Lye Peeling of Citron (*Citrus medica* L.)[1]

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INTRODUCTION

Citron (*Citrus medica* L.) is produced in the central mountainous region of Puerto Rico, in the vicinity of Adjuntas. The fruit is picked mature green, placed in tanks where brine is added, and then fermented. The fermented fruit is washed, halved, cored, and diced. The diced product is ready to be candied or stored in drums with fresh brine. A single processing firm at present is candying a portion of the fermented citron produced in Puerto Rico; the rest is exported in brine-filled drums to the U. S. mainland and Europe.

Candied citron is used only in limited amounts in confectionery and bakery (4). Market outlets have not increased; on the contrary, they are becoming rather uncertain (8). For this reason the Food Technology Laboratory is working toward the development of new marketable citron products.

Encouraging results in the production of a jelly-type citron preserve and marmalade led to the investigation of the various techniques involved in processing citron. Citron must be peeled prior to further processing candied citron.

Peeling usually is accomplished with hand peelers, abrasive surfaces, flame and radiant heat, steam, lye solutions (2), infrared (12), and caustic-peeling (6,13). The method employed is dependent on the type of fruit or vegetable to be processed, the final products for which the raw material is intended, and most importantly, the size and scope of the operation.

Lye peeling has been used successfully in peeling many fruits and vegetables, such as potatoes (9), peaches (10), sweet potatoes (1), apples (7), carrots (11), beets (13), figs (5), and papaya (2).

The present investigation was conducted for the purpose of determining proper lye-peeling conditions for citron such as time of treatment, temperature and concentration of lye solution. Results of this study are reported below.

MATERIALS AND METHODS

Commercially-grown citrons, obtained from different citron farmers and processors in the Adjuntas region, were used in all experiments. Completely

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green mature fruits were selected. These were oval or oblong in shape. They varied greatly in size (4 to 8 by 2 to 6 inches) and in weight (0.7 to 4.0 pounds). The skin was often rough or bumpy.

LYE SOLUTIONS

The lye solutions employed were 10-, 15-, 20-, and 25-percent, prepared from 76-percent pure sodium hydroxide flakes. Each concentration was readjusted periodically during the experiment to keep the lye level within the specified range.

Boiling temperatures for the four weight concentration solutions were 216° to 218° F. (102° to 103° C.), 220° to 222° F. (104° to 105° C.), 226° to 228° F. (108° to 109° C.) and 234° to 236° F. (112° to 113° C.), respectively.

Each batch test involved 175 pounds of solution.

LYE-PEELING PROCEDURE

The lye peeler employed was a rectangular stainless steel vessel divided into two chambers, one for the solution, the other for water. These chambers each contained a perforated basket providing for rapid separation of fruit from lye solution and quick immersion into fresh water. The lye solution chamber had a total capacity of 29.5 gallons, reduced to 23 gallons due to space occupied by heating coils. The volume of lye solution was maintained constant throughout the experiments at 18 gallons. It was heated by a high heating capacity steam coil.

The lye solution was heated to the boiling point. The citrons were immersed in the solution at this point for the predetermined period of time. Fifteen pounds of fruit were used in each trial. After the specified time elapsed, the citrons were removed from the hot solution and dumped into fresh cold water for fast cooling. The hot lye solution hydrolyzed the skin tissue of the fruit. The softened tissue first was removed with water sprays, then with a fiber brush, until all such tissue disappeared and the reaction of the surface of the peeled citron to a phenolphthalein indicator was no longer alkaline or when the color indicated slight alkalinity.

LYE-PEELING PROCESS EVALUATION: VISUAL RATING, PH, TOTAL ACIDITY, AND COLOR OF FRUIT

Visual evaluations of the peeled fruits were made by checking each one individually and determining the degree of peel removal. The fruit was rated in accordance with the following criteria: Very good, fruit completely peeled; good, one or two small spots of peel remained; acceptable, three or more small spots of peel remained but easily removed by trimming; and unsatisfactory, large spots or a large area of peel remained on the fruit.

Peeled and washed fruits from each test batch were skinned with a potato peeler to prepare samples for analyses. Thin slices of pulp, about $\frac{1}{32}$ inch thick, were cut from around the surface of each peeled fruit. The pulp removed was mixed and mashed in a high-speed grinding mill (Waring Blendor). Samples for the different analyses were weighed from the mashed stock.

The pH determinations were made from equal weights of pulp and distilled water. Total acidity was determined by titrating a given weight of the mashed pulp with 0.1 N NaOH to pH 8.1. The activity was calculated as percent citric acid. Color determinations were made on an acetone extract of the mashed pulp by measuring the transmittance at 665 mμ in a Beckman DBG spectrophotometer.

RESULTS AND DISCUSSION

HAND PEELING OF CITRON FRUIT

To obtain the information necessary for a comparative evaluation of the lye-peeling process, a series of experiments were performed using the hand-peeling method. Following is a tabulation of some of the results obtained from the eight samples tested:

Average weight per citron, and range	Peeled pulp per citron, and range	Quantity of peel
Pounds	*Percent*	*Percent*
2.5 (1.5–3.3)	68.8 (60.0–71.3)	14.6 (11.3–16.3)

No relationship was found between percent of peel obtained and size of fruit. These experiments showed hand peeling to be a time-consuming and a high-manufacturing cost operation on a commercial basis. The quality of the hand-peeled product, as well as the quantity of waste, were uncertain, although handling peeled fruit increased the bacteriological count.

RELATION BETWEEN TIME OF IMMERSION AND THE LYE SOLUTION CONCENTRATION ON THE LYE-PEELING OPERATION

To determine the effect of lye-solution concentrations and times of immersion, citrons were peeled in 10-, 15-, 20-, and 25-percent lye solutions, varying the immersion time from 4 to 9 minutes, 3 to 8 minutes, 1 to 6 minutes, and 1 to 5 minutes, respectively, for each concentration (table 1). Each treatment was replicated from three to six times. Results in average values and ranges are shown in tables 1 and 2. The data presented in table 1 show that when trimming is unnecessary, good peeling results from each of the four following treatments: 6 minutes in a 10-percent solution, 5 minutes in a 15-percent solution, 3 minutes in a 20-percent solution, and 2 minutes in a 25-percent solution.

When small amounts of peel are not detrimental to final product quality in a citron-processing operation, 5 minutes in a 10-percent solution, 4 minutes in a 15-percent solution, 2 minutes in a 20-percent solution, or 1 minute in a 25-percent solution is sufficient for peeling the fruit. An increase in fruit pulp yield ranging from 2.7 to 6.7 percent follows the short time period in the high concentration treatment.

TABLE 1.—*Relation between time of immersion and lye-solution concentration on the effectiveness of the lye-peeling operation of green citrons*

Lye solution concentration	Time of immersion in the lye solution	Visual evaluation of the peeling action	Loss in weight of the whole fruit in lye peeling	
			Average	Range
Percent/weight	*Minutes*		*Percent*	*Percent*
10	4	Questionable	14.4	13.0–15.0
	5	Good	16.7	16.0–17.0
	6*	Very good	19.4	18.0–20.0
	7	do.	20.6	20.0–21.7
	8	do.	22.9	20.0–30.0
	9	do.	26.9	21.7–30.0
15	3	Questionable	13.0	10.0–15.0
	4	Acceptable	15.0	10.0–18.3
	5*	Very good	19.0	16.7–21.7
	6	do.	21.0	20.0–21.7
	7	do.	23.0	21.7–25.0
	8	do.	24.8	23.3–26.7
20	1	Questionable	10.5	8.3–13.3
	2	Acceptable	12.9	10.0–16.7
	3*	Very good	19.6	16.7–23.3
	4	do.	20.4	16.7–25.0
	5	do.	24.5	20.0–26.7
	6	do.	26.8	23.3–30.0
25	1	Acceptable	12.8	8.3–15.0
	2*	Very good	17.5	13.3–21.7
	3	do.	22.2	16.7–26.7
	4	do.	27.2	20.0–31.7
	5	do.	28.6	21.7–33.3

* Good peeling operation, no hand-trimming necessary.

Solutions at this concentration were selected for peeling to increase operational speed of the process and to reduce the viscosity of the solution. By reducing viscosity, less solution is removed by fruits when taken from the peeler.

Table 2 shows results of analyses made to determine possible undesirable effects on peeled citron pulp. The data obtained indicates an increase in pH as the immersion time increases, corroborated by a decrease in titrable

TABLE 2.—*Effect on pH, titrable acidity, and spectrophotometric readings of the citron pulp at different immersion times and lye-solution concentrations*

Lye solution concentration	Time of immersion in the lye solution	pH		Titrable acidity (calculated as citric acid)		Transmittance at 665°A.	
		Average	Range	Average	Range	Average	Range
Percent/ weight	*Minutes*	*Units*	*Units*	*Percent*	*Percent*	*Percent*	*Percent*
10	4	5.31	(5.12–5.41)	0.088	(0.082–0.096)	14.2	(10.8–18.4)
	5	5.34	(5.30–5.42)	0.082	(0.071–0.090)	13.1	(8.6–16.0)
	6	5.45	(5.40–5.51)	0.082	(0.069–0.100)	9.8	(6.0–14.5)
	7	5.48	(5.35–5.59)	0.077	(0.060–0.094)	10.1	(5.7–14.2)
	8	5.50	(5.39–5.60)	0.076	(0.061–0.084)	7.4	(4.1–12.2)
	9	5.60	(5.41–5.81)	0.076	(0.064–0.088)	7.4	(5.6–10.7)
15	3	5.17	(5.02–5.21)	0.099	(0.082–0.120)	13.8	(9.3–19.3)
	4	5.22	(4.70–5.50)	0.102	(0.075–0.140)	9.0	(5.6–13.9)
	5	5.12	(4.48–5.40)	0.092	(0.071–0.140)	7.8	(4.6–11.8)
	6	5.21	(4.71–5.50)	0.084	(0.064–0.120)	6.4	(4.4–10.1)
	7	5.39	(5.20–5.60)	0.077	(0.058–0.092)	5.5	(2.4–9.5)
	8	5.58	(5.38–5.72)	0.078	(0.058–0.120)	5.1	(2.0–7.1)
20	1	5.16	(5.09–5.20)	0.109	(0.102–0.116)	26.9	(16.3–34.2)
	2	5.22	(5.18–5.33)	0.109	(0.105–0.115)	12.8	(8.1–16.2)
	3	5.23	(4.90–5.55)	0.097	(0.071–0.119)	7.6	(5.7–8.8)
	4	5.41	(5.30–5.60)	0.081	(0.066–0.099)	5.1	(2.9–8.5)
	5	5.51	(5.40–5.70)	0.066	(0.048–0.084)	2.7	(1.0–3.8)
	6	5.54	(5.30–5.92)	0.065	(0.044–0.084)	1.5	(1.0–2.0)
25	1	5.11	(5.02–5.18)	0.125	(0.098–0.150)	6.4	(2.1–11.9)
	2	5.20	(5.10–5.35)	0.110	(0.086–0.123)	2.6	(1.6–3.9)
	3	5.29	(5.20–5.41)	0.096	(0.088–0.106)	2.9	(0.5–6.4)
	4	5.36	(5.10–5.60)	0.084	(0.073–0.108)	1.6	(0.5–2.5)
	5	5.51	(5.28–5.62)	0.071	(0.052–0.093)	1.8	(1.0–2.4)

acidity. Although the difference is small, fruits peeled in high concentration solutions and less immersion time tend to have lower pH and higher acid content due apparently to the time of immersion which controls penetration of the lye solution into the pulp.

PEELING CAPACITY OF BOILING LYE SOLUTIONS

The peeling capacities of four boiling lye solution concentrations during four time exposure intervals were determined and the results of these experiments are given in Table 3.

The data indicates no relationship between good peeling, the volume of lye solution, and the amount of fruit processed. When the solution or the foam produced covers all the fruit being treated, good peeling results.

TABLE 3.—*Determination of the ratio of citron fruit to lye solution for proper peeling action*

Lye solution concentration	Time of immersion in lye solution	Boiling temperature of lye solution	Weight of citron fruit used	Number of fruit used in trial	Weight of peeled citrons	Weight lost by fruits in lye peeling	Visual evaluation of peeling action
Percent/ weight	*Minutes*	*Degree*	*Pounds*	*Units*	*Pounds*	*Percent*	
10	6	216°–218° F.	20	13	16.8	16.3	Very good
		(102.2°–103° C.)	26	16	21.3	18.3	do.
			28	17	22.5	19.6	do.
			30	22	23.5	21.7	do.
			34	25	26.5	22.1	do.
			38	27	29.8	21.7	do.
			42	29	33.3	20.8	do.
			46	28	33.3	26.6	do.
			50	35	39.0	22.0	do.
			58	32	46.0	20.7	do.
			70	52	53.8	23.2	do.
			76	31	58.3	16.8	do.
			79	38	65.0	17.7	do.
15	5	220°–222° F.	12	11	9.5	20.8	Very good
		(104.4°–105.6° C.)	14	13	11.3	19.6	do.
			16	15	12.5	21.9	do.
			18	13	14.3	20.8	do.
			20	12	16.0	20.0	do.
			22	12	17.0	22.7	do.
			24	17	18.8	21.9	do.
			28	21	21.3	24.1	do.
			70	48	55.0	21.4	do.
			62.5	40	50.3	19.6	do.
			70	43	59.0	15.7	do.
20	3	226°–228° F.	70	49	55.0	21.4	Very good
		(107.8°–108.9° C.)	58.8	41	46.3	21.3	do.
25	2	234°–236° F.	70.3	31	58.8	16.4	Very good
		(112.2–113.3° C.)	67.5	30	57.3	15.2	do.
			69.5	28	58.5	15.8	do.

The peeler was filled to capacity when using 20- and 25-percent lye solutions for this reason without regard for the low capacity ranges.

Citron is different from papaya (13) in this respect: There is no limiting ratio of citron fruit to lye solution for a proper peeling action and no indication was detected of any effect of the surface area of the fruit on the results of the peeling operation.

SUMMARY

Peeling of citron (*Citrus medica* L.) by means of boiling lye-solutions was investigated. Good peeling resulted without need for hand-trimming when

mature green citrons were subjected to any of the following: 6 minutes in a 10-percent, 5 minutes in a 15-percent, 3 minutes in a 20-percent, and 2 minutes in a 25-percent boiling lye solution. The average weight loss as peel under each of the above treatments was 19.4-, 19.0-, 19.6-, and 17.5-percent, respectively. For an acceptable operation tolerating some peel tissue remaining in the final product, the exposure/concentration ratio can be 5 minutes in 10-percent, 4 minutes in 15-percent, 2 minutes in 20-percent, and 1 minute in 25-percent boiling lye solution, with a corresponding increase in pulp yield which varied from 2.7 to 6.7 percent in these experiments. An increase in the time of exposure to lye-solutions increased the pH and decreased titrable acidity and color. No relationship was found between weight of fruit and volume of lye-solution necessary for good peeling. Citrons are peeled adequately when the solution or its foam makes contact with the fruit during treatment.

RESUMEN

Se estudiaron cuatro tratamientos para el pelado de la cidra (*Citrus medica* L.) usando una solución de soda cáustica en ebullición. Se logró pelar la cidra sin necesidad de remover la cáscara a mano, usándose frutas todavía verdes en el exterior pero que habían alcanzado ya su madurez. Los tratamientos o combinaciones fueron los siguientes: inmersión durante 6 minutos en una solución de soda cáustica en ebullición, al 10 per ciento; 5 minutos al 15 por ciento; 3 minutos al 20 por ciento; y 2 minutos al 25 por ciento. La merma atribuída al peso de la cáscara desprendida en cada uno de los tratamientos que se estudiaron promedió 19.4, 19.0, 19.6 y 17.5 por ciento, respectivamente. Se demostró que para lograr un producto aceptable que pueda tolerar una porción pequeña de la cáscara, los tratamientos o combinaciones pueden modificarse reduciendo la inmersión a 5, 4, 2 y 1 minutos en soluciones de 10, 15, 20 y 25 por ciento, respectivamente, de soda cáustica en ebullición. Esa modificación en los tratamientos aumenta el rendimiento de pulpa en un 2.7 a 6.7 por ciento.

El pH aumentó, y la acidez, determinada mediante un análisis volumétrico, y el color de la cidra pelada disminuyeron al aumentarse la duración del tratamiento. No pudo establecerse relación alguna entre el peso de la fruta y el volumen requerido de la solución de soda cáustica para lograr un buen pelado. Las cidras quedan peladas por completo cuando la solución las cubre enteramente o la espuma que forma hace contacto con la fruta durante el tratamiento.

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