The storage stability of passionfruit concentrate

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Passionfruit *(Passiflora edulis)* concentrates (542 g/kg soluble solids) prepared in a wiped-film evaporator were stored for up to 6 months at −18°, 4° and 20°C. Yeast and mould counts were taken and colour changes noted during storage. When suitably diluted, concentrate colour and flavour were acceptable for 1 month at 20°C, 3 months at 4°C and 6 months at −18°C. Commercial short-term storage of concentrate at temperatures above −18°C appears to be feasible.

Queensland is the main passionfruit *(Passiflora edulis)* growing state in Australia. Production for the year ending 31 March 1985 was 1876 t, representing 63.4% of the Australian crop (ABS 1986). Passionfruit juice provides the major processing outlet. In normal commercial practice pasteurised passionfruit juice is stored in the frozen state (Whittaker 1972) resulting in high storage and transport costs. Conversion to a concentrate would reduce these costs. Because of its high acidity, it might be feasible to store passionfruit concentrate at temperatures above its freezing point, provided that microbial stability and flavour can be retained.

There is no published information on the storage stability of passionfruit concentrate at temperatures above −18°C. The effects of storage at temperatures up to 4.4°C on orange concentrate quality have been reported by Kew (1955), Murdock and du Bois (1956), Murdock and Hatcher (1978), Crandall and Graumlich (1982) and Marcy *et al.* (1984), who noted that non-enzymic browning and flavour loss increased with storage temperature and time. Toribio and Lozano (1984) investigated non-enzymic browning in apple juice concentrates stored at temperatures up to 37°C and found that it increased with storage temperature and soluble solids level. Sulc (1984) evaluated the quality of strawberry juice concentrate stored at temperatures up to 22°C and reported that browning rate increased at the higher storage temperatures. The aim of this investigation was to determine whether passionfruit concentrate could be stored at temperatures above −18°C without significant quality loss.

Materials and methods

Juice concentration

Purple passionfruit *(Passiflora edulis)* juice which had been passed through a desludging centrifuge was obtained from a Queensland processor at weekly intervals over 6 sampling times. Centrifugation was necessary to prevent starch gelation problems during concentration (Casimir, Kefford & Whitfield 1981, da Fonseca 1976, Kwok *et al.* 1974). The juice was concentrated at the laboratory in a Luwa pilot scale wiped-film evaporator. Feed juice (136 g/kg soluble solids) was evaporated in a 2-pass operation to 391 g/kg soluble solids in the first pass and 623 g/kg soluble solids in the second pass. Operating temperatures were 31°C (feed), 58°C (first pass vapour) and 49.5°C (second pass vapour). The distillate from both passes was collected, combined and re-distilled to approximately 5% of its original volume, and added back to the concentrate. This was necessary to recover lost volatiles (Casimir *et al.* 1981, Pruthi 1963, Seale & Sherman 1960). The final average soluble solids of the concentrate was 542 g/kg. Concentrate samples were held in double polythene bags (103 mm x 175 mm) contained in sealed lacquered tinplate cans (83 mm x 87 mm).

Experimental design

A storage trial was designed as a randomised blocks layout comprising 10 treatments replicated over 6 sampling times. The treatments were 3 storage temperatures (−18°, 4° and 20°C) for each of 3 storage times (1, 3 and 6 months). In addition, single strength juice from each replication was stored for 6 months at −18°C as a control. Quality was assessed by measurement of yeast and mould counts, colour reflectance (Hunter *L, a, b*), and organoleptic ratings for colour and flavour. Data were interpreted by analysis of variance, followed by least significant difference testing at the $p = 0.05$ level.

Table 1. Effect of storage at various temperatures for several times on the colour of passionfruit concentrate and drinks, expressed as *L, a,* and *b* values* determined by Hunterlab Model D25

Storage temperature (°C)	Time (months)	Concentrate			Drink		
		L	*a*	*b*	*L*	*a*	*b*
	Control	—	—	—	27.2c	−3.2b	8.2c
−18	1	26.7a	18.7a	18.1a	28.2abc	−4.0a	10.1ab
−18	3	26.2ab	17.7ab	17.7ab	28.8ab	−4.5a	9.8b
−18	6	26.2ab	17.4b	17.7ab	27.7bc	−4.3a	10.2ab
4	1	25.5b	16.1c	17.1b	27.7bc	−4.0a	10.6ab
4	3	23.0c	13.8d	15.2c	28.2bc	−4.5a	9.9b
4	6	21.6d	12.7d	14.2d	27.5bc	−3.2b	10.2ab
20	1	21.9d	12.7d	14.5cd	29.6a	−4.6a	11.4a
20	3	18.9e	9.41e	12.21e	27.9bc	−3.7a	10.2ab
20	6	17.6f	8.71e	11.2f	26.7c	−3.1b	10.6ab
	Standard error	0.4	0.5	0.3	0.6	0.4	0.5

** Means followed by a common letter are not significantly different ($p > 0.05$)*

Analytical methods

Acidity was determined by titration (0.1N Na OH, pH 8.3 end-point) with a Metrohm autotitrator and expressed as anhydrous citric acid (AOAC 1984). Soluble solids was measured with an Atago IT Abbe refractometer. Yeast and mould counts were determined, after storage, by duplicate plating of 10-fold diluted concentrate in potato dextrose agar (pH 3.5, incubated 5 days at 25°C). Colour was measured by reflectance using a Hunterlab Model D25 Colour difference meter, Hunter Associates Laboratory Inc., Fairfax, VA, USA (aperature diameter 50 mm) calibrated on a yellow tile (L = 78.8, a = −1.5 and b = 23.4); readings were recorded as L (brightness), a (redness), and b (yellowness) values were recorded.

Organoleptic assessments

Samples from each storage time/temperature combination were removed and stored at −18°C, on the assumption that at this temperature quality changes with time would be negligible

(Crandall & Graumlich 1982). After the removal of the last sample (6 months storage), the samples were thawed and served to make passionfruit drinks. The drink formulation was standardised by addition of water to make 100 g/L juice, citric acid (adjusted to 5 g/L anhydrous citric acid) and sucrose adjusted to 120 g/L soluble solids. A taste panel of 15 adults selected from laboratory staff rated the drinks for colour and flavour on a 9-point hedonic scale, where 1 = disliked extremely, 5 = neither like nor dislike and 9 = like extremely. It was assumed that the drink was still acceptable with a mean score of 6 (like slightly). The panelists were familiar with taste panel techiques, but were not trained in passionfruit quality assessment. At each session, 4 samples (served at ambient temperature) were evaluated by the panel. To avoid colour bias, samples for flavour ratings were assessed under orange lights. Colour ratings were carried out under white light, using different sample codes.

Table 3. Passionfruit drink taste panel scores*

Storage temperature (C°)	Time (months)	Colour	Flavour
Control		6.3bc	6.9a
-18	1	6.9a	6.4bc
-18	3	6.9a	6.5b
-18	6	6.9a	6.4bc
4	1	6.7ab	6.3cd
4	3	6.2cd	6.3cd
4	6	6.2cd	5.91
20	1	6.5abc	6.2d
20	3	5.8d	5.91
20	6	5.11	5.5f
Standard error		0.2	0.1

** Means scores of 15 panelists*
Means followed by a common letter are not significantly different ($p > 0.05$)

Results

Yeasts and moulds

Viable yeast and mould counts averaged less than 10 cfu/mL for all storage temperatures up to 6 months storage; at none of the storage temperatures were there signs of fermentation, such as gas production or off-odour.

Hunter colour values

Mean Hunter colour values for the stored concentrates are shown in Table 1. There was little change in *L* value, *a* value or *b* value after storage at -18°C for up to 6 months. There were significant ($p < 0.05$) decreases in *L*, *a* and *b* values after one month at 4°C and 20°C. Concentrate stored for six months at 20°C developed a 'chocolate' brown colour.

Mean Hunter colour values for drinks formulated from the stored concentrates and control juice are also shown in Table 1. No significant changes were detected in the *L* value after six months at -18° and 4°C, but a significant decrease occurred after 6 months at 20°C. Differences in *L* value between drinks formulated from the control and concentrates were mostly not significant ($p > 0.05$). Samples stored for 6 months at 4° and 20°C and the control had significantly higher *a* values than the other treatments ($p < 0.05$). There were few differences among *b* values of the drink samples formulated from concentrates and all were significantly higher than for the control ($p < 0.05$).

Mean colour and flavour scores for the reconstituted drinks are shown in Table 2. Taste panel assessment indicated that there was no significant change in colour scores after 6 months storage at -18°C ($p > 0.05$). Mean panel scores were equal to 6.9 (like moderately). There was a significant decrease ($p < 0.05$) in colour scores after 3 months at 4° and 20°C. After 6 months at 20°C, the mean colour score was 5.1 (neither like nor dislike). The control colour score was significantly lower than those of concentrates stored at -18°C, but higher than for concentrates stored at 20°C for 3 and 6 months ($p < 0.05$). When reconstituted to a passionfruit drink, the Hunter colour values were similar, except for a slight increase in the *a* value (redness) of the 4° and 20°C for 6 months storage treatments and the control sample. The control was also less yellow (lower Hunter *b* value) than the stored concentrate treatments. Taste panel ratings on the drink indicate colour score was unchanged at -18°C but was still acceptable after 6 months at 4°C and only one month at 20°C.

There were no significant changes in flavour over 6 months at -18°C. There was a significant flavour decrease over 6 months at 4°C while at 20°C, scores decreased significantly after 3 months sotrage ($p < 0.05$). The control was scored significantly above all other treatments ($p < 0.05$) after 6 months storage at -18°C, with a mean flavour rating equal to 6.9 (like moderately).

Discussion

A good quality passionfruit concentrate was produced with a wiped-film evaporator, recovered volatiles had been added. It was stored at 20°C for up to 6 months without microbial spoilage, presumably due to its high acidity (pH 2.8) and soluble solids levels (542) g/kg). The absence of yeast spoilage concurs with the findings of Murdock and Hatcher (1978) for 650 g/kg orange concentrate stored at 4.4°C. They also showed that the level of yeasts surviving in the concentrate decreased as storage temperature rose to 4.4°C. However, mould growth was reported at temperatures above -17.8°C. The low pH of passionfruit concentrate could account for this discrepancy.

The darkening of the passionfruit concentrate at 4° and 20°C (as measured by Hunter *L*, *a* and *b* values) that occurred after 1 month's storage was considerable after 6 months at 20°C. This is in agreement with the findings of Murdock and Hatcher (1978), Crandall and Graumlich (1982) and Marcy *et al.* (1984) for orange concentrate stored at temperatures up to 26.7°C. The better colour scores of the frozen concentrate than the single strength control could be an additional benefit of storing passionfruit juice in concentrate form, rather than as a single strength juice, as is the current commercial practice (Whittaker 1972).

The retention of flavour in passionfruit concentrate stored at -18°C agrees with the findings of du Bois and Kew (1951) who reported no detectable change in orange concentrate sotred for 204 days at temperatures below -12°C and Kew (1955) who reported no flavour loss after 5 years at -20°C. Although significant flavour losses occurred in passionfruit concentrate stored at higher temperatures, the magnitude of loss was not great, with scores still averaging 'like slightly' after 6 months at 4°C and 3 months at 20°C. All concentrates when diluted to a drink exhibited less flavour compared to the frozen single strength control juice. This may have been due to some loss of volatiles during concentration even though re-distilled distillate was added back after concentration. However, the magnitude of the loss was small and would probably not be significant commercially.

Conclusion

This investigation indicates that passionfruit concentrate can be stored at -18°C for 6 months, 4°C for 3 months, and 20°C for 1 month with good colour and flavour retention and no microbial spoilage. Commercial short term storage at temperatures above -18°C therefore appears to be quite feasible.

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Table 2. Amino acid (mg/g N) crude protein (% wet weight basis) and moisture (%) contents of Australian Foods

	Essential Amino Acids													Non-Essential Amino Acids									
Food	His	Iso	Leu	Lys	Met	Cys	Met + Cys	Thr	Try	Tyr	Phe	Tyr + Phe	Val	Ala	Arg	Asp	Glu	Gly	Pro	Ser	NH But*	Protein†	TNR‡	Water
Cereal Products																								
Plain flour	131	250	451	141	98	147	245	179	65	212	326	538	272	196	228	326	1907	212	744	331	—	10.4	96.3	10.9
Wholemeal flour	149	231	403	181	91	136	227	186	63	199	286	485	276	213	304	349	1594	240	706	304	—	12.8	96.9	10.8
Rye flour	148	223	392	233	101	133	234	218	51	180	313	493	313	265	334	456	1413	259	681	302	—	11.8	97.6	9.2
Soya flour	173	318	500	432	111	99	210	259	86	227	324	551	349	272	491	804	1231	268	349	342	—	39.2	100.1	5.3
Brown rice	163	228	446	236	122	130	252	219	78	284	284	568	349	333	503	576	919	276	276	309	—	7.29	96.3	10.5
White rice	136	263	508	218	136	136	272	218	86	317	317	634	399	363	480	631	1031	263	308	344	—	6.51	98.3	11.4
Nuts & Legumes																								
Cashew nut	133	231	413	286	96	126	222	223	101	188	261	449	332	236	625	574	1225	251	219	332	—	18.4	99.8	4.5
Lima bean	157	314	526	405	69	69	138	281	66	229	402	631	350	264	383	878	862	253	259	452	—	22.7	99.2	10.5
Peanut	144	204	383	225	71	87	158	179	62	238	318	556	263	247	706	731	1163	351	261	342	—	26.4	101.7	6.7
Meat																								
Beef	231	305	524	572	156	78	234	304	76	236	253	489	336	383	416	604	967	314	276	284	—	19.8	102.9	74.9
Chicken	214	334	526	605	154	74	228	306	85	236	261	497	351	394	417	644	964	312	266	289	—	20.3	103.8	73.4
Lamb	193	286	499	577	147	73	220	294	84	230	249	479	319	371	412	586	942	312	281	277	—	20.8	101.3	73.7
Lamb kidney	171	269	552	441	119	107	226	306	91	261	311	572	392	376	387	611	776	366	310	329	—	16.4	103.7	79.0
Lamb liver	180	300	601	484	146	106	252	317	93	267	346	613	408	371	405	656	811	366	299	338	—	20.8	104.3	68.4
Bacon	246	315	519	548	125	74	199	320	83	240	256	496	341	381	414	642	971	308	268	299	—	21.3	104.8	67.0
Pork	280	306	506	573	156	78	234	304	73	238	248	486	336	366	411	604	931	289	216	284	—	22.4	103.7	73.7
Vegetables																								
French beans	111	221	339	241	106	61	167	290	86	131	192	323	319	339	261	1454	788	200	90	478	106	1.36	104.0	91.8
Broad beans	131	248	405	364	49	59	108	184	63	153	196	349	286	313	611	686	809	216	229	266	81	7.30	94.8	75.9
Butter beans	106	203	320	311	83	44	127	284	64	138	179	317	296	299	226	1048	558	206	194	402	173	2.11	89.6	91.6
Broccoli	112	217	360	328	86	72	158	229	57	137	211	348	293	364	301	547	1332	236	411	297	137	4.86	94.7	85.1
Brussel sprouts	91	155	238	214	46	57	103	166	59	93	127	220	233	281	418	416	1157	160	917	209	166	4.27	87.4	83.7
Cabbage	138	129	201	196	44	58	102	148	40	85	107	192	183	268	290	371	1398	152	714	206	139	1.85	82.2	87.5
Carrots	98	223	361	278	69	83	152	237	98	139	208	347	306	431	292	694	764	236	223	292	279	0.65	87.0	86.8
Cauliflower	114	248	431	308	84	84	168	248	84	168	233	401	365	368	368	548	721	269	233	305	93	2.08	84.4	91.0
Choko	115	239	378	288	58	74	132	164	49	222	271	493	263	222	329	526	461	181	173	239	180	0.52	78.6	93.7
Egg plant	111	208	272	289	51	47	98	111	68	106	170	276	251	196	404	719	1012	162	51	136	—	1.70	84.1	90.5
Kohlrabi	56	103	143	143	32	49	81	117	56	59	79	138	173	219	199	339	1776	114	278	149	225	1.72	82.7	92.4
Leeks	88	219	369	344	75	94	169	238	50	150	206	356	288	313	275	669	1206	244	200	288	24	2.04	93.2	80.8
Brown onions	89	102	191	268	38	64	102	128	83	115	153	268	121	121	784	485	1805	141	96	141	21	1.19	96.9	88.4
White onions	99	123	214	304	49	83	132	148	91	123	239	362	148	156	732	494	1612	156	107	181	16	0.99	100.3	87.8
Parsnip	113	201	296	304	72	72	144	233	104	113	176	289	264	224	962	809	585	184	176	208	136	1.57	101.7	80.9
Peas	105	234	404	404	63	67	130	223	63	149	228	377	268	243	716	714	960	212	199	286	65	6.93	95.2	76.9
Potato	107	219	304	310	96	54	150	208	75	171	240	411	331	160	353	1587	1170	149	139	203	149	2.27	103.5	81.7
Spinach	133	248	465	334	93	104	197	281	90	223	285	508	330	324	316	607	639	326	238	279	64	3.01	86.0	90.6
Swede	95	174	269	229	48	71	119	206	63	127	174	301	253	269	411	451	759	182	435	229	134	0.98	81.6	88.5
Sweet potato	113	256	379	287	93	82	175	277	103	205	328	533	369	287	246	1363	625	236	195	338	113	1.61	95.8	75.5
Taro	103	146	300	197	51	120	171	163	103	163	223	386	197	214	788	736	463	188	171	291	9	3.04	86.0	61.1
Tomato	104	149	211	228	46	71	117	186	38	108	170	278	153	158	191	762	2484	153	145	207	34	0.91	93.6	94.3
Turnip	101	162	224	201	31	69	100	224	85	116	162	278	254	231	224	533	1451	154	348	216	206	0.76	87.2	91.3
Zucchini	111	202	302	283	76	64	140	191	70	138	183	321	259	243	280	913	1073	181	154	393	86	1.56	90.0	93.8
Fruits																								
Avocado	121	219	371	317	85	112	197	237	81	598	223	821	308	281	268	473	625	259	228	294	—	1.32	80.7	67.6
Bananas	504	208	417	348	104	87	191	243	104	191	330	521	295	278	348	903	608	261	226	330	—	1.14	102.6	70.0
Grapefruit	77	121	208	241	55	66	121	143	143	88	109	197	164	263	362	1366	6514	154	647	318	200	0.75	91.0	87.7
Kiwi fruit	131	273	323	303	91	151	242	283	111	181	212	393	303	262	564	776	998	293	232	273	14	1.00	100.4	84.9
Mandarin	78	113	191	261	43	52	95	130	28	96	121	217	148	174	538	859	408	130	599	226	139	1.03	81.6	86.5
Mango	146	262	421	393	116	131	247	247	116	160	247	407	320	669	349	596	727	276	262	305	129	0.97	95.8	80.0
Nectarine	88	118	205	196	29	39	68	156	78	68	118	186	156	215	137	2656	479	146	244	205	19	1.31	96.8	82.4
Orange	86	151	247	269	64	67	131	151	108	108	139	247	204	204	537	988	483	161	666	269	196	0.83	88.4	86.7
Peach	74	111	174	184	46	28	74	147	74	64	92	156	156	184	111	3116	404	129	129	211	20	0.93	98.3	87.9
Human Requirements§																								
Child 2-5 y.	119	175	413	363			156	213	69			394	219											
Child 10-12 y.	119	175	275	275			138	175	56			138	156											
Adult	100	80	119	100			106	56	31			119	81											

* *Gamma amino butyric acid*
† *Crude protein (N x factor)%. See materials and methods text for factors*
‡ *Recovery of amino acid nitrgen as a percentage of total nitrogen*
§ *FAO/WHO/UNU (1985) Amino acid requirements*

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