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Carbohydrate Composition of Selected Plum/Prune Preparations

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Eighteen plum/prune preparations and byproducts were analyzed for proximate constituents and carbohydrate profiles. Plum puree and prune juice contained the highest concentrations of ash (13.0 and 13.8%, respectively). Crude protein (CP), acid-hydrolyzed fat (AHF), and total dietary fiber (TDF) concentrations were higher in byproducts (waste cake and dried plum pits) compared with the other fractions. Several classes of oligosaccharides were found in low concentrations in many of the substrates and were associated with the fruit rather than the pit. Maltooligosaccharides were found in very high concentrations in three of the preparations as a result of the addition of maltodextrin during processing. Monosaccharides, sugar alcohols, and oligosaccharides were found in higher concentrations in the fruit than in the pit and accounted for 2.9−84.7% of substrate organic matter. These results indicate that carbohydrates of various types constitute a significant proportion of plum/prune preparations and byproducts.

KEYWORDS: Plums; prunes; oligosaccharides; carbohydrate composition

INTRODUCTION

The concept of “functional foods” was introduced as scientists identified and defined physiologically active components in foods that provided benefit beyond their use as a source of nutrients (*1*, *2*). One such food, *Prunus domestica*, is thought to have originated near the Caucasus Mountains in the area bordering the Caspian Sea. Today, most dried plums (prunes) are the fruit of the cultivar *P. domestica* cv. d’Agen. In 1856, this cultivar was introduced into California, where 70% of the world’s dried plums are produced (*2*, *3*).

Compositionally, dried plums contain significant concentrations of nutrients and compounds associated with physiological benefits. For example, high concentrations of potassium, in conjunction with low concentrations of sodium, may ameliorate hypertension, whereas copper, boron, and calcium may aid in bone development of humans. Dried plums also contain phenolic compounds, responsible for antioxidant properties that may play a role in cancer prevention, inhibition of low-density lipoprotein oxidation, and antibiotic activity (*2*, *4*−*6*). The antioxidant properties of the phenolic compounds in dried plums have recently attracted the attention of the meat industry, by which they are used to reduce microbial growth, retain moisture, and prevent off-flavors of meat (*7*). Various carotenoids such as violazanthin, β-carotene, and lutein also have been detected in Italian dried plums (*8*).

Dried plums contain large concentrations of dietary fiber, reported to be up to 16.1 g/100 g as is (23.3% moisture fruit) (*3*). Dietary fiber and sorbitol concentrations in plum/prune preparations have been linked to enhanced regulation of blood glucose and cholesterol concentrations as well as laxation and bowel health (*2*, *9*). Diets containing 5−25% dried plums fed to hypercholesterolemic humans and rats have been successful in lowering plasma cholesterol concentrations significantly (*9*−*11*). The physiological benefits of ingested fibers are generally a result of water content alteration and changes in the viscosity and quantity of the microbial mass of intestinal contents, eliciting changes in transit time through the gastrointestinal tract.

The microbial population in the colon is responsible for fermenting undigested foods, including dietary fibers, and producing short-chain fatty acids that promote intestinal health and supply energy to colonocytes (*12*, *13*). Much research has been conducted on selective manipulation of the microflora of the intestine with the inclusion of prebiotics such as nondigestible oligosaccharides (NDO). Nondigestible oligosaccharides may create a more favorable colonic bacterial population, optimize stool characteristics, stimulate immune function, alter mineral absorption, and possibly improve glucose tolerance and lower plasma concentrations of ammonia and lipids (*14*). Limited research has elucidated certain compounds and nutrients in fresh dried plums, plums, and juices, but no information exists on the chemical composition of plum/prune preparations and byproducts, in particular, their carbohydrate composition.

The objective of this study was to analyze selected plum/prune preparations and byproducts for proximate constituents and their complete carbohydrate profile.

MATERIALS AND METHODS

Test Samples. Eighteen plum/prune preparations were obtained from the California Dried Plum Board. Five general categories were identified

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and analyzed. Group 1 consisted of powdered prune preparations, including prune powder (containing 3% calcium stearate as an anticaking ingredient), prune/pear powder, Plum Juicy 500 (powder containing mixed dried plums, pears, and apples), and spray-dried Plum Juicy 500 (spray-dried fresh plum juice with added maltodextrin and denoted SD-Plum Juicy 500). Group 2 included the juices: prune concentrate, fresh plum concentrate, and prune juice. Group 3 consisted of purees and butters including two dried plum puree substrates from different manufacturers, denoted plum puree and dried plum puree throughout this manuscript. Group 3 also contained fresh plum puree (fresh prune-making plums with added water), Lighter Bake (a prepared product used as a fat-replacer containing water with a mixed puree of dried plums and apples, dextrose, maltodextrin, and pectin), and dried plum butter (strained puree containing no skin or pits). Whole fruits including pitted prunes (non-sorbate), prunes 52/56-N/C (natural condition, pit-containing prunes, after dehydration, 50−60 count per pound), undersized plums (non-sorbate), and fresh prunes (fresh prune-making plums, not processed) comprised group 4. Group 5 contained the byproducts, dried plum pits (pits of prunes) and waste cake (the material left after the production of prune juice).

Chemical Analyses. The powdered substrates, purees, and liquids were analyzed for dry matter (DM), organic matter (OM), crude protein (CP) (*15*), and acid hydrolyzed fat (AHF) (*15*, *16*). The AHF analysis was used to determine fat concentration of the substrates because this procedure hydrolyzes and accounts for all fat associated with substrates and is, therefore, more accurate in quantifying fat concentration (*16*) than traditional crude fat analysis. As a result of product texture and to prevent losses during grinding, the whole fruits and pits were suspended in liquid nitrogen prior to grinding, followed by stabilization at room temperature until no differences in sample weight were observed.

Oligosaccharides, free monosaccharides, and free sugar alcohols were quantified via HPLC. Standards for quantification included sucrose, lactose, galactotriose, galactotetraose, cellobiose, cellotriose, cellotetraose, cellopentaose, raffinose, stachyose, verbascose, kestose, nystose, fructofuranosylnystose, maltose, maltotriose, maltotetraose, maltopentaose, maltohexaose, maltoheptaose, inulin (from chicory), and a maltosaccharide blend containing maltohexose through maltodecaose. Substrates were homogenized with water, placed in an 80 °C water bath, and incubated for 1 h. The incubation was followed by centrifugation utilizing a Centriprep with a 10000 molecular weight cutoff, and the filtrate was used for chromatographic analysis. Eluted OS and monosaccharides were quantified using a Dionex (DX-500) HPLC system consisting of an AS 50 autosampler, a GP 50 gradient pump module, and a pulsed electrochemical detector (PED), equipped with a gold working electrode. All assays were conducted using a CarboPac PA-1 column following methods cited by Smiricky et al. (*17*).

Following ethanol extraction of free sugars and subsequent drying at 57 °C, total dietary fiber (TDF) was analyzed according to AOAC (*15*) methodology. Monosaccharides associated with the TDF residue were detected after a two-step sulfuric acid hydrolysis (*18*). Monosaccharides were filtered prior to injection into a Dionex BioLC HPLC. The degassed mobile phase consisted of water with NaOH, and all eluants were purged with helium. The eluted monosaccharides were detected using a Dionex PED equipped with a gold working electrode (*19*).

Total uronic acids were quantified after subsequent reactions with sulfuric acid/tetraborate and *m*-hydroxydiphenyl reagents. The carbohydrates in the samples produced a pink chromagen that was read at 520 nm in a Beckman DU spectrophotometer following procedures previously cited by Blumenkrantz and Asboe-Hanson (*20*).

All chemical analyses were conducted in duplicate, and values were required to be within 5% of each other; otherwise, the analysis was repeated.

RESULTS

Proximate Analysis. Proximate analysis results for all substrates are presented in **Table 1**. The powdered substrates contained relatively high concentrations of DM and OM. Although SD-Plum Juicy 500 exhibited higher concentrations of DM and OM, it contained lower concentrations of CP (1.0%), AHF (0.6%), and TDF (3.9%) than the remaining three substrates in the group.

Table 1. Proximate Components of Plum/Prune Preparations and Byproducts[a]

substrate	DM, %	nutrient, % DM			
		OM	CP	AHF	TDF
powders					
prune powder	85.5	96.3	4.6	4.8	12.6
prune/pear powder	83.6	96.3	4.1	4.9	20.3
Plum Juicy 500	86.9	97.1	2.2	6.1	16.9
Plum Juicy 500 (spray-dried)	90.6	99.0	1.0	0.6	3.9
juices					
prune concentrate	61.7	96.7	3.1	1.2	6.8
fresh plum concentrate	63.0	96.9	2.9	1.6	1.6
prune juice	16.2	86.2	2.9	3.5	6.8
purees					
dried plum butter	46.0	91.7	3.0	1.5	9.7
plum puree	63.8	87.0	3.2	1.3	8.3
fresh plum puree	29.7	95.8	4.8	1.4	10.4
dried plum puree	74.4	98.1	2.2	1.1	7.0
Lighter Bake	48.8	99.1	0.4	0.8	3.3
fruits					
pitted prune	71.9	94.2	3.9	1.0	11.1
prune 52/56	76.8	96.8	4.6	1.2	11.0
undersized plums	75.2	95.6	6.2	1.6	14.5
fresh prune plums	43.0	94.8	4.7	1.1	6.3
byproducts					
waste cake	9.4	98.1	12.7	8.2	64.5
dried plum pits	90.4	98.8	8.3	10.2	78.2

[a] Abbreviations: DM, dry matter; OM, organic matter; CP, crude protein; AHF, acid-hydrolyzed fat; TDF, total dietary fiber.

Juices exhibited a wide range of DM concentrations ranging from 16.2 to 63.0% for prune juice and fresh plum concentrate, respectively (**Table 1**). Prune juice also contained a lower OM concentration (86.2%) compared with the two concentrates (96.9 and 96.7% OM for fresh plum and prune concentrates, respectively). Crude protein, AHF, and TDF concentrations for the juice substrates were low.

Large variation existed among the puree substrates for proximate constituents (**Table 1**). Dry matter concentrations of the substrates in this group varied between 29.7% for fresh plum puree and 74.4% for dried plum puree. Fresh plum puree contained the highest concentrations of CP (4.8%) and TDF (10.4%) compared with Lighter Bake, which contained the lowest concentrations of CP (0.4%), TDF (3.3%), and AHF (0.8%). The highest concentration of AHF for the puree group was observed for dried plum butter (1.5%).

Dry matter content in the four fruit substrates varied from 43.0 to 76.8% for fresh prune plums and prunes 52/56, respectively. Organic matter concentrations varied little among fruits. Pitted prunes contained the lowest concentrations of CP (3.9%) and AHF (1.0%) within this group, whereas undersized plums contained the highest concentrations of CP (6.2%) and AHF (1.6%). Total dietary fiber concentrations of the fruit substrates ranged from 6.3% in fresh prune plums to 14.5% in undersized plums.

The DM content of the two byproducts ranged from a low of 9.4% for waste cake to 90.4% for dried plum pits. Organic matter contents were similar, however. Crude protein, AHF, and TDF were found in high concentrations in the byproducts compared with the other four groups of substrates.

Oligosaccharides (OS). Glucooligosaccharides measured included cellobiose, cellotriose, cellotetraose, and cellopentaose (data not shown). Cellobiose concentrations of substrates ranged

Table 2. Concentrations of the Maltooligosaccharides (Micrograms per Gram of Dry Matter)

substrate	maltose	malto-triose	malto-tetraose	malto-pentaose	malto-hexaose	malto-heptaose	long-chain maltooligosaccharides
powders							
prune powder	3456.6	446.3	112.5	0.0	0.0	0.0	5587.2
prune/pear powder	3949.3	386.0	96.1	0.0	0.0	0.0	4598.2
Plum Juicy 500	7518.6	802.8	107.9	0.0	83.7	0.0	3141.0
Plum Juicy 500 (spray-dried)	10462.9	11076.3	8857.7	12299.8	18280.8	29065.1	258966.6
juices							
prune concentrate	450.1	0.0	0.0	0.0	0.0	0.0	1895.2
fresh plum concentrate	1321.9	162.2	tr[a]	1.04.5	tr	0.0	5031.6
prune juice	tr	0.0	0.0	tr	0.0	0.0	tr
purees							
dried plum butter	0.00	0.00	0.00	0.00	0.00	98.83	0.0
plum puree	1397.7	0.0	tr	0.0	0.0	tr	1657.0
fresh plum puree	309.1	0.0	0.0	0.0	0.0	0.0	0.0
dried plum puree	42154.2	31700.7	16834.5	13791.0	9361.9	6627.2	76761.1
Lighter Bake	14094.6	13646.2	9611.9	14187.7	18507.1	23858.4	161975.7
fruits							
pitted prune	3300.2	0.0	0.0	116.9	0.0	274.7	1676.5
prune 52/56	2305.0	tr	tr	0.0	0.0	0.0	2401.6
undersized plums	740.1	tr	0.0	356.1	0.0	0.0	5937.3
fresh prune plums	4894.8	tr	0.0	0.0	0.0	0.0	640.0
byproducts							
waste cake	0.0	0.0	0.0	0.0	0.0	0.0	0.0
dried plum pits	0.0	0.0	0.0	0.0	0.0	0.0	186.5

[a] Trace.

from 0 to 536.3 μg/g DM. Although there was large variation among substrates within a group, the highest concentrations of cellobiose were associated with the fruit substrates. Cellotriose concentrations ranged from 0 to 1819.0 μg/g DM. The only substrates containing detectable concentrations of cellotriose were Plum Juicy 500 (1819.0 μg/g), dried plum puree (991.6 μg/g), prune/pear powder (758.8 μg/g), fresh plum concentrate (214.5 μg/g), and prune powder (153.4 μg/g). Cellotetraose was found only in Plum Juicy 500 (140.0 μg/g), pitted prunes (88.8 μg/g), and prune powder (70.6 μg/g). Cellopentaose concentrations ranged from 0 to 3694.6 μg/g of DM. The highest concentrations of cellopentaose were found in fresh plum concentrate, prune/pear powder, and prune concentrate.

Six oligosaccharides comprised the maltose series of oligosaccharides and included maltose, maltotriose, maltotetraose, maltopentaose, maltohexaose, and maltoheptaose (**Table 2**). No detectable amounts of maltooligosaccharides were observed in either of the byproducts. On the other hand, dried plum puree, Lighter Bake, and SD-Plum Juicy 500 consistently exhibited the highest amounts of maltooligosaccharide. Concentrations of long-chain maltooligosaccharides ranged from 0 to 258,966.6 μg/g of DM, with the highest concentrations found in SD-Plum Juicy 500, Lighter Bake, and dried plum puree (258,966.6, 161,975.7, and 76,761.1 μg/g of DM, respectively).

Raffinose, stachyose, and verbascose comprised the galactooligosaccharides measured (data not shown). Whereas raffinose ranged from 0 to 359.3 μg/g of DM, the only substrates containing detectable concentrations were Plum Juicy 500, prune/pear powder, and fresh plum concentrate. Stachyose was detected only in pitted prunes (630.6 μg/g of DM). Verbascose was detected in two of the powders and all of the fruits, ranging from 136.9 to 443.3 μg/g of DM for pitted prunes and prune powder, respectively.

Kestose, nystose, and fructofuranosylnystose comprised the fructooligosaccharides found in plum substrates (data not shown). Kestose concentrations ranged from 0 to 2152.6 μg/g of DM. The only substrates containing detectable concentrations of kestose were prune powder, prunes 52/56 N/C, fresh plum concentrate, and plum puree. The concentration of nystose ranged from 0 to 1581.2 μg/g of DM and was detected in prune powder, prune/pear powder, Plum Juicy 500, fresh plum concentrate, plum puree, and dried plum puree. Fructofuranosylnystose concentrations were detected only in dried plum puree and pitted prunes at concentrations of 311.6 and 178.6 μg/g of DM, respectively.

Table 3. Concentrations of Unidentified Oligosaccharides with a Degree of Polymerization (DP) > 10 (Micrograms per Gram of Dry Matter)

substrate	OS with DP > 10
powders	
prune powder	8634.9
prune/pear powder	6868.8
Plum Juicy 500	2418.3
Plum Juicy 500 (spray dried)	0.0
juices	
prune concentrate	2920.5
fresh plum concentrate	4194.3
prune juice	1699.0
purees	
dried plum butter	2287.8
plum puree	4108.8
fresh plum puree	0.0
dried plum puree	2479.3
Lighter Bake	0.0
fruits	
pitted prune	2466.3
prune 52/56	2266.0
undersized plums	6064.3
fresh prune plums	0.0
byproducts	
waste cake	0.0
dried plum pits	385.6

Unidentified long-chain oligosaccharides (DP > 10) were found in concentrations ranging from 0 to 8634.9 μg/g of DM (**Table 3**). The highest concentrations of these OS were found in prune powder, prune/pear powder, and undersized plums.

Monosaccharides, Disaccharides, and Sugar Alcohols. Values for sucrose ranged from a low of 0 for waste cake to 119.3 mg/g of DM for fresh plum concentrate (data not shown). As a group, the powdered substrates contained the highest

Table 4. Concentrations of Free Monosaccharides (Micrograms per Gram of Dry Matter)

substrate	fucose	arabinose	galactose	glucose	xylose	mannose	fructose
powders							
prune powder	208.2	0.0	804.4	266568.9	504.0	1786.3	140457.1
prune/pear powder	497.4	537.0	1600.8	204877.8	1691.4	2813.7	257230.1
Plum Juicy 500	74.5	423.9	1108.3	168404.1	3000.4	1752.5	279611.9
Plum Juicy 500 (spray-dried)	54.0	30.4	205.1	81433.6	378.2	18.6	37574.0
juices							
prune concentrate	478.2	1312.6	847.9	344113.8	738.9	3377.8	217047.6
fresh plum concentrate	358.5	2283.9	2830.6	320090.9	1442.2	2262.9	183461.5
prune juice	687.8	1247.4	1278.6	301877.7	671.4	3280.1	187087.6
purees							
dried plum butter	422.0	573.6	731.9	269090.4	711.8	1782.1	168852.6
plum puree	531.8	823.0	650.0	332792.9	630.5	2257.2	210406.3
fresh plum puree	350.3	413.7	0.0	328433.3	1685.5	0.0	174805.7
dried plum puree	202.0	42.1	903.6	224204.1	435.1	1090.4	211427.2
Lighter Bake	90.5	164.6	287.5	271412.8	347.9	646.2	64793.4
fruits							
pitted prune	410.9	0.0	449.3	212129.9	707.6	921.1	130534.5
prune 52/56	404.5	0.0	1512.8	288033.8	929.2	1093.3	203951.4
undersized plums	384.7	0.0	1802.0	326828.7	707.5	1477.8	189850.5
fresh prune plums	287.0	0.0	791.5	348195.4	1520.8	0.0	214155.8
byproducts							
waste cake	0.0	0.0	0.0	2356.6	0.0	0.0	0.0
dried plum pits	116.5	305.8	192.5	27757.6	92.0	692.4	24014.3

concentrations of sucrose (27.7−86.3 mg/g of DM) with the exception of SD-Plum Juicy 500 (1.6 mg/g of DM). *myo*-Inositol concentrations ranged from 11.4 mg/g of DM for SD-Plum Juicy 500 to 46.5 mg/g of DM for fresh plum puree (data not shown). Sorbitol concentrations were highest in juices and concentrates (166.0−171.4 mg/g of DM). The lowest concentrations of sorbitol (5.1 and 15.9 mg/g of DM) were detected in waste cake and dried plum pits, respectively (data not shown).

Amounts of free fucose, arabinose, galactose, glucose, xylose, mannose, and fructose are presented in **Table 4**. SD-Plum Juicy 500 consistently contained the lowest concentrations of all seven monosaccharides compared with the other powdered substrates (with the exception of arabinose, which was not detected in prune powder). Prune/pear powder contained the highest concentrations of fucose, arabinose, galactose, glucose, and mannose, whereas Plum Juicy 500 contained the highest concentrations of xylose and fructose.

Fucose concentrations in the three juice substrates ranged from 358.5 to 687.8 μg/g of DM for fresh plum concentrate and prune juice, respectively. Arabinose, galactose, glucose, and mannose were detected in relatively higher concentrations within this group compared with the other four groups of substrates. The highest concentration of fructose within this group of substrates was found in prune concentrate (217,047.6 μg/g of DM), whereas the lowest concentration was detected in fresh plum concentrate (183,461.5 μg/g of DM).

Purees contained variable concentrations of free monosaccharides (**Table 4**). Plum puree contained the highest concentrations (micrograms per gram of DM) of fucose (531.8), arabinose (823.0), glucose (332,792.9), and mannose (2257.2), whereas dried plum puree contained the highest concentrations of galactose (903.6) and fructose (211,427.2). Although xylose concentrations were highest in fresh plum puree (1685.5), no detectable concentrations of galactose or mannose were found in this substrate. Lighter Bake contained the lowest concentrations of fucose (90.5), xylose (347.9), and fructose (64,793.4), whereas dried plum puree contained the lowest concentrations of arabinose (42.1) and glucose (224,204.1).

Arabinose was not detected in any of the four fruit substrates (**Table 4**). Fucose concentrations ranged from 287.0 to 410.9 μg/g of DM for fresh prune plums and pitted prunes, respectively. Undersized plums contained the highest concentrations of galactose (1802.0 μg/g of DM) and mannose (1477.8 μg/g of DM); however, they contained the lowest concentration of xylose (707.5 μg/g of DM). Xylose was detected in highest concentration (1520.8 μg/g of DM) in fresh prune plums. Fresh prune plums also contained the highest concentrations of glucose and fructose, whereas pitted prunes contained the lowest concentrations of these two monosaccharides.

The lowest concentrations of free monosaccharides were found in the byproducts when compared with the other four groups of substrates. Glucose was the only monosaccharide detected in low concentration (2356.6 μg/g of DM) in waste cake. Dried plum pits contained all seven monosaccharides in relatively low concentrations (**Table 4**).

Total OS concentrations are presented in **Table 5**. Of the OM contained in SD-Plum Juicy 500, 35.1% was attributed to OS. Additionally, Lighter Bake (25.9%), dried plum puree (20.5%), fresh plum concentrate (13.6%), and Plum Juicy 500 (10.5%) contained high concentrations of OS. Free monosaccharides and sugar alcohols also accounted for a large percentage of the OM content of the plum/prune substrates with the exception of the two byproducts (**Table 5**). Prune concentrate, plum puree, and fresh prune plums contained the highest concentrations of free monosaccharides and sugar alcohols, accounting for 76.5, 75.1, and 73.7% of their OM contents, respectively. The combination of total OS, total free monosaccharides, and sugar alcohols accounted for 49.2−84.7% of OM content of the plum/prune substrates with the exception of waste cake and dried plum pits. Total OS, free sugars, and sugar alcohols accounted for only 2.9 and 8.6% of the OM content of waste cake and dried plum pits, respectively.

Fiber-Associated Monosaccharides and Uronic Acids. Fiber-associated monosaccharides and uronic acids were quantified and expressed as a percentage of the TDF residue (data not shown). Fiber-associated fucose and rhamnose concentrations were low in all 18 substrates, ranging from 0.1 to 0.6%. Fiber-associated xylose was detected at 15.9% in dried plum pits, followed by Plum Juicy 500, containing 9.8%. The remaining substrates contained fiber-associated xylose at concentrations ranging from 0.3 to 3.6%. Fiber-associated mannose was detected in SD-Plum Juicy 500 at 8.8% compared to the

Table 5. Concentrations of All Oligosaccharides Combined and of Free Monosaccharides and Free Sugar Alcohols (Percent Dry Matter)

substrate	total oligo-saccharides	free mono-saccharides and sugar alcohols	free sugars and oligo-saccharides
powders			
prune powder	5.0	57.2	62.1
prune/pear powder	5.3	62.1	67.4
Plum Juicy 500	10.5	54.8	65.2
Plum Juicy 500 (spray-dried)	35.1	16.9	51.9
juices			
prune concentrate	1.0	76.5	77.5
fresh plum concentrate	13.6	71.1	84.7
prune juice	0.6	71.1	71.7
purees			
dried plum butter	0.7	62.3	63.0
plum puree	1.1	75.1	76.2
fresh plum puree	0.3	70.0	70.3
dried plum puree	0.7	62.3	63.0
Lighter Bake	25.9	41.5	67.5
fruits			
pitted prune	1.4	47.8	49.2
prune 52/56	2.2	66.0	68.2
undersized plums	2.0	66.4	68.3
fresh prune plums	1.3	73.7	75.0
byproducts			
waste cake	0.0	2.9	2.9
dried plum pits	0.3	8.3	8.6

remaining substrates containing 0.6−4.7%. Fiber-associated arabinose was detected at intermediate concentrations ranging from 1.4 to 18.8% for dried plum pits and prunes 52/56, respectively. The four fruit substrates contained the highest amounts, ranging from 13.2 to 18.8%. Fiber-associated galactose and glucose concentrations were found to range from 0.4 to 24.6%. The four fruit substrates contained the highest concentrations of both components, ranging from 13.7 to 24.6%. Fiber-associated uronic acids ranged from 0.7 to 108.3%, with juices containing the highest concentrations (74.5−108.3%) and byproducts containing the lowest concentrations (0.7 and 1.2%).

DISCUSSION

The plum/prune substrates exhibited wide variation in concentrations of proximate constituents (**Table 1**). Ash content ranged from 0.9 to 13.8% for Lighter Bake and prune juice, respectively. Mineral nutrition of humans might be enhanced if prune juice were consumed on a routine basis, provided the mineral content is bioavailable. Interestingly, the dry matter content of waste cake was much lower than expected (9.4%) as it was lower than the dry matter concentration of prune juice (16.2%). Waste cake is the material remaining after the production of prune juice and contained a high percentage of TDF and, therefore, apparently had a very high water-holding capacity.

Crude protein concentrations were consistently low in prune substrates with the exception of dried prune pits and waste cake, which contained 8.3 and 12.7% CP, respectively (**Table 1**). Total nitrogen was analyzed; therefore, some crude protein found in the pit may include free amino acids or nonproteinaceous nitrogenous compounds. Although the pit substrates contained higher concentrations of crude protein, the bioavailability of the protein would be questionable. No data are available regarding the digestibility and bioavailability of nutrients contained within the pits. The other 16 substrates ranged from 0.4 to 6.2% CP. Stacewicz-Sapuntzakis et al. (*2*) reported CP concentrations of 0.8 and 2.6 g/100 g of fresh plums (edible parts only) and dried prunes, respectively. In the current study, fresh prune plums contained 2.0% CP and pitted prunes contained 2.8% CP when expressed on a wet basis.

Waste cake and dried plum pits contained high concentrations of AHF, whereas the other substrates contained low concentrations, ranging from 0.6 to 6.1%. According to data gathered by the U.S. Department of Agriculture for nutritional labeling purposes, Gebhardt et al. (*21*) reported fat concentrations for fresh plums and dried prunes of 0.2 and 0.5 g/100 g of edible parts, respectively. At this low concentration, the amounts of reported total lipid vary among laboratories and analytical methodologies (*21*). In the current study, fresh prune plums and pitted prunes contained 0.5 and 0.8% AHF (wet basis), respectively. None of the edible plum/prune substrates would be viewed as significant sources of fat in human nutrition.

The TDF concentrations of waste cake and dried plum pits were very high compared with the remaining substrates (**Table 1**). Stacewicz-Sapuntzakis et al. (*2*) reported TDF concentrations of 1.5 and 6.1 g/100 g of edible portion of fresh plums and dried prunes, respectively. Expressed on a wet basis, the four fruit substrates in the current study contained TDF concentrations ranging from 2.7 to 10.9%. On the basis of the available data, it can be concluded that the majority of protein, fat, and fiber is associated with the inedible pit rather than the edible fruit.

Several categories of OS (glucooligosaccharides, galactooligosaccharides, fructooligosaccharides, and long-chain OS with DP > 10) were found in low concentrations in many of the substrates and were associated with the fruit rather than the pit. With the exception of SD-Plum Juicy 500, the powders and fruit products contained low concentrations of glucooligosaccharides, fructooligosaccharides, galactooligosaccharides, and long-chain OS. The juices contained low amounts of glucooligosaccharides, fructooligosaccharides, and long-chain OS. Raffinose was the only galactooligosaccharide found in very small concentrations in fresh plum concentrate. All four OS categories were detected in low concentrations in the puree products with the exception of fresh plum puree and Lighter Bake, which were devoid of all glucooligosaccharides, fructooligosaccharides, galactooligosaccharides, and long-chain OS. Of the two byproducts, dried plum pits contained a very low concentration of glucooligosaccharides and long-chain OS, whereas waste cake did not contain any detectable concentrations of OS.

Maltooligosaccharides were found in low concentrations in the fruit substrates and were not detected in the two byproducts. High concentrations of maltooligosaccharides were found in dried plum puree, Lighter Bake, and SD-Plum Juicy 500 (**Table 2**). This is a result of maltodextrin addition during processing. Maltodextrins are commonly used in the food industry as additives to provide texture, aid in spray-dry processing, replace fat, form films, prevent crystallinization, and provide bulk or serve as a carrier (*22*).

Although waste cake and dried plum pits contained detectable concentrations of sugar alcohols and dried pits contained sucrose, the majority of these compounds were associated with the fruit rather than the pit. The four fruit substrates contained 6.0−12.6 mg of sucrose/g of DM (data not shown). In comparison, Stacewicz-Sapuntzakis et al. (*2*) reported that fresh prunes contained concentrations of sucrose ranging from 2.9 to 6.2 g/100 g and that dried prunes contained 0.6 g/100 g of wet edible parts. Variation in sucrose content may be a result of growing conditions and (or) degree of ripeness (*2*).

Sorbitol concentrations were highest in juices and concentrates with a maximum concentration of 171.4 mg/g of DM measured in fresh plum concentrate. In comparison, Stacewicz-Sapuntzakis et al. (*2*) reported a mean of 6.1 g of sorbitol/100 g of fresh weight for prune juice made from various prune cultivars. High concentrations of *myo*-inositol were detected in all substrates ranging from 11.4 to 46.5 mg/g of DM (data not shown). Although sorbitol and *myo*-inositol were detected in the byproducts, the majority of sugar alcohols were more concentrated in the fruit as compared with the pit.

Concentrations of total sugars and OS (**Table 5**), CP, AHF, and TDF (**Table 1**) were summed to determine the OM concentration accounted for by our chemical analyses. These values then were compared with the analyzed concentrations of OM presented in **Table 1**. The summation of monosaccharides, sugar alcohols, and OS accounted for the majority of OM in most substrates. In the case of prune/pear powder, plum puree, and dried plum pits, 100% of the OM was accounted for in our analyses. On the other hand, the OM concentration of SD-Plum Juicy 500 was 99.0%, but organic components added to only 57.4%. Obviously, additional compounds such as vitamins, phenolics, and volatile compounds in the substrates may exist that were not accounted for by our analyses. Phenolic compounds may have accounted for a large proportion of the organic matter not accounted for in our analyses. Dried prunes and fresh prune-making plums contain approximately 184.0 and 111.0 mg of total phenolic compounds per 100 g of fruit, respectively (*2*). For the remaining substrates, our analyses accounted for 70−98.5% of the analyzed OM.

Two major monosaccharides found in prunes and plum products are glucose and fructose. These sugars, along with other monosaccharides, are affected during drying as a result of chemical reactions such as acid hydrolysis, Maillard product formation, and caramelization that are responsible for the aroma and color formation of prune products (*2*, *23*, *24*). Glucose was found in high concentrations in all substrates (**Table 4**). Previous studies have reported glucose concentrations of 12.1 g/kg of wet weight in fresh plums (*24*), 4.4% of fresh plum weight (*25*), and 6.1 g/100 g of fresh plum weight (*2*). Variation in glucose and other monosaccharide concentrations may be a result of cultivar, growing conditions, ripeness, and (or) processing conditions (*2*).

Although fructose was detected in high concentrations for most of the substrates, no detectable concentrations were found in waste cake (**Table 4**). Additional monosaccharides such as fucose, arabinose, galactose, xylose, and mannose also were detected in variable concentrations in the substrates (**Table 4**). Substrate variation in monosaccharide concentration can be a result of fruit ripening (*26*) and processing reactions such as dehydration and Maillard reactions (*23*, *27*). The two byproducts contained low concentrations of monosaccharides. Dried plum pits contained detectable concentrations of all seven analyzed monosaccharides; however, glucose was the only monosaccharide found in waste cake. It can be concluded that monosaccharides were associated with the flesh of the fruit rather than the pit.

The four whole fruit substrates contained higher concentrations of the fiber-associated monosaccharides compared with the remaining substrates. Of the fiber-associated sugars, arabinose and galactose were detected in the greatest concentrations (data not shown). Similarly, Gross and Sams (*26*) found high concentrations of arabinose and galactose in plums at various stages of ripeness. Uronic acids associated with the TDF fraction also were observed in high concentrations, particularly for the concentrates and prune juice substrates. Uronic acid, along with hexosamine, comprises the repeating units of most acid mucopolysaccharides and pectins (*20*). Uronic acids in fresh plum concentrate accounted for >100% of the sugars associated with TDF. The reasons for this overestimation may be a result of free uronic acids contaminating the sample or the use of an incorrect multiplication factor to account for the water of hydration associated with compounds bound to other moieties.

Variation in composition among plum/prune substrates may be due to several factors including harvesting equipment used, processing methodologies, fruit handling conditions, and preparation of the substrates. Powdered substrates are used in the food industry for reduced and low fat dry mixes and for processed meat products. Some powders such as Plum Juicy 500 and prune/pear powder contain additional fruits or mixes of fruits that can alter the chemical composition of the substrate. For instance, blended powders may contain tapioca flour, additional starch, and pectin that lighten the color of the substrate and provide additional manufacturing applications, particularly for the meat industry. Powders also may be obtained by spray-drying juices and concentrates. Spray-drying fresh plum concentrate produces SD-Plum Juicy 500. This substrate is prepared with 30% fresh plum concentrate and 70% maltodextrin as a carrier to recover the majority of the juice in a dry powdered form. Therefore, this substrate differs from the other three powders because it originates as a juice, and the addition of maltodextrin results in an increased concentration of maltooligosaccharides and total OS compared with the other powders and juices (*28*).

The three substrates in the juice group included juices and concentrates. Although they are all liquid in nature, these substrates vary in composition and industry application. Juices contain preservatives and acidifying agents, such as lemon or lime juice or citric acid, to impart a slightly tart flavor for consumption by consumers, whereas concentrates are viscous forms of juices without preservatives, used in foods ranging from bakery products to meats, that can act as mold inhibitors, moisture retention agents, and inhibitors of foodborne pathogens (*28*). On the basis of the data from this study, this group contained more free sugars such as sucrose, glucose, and arabinose compared with the other groups of substrates. The substrates within the juice group were produced using different processing methods. Prune concentrate is a viscous form of dried plum juice compared with fresh plum concentrate, which originates from the juice of mature fresh plums. Fresh plum concentrate contained more glucooligosaccharides and maltooligosaccharides compared with the other two substrates in this group.

Purees are made from fruit blended with juices or concentrates. Purees may contain added sweeteners, syrups (corn or rice), dextrins, or maltodextrins. Fresh plum puree is made from fresh plums prior to drying. Dried plum purees (including dried plum puree and plum puree in the current study) are made from dried plums and prune concentrate. Dried plum butter is made with dried plums and is put through a screening process to remove all skin and pit particulates. Lighter Bake is a prepared product used as a fat-replacer in baked goods and is made from a puree of dried plums and apples with added dextrose, maltodextrin, and pectin. Due to the addition of maltodextrins, Lighter Bake contained more maltooligosaccharides compared with the other purees. On the basis of data from the current study, purees contain high concentrations of free sugars and sugar alcohols compared with the other groups of substrates. This is a result of added sweeteners, syrups, and maltodextrins.

The fruit and byproduct groups exhibited few differences in composition within group. Both groups contained more CP and TDF compared with the other substrates. This is probably a result of skin and pit particulate composition. Byproducts contained very low concentrations of sugars and oligosaccharides, whereas the fruits contained moderate concentrations of OS and very high sugar concentrations.

Results of this study indicated that a large proportion of the chemical composition of selected plum/prune substrates is carbohydrate. Total monosaccharide and sugar alcohol content accounted for a large proportion of plum/prune substrate OM (**Table 5**). With the addition of the OS, the percentage of OM accounted for increased to a high of nearly 85% for fresh plum concentrate. Plums/prunes are healthful foods with many functional and nutritional properties. Quantification of their carbohydrate and proximate components should be useful to those charged with making greater use of them in food products.

ABBREVIATIONS USED

AHF, acid-hydrolyzed fat; CP, crude protein; DM, dry matter; DP, degree of polymerization; NDO, nondigestible oligosaccharides; OM, organic matter; OS, oligosaccharides; SD, spray-dried; TDF, total dietary fiber.

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