent through conventional processing machinery at Taylor Brothers Farms (Yuba City, CA). Processing consisted of a high-pressure steam bath for 12 minutes followed by pitting in a PP prune pitter (Ashlock Company, San Leandro, CA) and a spray application of 50% potassium sorbate sufficient to coat each fruit. Potassium sorbate is used by the prune industry to prevent growth of mold and yeast. The fruit was then stored in sealed plastic bags for several weeks to allow the moisture to equilibrate. Subsequent to storage three 10-fruit subsamples per genotype were tested for sugars as explained above.

Data Analysis. The sugar concentrations provided by the UCD Analytical Lab were on a "percent of a given sample" basis. Values were normalized according to their respective sample sizes to provide fresh weight (FW) concentrations of g/100g. The term FW is used to describe the fruit at a non-100% dry weight basis, for example: 80% moisture juice; 20% moisture dried fruit; or 30% moisture processed fruit.

Results and Discussion

2010 Fresh Sugar Analysis. Both the total sugars and the ratios between glucose, fructose, sucrose, and sorbitol varied substantially among fruit from different genotypes (Table I). 'Improved French', the primary prune cultivar grown in California, had the most sorbitol. Interestingly, 'Sutter' had relatively high sorbitol concentrations but even higher sucrose concentrations; this cultivar

Table 1. Total sugar and proportions of glucose, fructose, sucrose, and sorbitol in 17 genotypes of fresh (FW) and dried plum (FW) in 2010.

Variety	Fruit State	Fresh Glucose (g/100g)	Fresh Fructose (g/100g)	Fresh Sucrose (g/100g)	Fresh Sorbitol (g/100g)	Total Sugars[y] (g/100g)
Imp. French	Fresh	7.40	2.30	5.10	7.30	22.10
	Dried[z]	23.10	10.30	3.28	23.98	60.70
Sutter	Fresh	5.50	1.90	9.80	6.40	23.60
	Dried[z]	17.77	10.83	12.40	18.80	59.80
Muir Beauty	Fresh	4.30	1.60	9.60	4.80	20.30
	Dried[z]	17.10	10.37	14.10	17.77	59.30
D6N-103	Fresh	6.90	3.10	4.00	4.60	18.60
	Dried[z]	23.93	12.57	4.33	17.73	58.60
D2N-76	Fresh	6.30	2.10	4.70	5.70	18.80
	Dried[z]	20.93	10.17	3.63	20.90	55.60
D18S-12	Fresh	3.40	1.20	5.10	4.30	14.00
	Dried[z]	14.27	7.27	14.47	20.70	56.70
F9N-21	Fresh	6.00	2.60	3.30	4.90	16.80
	Dried[z]	24.27	12.63	2.00	22.47	61.40
F13S-46	Fresh	4.00	1.20	8.30	4.70	18.20
	Dried[z]	19.83	10.40	12.37	17.20	59.80
F13N-24	Fresh	3.30	1.60	6.80	4.90	16.60
	Dried[z]	18.07	11.17	6.20	18.67	54.10
G3S-2	Fresh	5.30	2.60	6.50	3.60	18.00
	Dried[z]	19.63	12.50	11.70	14.37	58.20
D10S-8	Fresh	5.00	1.90	6.20	5.90	19.00
	Dried[z]	20.23	11.23	9.57	18.63	59.70
F2N-32	Fresh	9.60	4.70	3.80	4.50	22.60
	Dried[z]	22.33	11.43	8.10	14.90	56.80
Sugar	Fresh	6.00	2.20	4.70	4.70	17.60
	Dried[z]	24.90	13.13	0.40	18.57	57.00
Burton	Fresh	4.00	1.30	5.70	3.50	14.50
	Dried[z]	18.07	8.50	14.67	14.37	55.60
3-8E-46RR	Fresh	4.40	2.60	4.00	5.00	16.00
	Dried[z]	17.67	13.10	0.27	17.67	48.70
F11N- 27	Fresh	3.10	1.60	13.40	6.40	24.50
	Dried[z]	11.87	7.80	23.17	16.73	59.60
E6S-12	Fresh	4.60	1.70	13.00	5.00	24.30
	Dried[z]	16.83	10.27	27.17	10.17	64.40

[z] n=3

[y] Sum of glucose, fructose, sucrose and sorbitol

was discovered to have problems withstanding rough handling during drying and processing a few years after its release in 2000. The Glu/Fru ratio has been widely used as a taxonomic trait and the ratios among the genotypes in this study were similar to other reports (vanGorsel et al., 1992; Wrolstad and Shallenberger, 1981). The Glu/Fru ratios ranged from 1.69 ('3-8E-46RR') to 3.33 ('F13S-46'), within the range of 0.9 to 4.1 reported for Rosaceous species in general.

2010 Dried Fruit Sugar Analysis. As expected, the concentrations of sugars in the dried fruit samples were approximately three times greater than the concentrations in the fresh fruit, reflecting water loss during drying (Table I). However, fresh and dried fruit sugar ratios changed upon dehydration. For example, sucrose in 2-8E-46RR went from 4.0 g/100g in the fresh fruit to 0.27 g/100g in the dried fruit, despite the water content in the fruit decreasing by 60%. This suggests that sucrose was indeed hydrolyzed into glucose and fructose. There was a consistent slight decrease in the Glu/Fru ratio from fresh to dried across all genotypes, thus suggesting that fructose degraded faster than glucose.

2011 Fresh, Dried, and Processed Fruit Sugar Analysis. The fresh weight (FW) sugar concentrations normalized to a fresh weight basis for fresh, dried, and processed fruits from ten plum genotypes in 2011 are shown in Table 2. FW Sugar concentrations increased from fresh to dried and decreased slightly from dried to processed due to the decrease in water content upon drying and increase upon processing rehydration. In 2011, the total sugars (the sum of glucose, fructose, sucrose, and sorbitol) were generally lower than in 2010. An extreme example was FW fresh juice of 'Muir Beauty' which had 20.3 g total sugars/100 g in 2010, but only 14.5 in 2011. The difference between years varied with the variety; e.g. fresh juice of 'F13N-24' had a less extreme difference of 16.6 g total sugars/100 g in 2010 and 15.8 in 2011. Except for 'F9N-21', total sugars were lower in 2011 than in 2010. The genotypes with the most sorbitol, 'F9N-21', 'D2N- 76', 'F13N-24', 'D13N-53'and 'Improved French', were highest in both years. Similarly, the genotypes with low sorbitol were consistently low in both years. For example, 'E6S- 12' had the least sorbitol and most sucrose. As with sorbitol, the genotypes with the most sucrose were consistent in both years ('E6S-12', 'Muir Beauty', 'D10S- 8', and 'F13N-24'). Due to the loss of water, a majority of the high fresh juice sucrose genotypes gained in g/100g of sucrose upon dehydration. Despite the drastic decrease in water, low sucrose items had a decrease in sucrose when going from fresh to dried to processed. More specifically, the 4 genotypes with some of the lowest sucrose, 'D6N-103', 'Improved French', 'F9N-21' and 'D2N-76' had some of the largest changes in the ratio between sorbitol and sucrose between fresh and processed fruit. The sum of reducing sugars changed very little in relationship to the sorbitol from fresh to dried to processed. Apparently the sucrose lost in hydrolysis was compensated for by the increase in glucose and fructose. Despite the change in water status, the various genotypes had consistent sugar proportions as fruit were dried and processed. The sugar with the most variation between fresh and processed fruit was sucrose while fructose exhibited the least variation.

For a more uniform sugar comparison, the moisture in each fruit type was subtracted from the sugar concentrations to determine an estimated molar sugar concentration in 100% Dry Weight (DW) fruit. There were substantial variations in soluble solids among genotypes. The fresh juice of 'E6S-12' had the most sucrose and least sorbitol, glucose, and fructose while F9N- 21 had the highest amount of sorbitol. Even on a DW basis, the concentrations of sugars changed from fresh to dried: glucose and fructose increased, sucrose decreased, while sorbitol remained relatively stable. The sugars changed independent of each other and there was little correlation between changes in sugars and initial sorbitol concentrations (Fig. 1). The

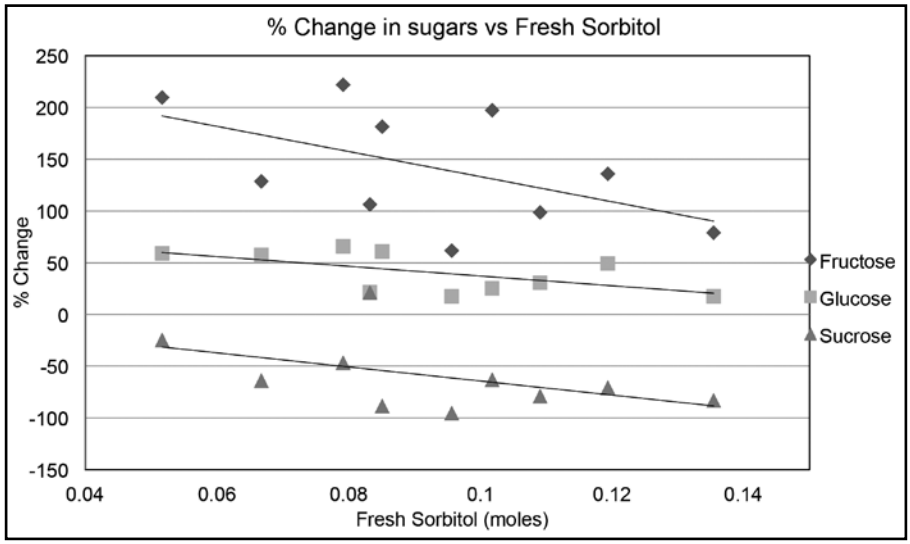

Fig. 1: Correlation between percent change in reducing sugars from fresh to processed fruit and fresh fruit sorbitol concentration in 2011. R squared values were R^2=0.2804, R^2=0.3516 and R^2=0.233 for fructose, glucose and sucrose respectively.

change in DW molar sugar concentrations from dried to processed fruit in 2011 was much smaller than the change observed from fresh to dried fruit in both years. This was not surprising, since fruit experienced just 15 minutes of heat during processing compared to 20 hours during drying. In general, processing increased fructose concentrations and decreased sucrose concentrations. The sorbitol and glucose concentrations changed least and no pattern was detected.

The total molar DW of sugars of most genotypes increased as the fruit went from fresh to dried to processed, independent of the initial ratio. 'E6S-12' and 'Improved French', with the highest and lowest sucrose to sorbitol ratios, respectively both had increased total sugars after drying and processing. Since no additional sugar was added at any time during this experiment, it is possible that upon dehydration and rehydration some other non-sugar, non-water part of the fruit also degraded. If so, calculating sugar concentrations from percentages could give the illusion that the sugar is increasing when instead other parts of the fruit are being lost. Plum fruit does release volatile compounds through enzymatic reactions when heated (Stacewicz-Sapuntzakis et al., 2001). The disappearance of certain phenolic compounds from *P. domestica* upon drying has been reported (Raynal et al., 1989). Sabarez et al. (2000) identified changes in volatiles that occur in prunes during dehydration due to MR and/or caramelization.

The fruit quality of the processed fruit was different according to the genotype. Despite this, there was no direct correlation between processing quality and sugar profiles. Fruit size, flesh texture and skin thickness are all factors that might influence processing as much as high sorbitol. The fresh flesh texture and skin thickness are two influential factors in processing tolerance that need to be addressed in future research.

Sorbitol and sucrose effects on sugar changes. The soluble solid ratios changed during dehydration and processing as sucrose likely hydrolyzed and created more glucose and fructose. Glucose and fructose were also likely degraded in the MR, but the actual rate of degradation was impossible to

quantify in this study since the breakdown of sucrose likely added more reducing sugars at the same time. Contrary to expectations, high sorbitol fruit concentrations did not seem to inhibit sugar degradation. Under the conditions of this experiment, high fresh fruit sorbitol concentrations had little to no influence on sucrose hydrolysis during drying and processing and fruit with low sorbitol concentrations exhibited less change in sucrose concentrations between fresh and processed fruit (Fig. 1). Another surprise was the greater variability in the percent change in fructose than in glucose between fresh and processed fruit. There was an apparent positive correlation between fresh fruit sucrose concentration and the change in fructose during processing (Fig.2). This is especially interesting because a similar relationship was not observed with the other reducing sugar, glucose. This suggests that glucose may be more susceptible to the Maillard reaction than fructose or that more fructose than glucose is produced when sucrose is hydrolyzed. The greater changes in fructose may correspond with the differences in observed changes from dried to processed fruit. Fructose consistently increased during rehydration while glucose did not.

The 17 California selections that were tested in 2010 had slightly different sugar concentrations than 15 previously tested European cultivars (Forni et al., 1992). The European cultivars had total sugars ranging from 9.3% to 26.6%. The total sugars reported here for California cultivars in 2010 ranged from 19.9% to 33.0% (Table 2). The same cultivars often produce fruit with higher sugar in California's climate than when grown elsewhere in the U.S. or in Europe. The cultivar 'Sugar', common to both studies, produced 11.28 g total sugars /100 g in Europe but 17.6 g total sugars/100 g in California (Table I). In both studies, glucose was 34% of the total sugars in this cultivar. Fructose, sucrose, and sorbitol were 8.3%, 41.5%, and 16.0% of total sugars in Europe, respectively, but 12.0%, 26.7% and 26.7%, respectively, in California. These data, along with the 2010 and 2011 comparison of genotypes, suggest the relative sugar makeup of a plum fruit genotype is consistent among years and environments. There was greater variability in the specific fruit sugar ratio between European and California cultivars. The European cultivars had higher sucrose and glucose concentrations than fructose and sorbitol. In

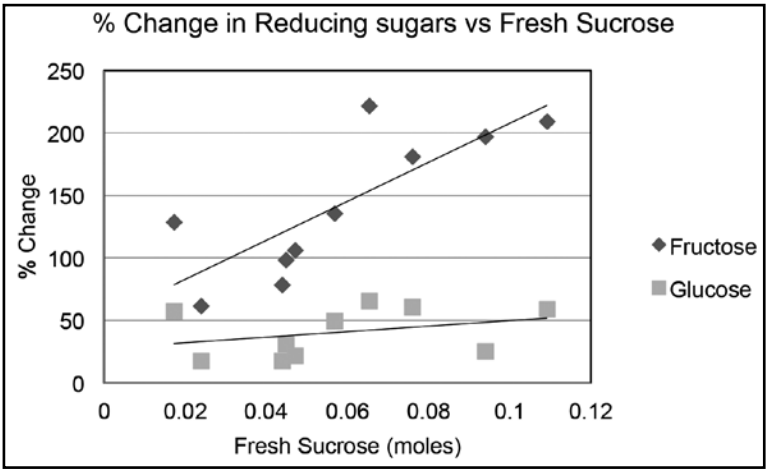

Fig. 2: Correlation between percent change in reducing sugars from fresh to processed fruit and fresh fruit sucrose concentration in 2011. R squared values were R^2=0.6321, R^2=0.1063 for fructose, and glucose respectively.

Table 2. Fruit sugar composition dry weight (DW) concentrations in fresh, dried and processed plums from 10 genotypes in 2011. Concentrations were calculated from the percentage of estimated DW.

Genotype	Fruit type	Glucose		Fructose		Sucrose		Sorbitol	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Muir Beauty	Fresh Juice	20.17	0.46	5.49	0.15	32.16	0.54	18.53	0.64
	Dried	23.01	0.31	12.47	0.19	14.86	0.56	18.35	0.75
	Processed	25.89	0.48	16.7	0.13	12.21	1.33	18.54	0.76
F9N-21	Fresh Juice	26.17	0.67	8.80	0.23	15.02	0.65	24.66	0.72
	Dried	29.81	0.78	13.70	0.23	3.23	0.49	24.20	0.59
	Processed	31.24	1.28	15.95	0.42	2.57	0.72	25.86	0.30
D2N-76	Fresh Juice	22.06	0.62	7.26	0.12	15.33	1.00	19.86	1.20
	Dried	27.83	0.37	12.55	0.40	4.47	0.44	23.11	0.75
	Processed	29.26	0.73	14.63	0.17	3.25	0.48	23.40	0.15
D10S-8	Fresh Juice	17.93	0.67	6.54	0.43	16.11	1.76	15.15	0.78
	Dried	22.73	0.29	14.13	0.12	19.79	1.35	16.18	0.29
	Processed	22.11	1.83	13.70	0.96	19.77	4.62	16.69	1.73
F13N-24	Fresh Juice	15.46	0.72	6.66	0.32	19.46	0.59	21.73	1.18
	Dried	21.31	0.40	13.15	0.31	9.13	0.80	25.40	1.63
	Processed	23.47	0.52	15.95	0.47	5.79	0.40	23.66	1.06
Imp. French	Fresh Juice	19.83	0.71	7.47	0.28	5.91	0.86	12.15	1.38
	Dried	31.88	0.30	13.70	0.16	2.06	0.37	18.18	0.82
	Processed	31.70	0.35	17.34	0.87	2.17	0.08	23.94	1.19
D6N-103	Fresh Juice	29.69	0.90	11.59	0.73	8.18	1.13	17.42	0.95
	Dried	34.26	0.86	16.13	0.62	1.26	0.27	17.62	0.27
	Processed	35.44	0.47	19.02	0.44	0.39	0.10	17.30	0.85
Burton	Fresh Juice	15.36	0.84	4.56	0.45	22.39	1.021	14.42	1.21
	Dried	23.83	0.81	12.51	0.59	12.44	1.41	17.76	1.00
	Processed	25.87	0.74	14.93	0.63	12.16	1.36	18.72	0.96
E6S-12	Fresh Juice	12.84	0.62	4.35	0.21	37.36	2.318	9.40	0.64
	Dried	18.70	0.65	10.65	0.36	28.98	1.03	11.26	0.68
	Processed	20.72	1.06	13.67	1.31	28.54	1.29	14.58	1.95
D13N- 53	Fresh Juice	19.64	6.07	7.50	2.14	16.1	4.032	21.19	7.09
	Dried	24.60	0.50	14.20	0.80	3.81	0.93	24.47	0.37
	Processed	25.84	0.05	16.60	0.25	3.03	0.13	25.32	0.62

contrast, the California genotypes were more variable: some selections had high glucose and sucrose, others had high sucrose and sorbitol, and yet others had high glucose and sorbitol (Table 1). Only one California genotype, 'F2N-32', had a greater percent fructose than sucrose.

Sugar concentrations among genotypes changed from 2010 to 2011, confirming that sugar concentrations were influenced by environment, as reported for peaches (Brooks et al., 1993; Cantin et al., 2009). Spring and summer temperatures differed substantially between the two years of the study. 2010 had a cool spring and summer, while 2011 had a very wet spring and hot summer. These factors and others like crop load could have influenced the differences in sugar concentrations in 2010 and 2011. Despite these differences, there was a positive correlation

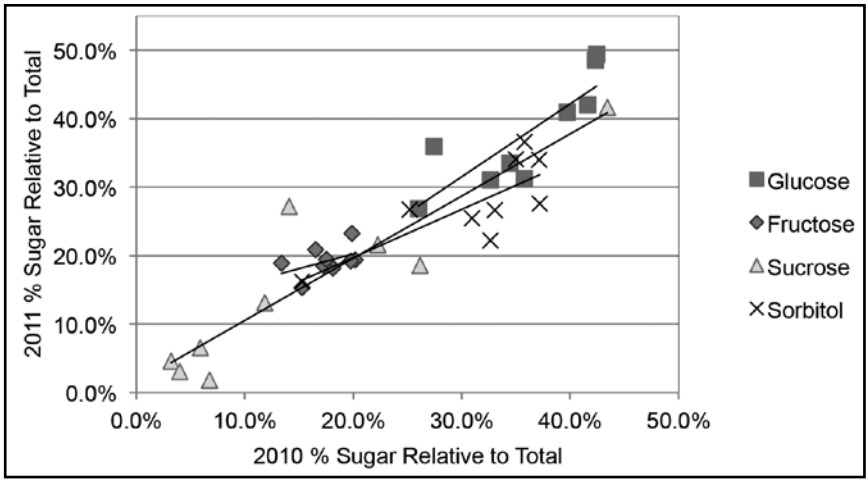

Fig. 3: Correlation between the percentages of four sugars in dried plums from nine genotypes in 2010 and 2011. Each data point is a mean of at least three subsamples.

between the data from 2010 and 2011, suggesting that the relative ratios of fruit sugars remained relatively stable from year to year (Fig. 3). This consistency can help the breeding program predict the ratio of sugars a genotype will produce under commercial cultivation. The length of the trend lines in Figure 3 also indicates the variability of each sugar type between years. For example, fructose only varied from ~ 14% to 23%, producing a very short trendline, while sucrose had a much wider variation from ~ 4% to 45%. These data on germplasm variability in specific sugars may indicate the breeding potential for increasing or decreasing different fruit sugars. For example, breeding a high-fructose fruit would be more challenging than a high-sucrose fruit because of the lower variation in fruit fructose content the germplasm.

Differences in the acidity of the plums might explain why fructose and glucose did not degrade at the same rate during processing. When heated, fructose and glucose stability is dependent on pH (Shallenberger and Mattick, 1983). Therefore, changes in sugar ratios may be influenced by fruit acidity. Fructose is most stable between pH 4 and 6, while glucose is more stable between pH 2 and 6 (Shallenberger and Mattick, 1983). Malic acid is a primary acid in fresh plums. Malic acid combined with fructose increases the tendency for fruit browning (Livingston, 1953). Fructose and glucose did not change at the same rate during processing in this experiment. It is possible that fruit pH and titratable acidity could have influenced the rates of sugar catabolism in the diverse California germplasm used in this project however details on titratable acidity at each step in the processing were not determined.

This experiment was conducted to determine what effect different sorbitol concentrations had on the other sugars within the fruit. The expectation was that genotypes with higher sorbitol concentrations would have less degradation of sucrose, fructose, and glucose when heated during drying and processing. The various concentrations of sorbitol in the tested genotypes did not affect the rates of change in sucrose, fructose, and glucose upon dehydration. Since fruit of genotypes with high sorbitol concentrations reacted during processing the same as low-sorbitol genotypes, it is not likely that sorbitol affects the rate of hydrolysis or caramelization of other fruit sugars. Sucrose hydrolyzed upon heating regardless of sor-

bitol concentration, which did influence the percent change in fructose concentration. While sorbitol did not stabilize other fruit sugars as expected, it was relatively resistant to breakdown during heating and thus was the most stable sugar compound in the fruit during processing. Thus, while high fruit sorbitol may not help stabilize other sugars during fruit processing, selecting for genotypes with high sorbitol may still increase a fruit's ability to withstand processing if the sorbitol concentration relative to that of other sugars is high. Sorbitol's known preservative qualities likely assist in other aspects of dried fruit quality.

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