

Chapter VI

EXPERIMENTAL RESULTS

Experimental results of vacuum evaporation of orange juice are as followed:

6.1 The Mass Balances

The precision of the experimental results was considered by taking mass balances around the evaporating chamber in which the process of evaporation had taken place. The results are shown below:

6.1.1 Overall mass balance

Table 4. Overall Mass Balance

Run NO.	Feed rate liter/ min	Hot plate temp., °C	Weight for the entire period of the exp. run, kg					
			Feed, F	Concentd P	Measd. Cond. Cm	Calcd. Cond. Cc	loss	%loss
1	0.240	61.2	14.70	8.20	6.50	6.50	0	0
2	0.265	65.1	14.72	5.00	9.70	9.72	0.02	0.136
3	0.290	65.8	13.20	4.80	8.40	8.40	0	0
4	0.318	66.1	9.65	3.53	6.10	6.12	0.02	0.26
5	0.344	68.7	16.35	6.80	9.25	9.55	0.35	1.83
6	0.370	57.7	14.55	8.97	5.50	5.58	0.08	0.52
7	0.265	64.2	14.40	6.25	8.05	8.15	0.10	0.69

6.1.2 Component mass balance

Table 5. Component Mass Balance

Run NO.	Concentration Brix		Solid content, kg				Water content, kg			
	Feed, C _F	Product C _P	in Feed S _F	in Pro- duct, S _P	loss	%loss	in Feed, W _F	in Product W _P	C _m	C _c
1	9	16	1.323	1.310	0.013	0.98	13.377	6.890	6.50	6.487
2	9	26	1.326	1.300	0.026	1.96	13.394	3.700	9.70	9.694
3	11	28.5	1.452	1.368	0.084	5.78	11.748	3.432	8.40	8.316
4	10	25.0	0.965	0.880	0.085	8.80	8.685	2.645	6.10	6.040
5	10	24	1.635	1.632	0.003	0.18	14.725	5.168	9.25	9.557
6	10.5	16.8	1.527	1.507	0.020	1.31	13.022	7.485	5.50	5.537
7	12.2	28	1.756	1.750	0.007	0.39	12.643	4.500	8.05	8.143

6.2 Evaporation/Concentration Ratio

The ratios of C_P to C_F and F to P were calculated. The results are shown in Table 6 and plotted in Figure 16.

Table 6. Evaporation/Concentration Ratio (e)

Run NO.	Feed rate liter/min	Concentration, Brix		e	weight, kg		e
		C_F	C_P		F	P	
1	0.240	9	16.0	1.78	14.70	8.2	1.79
2	0.265	9	26.0	2.89	14.72	5.0	2.94
3	0.290	11	28.5	2.59	13.20	4.8	2.75
4	0.318	10	25.0	2.50	9.65	3.52	2.74
5	0.344	10	24.0	2.40	16.35	6.8	2.40
6	0.370	10.5	16.8	1.60	14.55	8.98	1.62
7	0.265	12.2	28.0	2.30	14.40	6.25	2.30

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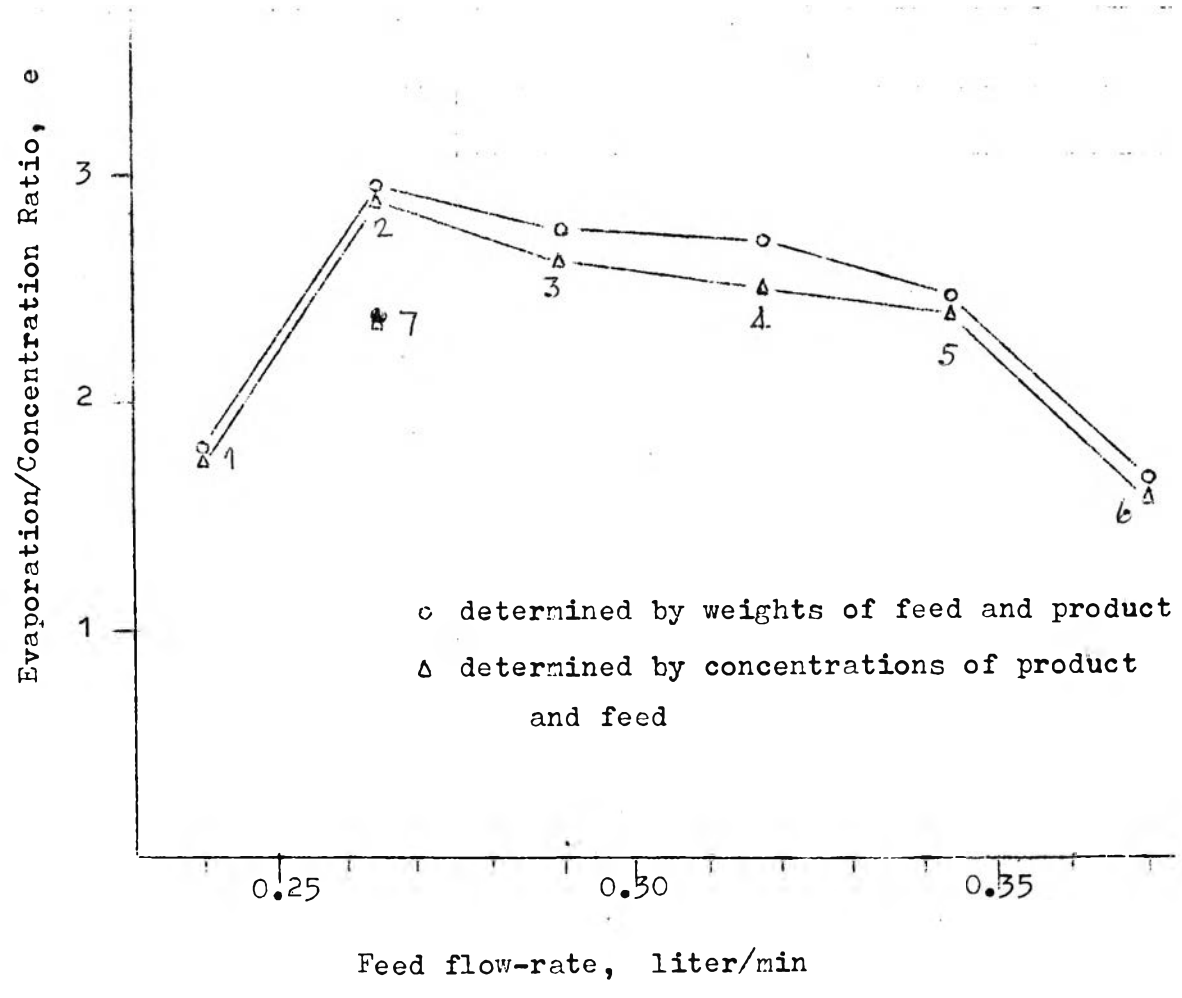


Figure 16. Variation of Evaporation/Concentration Ratio with Feed Flow-rate

6.3 The Heat Balance

Heat balance around the evaporating chamber was also taken, and the amount of heat transferred from the hot water to the evaporating chamber was calculated for each of the experimental runs.

The results are shown in Table 7.

Table 7. Heat Balance Around the Evaporating Chamber

Run NO.	Enthalpy of feed, q_1 Cal $\times 10^3$	Enthalpy of product, q_2 Cal $\times 10^3$	Enthalpy of condensate, q_3 Cal $\times 10^3$	Amount of heat transfer, q_4 Cal $\times 10^3$
1	558.6	342.7	4026.7	3810.8
2	699.2	149.6	6016.7	5467.1
3	620.4	151.2	5208.0	4738.8
4	547.1	121.5	3784.0	3358.4
5	772.5	235.5	5739.6	5202.6
6	959.4	374.4	3412.1	2827.1
7	803.5	200.7	4998.6	4395.8

6.4 Temperature Difference and Heat Transfer Coefficient

From the experimental data, the Seban-Shimazaki's correlation equation and the Fourier's equation, the temperature differences for heat transfer and the heat transfer coefficient on the hot-water side were calculated. The results are shown in Table 8.

Table 8. Temperature Differences and Heat Transfer Coefficient of Hot-water

Run NO.	h Cal/sec cm ² °C	T_v °C	$T_h - T_v$ °C	$T_h - T'_s$ °C	$T'_s - T_s$ °C	$T_s - T_v$ °C
1	0.025	51.5	33.1	15.6	6.8	9.7
2	0.035	53.0	36.2	15.3	8.8	12.1
3	0.040	52.5	35.3	13.3	8.7	13.3
4	0.037	53.0	35.8	14.1	8.6	13.1
5	0.035	53.5	34.2	12.1	6.9	15.2
6	0.022	55.0	31.7	16.5	6.0	9.2
7	0.037	54.0	30.9	12.9	7.8	10.2

h denoted heat transfer coefficient of the hot-water

T_v denoted average temperature of boiling liquid

T_h denoted average temperature of hot-water

T'_s denoted plate temperature (hot-water side)

T_s denoted plate surface temperature

6.5 The Mass Flow-Rate of Concentrated Juice

The mass flow-rates per unit width of concentrated juice were calculated from the theoretically derived equation, and the results are compared with the experimental values, as shown in Table 9.

Table 9. Comparison between Experimental Mass Flow-rate and Theoretical Mass Flow-rate of Concentrated juice

Experimental Run NO.	1	2	3	4	5	6	7	
Mass flow-rate of concentrated juice, g/socm.	Experimental	.1560	.0856	.0945	.0958	.1013	.2050	.1189
	Theoretical	.0245	.0365	.0835	.1140	.1068	.2600	.1174

6.6 Analysis of Juice Before and After Processing

The solid content, pH value, acidity, and vitamin C content of orange juice used in the experiments were determined before and after processing. The results are listed in Table 10.

Table 10. Analysis of Juico Before and After Processing

Run NO.	Before processing				After processing			
	Bx	pH	acidity, %	vit.C mg/100ml	Bx	pH	acidity, %	vit.C mg/100ml
1	9	4.0	1.08	29.5	16	3.9	2.03	*
2	9	4.3	0.44	32.7	26	4.3	1.41	-
3	11	4.2	0.63	24.5	28.5	4.2	1.88	-
4	10	4.4	0.42	37.6	25	4.3	1.22	-
5	10	4.5	0.42	27.0	24	4.5	1.01	-
6	10.5	4.4	0.36	40.5	16.8	4.3	0.60	-
7	12.2	4.1	0.56	23.5	28	4.1	1.40	-

* vitamin C contents after processing were untitratable

6.7 The Characteristics of Concentrate Juice

The characteristics of concentrated juice : color, appearance, taste, and aroma, were noted immediately after processing. The results are shown in Table 11.

Table 11. The Characteristics of Concentrate Juice

Run NO.	1	2	3	4	5	6	7
color	good	good	good	good	good	good	good
appearance	good	good	good	good	good	good	good
taste	bitter	bitter	bitter	bitter	bitter	bitter	bitter
aroma	very bad	very bad	very bad	very bad	very bad	very bad	very bad

The color was decided by visual consideration as well as the appearance, the aroma by smelling, and the taste by tasting. The color was bright orange yellow and the appearance was seemed thick and consistency. Aroma was somewhat with metallic, boiled pumpkin, and a little orange, while the taste was quite bitter.

Since the last two characteristics were unable to be tolerant, the further study of these characteristics would be carried out only for the first two ones.

6.8 The Storage Test

The variations of quality (with and without preservatives), color, and appearance of concentrate juice with the period of storage were investigated. The results are listed in Tables 12,13,14 and 15. The addition of preservative was performed before packing.

Table 12. The Study of Keeping Quality

Meth.	Run NO. day	1	2	3	4	5	6	7	Denoted
1*	1	-	-	-	-	-	-	-	- no signs of microorganism + development of mold on the surface
	2	+	+	+	+	+	-	+	
	3	+	+	+	+	+	+	+	
	4	+	+	+	+	+	+	+	
	5	+	+	+	+	+	+	+	
2*	1	-	-	-	-	-	-	-	- no signs of microorganism + development of mold on the surface
	2	+	+	+	+	+	+	+	
	3	+	+	+	+	+	+	+	
	4	+	+	+	+	+	+	+	
	5	+	+	+	+	+	+	+	
3*	1	-	-	-	-	-	-	-	- no signs of microorganism + development of mold on the surface
	2	+	+	+	+	+	+	+	
	3	+	+	+	+	+	+	+	
	4	+	+	+	+	+	+	+	
	5	+	+	+	+	+	+	+	
4*	1	-	-	-	-	-	-	-	- no signs of microorganism + development of mold on the surface
	2	-	-	-	-	-	-	-	
	3	-	-	-	-	-	-	-	
	4	-	-	-	-	-	-	-	
	5	-	-	-	-	-	-	-	

1* concentrate juice with no additives pasteurized at 70°C packed in lighted bottle

2* concentrate juice with added citric acid to pH around 3.7 and 100 ppm. sodium metabisulfite, pasteurized and packed by the same way as 1

3* and 4*, the same as 2* except 200 and 300 ppm. of sodium metabisulfite were used respectively.

Table 13. The Color Observation of Concentrate-Juice

The samples were added with citric acid to pH around 3.7 and 300 ppm sodium metabisulfite and kept at room temperature.

Run NO	1	2	3	4	5	6	7
concn Bx week	16	26	28.5	25.0	24	16.8	28
1	accep- table	accep- table	accep- table	accep- table	accep- table	accep- table	accep- table
2	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"
4	"	"	reject	"	"	"	reject
5	"	reject	"	"	"	"	"
6	"	"	"	reject	"	"	"
7	"	"	"	"	reject	"	"
8	"	"	"	"	"	"	"
9	"	"	"	"	"	"	"
10	"	"	"	"	"	"	"
11	"	"	"	"	"	"	"
12	"	"	"	"	"	"	"

Table 14. The Appearance Observation of Concentrated -
juice. Conditions were the same as of color observation.

Run NO.	1	2	3	4	5	6	7
concn week	16	26	28.5	25.0	24	16.8	28
1	-	-	-	-	-	-	-
2	+	-	-	-	-	+	-
3	++	-	-	+	+	++	-
4	++	+	+	+	+	++	+
5	++	++	+	++	++	++	+
6	++	++	++	++	++	++	++
7	++	++	++	++	++	++	++
8	++	++	++	++	++	++	++
9	++	++	++	++	++	++	++
10	++	++	++	++	++	++	++
11	++	++	++	++	++	++	++
12	++	++	++	++	++	++	++

- no precipitation

+ cloud begins to develop, no precipitation

++ two separated layers were seen

Remarks : the developed cloud disappeared as the bottle was
reversed.

Table 15. The Appearance and Color* Observation of Concentrate.-Juico.

The samples were kept at home refrigerator with no additive and no pasteurization.

Run NO	1	2	3	4	5	6	7
concn week	16	26	28.5	25	24	16.8	28
1	-	-	-	-	-	-	-
2	+	-	-	-	-	+	-
3	++	+	+	+	+	++	-
4	++	++	++	++	++	++	+
5	++	++	++	++	++	++	++
6	++	++	++	++	++	++	++
7**							

- denoted no precipitation

+ cloud begins to develop , no precipitation

++ two separations were seen

* color still acceptable

** after the end of the 6th week, short-circuit occurred within the refrigerator and it took 2 days to repair, all the samples became sour with thin layer of molds on the surface, gases were also produced, and the precipitate was scattered.