Effect of Storage at 45° F (7° C) on Keeping Quality of Five Chironja Clones[1]

Noemí Díaz[2]

ABSTRACT

The chironja is a citrus fruit with some morphological characteristics of the orange (*Citrus sinensis*) and some of the grapefruit (*Citrus paradisi*). Because of the lack of information on the response of chironja to storage conditions, a study was conducted to evaluate its keeping quality. Five clones grown at the Corozal Substation were used for this study. The fruit was harvested at 5 and 7 months after fruit set date. Clean fruit was stored in polyethylene gags at 7° C and 90% relative humidity for 70 days. Differences in quality and chemical composition of the five clones of fruit were studied.

Appearance and flavor of the fruit were found acceptable throughout the storage period. However, fruit stored between 25 and 55 days, regardless of the age of the fruit at harvesting, was preferred. The gas chromatographic pattern of peel oil of the fruit was similar for all clones. Higher concentrations were found in some fractions from the 7-month harvest. No significant difference was found in the flavor of the five clones.

A decrease in the percentage of reducing and total sugars was noticed during the first month of storage in fruit harvested 5 months after fruit set, in contrast to an increase in the percentage of total sugars in fruit harvested 7 months after fruit set. Weight loss of fruit throughout the storage period was less than 1% for all clones, irrespective of their age at harvest.

In general, there were more significant differences in chemical composition with respect to clones of fruit harvested at 7 months than those harvested at 5 months after fruit set.

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[3] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment or materials not mentioned.

INTRODUCTION

The chironja was reported (10) as a new type of citrus fruit growing in the mountains of Puerto Rico. There is an abundant population of orange (*Citrus sinensis*) and grapefruit (*Citrus paradisi*) in the region. The name of the fruit (chironja) is a combination of the words *china* (a local name for orange) and *toronja* (for grapefruit) since some of the morphological characteristics of the fruit resemble those of the orange and the grapefruit (10, 11). Cytological studies reported by Moscoso and Shambulingappa (12) seemed to indicate that the chironja is a hybrid.

Experimental orchards of chironja have been established at different substations including Corozal, Isabela and Limaní. A large number of trees were propagated from seeds. According to Moscoso (12), thus far, all have been true-to-type.

There is great interest in the possibilities of propagating this fruit on a large scale. A commercial orchard located in the northwest region of Puerto Rico is in full production, and a local food chain store has been marketing most of the fruit.

Because of the commercial potential of the chironja, a study of its keeping quality was initiated to determine the effect of cold storage at 45° F (7° C) and 90% relative humidity on the quality of five chironja clones.

MATERIALS AND METHODS

Five chironja clones grown at the Corozal Substation were selected for this study on the basis of the following criteria: yield per tree, fruit size, flavor, amount of seed, and tolerance to rough handling. Fruit from branches that were labeled on the date of fruit set was harvested at 5 and at 7 months after fruit set. They were picked by hand and handled carefully to avoid physical damage prior to storage. From each of the selected clones 50 chironjas were studied at each harvesting date. The fruit were thoroughly washed in running water and blot-dried. The weight of each fruit was recorded. Fruit was stored in polyethylene bags to maintain a uniform microenvironment during cold storage at 45° F (7° C) and 90% relative humidity for 70 days.

Respiration rate must be reduced to a minimum to extend the shelf-life of fruit. This is generally accomplished by combining temperature, relative humidity, and in some cases an inert gas in a controlled atmosphere.

The response of the chironja to refrigeration temperature has not been reported in the literature. Grapefruit, if properly handled and stored at the recommended temperature, can be stored for 4 to 6 weeks without serious spoilage. A temperature of 58° F (14.5° C) to 60° F (15.5° C) is recommended for California and Arizona grapefruit. For Florida and

Texas grapefruit, a temperature of 50° F (10° C) is generally recommended. Valencia oranges from Florida and Texas can be stored successfully with a minimum of decay and rind pitting for 8 to 12 weeks at 32° F (0° C) with a relative humidity of 85 to 90% (15). The temperature of 45° F (7° C), selected for this study, is an intermediate temperature between those recommended for the storage of orange and grapefruit.

Fruit samples were withdrawn at 3, 30, 40, 55, and 70 days of storage at 45° F (7° C) for fruit harvested 5 months after fruit set, and at 1, 25, and 70 days for fruit harvested 7 months after fruit set. The weight of each fruit was recorded during each sampling. Sensory evaluation was performed parallel to chemical analysis. The ± 2 hedonic scale described by Kramer and Ditman (7) was used to evaluate flavor quality and appearance of fruit and to determine differences among clones. Flavor was evaluated as: very good, good, acceptable, poor, and bad. Appearance of the fruit ranged from very attractive to unattractive.

The juice of the fruit used for sensory evaluation was filtered through a cloth and assayed for °Brix, pH, total acidity, reducing and total sugar content, following the methods of the A.O.A.C. (13). The peels of the fruit that were evaluated were placed in Cryovac bags, sealed under vacuum, and kept frozen at −10° F until assayed by gas chromatography. A composite sample of the peels of each selected clone throughout the 70 days cold storage was used for the gas chromatographic analysis.

From 800 g to 1 kg of peels were ground in a Waring blender and mixed with 5 l of distilled water in a 12-l flask and distilled under vacuum for 3½ hr. The oil droplets were collected in a 6-ml hexane 99 mol % pure (Fisher) column over water connected to a hydrostatic column. Most of the hexane was removed by flushing N over the extract at ambient temperature. The oil extract was then dried over anhydrous sodium sulfate and transferred to the storage vial.

The separation of the components of the peel was made with a chromatographic column, using a Perkin-Elmer 900 gas chromatograph equipped with a hydrogen flame detector system. The column was 12 ft × ⅛ in o.d. stainless steel containing 5% OV-101 supported on acid-washed 80–100 mesh Chromosorb W. Helium flow rate was maintained at 20 ml/min with an initial column temperature of 90° C. Temperature programming was set at a rate of 4° C/min to a final temperature of 185° C for 12 min.

RESULTS AND DISCUSSION

Tables 1 and 2 show the results of the chemical analysis, statistical interpretation, and sensory evaluation of the five chironja clones throughout the storage period.

TABLE 1 —*Chemical analysis and sensory evaluation of chironja harvested 5 months after fruit set under storage at 45° F (7° C) and 90% relative humidity for 70 days*

Clones	Days in storage					
	3	30	40	55	70	Mean
			Brix			
2-3	9.2	9.5	8.9	7.2	7.6	8.48 a
2-4	9.0	9.5	9.6	9.4	9.2	9.34 b
3-8	9.5	9.6	9.9	10.4	9.8	9.84 b
4-11	9.8	10.8	9.1	9.8	9.5	9.80 b
2-7	9.2	9.2	9.6	9.2	9.8	9.40 b
Mean	9.3 a[1]	9.7 a	9.7 a	9.4 a	9.2 a	
			pH			
2-3	3.95	3.70	3.90	3.80	3.90	3.85 a
2-4	3.95	3.75	3.64	3.83	3.90	3.82 a
3-8	3.95	3.70	3.65	3.80	3.90	3.80 a
4-11	3.62	3.95	3.80	3.90	3.45	3.74 a
2-7	3.90	3.80	3.82	3.85	3.83	3.84 a
Mean	3.87 a	3.78 a	3.76 a	3.84 a	3.80 a	
			Total acidity, %			
2-3	0.51	0.68	0.55	0.61	0.43	0.56 a
2-4	0.52	0.66	0.79	0.63	0.70	0.66 a
3-8	0.45	0.72	0.78	0.69	0.38	0.60 a
4-11	0.83	0.44	0.62	0.59	0.57	0.61 a
2-7	0.55	0.57	0.59	0.60	0.62	0.59 a
Mean	0.57 a	0.61 a	0.67 a	0.62 a	0.54 a	
			Reducing sugars, %			
2-3	4.99	3.00	3.62	3.46	4.18	3.85 a
2-4	5.06	3.29	3.21	3.51	3.21	3.66 a
3-8	4.57	2.82	3.34	4.03	3.35	3.62 a
4-11	3.76	4.45	3.32	3.51	3.41	3.69 a
2-7	4.00	3.17	3.61	3.39	3.62	3.56 a
Mean	4.48 a	3.55 b	3.42 b	3.58 b	3.55 b	
			Total sugars, %			
2-3	7.46	6.34	6.18	6.22	6.51	6.54 a
2-4	7.41	6.47	6.22	6.32	6.23	6.55 a
3-8	7.86	6.34	6.32	7.05	6.22	6.75 a
4-11	7.71	7.40	6.66	6.63	6.24	6.93 a
2-7	7.36	6.14	6.13	6.13	6.53	6.50 a
Mean	7.56 b	6.54 a	6.10 a	6.47 a	6.35 a	

TABLE 1.—*Continued*

Clones	Days in storage					
	3	30	40	55	70	Mean
			Brix/acid			
2-3	18	14	16	15	22.3	17.1 a
2-4	17	14.4	12	15	13	14.4 a
3-8	21	12	14.7	15	25.8	17.3 a
4-11	11.8	24.5	16.3	16.6	16.6	16.8 a
2-7	16.7	16.1	16.3	16.4	15.8	16.3 a
Mean	16.9 a	16.2 a	15.1 a	15.6 a	18.7 a	
			Flavor			
2-3	0.81	1.31	0.64	0.87	0.70	0.87 a
2-4	0.46	1.23	0.71	0.83	0.63	0.77 a
3-8	0.58	0.96	0.89	0.97	0.77	0.83 a
4-11	0.92	0.77	0.82	1.00	0.27	0.76 a
2-7	0.23	1.19	1.07	0.50	0.57	0.71 a
Mean	0.60 a	1.09 b	0.83 b	0.83 b	0.59 a	
			Visual appearance			
2-3	0.10	0.77	0.50	0.83	0.54	0.55 a
2-4	0.20	0.85	0.70	0.37	0.75	0.57 a
3-8	1.10	0.88	0.93	0.93	0.93	0.95 b
4-11	1.60	1.54	1.36	1.03	0.97	1.30 b
2-7	0.65	0.92	1.07	1.33	0.97	0.99 b
Mean	0.73 a	0.99 a	0.91 a	0.90 a	0.83 a	

[1] Means with the same letter do not differ significantly at the 5% level.

Total acidity (citric acid/100 g juice) of fruits from all clones harvested 7 months after fruit set decreased during the first month in storage (table 2). An increase in total acid content was observed for all five clones at 70 days compared to the first month in storage. No apparent changes in total acid content of fruit harvested 5 months after fruit set, were observed during storage nor were there apparent differences among clones (table 1). Martin et al. (9) reported an increase in citric acid content followed by a steady decrease in grapefruit stored for prolonged time at 60° F (15.5° C) and 80% relative humidity. Schiffman-Nadel et al. (14) reported a reduction in acid content of grapefruit after storage for 16 weeks or more at temperatures of 35.5° to 62.5° F (2° to 17° C).

Reducing and total sugars of chironja harvested 5 months after fruit set decreased significantly during the first month in storage with exception of clone 4-11 (table 1). In contrast, percentage of total sugars

TABLE 2 —*Chemical analysis and sensory evaluation of chironja harvested 7 months after fruit set under storage at 45° F (7° C) and 90% relative humidity for 70 days*

Clones	Days in storage			
	1	25	70	Mean
		Brix		
2-3	10.6	9.8	10.0	10.2 c
2-4	10.4	9.2	9.6	9.73 a
3-8	11.6	10.8	10.0	10.8 b
4-11	10.6	10.8	11.0	10.8 b
2-7	9.6	9.2	9.6	9.47 a
Mean	10.7 a[1]	10.0 a	10.0 a	
		pH		
2-3	4.13	4.20	4.15	4.16 b
2-4	3.95	4.30	4.15	4.13 b
3-8	3.90	4.08	3.95	3.98 a
4-11	3.90	3.96	3.98	3.95 a
2-7	3.90	4.10	3.95	3.98 a
Mean	3.96 a	4.13 b	4.04 a	
		Total acidity, %		
2-3	0.45	0.39	0.46	0.43 a
2-4	0.47	0.33	0.45	0.42 a
3-8	0.53	0.52	0.68	0.58 b
4-11	0.57	0.56	0.64	0.59 b
2-7	0.56	0.44	0.56	0.52 b
Mean	0.52 b	0.45 a	0.56 b	
		Reducing sugars, %		
2-3	4.63	4.69	5.00	4.77 a
2-4	4.27	3.84	4.49	4.20 a
3-8	4.32	5.49	5.61	5.14 a
4-11	4.22	4.71	4.85	4.59 a
2-7	4.25	5.14	4.74	4.71 a
Mean	4.34 a	4.77 a	4.94 a	
		Total sugars, %		
2-3	8.17	8.03	8.38	8.19 a
2-4	8.27	7.47	9.47	8.40 a
3-8	9.00	9.12	9.96	9.36 ab
4-11	8.87	9.06	9.61	9.18 ab
2-7	8.16	7.72	7.92	7.93 a
Mean	8.49 bc	8.28 b	9.07 c	

TABLE 2—*Continued*

Clones	Days in storage			
	1	25	70	Mean
		Brix/acid		
2-3	23.6	25.1	21.7	23.5 b
2-4	22.1	27.8	21.3	23.7 b
3-8	21.9	20.8	14.7	19.1 a
4-11	18.6	19.3	17.1	18.3 a
2-7	17.1	20.9	17.1	18.4 a
Mean	18.1 a	22.8 b	18.4 a	
		Flavor		
2-3	0.87	1.20	0.63	0.90 a
2-4	0.83	1.04	0.70	0.86 a
3-8	0.97	1.07	0.47	0.84 a
4-11	1.00	1.20	0.23	0.81 a
2-7	0.50	0.97	0.70	0.72 a
Mean	0.83 b	0.86 b	0.55 a	
		Visual appearance		
2-3	0.83	1.20	0.30	0.78 a
2-4	0.37	0.47	0.90	0.58 a
3-8	0.93	1.10	0.93	0.99 a
4-11	1.03	1.40	1.20	1.21 a
2-7	1.33	1.20	1.03	1.19 a
Mean	0.90 a	1.07 a	0.87 a	

[1] Means with the same letter do not differ significantly at the 5% level.

increased after the first month in storage of fruit harvested 7 months after fruit set (table 2). Clones 3-8 and 4-11 showed the highest values.

In studies conducted by Lodh et al. (6), and Kohli (8) on the storage of Indian oranges and mandarins kept for 75 to 90 days at 40° F (4.5° C), the trends in composition followed the pattern of increasing sugar content and decreasing acidity. Gershtein (3) observed a similar pattern during maturation and storage of Russian oranges. These changes in composition were also confirmed by Harding et al. (4) with Florida oranges, mandarins, and hybrids, and by Bowden (1) in Queensland. The chironja, when harvested 7 months after fruit set, appears to follow more closely the expected pattern of increasing sugar content and decreasing acidity during maturation and storage, which is typical of oranges, mandarins, and citrus hybrids.

Fruit harvested 7 months after fruit set showed significantly higher

soluble solids-to-acid ratio values at the 25th day in storage. Most outstanding values were shown by clones 2-3 and 2-4 with values of 23.5 and 23.7, respectively, which was expected because of the low acid content of these clones. The values at the end of the storage period were not significantly different from those at the beginning of storage. Fruit harvested 5 months after fruit set showed no significant differences for the entire storage period.

Appearance and flavor of the fruit were evaluated as "good" by a sensory evaluation panel throughout the storage period. However, the panel showed a significant preference (at the 5% level) for the flavor of fruit stored between 30 and 55 days for fruit harvested 5 months after fruit set, and at 25 days for fruit harvested 7 months after fruit set (tables 1 and 2). Schiffmann-Nadel et al. (14) studied the response of grapefruit to different storage temperatures ranging from 35.5° to 62.5° F (2° to 17° C) and observed that fruit developed better flavor when stored at 46° to 62.5° F (8° to 17° C).

No significant difference with respect to flavor was found among the five clones from the 7-month harvest. Clones 4-11, 2-7, and 3-8 from the 5-month harvest showed better appearance than the other clones studied.

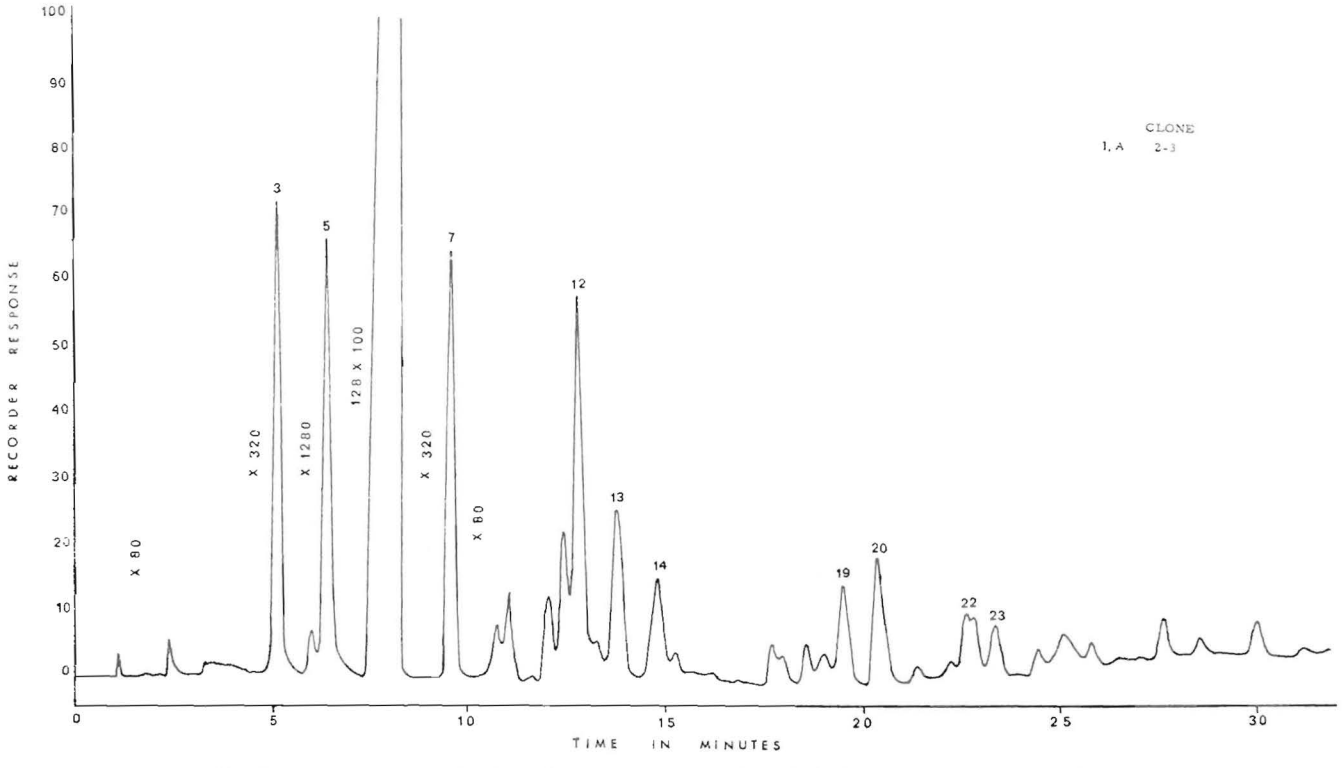
Average values for loss in weight (whole fruit) during storage for 70 days at 45° F (7° C) and 90% relative humidity with different dates from fruit set to harvest of the five clones studied were as follows:

Clones	5-month harvest	7-month harvest
	%	%
2–3	0.92	0.30
2–4	.73	.23
3–8	.83	.31
4–11	.81	.23
2–7	.73	.37

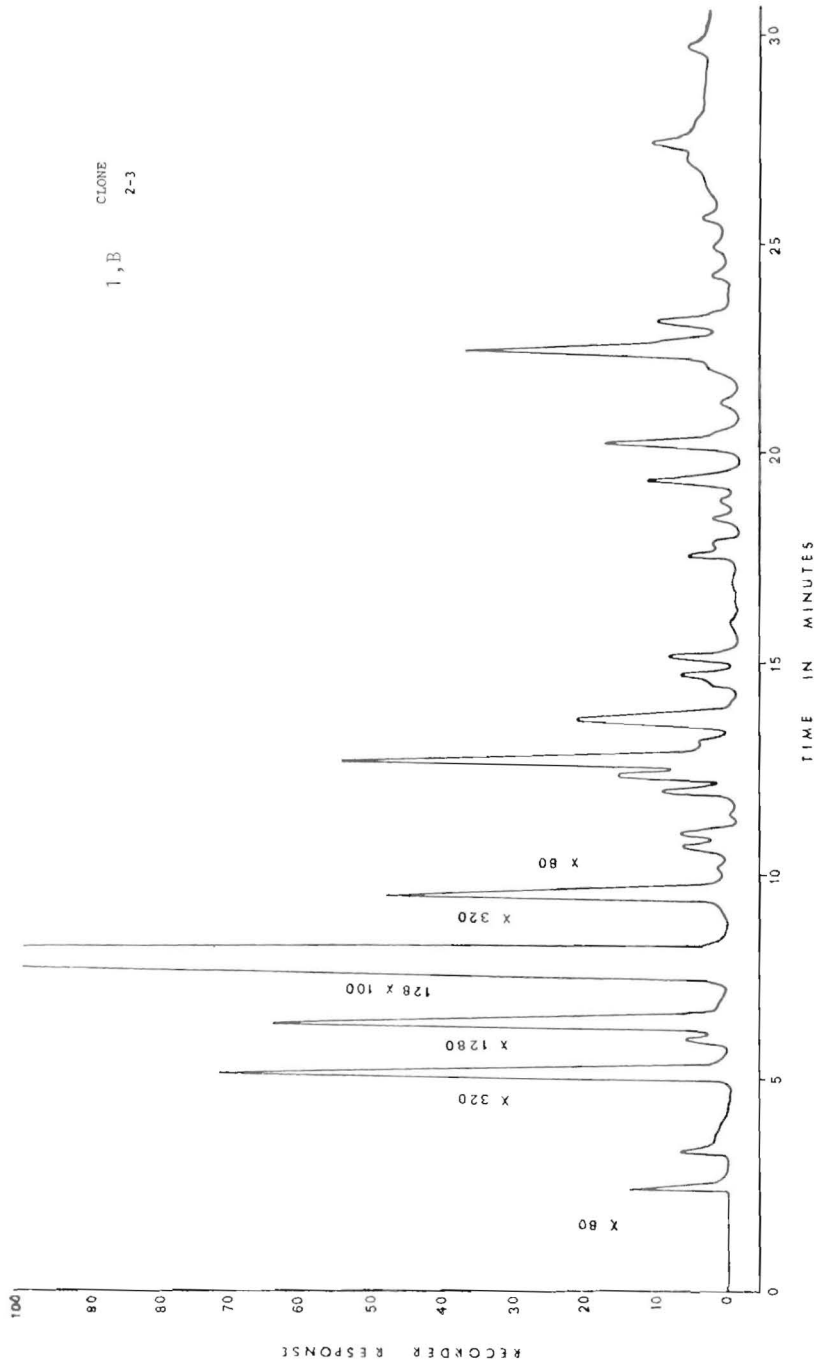
Fruit harvested 7 months after fruit set lost less weight than fruit harvested 5 months after fruit set. In all cases the loss was less than 1%. There were no significant differences among clones with respect to weight loss since they all followed the same trend for their age at harvest. Although the fruit was not waxed, it was placed in polyethylene bags, which protected it from loss of moisture to the environment. Internal quality of the fruit was excellent throughout the 10-week duration of storage.

The gas chromatograms of the peel oil extracts, obtained from distillation of composite samples of each clone are presented in figures 1 to 5. The chromatographic pattern is similar for all clones studied.[4] The major differences in the chromatograms were the higher concentrations ob-

[4] Fraction numbers from Fig. 1, A apply to all figures.



FIGS. 1–5, A and B—Gas chromatograms of chironja peel oil. Fruit stored at 45°F (7° C) and 90% relative humidity for 70 days; A, 5-month harvest, B, 7-month harvest.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X 1280
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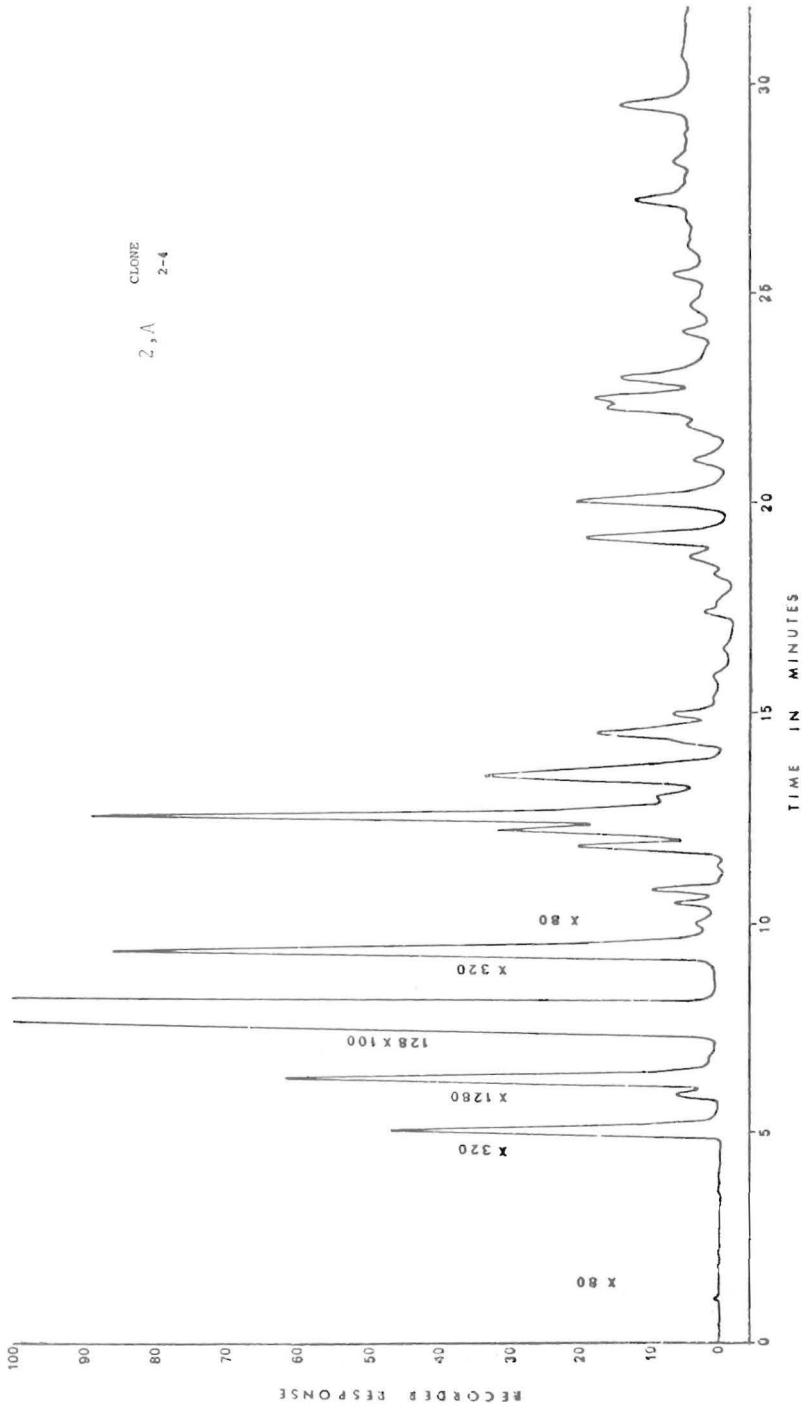
X 320
X 80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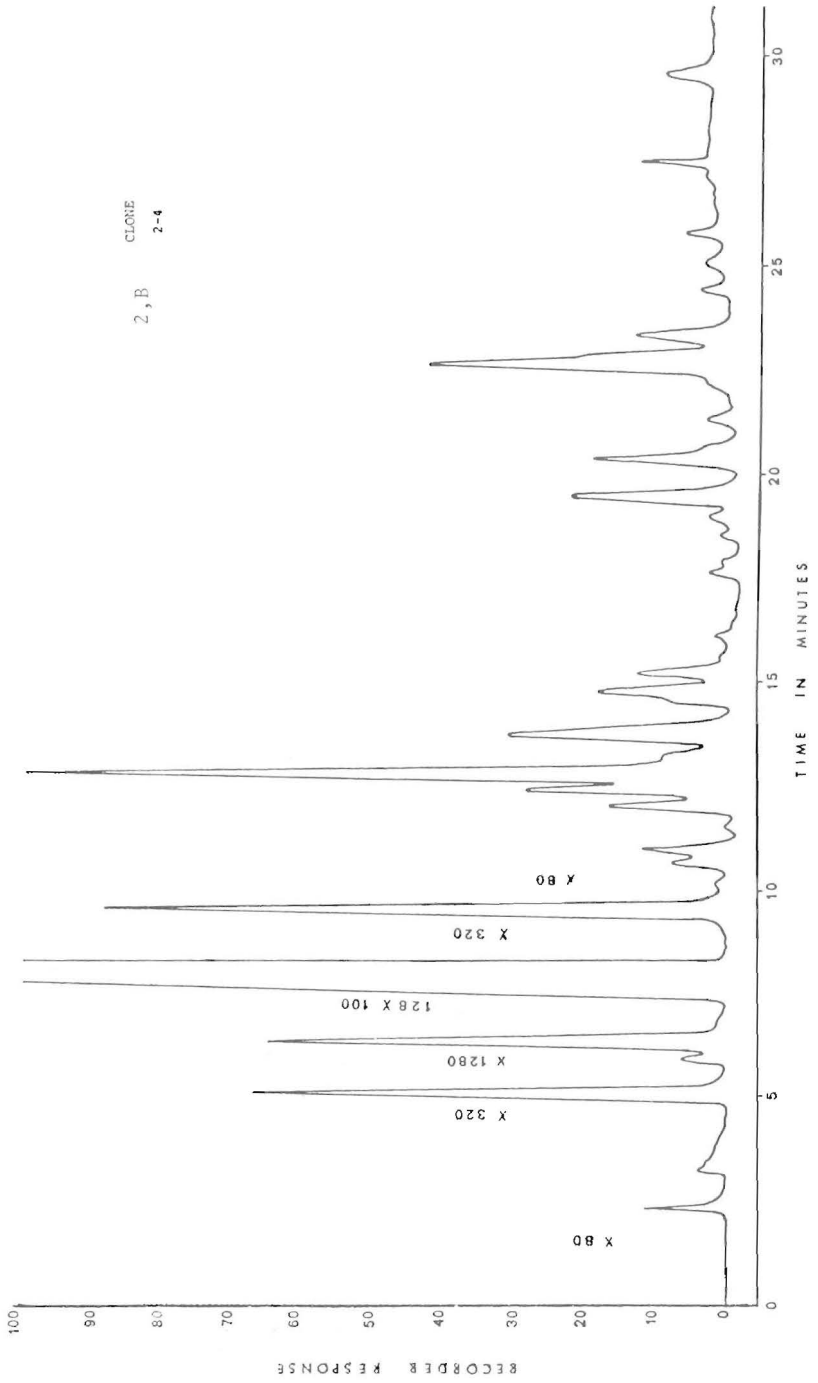
X 80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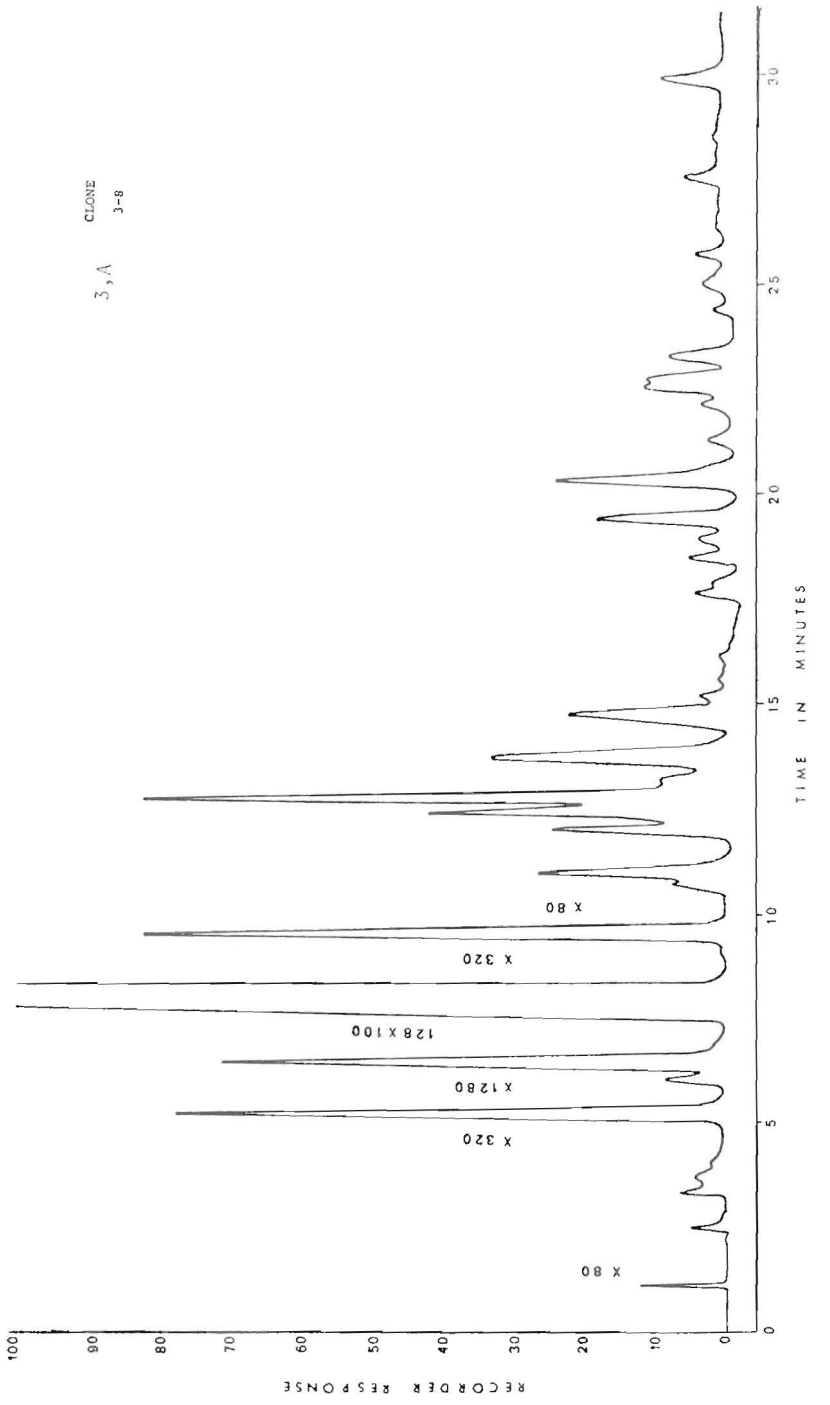
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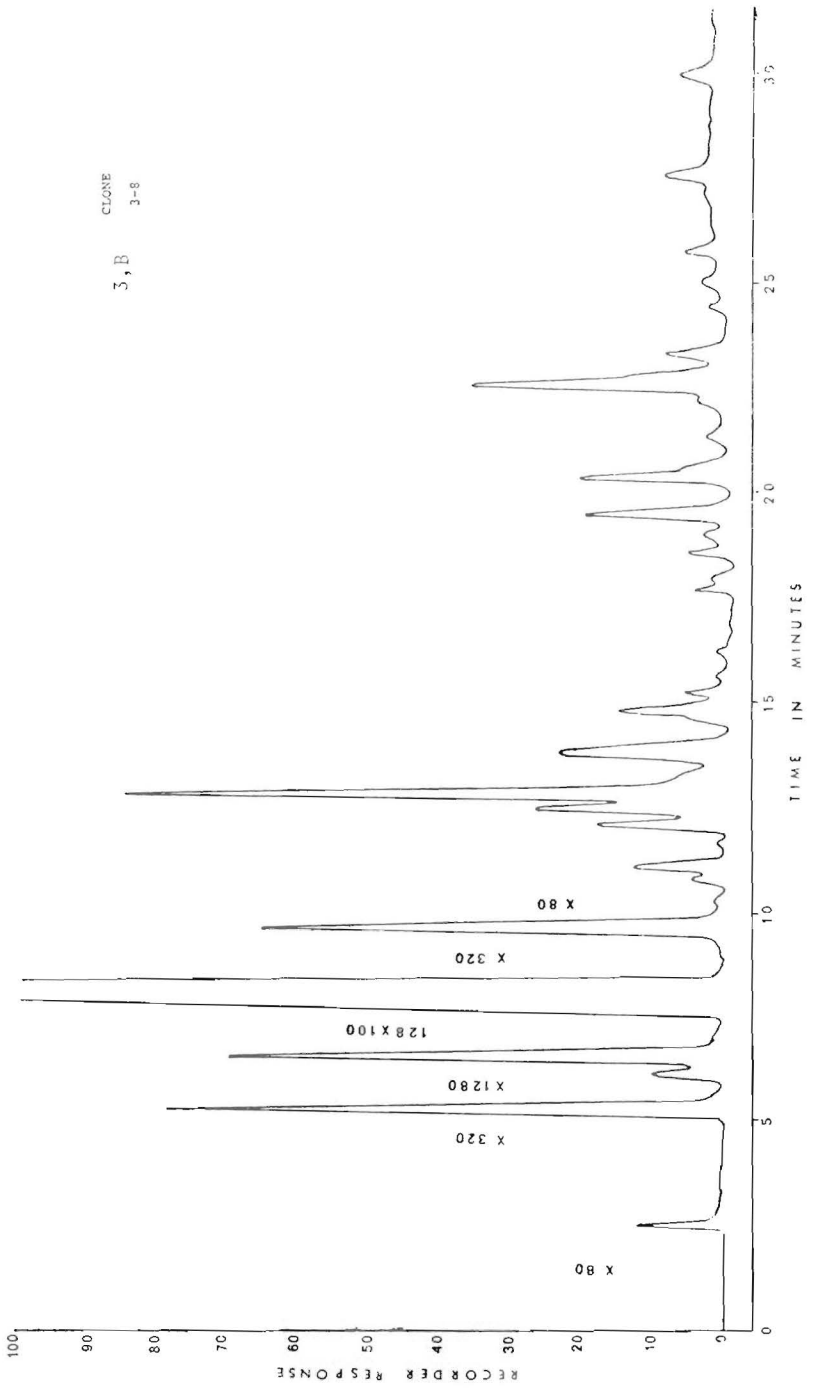
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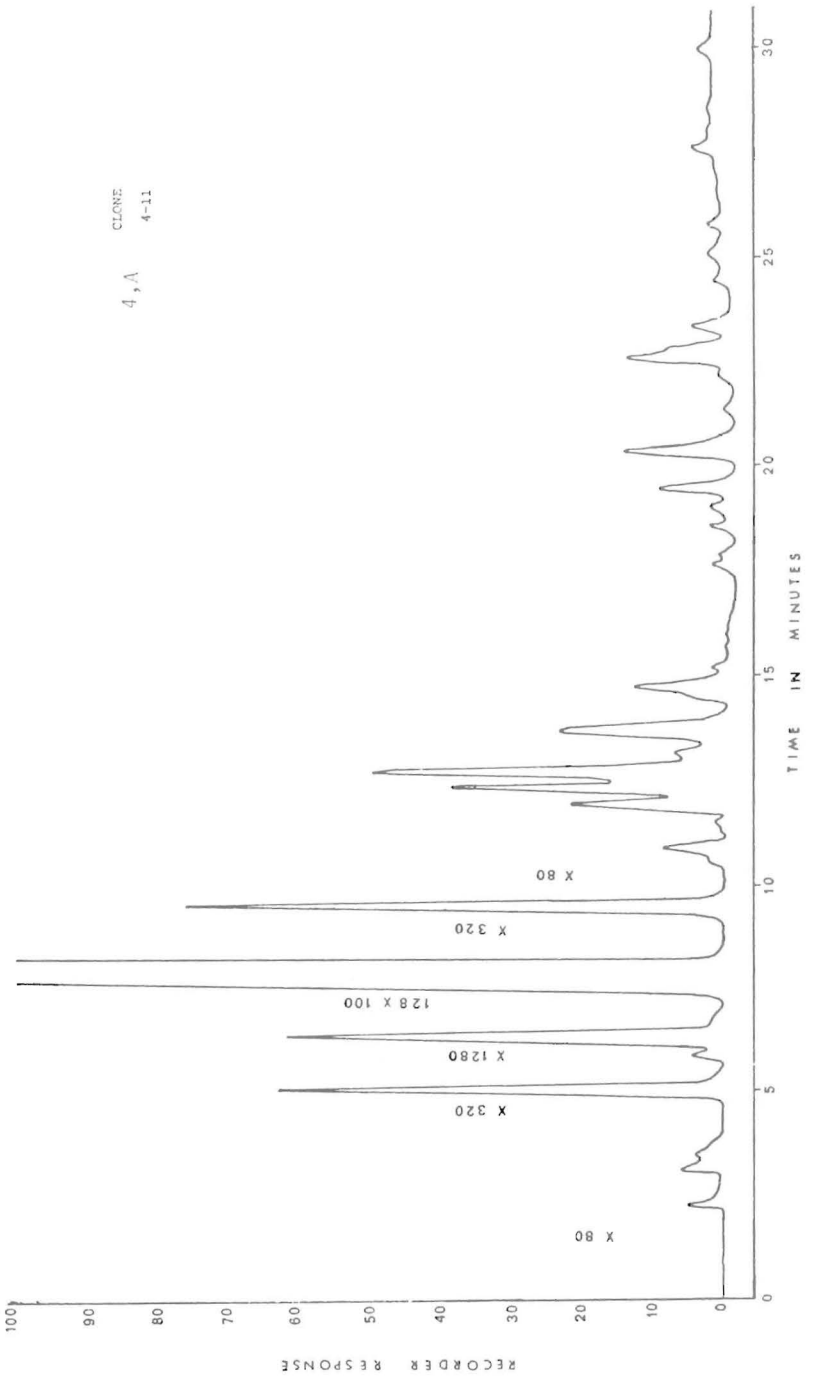
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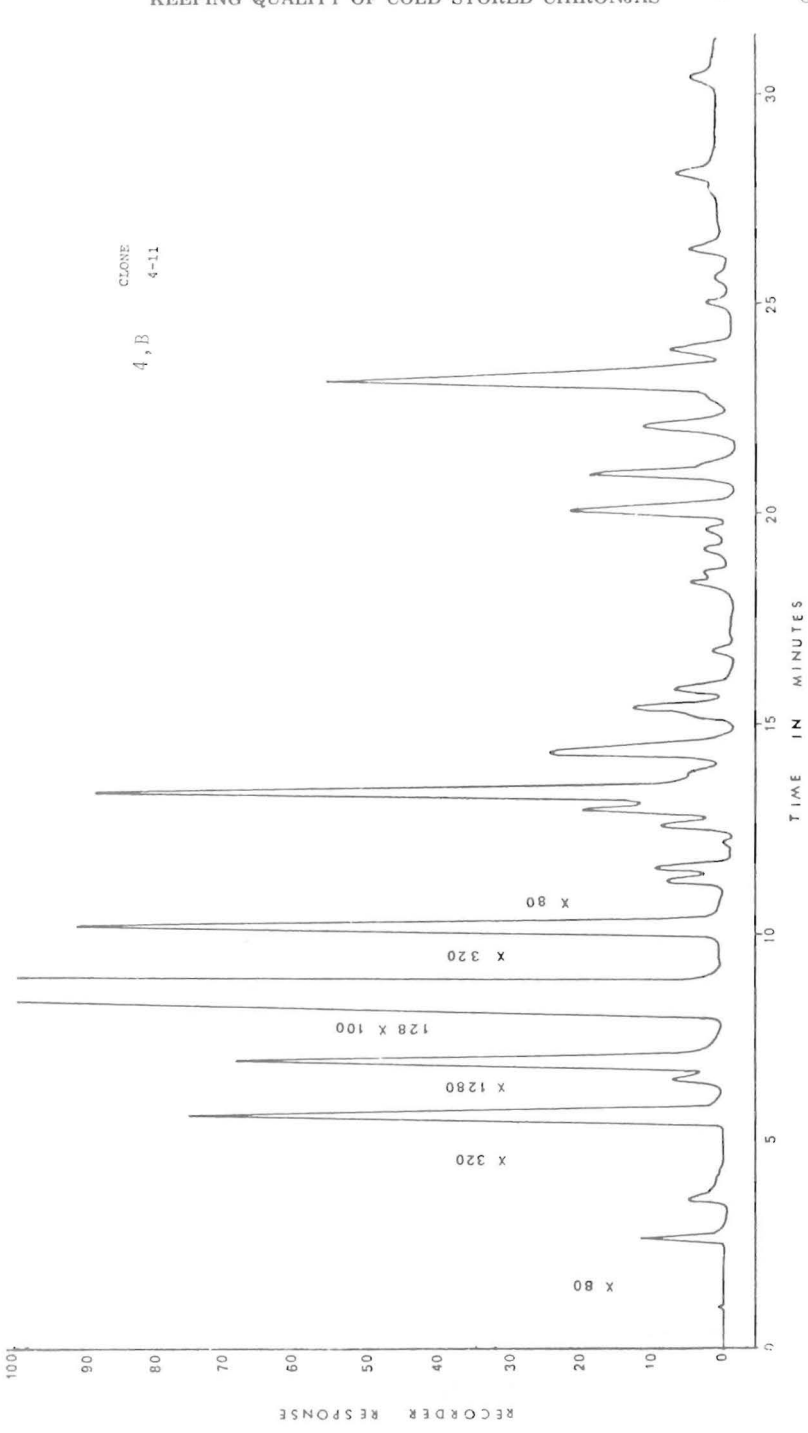
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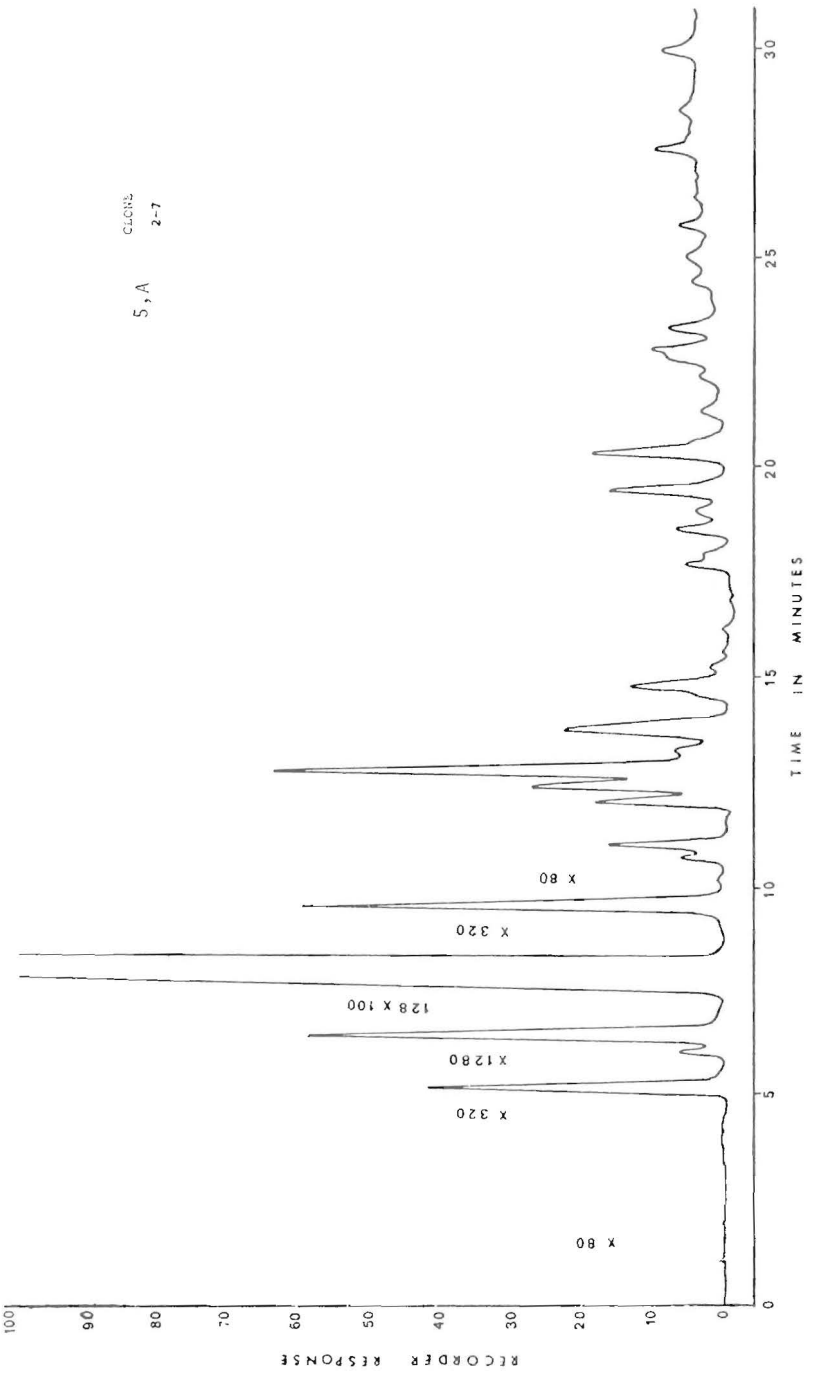
S, A
CLCN2
2-7
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x 320
x 1280
128 x 100
x 320
x 80
RECORDER RESPONSE
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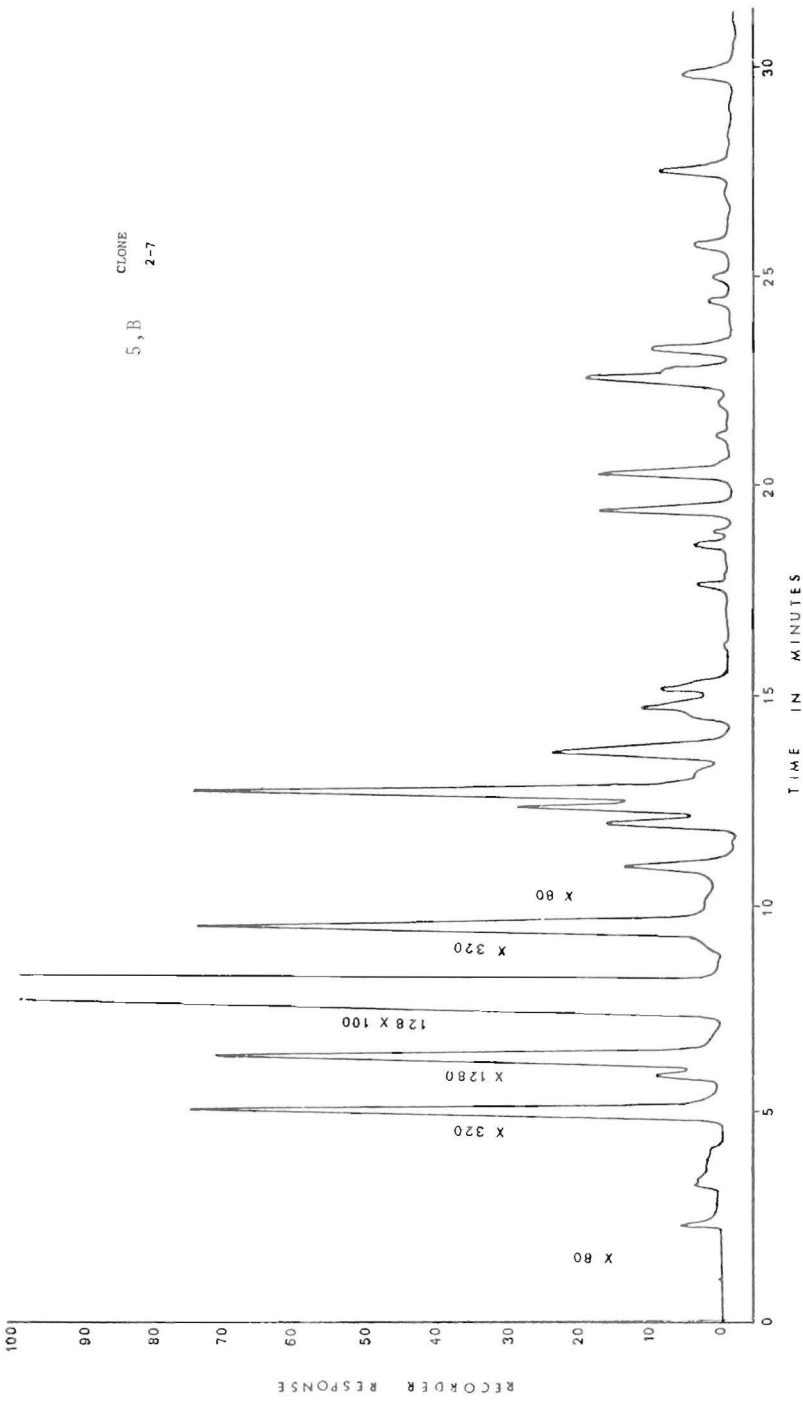
CLONE
5, B 2-7
X 80
X 320
X 1280
128 X 100
X 320
X 80
RECORDER RESPONSE
TIME IN MINUTES
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TABLE 3.—*Relative peak heights of outstanding individual fractions obtained by gas chromatography on the peels of five clones of chironja stored at 45° F for 70 days*

Clones	Relative peak height									
	3	5	7	12	13	14	19	20	22	23
					5 months after fruit set					
2-3	72	66	65	58	26	15	14	18	10	8
2-4	46	61	86	89	33	18	19	20	18	14
3-8	78	72	83	83	34	23	19	25	12	9
4-11	72	70	90	58	27	16	13	19	18	8
2-7	42	59	60	64	23	14	17	19	11	8
					7 months after fruit set					
2-3	72	65	48	53	20	6	12	17	38	11
2-4	67	65	88	100	31	18	23	20	43	14
3-8	78	70	66	85	24	15	20	21	36	8
4-11	75	69	91	89	24	13	22	19	56	8
2-7	75	72	74	75	24	9	18	15	17	8

[1] The values represent the percent in height of each peak.

served in fractions 3, 7, 12, and 22. Table 3 represents the relative heights of the outstanding peaks. Clones 2-4 and 2-7, harvested 5 months after fruit set, showed a lower content in fraction 3 compared with the others. The same clones (2-4 and 2-7) showed concentrations of fraction 3 comparable to the other clones when harvested at 7 months from fruit set. Fraction 7 showed similar concentration for clones 2-4 and 4-11 regardless of age at harvest and the effect of storage conditions. An apparent reduction in the concentration of fraction 7 was observed for clone 3-8. The concentration of fraction 12 increased considerably in clones 2-4 and 4-11. A significant increase in the concentration of fraction 22 was observed for all clones (except 2-7) for fruit harvested 7 months after fruit set.

Significant correlations at the 5% level were established between fraction component 22 and both total soluble solids and total sugar content. Fraction 3 also showed significant correlation with soluble solids content.

Results obtained with the chromatographic technique seemed to indicate that the larger concentration in some of the individual components may be associated with more mature fruit.

RESUMEN

La chironja es una fruta cítrica cuyas características morfológicas reflejan algunas de las de la naranja dulce y otras de la toronja (pomelo). Hay gran interés en propagar esta fruta en escala comercial en Puerto Rico. Por falta de información acerca del comportamiento de la chironja

bajo condiciones de almacén, se inició un estudio para avaluar la calidad de la fruta cosechada cinco y siete meses después de la fructificación. El estudio comprendió frutas de cinco clones cultivados en la Subestación Experimental de Corozal. Estas se limpiaron y se almacenaron en bolsas de polietileno a temperatura de 7° C. y a humedad relative de 90 por 100 por un período de 70 días. Se observaron diferencias en calidad y composición química entre los cinco clones.

Las frutas conservaron una guena apariencia y un guen sabor durante el período de almacenamiento de 70 días según la avaluación hecha por un panel de catadores. No obstante, los catadores prefirieron, por su sabor, las frutas almacenadas entre 25 y 55 días, independientemente de la edad al momento de la cosecha. Las diferencias en preferencia fueron significativas al 5 por 100 de probabilidad.

No se encontró diferencia significativa en el sabor entre los clones.

Se observó una disminución tanto en los azúcares reductores como en los azúcares totales durante el primer mes de almacenamiento de las frutas cosechadas a los cinco meses de edad en contraste con un aumento en el porcentaje de azúcares totales en las cosechadas a los siete meses de edad.

En general, entre las frutas cosechadas a los siete meses, había más diferencias significativas en composición química, dependiendo de los clones, que en las cosechadas a los cinco meses.

La pérdida de peso de la fruta no llegó al 1 por 100 durante todo el período de almacenamiento, independientemente de los clones o de la edad al momento de la cosecha.

El patrón cromatográfico de los componentes de sabor y aroma de la cáscara de chironja fue similar para todos los clones estudiados. Se observaron concentraciones más elevadas en algunas fracciones de las frutas cosechadas a los 7 meses.

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