PD-AAW-317

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INDUSTRIALIZATION OF COFFEE PECTIN

(Grant No. 936-5542-G-00-2041-00)

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PD-AAW-317

INSTITUTO CENTROAMERICANO DE INVESTIGACIC Y TECNOLOGIA INDUSTRIAL (ICAITI)

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FINAL PROGRESS REPORT

INDUSTRIALIZATION OF COFFEE PECTIN

(Grant No. 936-5542-G-00-2041-00)

4295

Presentado por el ICAITI a

ROCAP
Office of the Science Advisor AID/Washington
Energy Officer
Bureau of Science and Technology LAC/DR, AID/W

Guatemala, June 19 86

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SUMMARY

Pectin from three coffee (C. arabica) varieties: bourbon, caturra and catimor, was extracted and purified. Its physico chemical characteristics were compared with those from eight samples of commercial citrus and apple pectins. Coffee pectin was low methoxyl and of smaller weight average molecular weight than citrus and apple pectin. It did not form consistent gels with sucrose and acid nor with Ca++ salts. Coffee pulp (exocarp) was richer in pectin than coffee mucilage.

Three methods for pectin purification were tested for purifying alcohol-insoluble solids (marc) from the mucilage of ripe coffee fruits (Coffea arabica var. bourbon): the copper II salt method (cupric sulfate pentahydrate), aluminum salt method ($AlCl_3$), and the quaternary ammonium salt method (hexa-decyl-trimethyl ammonium bromide). The effect of temperature, reaction time and pH on pectin purity and yield was studied in 2^3 factorial designs for each method. Lower pH values caused better yields in all methods. Time-pH interaction at the high level improved purity in the copper method, while temperature-pH interaction at high level favored purity in the other methods. The quaternary ammonium salt method was considered the best. The aluminium salt method gave the lowest yields and the copper salt caused a difficult to remove greenish color in the pectin.

A preliminary economic study was made to explore the feasibility of producing pectin (low methoxyl) from coffe in Central America. Local pectin consumption in Central America is small and most of the production should be

exported. The dominant cost in producing coffee pectin is interest on capital, followed by chemicals used in pectin extraction and purification. A minimum economic size of 350 metric tons/year was determined, although it could be smaller if most of the equipment is made locally. However, since the gelling properties of the pectin from the three coffee varieties tested were not adequate for jelly manufacture, its economic perspectives are uncertain.

CONCLUSIONS

2.1 Pectin from **C. arabica** varieties bourbon, caturra and catimor, cultivated at 1 500 m. altitude is low-methoxyl.

2.2 Weight average molecular weights from the coffee pectins assayed are within a smaller range than those of citrus and apple pectin. They fell in the range of 36,000 to 48,000.

2.3 Pectin from the coffee varieties mentioned in 2.1 did not form consistent gels after the addition of Ca++ ions.

2.4 Coffee pulp (exocarp) is about 1.9 times richer in pectin than coffee mucilage.

2.5 The quaternary ammonium salt method was considered the best of the purification methods tested because it gave adequate yields and purity without adverse side-effects like the greenish color of the copper-purified pectin.

2.6 The best extraction conditions for the quaternary ammonium salt method were 15 min. at 60°C, and pH 1.86.

2.7 Since the gelling properties of the pectin from the three coffee varieties tested were not adequate for jelly manufacture, its economic perspectives are uncertain.

BACKGROUND

The project started in July, 1983. Its general objective was to obtain experimental information required to determine the feasibility of using pectins from the coffee mucilage in food applications.

Its specific objectives were:

a) To determined the food-related chemical and physical properties of pectin from the mucilage of the three principal commercial coffee varieties from Central America.

b) To study the influence of known extraction and purification methods on yield and quality of pectin from coffee mucilage.

c) To characterize pectin from mechanically removed mucilage at a coffee processing plant.

The present report covers five and a half semesters of project activities.

ACTIVITIES

The original objectives of the project have been met, except for specific objective (c.), that was not feasible because it required a drastic change in the operating methods of the coffee processing plant. Specific objectives (a.) and (b.) were expanded to include pectin from the coffee pulp solids and juice.

The activities, results and conclusions obtained during 33 months of research (covering three coffee seasons) have been prepared in the form of three research papers that are being submitted to scientific journals for publication. Copies of the manuscripts are enclosed.

EXTENSIONS

Two time extensions for the project were requested to U.S.A.I.D.; the first, a six month extension ending in December 1985, and a three month extension to March 31, 1986.

APPENDICES

The following research papers were prepared and submitted to scientific journals for publication:

a) Characterization of coffee pectin

b) Purification of coffee pectin

A third paper was prepared but due to its nature of preliminary information it will not be sent for publication and will only remain as an internal report:

c) Preliminary economics for the industrial production of coffee pectin

CHARACTERIZATION OF COFFEE PECTIN

CHARACTERIZATION OF COFFEE PECTIN

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SUMMARY

Pectin from three coffee (*C. arabica*) varieties : bourbon, caturra and catimor, was extracted and purified. Its physico chemical characteristics were compared with those from eight samples of commercial citrus and apple pectins. Coffee pectin was low methoxyl and of smaller weight average molecular weight than citrus and apple pectin. It did not form consistent gels with sucrose and acid nor with Ca^{++} salts. Coffee pulp (exocarp) was richer in pectin than coffee mucilage.

I. INTRODUCTION

All the coffee varieties produced in Central America are of the *Coffea arabica* species. The mesocarp is 15 to 20% w/w of the coffee fruit and it is comprised by a mucilaginous substance (mucilage) which is rich in pectin, although the amounts reported in the literature vary (1, 2, 3, 4, 5). Utilization of coffee pectin has worried researchers for many years. Cleves (6) , mentions analytical determinations made in Costa Rica in 1931 where pectic substances were identified in coffee mucilage. Carbonell and Vilanova (7) , characterized the coffee mucilage as an hydrogel without cellular structure. Coleman et all (8) , identified galacturonic acid in mucilage removed by diluted alkali from Guatemalan coffee cherries. Calle (9) , from Colombia, reports that extraction of the mucilage with NaOH solutions gave a substance that gelled after a long resting time. Consistent gels were obtained by addition of sodium hypochlorite to mechanically recovered mucilage. Fresh coffee pulp (exocarp) immersed in 0.5 - 2.0% HCl solutions and autoclaved at 120 °C for 30 min. was latter pressed to obtain a red colored transparent syrup which gellified by cooling after sugar addition. The same author (10) reported later a process to extract pectin from coffee mucilage with HCl 50% and hexametaphosphate as Ca scavenger, to produce a stable gel. Qualitative tests were positive for methanol in the liquid which separated from this gel by syneresis, and the author concluded that it was formed by low methoxyl pectins. The coffee pulp or exocarp was also extracted by boiling with dilute HCl and hexametaphosphate to yield a liquid which gelled on cooling. Pectins from the mucilage had no pigments and phenolic compounds like those from the pulp. Other pectin extraction methods were reported later by Calle (11), consisting in adding calcium gluconate to the mucilage to form a gel, or separating mechanically the mucilage inside an acid bath, screened and spread over glass surfaces were methanol was sprinkled to

gellify the pectin.

However, there was no information in the literature reviewed about the physicochemical properties of coffee pectin gels, which are important to determine its suitability as a food additive, specially for the production of jellies. It was considered then necessary to make a physical and chemical characterization of coffee pectin, comparing it with commercial citrus and apple pectins.

II. MATERIALS AND METHODS

2.1 Coffee samples:

For preliminary tests, whole ripe coffee fruit was obtained from Palin, Escuintla, Guatemala, located at 1000 m. altitude (a mixture of several varieties of *C.arabica*). Another sample was obtained from a coffee plantation in Parramos, Chimaltenango, Guatemala; at 2000 m. altitude, which contained a mixture of at least 2 varieties, according to the different sizes of the coffee beans.

Later, fruits from Bourbon, Caturra and Catimor varieties of *C.arabica* were obtained from a farm in Sacatepéquez, Guatemala, at 1500 m. altitude.

2.2 Commercial pectin samples:

The following samples were tested to compare their properties with coffee pectin:

Purple Ribbon, Rein pure, LM ; Brown Ribbon, 150° US-SAG; Purple Ribbon, D-075, LM; Green Ribbon, 150° US-SAG; Blue Ribbon, 150° US-SAG; from Obipektin AG, CH-9220 Bischofszell, Industriestrasse, Switzerland. Genu pectin Type D, slow set, 150° US-SAG; Genu pectin Type B, rapid set, 150° US-SAG; Genu pectin Type A, med.-rapid set, 150° US-SAG; from A/S Kobenhavns Pektinfabrik, Denmark. Citrus pectin, Type 603, unstandarized; H.P.Bulmer Ltd., Ryelands Street, Hereford HR4 OLE, England.

2.3 Pectin extraction methods:

Sample A: Whole ripe coffee fruits from Palin were immersed in an alkaline sodium sulfite solution (described in 10), and the peel was broken by mannually pressing with a wooden pallet. Then the coffee-alkaline sulfite solution mixture was boiled at 95 °C for 20 min. The liquid was separated from the solids by means of a cheese-cloth and then treated with a 95% ethanol solution, added in a 2:1 proportion by volume, to precipitate the material insoluble in alcohol (marc). The solid part which was separated with the cheese-cloth contained the coffee beans and pulp.

Sample B: A sample of coffee brought from Palin was depulped (elimination of skin) in a manual pulper machine and then processed in a locally made Fukunaga pilot plant demucilaginator. Water was added to the Fukunaga (about 6:1 v/w of mucilage) untill the processed coffee beans plus the mucilage solution flowed out of the machine. After separating the solids in a rotating screen, the diluted mucilage solution was concentrated in a Kontro scrapped

surface vacuum pilot plant evaporator at about 60° C.

The concentrated solution was treated with ethanol to precipitate the marc.

Sample C: About 90 Kg. of ripe coffee fruit from Parramos were depulped and processed in the Fukunaga demucilaginator, but this time only an initial amount of water was added and then the liquid outlet of the machine was recirculated to prevent excessive dilution of the mucilage solution. The resulting concentrated solution was treated with ethanol to precipitate the marc.

Sample D: A portion of coffee mucilage from Sample C was vacuum dried at 0 °C in a Stokes laboratory freeze dryer.

Sample E: Coffee pulp obtained from Palin coffee fruit was extracted by boiling in alkaline sulfite solution by the method described in (10).

Sample F: Pectin extraction tests were performed with ripe coffee fruit samples from Sacatepéquez, Guatemala. Three well identified varieties were used: Bourbon (F-1) , Caturra (F-2) and Catimor (F-3) , all of the *C.arabica* species.

Coffee fruit samples were brought to ICAITI's pilot plant in the same day they were harvested. The first operation was washing with water and detergent, followed by selection to eliminate immature fruits and floats; then it was depulped. The mucilage-covered coffee beans were then placed in a locally made batch demucilaginating machine with a 3 HP electric motor (Sexilago), which resembles a big waring blendor. This operation requires the addition of a certain amount of water, and lasts about 15 min. All materials were weighed to obtain data for a mass balance. The mucilage coming out of the demucilaginator was collected in a plastic container with a 95% v/v ethanol solution to precipitate the marc, which contains the pectin. The precipitate was separated in a basquet centrifuge, then washed with a 95% ethanol solution to eliminate sugars and some pigments, followed by washing with acetone and finally left to dry in trays at ambient temperature.

Sample G: Coffee fruit samples of the Bourbon variety of *C.arabica* from Sacatepéquez were used. Processing was the same as in Sample F, except that the liquid mucilage with coffee beans coming out of the demucilaginating machine was screened in a screening machine (Russel 2758 W.G.2) to separate the beans, and then received in a plastic container with an 81% ethanol solution, acidified with HCl (750 ml. 95% ethanol, 50 ml. HCl conc., 200 ml. water). The precipitate formed was separated by decantation, washed with 75% v/v ethanol, then with 81% v/v ethanol and finally with acetone. The precipitate was then dried for 48 h. at 35 °C, to obtain the marc.

Figure 1 shows an average mass balance for the pectin extraction operations to obtain Sample G.

Sample H: the coffee pulp (exocarp) from Sample G was pressed in a locally made continuous screw press to obtain coffee pulp juice, which was mixed with 2 volumes of acidified ethanol (the same as in Sample G) to precipitate the alcohol-insoluble solids, that

were purified with the same procedure used for Sample G, to obtain the marc.
Figure 2 shows an average mass balance for the pectin extraction operations to obtain Sample H.

Sample I: the solid residue collected after pressing the coffee pulp from Sample G was extracted by boiling for 1 hr. in an aqueous HCl solution of pH 1.

Sample J: the same as Sample I, except that the solution used for the extraction had pH 2.
Figure 2 also shows an average mass balance for the pectin extraction operations to obtain Sample H.

2.3 Chemical determinations:

2.3.1 Purification:

The marc from the mucilage and pulp obtained from samples B, C, and E was purified by a method proposed by F. Rombouts (12), consisting in suspending 30 g. of marc in 3 L. deionized water, adjusting pH to 2.0 with 5N HCl, heating at 80 °C with stirring for 2 h., adding water to compensate evaporation; after which the pH was adjusted to 3.5 with 10% Na_2CO_3 solution, then adding water to 3250 ml. and filter aid, vacuum filter with 2 cloth layers in a Buchner funnel, then vacuum filter through a gross filter paper with filter aid in a Buchner, and adding 1.5 volumes of 96% v/v ethanol to precipitate the pectin. After a 2 h. rest, filtering through a cheese cloth and suspending the solids in 1 L 70% v/v ethanol, vacuum filter through gross filter paper in a Buchner and then wash again with 96% v/v ethanol; after which the solids are left to dry at ambient temperature and milled.

The marc from samples F-1, F-2 and F-3 was purified by the method described by Tuerena (13).

For samples G and H, the marc was suspended in acidified water at pH 1.86, heated at 80 °C for 15 min., and then the quaternary ammonium salt method described by Rombouts (12), adapted to coffee pectins, was followed: after obtaining a clear pectin solution, its pH is adjusted to 4.5 and 1 L. of this solution is mixed with 5 ml. of 1M ammonium sulfate solution; then the temperature is raised to 37 °C, and 250 ml. of a 2% quaternary ammonium salt (hexa decyl trimethyl ammonium bromide) is added, as recommended by Scott (14). The sample was kept at 37 °C for 1 hour before centrifuging and then washing the precipitate 3 times with distilled water, followed by suspending 300 ml. of 1% NaCl solution, adjusting pH to 3.2, and kept at 37 °C untill complete disolution of the complex. Then 900 ml. acidified ethanol are added, after which the precipitate is homogenized by stirring and filtered through a cheese-cloth The precipitate is washed 4 times with the following solutions: i) Acidified ethanol (4:1 ethanol 95% /HCl conc.). ii) Ethanol 50% iii) Ethanol 70% iv) Ethanol 95%; and then vacuum filtered through a cloth. Finally it is left to dry at ambient temperature.

The marc from samples I and J was extracted in the same way as for G and H, and then purified by repeated precipitation in

acidified ethanol.

2.3.2 **Anhydrogalacturonic acid:** The m-hydroxydiphenyl method described by Kinter and van Buren (15) as used for anhydrogalacturonic acid (percent AGA) determination.

2.3.3 **Methoxyl and degree of esterification:** gas chromatographic method of Walter et al (16).

2.3.4 **Acetyl content:** gas chromatographic method by Rizzo (17).

2.3.5 **Nitrogen:** micro Kjeldahl, AOAC (18)

2.3.6 **Carbohydrates:** phenol-sulphuric method,Hodge & Hofreiter (19).

2.3.7 **Moisture:** oven method, FAO (20).

2.3.8 **Total ash:** calcination method, AOAC (18)

2.3.9 **Acid insoluble ash:** HCl boiling method, FAO (21).

2.3.10 **Equivalent weight:** NaOH titration method, Schultz (22).

2.3.11 **Weight Average molecular weight:** the viscosity method described by Rombouts (12), based in the work by Owens et al (23).

2.3.12 **Setting time:** twist method by Joseph & Baier (24).

2.3.13 **Firmness of pectin jellies:** for high methoxyl samples, ^{o}SAG, official IFT method (25). For low methoxyl samples, the method described by Gross and Rao (26).

III. RESULTS AND DISCUSSION

Tables 1 and 2 present a physicochemical characterization of several coffee pectin samples, compared with a commercial unstandarized citrus pectin (Bulmer Citrus 603). Table 3 contains a characterization for 8 commercial pectins. Table 4 presents confidence ranges (λ) at the α = 0.05 level for the chemical determinations, based on the standard deviation from 6 replicates of a known sample, calculated by the equation:

$$\lambda = +/- \; ts(x)$$

Where: x is an estimate of the true mean μ; and the t value is taken at the 0.05 significance level (95% confidence range of the mean), for the degrees of freedom associated with s(x).

3.1 **Percent A.G.A:** The percent anhydro galacturonic acid indicates the amount of pectin in the sample after purification (except for sample D which was crude), and thus will be affected by the extraction and purification procedures used. Since those methods

were different for samples B, C, D and E (Table 1) than for samples F-1, F-2, F-3, G, H, I and J (Table 2), they can not be directly compared.

3.2 Percent Methoxyl and Degree of Esterification: methoxylation of coffee pectin from samples B and C is similar to natural citrus and apple pectins (Tables 1 and 3). Sample E (coffee pulp) was demethoxylated by the alkaline extraction process used. The degree of esterification expected for natural pectins should not be higher than 76% (Pedersen, 27), and all samples assayed where below this limit. Purple Ribbon D-075 and Purple Ribbon Pure (unstandarized) are low-methoxyl pectins, but the percent methoxyl of the D-075 sample was higher than what would be normally expected. On the other hand, the Brown Ribbon sample was classified as high methoxyl by the manufacturer, but the degree of esterification obtained was below 50% (Table 3).

Coffee pectin samples F-1, F-2, F-3, H, I and J were low methoxyl, with esterification degrees lower than that of the commercial LM samples (Tables 2 and 3).

3.2 Acetyl: The acetyl content in pectins should be lower than 2.6% for adequate gelling properties (Pippen et al, 28). Pectin from the coffee mucilage samples B, C and E gave an acetyl content within the same order of magnitude of that of commercial citrus pectin (Table 1). Other coffee pectin samples had sligthly higher acetyl contents (Table 2), but still less than 2.6%.

3.3 Nitrogen: All samples assayed (Tables 1 and 3), except one (Purple Ribbon D-075,L.M.), were within the FAO standard of 0.5 % maximum nitrogen content (20).

3.4 Carbohydrates: Carbohydrate contents of coffee pectin samples (Table 1) were within the same order of magnitude as unstandarized (pure) commercial pectins, like Citrus Pectin 603 and Purple Ribbon Pure (Tables 1 and 3).

3.5 Molecular weight: The low molecular weight of the coffee pectin samples B, C, (Table 1) and F-1, F-2, F-3 (Table 2) was probably caused by enzymatic degradation during the extraction process at neutral pH of the mucilage. Values reported in the literature for commercial citrus and apple pectins are higher than 50000, while a citrus pectin sample degraded by heating at 119 ^{o}C for 20 min. gave a molecular weight of 20000-30000 (Owens et al, 29). For this reason, for samples G and H, an acidified ethanol solution was used to precipitate the pectin, as proposed by Joslyn and Deuel (30). Weight average molecular weights for pectin purified from samples G and H were the highest of all coffee samples (Table 2), being about the same order of magnitude as that of the Green Ribbon apple commercial pectin (table 3). The small molecular weight of sample I (Table 2) may have been caused by the low extraction pH used.

3.6 Total ash: Total ash content for coffee pectin samples (Tables 1 and 2) is higher than that of commercial citrus and apple samples (table 3), but it meets the Food Chemicals Codex standard (31) 1981 of less than 10%; although not the Bulgarian standard of less than 5% (32).

3.7 Acid insoluble ash: Only the crude coffee mucilage, sample D (Table 1) and pectin from sample F-2 (Table 2) had detectable acid insoluble ash content. The latter does not meet the FAO and Food Chemicals Codex standars that require a value of less than 1% (20,31).

3.8 Equivalent weight: Results for this determination are presented in Tables 1 & 3. Equivalent weight decreases with demethylation of pectins (33). A significant coefficient of determination r , at the 5% level, was found for an exponential correlation of equivalent weight vs. esterification degree obtained from experimental data for coffee and commercial pectins. Equivalent weight results for coffee mucilage samples (B and C) are within the same order of magnitude of the data for tangerine peel pectin reported by Moon et al, (34). However, standard deviation for this analytical method was high, producing a confidence range (Table 4) which is too wide to be acceptable.

3.9 Setting time: Setting times were determined for most commercial pectin samples (Table 3). Results were in accordance with the label designations (fast, medium, slow). It was not possible to obtain setting times for coffee pectin samples B and C because these samples didn't form a jelly, probably due to their low molecular weight. Coffee samples A, E, and D were not assayed; while samples F-1, F-2, F-3, G, H, I & J were low-methoxyl. Olsen et al, (33), demonstrated that setting time is a function of equivalent weight. A significant coefficient of determination r, at the 5% level, was found for a power correlation of equivalent weight vs. setting time obtained from experimental data for commercial pectins. However, the setting times predicted for samples B and C by this correlation were not achieved experimentally.

3.10 Jelly grade (^{o}SAG): Only the commercial pectin samples were graded, because coffee mucilage samples B and C didn't form a jelly for the conditions required by this test. The IFT Sag test (25) is not applicable to low-methoxyl pectins. Results can be seen in Tables 1 & 3. All standarized commercial pectin samples were labeled 150 ^{o}SAG, but apple pectins averaged only 124.2 ^{o}SAG; probably because of jelly grade losses during storage (Pedersen, 26).

Pectin from samples G and H formed clear jellies by adding Ca^{++} ions, but this could not be replicated. Pectin from samples F-1, F-2, F-3, I and J did not form a consistent gel after the addition of a $CaCl_2$ solution, following the method described by Gross and Rao (26).

3.11 Yields: Adding the amounts of pectin purified from mucilage, pulp juice and pulp solids from bourbon coffee (see Table 2), a pectin yield of 0.256% w/w (wet base) or 1.22% w/w of the fresh fruit was obtained; on fresh coffee of 79% average moisture content. This yield is smaller than the pectin contents mentioned in the literature: Picado (1) reported pectic substances in the mucilage of *C.arabica* as 33% dry basis, or about 4.95% of the ripe fruit, dry basis. Menchu et al (3), found 15.9 to 18.2% pectin dry basis in mucilage samples from Guatemalan coffee (2.3 to 3.6% dry base of the ripe fruit), around 50% of which were water soluble. Orozco (4) , calculated 3.19% pectin dry basis of the ripe fruit, from Costa Rican coffee samples. Sudhakara Rao (5) , reported 2.39% pectin, dry basis, of ripe *C.arabica* fruits. Cleves (6) presents analytical data from Costa Rican coffee samples of 1.74% wet basis of pectin in the ripe coffee fruits. But comparison is hindered because most values previously reported in the literature were calculated from percent A.G.A determinations directly on the mucilage, without previous purification.

IV. CONCLUSIONS

Pectin from *C. arabica* varieties bourbon, caturra and catimor, cultivated at 1500 m. altitude is low-methoxyl.

Weight average molecular weights from the coffee pectins assayed are within a smaller range than those of citrus and apple pectin.

Pectin from the three coffee varieties tested did not form consistent gels after the addition of Ca^{++} ions.

Coffee pulp (exocarp) is about 1.9 times richer in pectin than coffee mucilage.

V. AKNOWLEDGEMENTS

This research was supported by grant N° 936-5542-6-00-3065-00 from U.S.A.I.D.'s Program in Science and Technology Cooperation (PSTC). The authors are also grateful for the collaboration received from Dr. Franz Rombouts of the Agricultural University, Wageningen, The Netherlands, and from Mr. David R. Stevens, HP Bulmer Ltd; Hereford, England.

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TABLE 1

PHYSICO-CHEMICAL CHARACTERIZATION OF COFFE PECTINS

ANALYSIS (All determinations in dry base).	COFFEE MUCIL. PALIN B	COFFEE MUCIL. PARRAM. C	COFFEE PULP. PALIN E	CRUDE MUCIL. PALIN D	CITRUS PECTIN 603
% ANHYDRO GALACTURONIC ACID m-PHENYL PHENOL method	93.00	86.80	95.24	8.83	93.20
% METHOXYL CONTENT Gas Chromatography	9.98	10.78	0.41		11.65
DEGREE OF ESTERIFICATION Gas Chromatography	65.76	76.10	2.64		76.59
% ACETYL CONTENT Gas Chromatography	0.38	0.09	0.34		0.30
% NITROGEN, micro Kjeldahl	0.10	0.14	0.08		0.24
% CARBOHYDRATE CONTENT PHENOL-SULFURIC method	49.53	47.75	51.73		42.60
% MOISTURE (oven method)	13.74	16.85	14.57	26.87	8.35
% TOTAL ASH CONTENT	6.20	5.63	1.97	5.50	2.96
EQUIVALENT WEIGHT NaOH titration	4073	5611			2032
AVERAGE MOLECULAR WEIGHT viscosity method	20965	26881			86774
% ACID-INSOLUBLE ASH HCL boiling method					0.27

TABLE 2

PHYSICO-CHEMICAL CHARACTERIZATION OF PECTINS FROM 3 COFFEE VARIETIES

ANALYSIS (All determinations in dry base).	COFFEE WHOLE PALIN A	MUCIL. BOURB. F-1*	MUCIL. CATUR. F-2*	MUCIL. CATIM. F-3*	MUCIL. BOURB. G**	PULP JUICE BOURB. H**	PULP SOLID BOURB. I***	PULP SOLID BOURB. J***	BELMER CITRUS PECTIN 603
% ANHYDRO GALACTURONIC ACID m-PHENYL PHENOL method		50.79	74.43	46.60	94.71	79.70	97.72	91.19	93.20
% METHOXYL CONTENT Gas Chromatography		2.11	2.3	1.82		3.97	3.68	3.54	11.65
DEGREE OF ESTERIFICATION Gas Chromatography		25.5	18.97	23.88		30.55	23.08	23.81	76.59
PECTIN YIELD % w/w of coffee fruit	0.11	0.055	0.039	0.040		0.025	0.009	0.089	
PECTIN YIELD % w/w of marc	7.9	10.86	7.57	8.26	21.57	15.98	18.60	10.65	
MARC YIELD % w/w of coffee fruit	1.35	0.51	0.51	0.49		2.0/1	2.22	3.81	
% MOISTURE (oven method)		16.22	16.67	16.06	26.61	24.15	23.81	20.66	8.35
% TOTAL ASH CONTENT		1.7	2.61	7.84	4.67	2.57	2.06	0.71	2.96
% ACID-INSOLUBLE ASH HCL boiling method			1.39						
AVERAGE MOLECULAR WEIGHT viscosity method		37582	39367	36638	47868	42371	15828	22359	86774

* Purified by method described in (13)
** Purified by quaternary ammonium salt method, pH 2, 80 °C, 15 min.
*** Purified by precipitation with acidified ethanol.
/1 Vol./Vol.

TABLE 3

PHYSICO-CHEMICAL CHARACTERIZATION OF COMMERCIAL PECTINS

ANALYSIS (All determinations in dry weight base).	GENU PECTIN TYPE A CITRUS	GENU PECTIN TYPE B CITRUS	GENU PECTIN TYPE D CITRUS	PURPLE RIBBON PURE APPLE	BROWN RIBBON APPLE	PURPLE RIBBON D-075 APPLE	GREEN RIBBON APPLE	BLUE RIBBON APPLE
% ANHYDRO GALACTURONIC ACID m-PHENYL PHENOL method	72.94	66.11	81.79	98.92	81.03	67.38	83.51	88.08
% METHOXYL CONTENT Gas Chromatography	6.63	7.00	7.54	5.85	6.15	7.69	10.13	9.20
DEGREE OF ESTERIFICATION Gas Chromatography	55.70	64.88	56.49	36.24	46.51	69.93	74.33	64.00
% ACETYL CONTENT Gas Chromatography	0.30	0.32	0.36	0.35	0.28	0.35	0.38	0.38
% NITROGEN, micro Kjeldahl	0.23	0.38	0.35	0.09	0.20	2.08	0.33	0.13
% CARBOHYDRATE CONTENT PHENOL-SULFURIC method	55.65	55.36	54.99	51.69	62.60	59.06	62.05	59.44
% MOISTURE (oven method)	2.74	3.24	6.08	9.87	5.53	8.39	10.02	10.19
% TOTAL ASH CONTENT	1.49	1.08	2.21	5.12	1.01	4.01	4.16	1.63
EQUIVALENT WEIGHT NaOH titration	1053.4	1772.1	839.1	299.53	914.44	990.97	572.11	410.09
AVERAGE MOLECULAR WEIGHT viscosity method					66322		44322	
GELLING TIME, sec.	145.05	30.55	213.8		155.95		472.4	472.65
°BAG	142.63	139.31	145.00		121.10		125.45	126.12

TABLE 4

CONFIDENCE RANGES FOR SOME ANALYTICAL RESULTS

ANALYSIS (All determinations in dry base)	CONFIDENCE RANGE $\alpha = 0.05$	METHOD REF.#
% ANHYDRO GALACTURONIC ACID m-PHENYL PHENOL method	1.0140	15
% METHOXYL CONTENT Gas Chromatography	0.6503	16
DEGREE OF ESTERIFICATION Gas Chromatography	4.2754	16
% ACETYL CONTENT Gas Chromatography	0.0363	17.
% NITROGEN, micro Kjeldahl	0.0253	18
% CARBOHYDRATE CONTENT PHENOL-SULFURIC method	1.4330	19
% MOISTURE (oven method)	0.3036	20
% TOTAL ASH CONTENT	0.4641	18
EQUIVALENT WEIGHT NaOH titration	202.7	22
SETTING TIME, sec.	9.7430	24
° SAG	3.4467	25

FIGURE Nº 1

EXTRACTION OF PECTIN FROM COFFEE MUCILAGE: MASS BALANCE

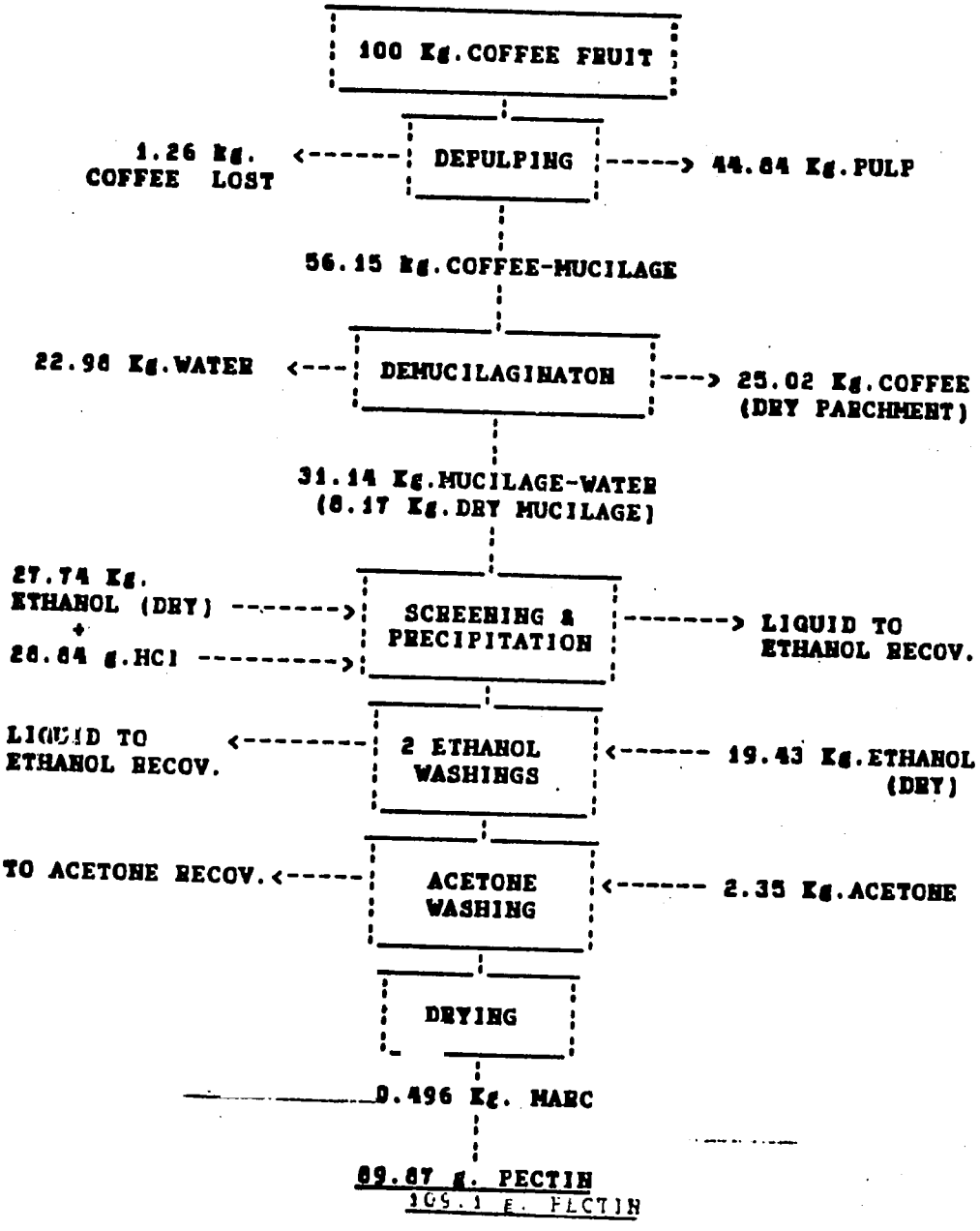
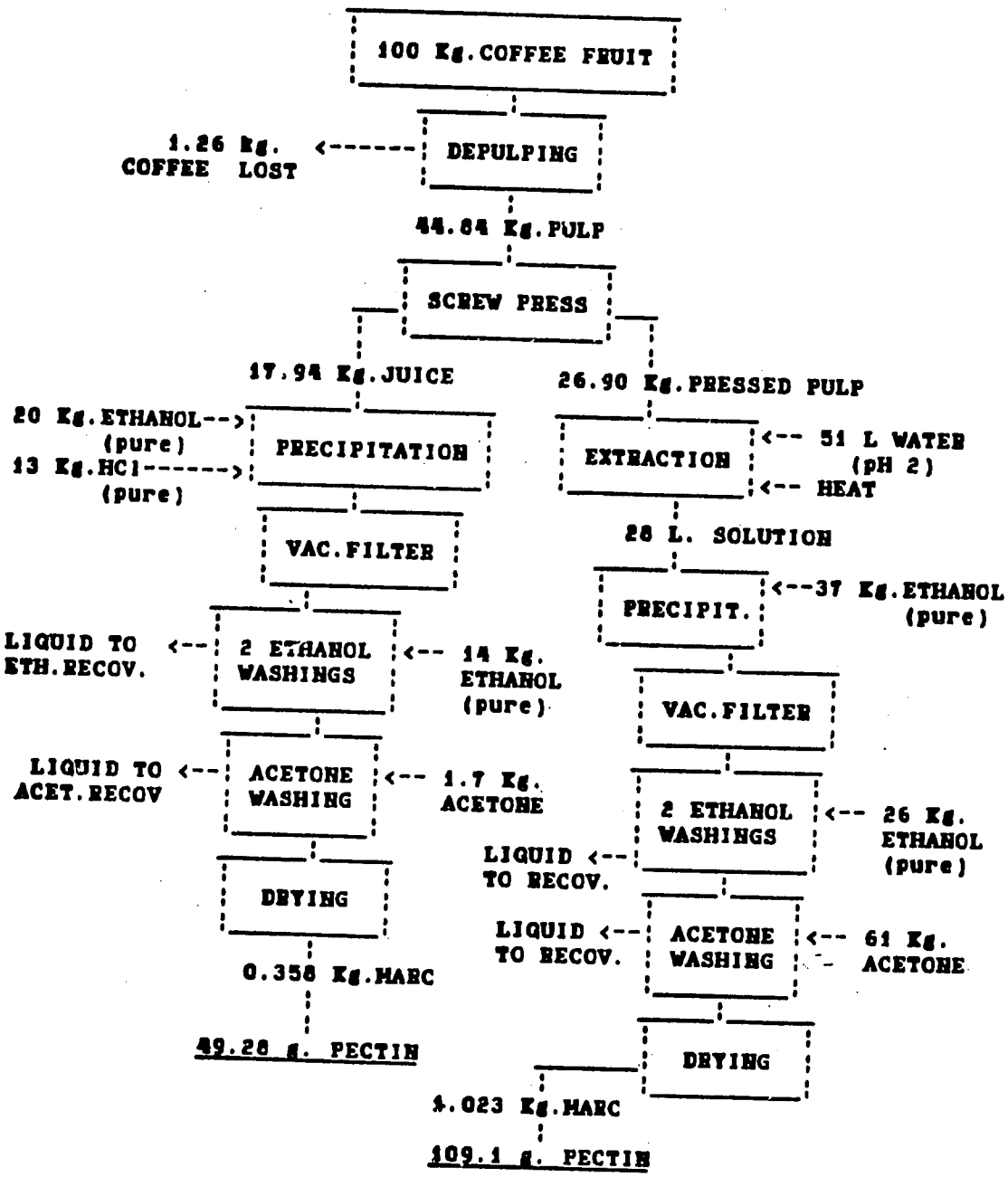


FIGURE N°2

EXTRACTION OF PECTIN FROM COFFEE PULP: MASS BALANCE



PURIFICATION OF COFFEE PECTIN

PURIFICATION OF COFFEE PECTIN

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SUMMARY

Three methods for pectin purification were tested for purifying alcohol-insoluble solids (marc) from the mucilage of ripe coffee fruits (*Coffea arabica* var. bourbon): the copper II salt method (cupric sulfate pentahydrate), aluminum salt method ($AlCl_3$), and the quaternary ammonium salt method (hexa-decyl-trimethyl ammonium bromide). The effect of temperature, reaction time and pH on pectin purity and yield was studied in 2^3 factorial designs for each method. Lower pH values caused better yields in all methods. Time-pH interaction at the high level improved purity in the copper method, while temperature-pH interaction at high level favored purity in the other methods. The quaternary ammonium salt method was considered the best. The aluminum salt method gave the lowest yields and the copper salt caused a difficult to remove greenish color in the pectin.

I. INTRODUCTION

In order to compare its physicochemical properties with available commercial pectins, the alcohol-insoluble solids extract from coffee mucilage or coffee pulp juice must be purified. Several purification methods have been tried for pectin purification. Among the most common are the use of inorganic salts like Cu^{+2} salts (1, 2, 3, 4, 5); aluminum salts (6, 7, 8); ammonium salts (2, 10); acidified alcohol (2, 9, 11, 12, 13); ion-exchange resins (4, 14, 15, 16, 17); neutral alcohol (18); ultrafiltration (19) and amilolytic enzymes (20, 21).

Purification with inorganic salts was selected for coffee pectin because of the availability of the various chemicals, and also because these methods were developed specially for the removal of sugar impurities which are not part of the pectin molecule. Since there is no starch in the mucilage from ripe coffee fruits, there is no use for amilolytic enzymes.

II. MATERIALS AND METHODS

2.1 Coffee: Coffee fruit of the Bourbon variety of *Coffea arabica* was obtained from a farm in Sacatepéquez, Guatemala, at 1500 m. altitude.

2.2 Pectin extraction: Coffee fruit samples were brought to the pilot plant in the same day they were harvested. The first operation was washing with water, followed by selection to eliminate immature

fruits and floats; then the skin or exocarp was mechanically eliminated (depulping). The mucilage-covered coffee beans were then placed in a locally made batch demucilaginating machine with a 3 HP electric motor (Sexilago), which resembles a big waring blendor. This operation requires the addition of a certain amount of water, and lasts about 15 min. The liquid mucilage with coffee beans coming out of the demucilaginating machine was screened to separate the beans, and then received in a plastic container with an 81% ethanol solution, acidified with HCl (750 ml. 95% ethanol, 50 ml. HCl conc., 200 ml. water). The precipitate formed was separated by decantation, washed with 75% v/v ethanol, then with 81% v/v ethanol and finally with acetone. The precipitate was then dried for 48 h. at 35 °C, to obtain the marc.

2.3 Purification: All assays were made utilizing the marc obtained by the previously mentioned extraction method, prepared as 1% w/v suspensions in distilled water.

2.3.1 Aluminum salt method: Since there was no specific method for coffee pectin, several experiments were carried on to adapt a method based in the work reported by De Luca and Joslyn, (5); Bhatia et al, (7); and Tuerena, (8).

Extraction conditions applied to the marc (high and low levels for the factorial design) were: pH adjusted to 3.0 or 1.86 with HCl 5N, 80 or 60 °C for 30 or 15 min., after which the extract was filtered first through cotton and then through diatomaceous earth in a Buchner funnel under vacuum, to obtain a clear solution. The former filtration step lasted from 2 to 6 hours. Then the pH of the solution was again adjusted with HCl to 4.1 and mixed with a 5% w/v aluminum chloride solution with pH also adjusted to 4.1, in a proportion of 60 ml.$AlCl_3$/L.pectin soln., to obtain an aluminum pectinate precipitate, which was washed 4 times with the following solutions: i) Acidified ethanol (4:1 ethanol 95% /HCl conc.). ii) Ethanol 60% iii) Ethanol 70% iv) Ethanol 95%; and then vacuum filtered through a cloth.

After washing, the sample was dried at ambient temperature.

2.3.2 Copper II salt method: The procedure recommended by Rombouts, (10), was modified: the pectin extraction conditions were varied in the same way as with the aluminum salt method; then the sample is vacuum filtered in a Buchner funnel, first with cotton and then with diatomaceus earth until a clear solution is obtained. The pH of the clear solution was adjusted to 4.0 before adding the same volume of the copper reagent (prepared by mixing 18.8 g. cupric sulfate pentahydrate, 54.4 g. sodium acetate trihydrate, 24 ml. glacial acetic acid and distilled water to complete 2 L) in an intermittent form (1/4 of the volume each 5 min.), under gentle stirring, to precipitate a copper pectinate, and then letting it stand overnight. The next day it was vacuum filtered with a cloth and the solids washed 3 times with an acidified alcohol solution (4:1 ethanol 95%/HCl conc.), to eliminate the copper, and then washing by suspending the solids in: a) ethanol 60%; b) ethanol 70%; and c)

ethanol 95%; after which the purified pectin was left to dry at ambient temperature.

2.3.3 Quaternary ammonium salt method: the method described by Rombouts, (10), was adapted to coffee pectin: the pectin extraction conditions were varied in the same way as with the aluminum salt method; after obtaining a clear pectin solution, its pH is adjusted to 4.5 and 1 L. of this solution is mixed with 5 ml. of 1M ammonium sulfate solution; then the temperature is raised to 37 °C, and 250 ml. of a 2% quaternary ammonium salt (hexa-decyl-trimethyl ammonium bromide) is added, as recommended by Scott, (9). The sample was kept at 37 °C for 1 hour before centrifuging and then washing the precipitate 3 times with distilled water, followed by suspending the pectin precipitate in 300 ml. of 1% NaCl solution, and then the temperature was raised to 37 °C for 10 min., after which 600 ml. of acidified ethanol are added (1:4 HCl conc./ethanol 95%) to precipitate the pectin. It is left to rest between 1 and 12 hr. for complete precipitation before vacuum filtering with a cloth, followed by washing with alcoholic solutions in the same way as in the copper II method; and finally it is left to dry at ambient temperature. Figure 1 shows a block diagram for this method, with the amounts calculated for purifying 100 Kg. of fresh coffee fruit; with low levels of pH and extraction time and high level of temperature.

2.4 Statistical analysis: 2^3 factorial designs (22) were performed for each of the above mentioned purification methods, to determine the influence of extraction conditions like temperature, time and pH on two responses: purity as % anhydro galacturonic acid, and yield as % pectin w/w in the marc. The higher and lower levels for the 3 factors are shown in Table 1.

III. RESULTS AND DISCUSSION

3.1 Copper II salt method: Table 2 presents results for purity expressed as % of anhydrogalacturonic acid and identified as %AGA. The F values indicate that the time-pH interaction and the triple interaction were significant at the 0.05 level, with a positive mean effect Z, indicating that simultaneously increasing the values of temperature, time and pH will increase the purity of the pectin. However, the purified pectin had a greenish color which was very difficult to remove, probably caused by copper impurities.

Table 5 shows the yields obtained with this method, expressed as % w/w pectin/marc. For this response, only the effect of factor b (pH) was significant at the 0.05 level, with a negative Z, indicating that decreasing the pH value will increase the yield.

3.2 Aluminum salt method: Purity results can be seen in Table 3. This method gave the lowest purity values. The temperature-pH interaction and the triple interaction were significant at the 0.05 level, with positive mean effect Z.

Yield values are presented in Table 6. In the same way as in

the copper II method, only the pH had a significant effect on yield, with a negative mean effect.

3.3 Quaternary ammonium salt method: Table 4 contains the purity results for this method. The effect of pH was significant at the 0.05% level, with a negative mean effect Z. The temperature-pH interaction and the triple interaction were also significant, with negative and positive Z values, respectively. With regard to yield, it can be seen in table 7 that the effect of pH was significant with a negative mean effect, in the same way as the other two methods tested.

IV. CONCLUSIONS

The quaternary ammonium salt method was considered the best of the 3 methods tested because it gave adequate yields and purity without adverse side-effects like the greenish color of the copper-purified pectin.

The best extraction conditions for the quaternary ammonium salt method were 15 min. at 60 °C, and pH 1.86.

V. ACKNOWLEDGEMENTS

This research was supported by grant N° 936-5542-6-00-3065-00 from U.S.A.I.D.'s Program in Science and Technology Cooperation (PSTC). The authors are also grateful for the collaboration received from Dr. Franz Rombouts of the Agricultural University, Wageningen, The Netherlands.

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TABLE 1

CODES FOR FACTORIAL DESIGNS

	a	b	c
LEVEL	EXTRACTION TEMP.	EXTRACTION TIME	EXTRACTION pH
HIGH	1 = 80 °C	1 = 30 min.	1 = 3.01
LOW	0 = 60 °C	0 = 15 min.	0 = 1.86

$F^{(1/7)} = 5.6; \alpha = 0.05$

TABLE 2

COPPER METHOD, DRY BASE, RESPONSE = % AGA

PECTIN PURIFICATION FACTORIAL DESIGN

CODE		%AGA1	%AGA2	AVG.	TOTAL	MEAN EFFECT %	$Z^2/16$	F
000	(1)	90.69	89.71	90.20	180.40	1381.47		
100	a	89.86	78.33	84.10	168.19	25.17	39.60	1.46
010	b	86.62	68.03	77.33	154.65	41.49	107.59	3.98
110	ab	91.04	89.27	90.16	180.31	44.99	126.51	4.68
001	c	77.89	81.66	79.78	159.55	14.37	12.91	0.48
101	ac	80.31	81.54	80.93	161.85	-1.73	0.19	0.01
011	bc	92.43	91.12	91.78	183.55	68.75	295.41	10.92 *
111	abc	98.28	94.69	96.49	192.97	59.45	220.89	8.17 *

* = Significant at the $\alpha = 0.05$ level

TABLE 3

ALUMINUM DRY BASE, RESPONSE = % AGA

PECTIN PURIFICATION FACTORIAL DESIGN

CODE		%AGA1	%AGA2	AVG.	TOTAL	MEAN EFFECT %	$Z^2/16$	F
000	(1)	41.44	62.38	51.91	103.82	977.92		
100	a	60.07	49.74	54.91	109.81	65.58	268.80	2.96
010	b	81.07	63.85	72.46	144.92	67.22	282.41	3.11
110	ab	58.46	50.68	54.57	109.14	-28.08	49.28	0.54
001	c	57.77	42.67	50.22	100.44	42.54	113.10	1.25
101	ac	68.43	72.85	70.64	141.28	125.16	979.06	10.78 *
011	bc	47.52	59.[illegible]7	53.50	106.99	-13.64	11.63	0.13
111	abc	82.72	78.80	80.76	161.52	107.37	720.52	7.93 *

* = Significant at the $\alpha = 0.05$ level

TABLE 4

AMMONIUM DRY BASE, RESPONSE = % AGA

PECTIN PURIFICATION FACTORIAL DESIGN

CODE		%AGA1	%AGA2	AVG.	TOTAL	MEAN EFFECT %	$Z^2/16$	F
000	(1)	90.44	86.38	88.41	176.82	1367.71		
100	a	98.00	94.90	96.45	192.90	-56.19	197.33	4.97
010	b	93.56	95.85	94.71	189.41	-17.01	18.08	0.46
110	ab	89.44	86.62	88.03	176.06	-55.67	193.70	4.88
001	c	84.04	85.45	84.75	169.49	-102.67	658.82	16.58 *
101	ac	74.33	78.82	76.58	153.15	-61.65	237.55	5.98 *
011	bc	85.87	90.36	88.12	176.23	-8.51	4.53	0.11
111	abc	78.29	55.36	66.83	133.65	91.60	524.41	13.20 *

* = Significant at the $\alpha = 0.05$ level

TABLE 5

COPPER METHOD DRY BASE, RESPONSE = % YIELD

PECTIN PURIFICATION FACTORIAL DESIGN

CODE		%YIELD1	%YIELD2	AVG.	TOTAL	MEAN EFFECT %	$Z^2/16$	F
000	(1)	14.251	13.881	14.07	28.13	131.70		
100	a	16.234	15.028	15.63	31.26	9.97	6.22	0.98
010	b	17.828	7.928	12.88	25.76	0.47	0.01	0.00
110	ab	15.935	15.463	15.70	31.40	4.24	1.12	0.18
001	c	2.719	0.523	1.62	3.24	-101.39	642.52	101.65 *
101	ac	1.173	1.806	1.49	2.98	-7.57	3.56	0.57
011	bc	1.691	2.044	1.87	3.74	4.95	1.53	0.24
111	abc	2.023	3.177	2.60	5.20	13.28	11.03	1.74

* = Significant at the $\alpha = 0.05$ level

FIGURE Nº 1

COFFEE PECTIN PURIFICATION, AMMONIUM SALT METHOD

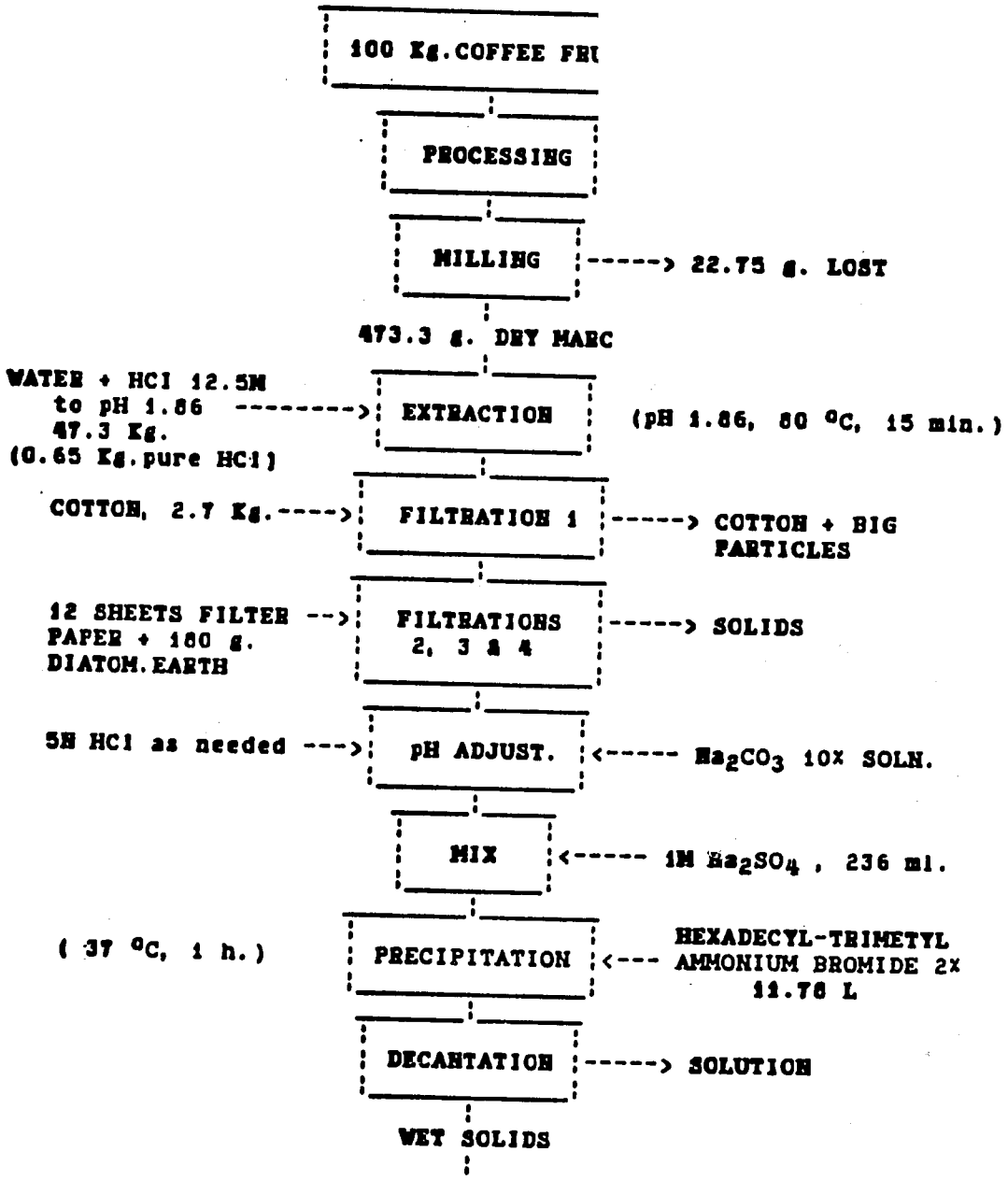


FIGURE N° 1 (CONTINUATION)

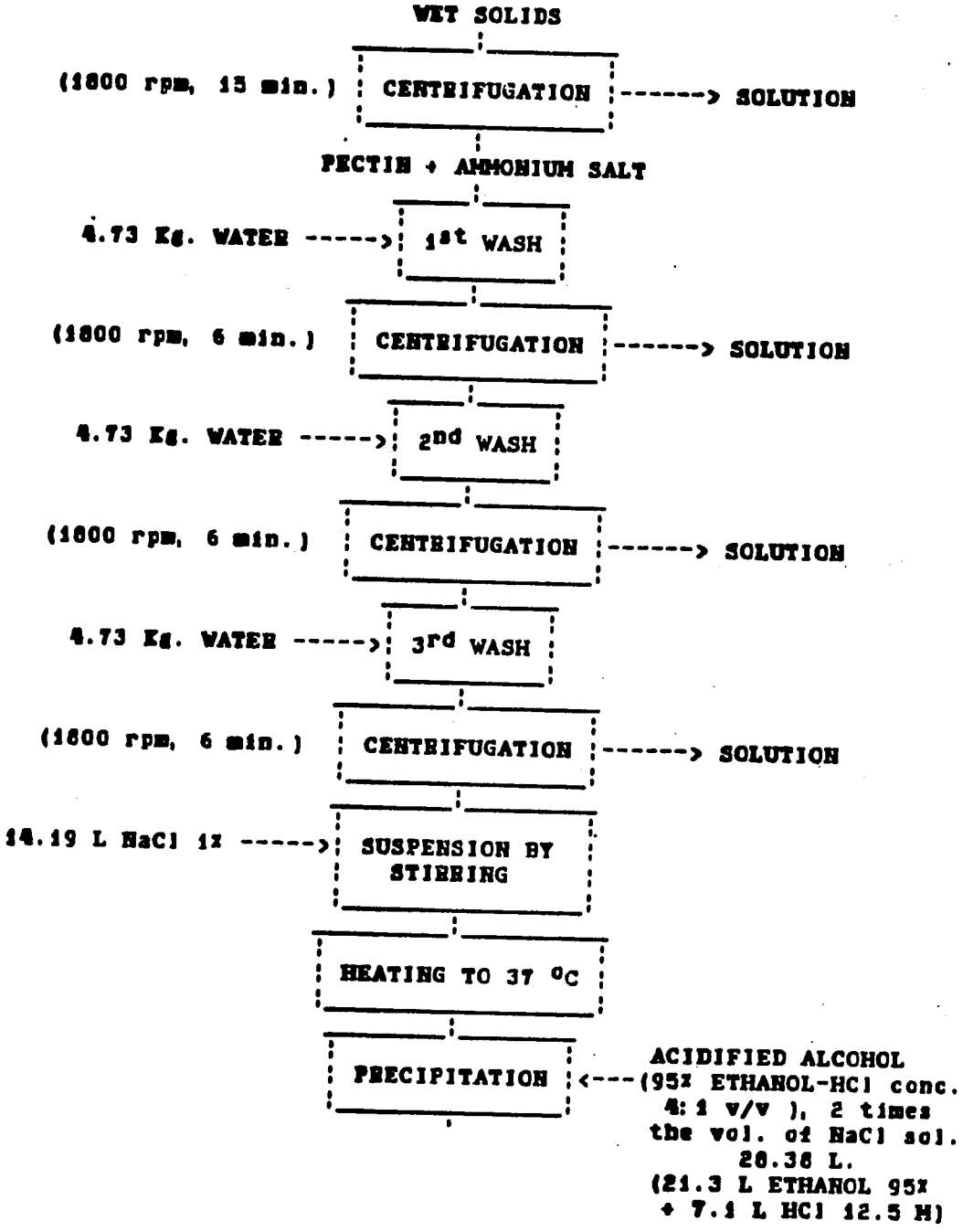
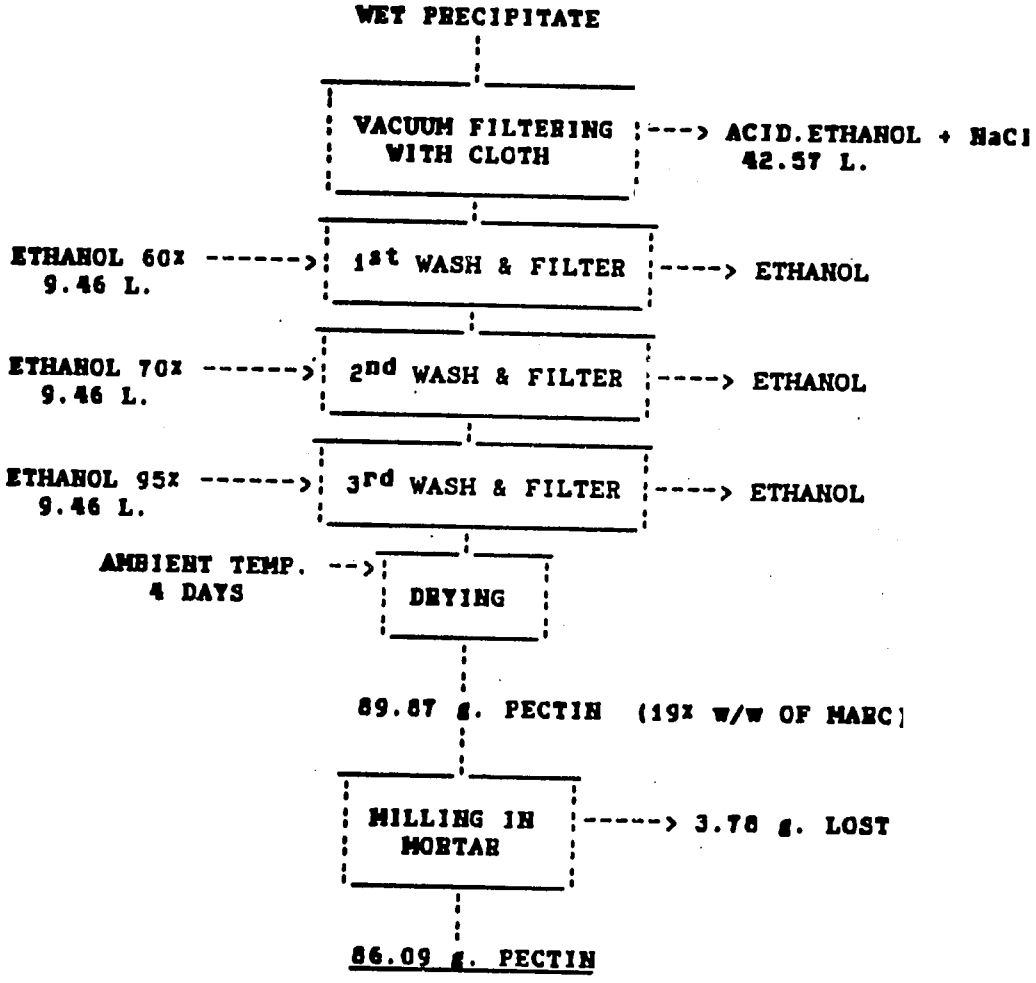


FIGURE Nº 1 (CONTINUATION)



PRELIMINARY ECONOMICS FOR THE INDUSTRIAL PRODUCTION OF COFFEE PECTIN

PRELIMINARY ECONOMICS FOR THE INDUSTRIAL PRODUCTION OF COFFEE PECTIN

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SUMMARY

A preliminary economic study was made to explore the feasibility of producing pectin (low methoxyl) from coffee (*Coffea arabica*) in Central America. Local pectin consumption in Central America is small and most of the production should be exported. The dominant cost in producing coffee pectin is interest on capital, followed by chemicals used in pectin extraction and purification. A minimum economic size of 350 metric tons/year was determined, although it could be smaller if most of the equipment is made locally.

1.INTRODUCTION

Coffee is a very important crop in many less developed countries of Latin America and Africa. In Central America, 494700 metric tons of green coffee were produced in the 1980-81 season. Coffee is the principal export crop for Guatemala, El Salvador and Costa Rica. It is a good source of employement in rural areas; in Guatemala, it absorbs directly or indirectly about 1.7 million people (around 25% of the total population of the country). However, the international coffee market have been characterized by short periods of high prices followed by prolongued periods of depressed values. A better by-product utilization may be a way to stabilize the economy of coffee production.

In the traditional wet coffee processing used in Central America, Colombia, Venezuela, Mexico and some other Latin America and African countries, ripe coffee fruits are fed to a pulper machine wherein, by friction, the exocarp (skin) and part of the mesocarp (mucilage) are eliminated. A layer of mucilage remains adhered to the coffee bean, and in order to remove it, it is submitted to a fermentation process in tanks where excess water is drained and a mostly anaerobic fermentation is accomplished by the natural microflora of the beans for 48-90 hours. In this process the mucilage is broken down and the products of its hydrolysis are washed down with water when fermentation ends. In most coffee processing plants or "beneficios", water from the fermentation tanks is mixed with other wash and processing waters and recycled, producing a solution with a chemical oxygen demand up to 30000 ppm. (Rolz et al, 1971) which is dumped into rivers causing severe pollution problems. However it is possible to remove the mucilage adhering to the coffee beans by mechanical means without the fermentation step, with commercially available demucilaginating machines, making it possible to recover pectin from the mucilage.

Unfortunately there is no information about the economical feasibility of industrial coffee pectin recovery. For this reason, the Central American Research Institute for Industry (ICAITI) carried out a research project in which it made a physicochemical characterization of pectin from coffee mucilage, coffee pulp (exocarp) and coffee pulp juice, having determined that for Guatemalan *Coffea arabica* var. Bourbon, Caturra and Catimor, the pectin was low-methoxyl, low molecular weight, forming gels with Ca^{+2} ions (García et al, 1986).

2.MARKET

Pectin consumption in Central America is low. In a survey made in 1971 (ICAITI, 1971), it was reported that 927 metric tons of jellies and marmelades were produced in Central America. Estimating 1% w/w pectin added, only about 9.27 metric tons of pectin were consumed that year. Assuming that jelly production increased at the same rate of demographic growth, 13.2 t. of pectin would have been consumed for 1986, and around 16.8 t. will be used in 2000. It is clear that the local market is too small for sustaining pectin production, and external markets must be sought.

Since there is more than enough raw material supply for pectin production in the world, and only about 12% of the pectin produced is low-methoxyl (Towle and Christensen, 1973), coffee pectin must be able to compete both in price and quality as a natural low methoxyl product.

3.RAW MATERIAL

It has been determined (García et al, 1986) that around 450 metric tons of fresh coffee fruit is required to produce 1 metric ton of pectin. The amount of coffee produced in Central America would yield over 1000 t of pectin/year , but since much of the coffee crop is processed in small "beneficios", perhaps only in El Salvador, that has the biggest wet coffee processing plants in the world, may it be possible to develop an industrial pectin recovery project.

4.PLANT CAPACITY

The process equipment was designed initially for a 11 metric ton/year plant, and its cost was estimated from U.S. and european equipment manufacturers quotations and from literature data (Peters and Timmerhaus, 1980), updated by Marshall and Swift installed equipment indexes. The total unit product cost was then calculated based on estimations for chemicals, labor, energy , indirect and fixed costs. With the total product cost, the internal rate of return was calculated. Since the 11 t/year plant gave a negative rate of return, the plant size was increased and the equipment cost was adjusted by the six-tenths-factor rule (Peters and Timmerhaus, 1980). The total product cost and the internal rate of return were

then recalculated. The procedure was repeated for several plant capacities. The results can be seen in Figures 1 and 2. It was estimated that a plant capacity of around 350 t/year of coffee pectin may be the minimum size for recovering the investment, depending on bank interest rates . Since most of the equipment could be made in Central America at a substantial reduction in cost, and the mimimum size for the plant would be smaller, a simulation was made assuming equipment cost reductions up to 50% and then calculating the minimum plant capacity that could give a 16% internal rate of return. Results of this simulation are presented in Figure 3. It can be seen that a 50% reduction in equipment cost will produce about a 47% decrease in the minimum plant capacity required to obtain a 16% internal rate of return.

5. ENGINEERING

A preliminary design was made based on laboratory data concerning use of solvents, yields, stream concentrations, etc. Pilot plant tests will be necessary to obtain engineering data for scale-up. For this reason, the present work has to be taken only as a rough initial estimation.

An outline of thc process is presented in Figure 2

5.1 Extraction

After depulping in the coffee "beneficio", the mucilage-covered coffee beans will be transported to batch demucilaginating machines (locally made), that resemble waring blendors. This operation requires the addition of a certain amount of water, and lasts about 15 min. The mixture of coffee beans and separated mucilage coming out from the demucilaginating machines is separated in a screener. The coffee beans will be sent back to the "beneficio" for further processing as the principal product, while the mucilage will be fed to extraction tanks where it will be blended with an HCl solution at pH 2.0, and heated at 80 °C for 30 min.

The coffee pulp or exocarp separated from the coffee fruit in the depulping machines of the "beneficio", will be transported to locally-made screw presses that will separate about 45% by weight of a liquid called coffee pulp juice. The solid residue, called pressed pulp, and the juice, will be sent to extraction tanks for an operation similar to that described for the mucilage.

5.2 Concentration

After extraction, the pectin solution will be pumped to a double effect evaporator, for a 5:1 concentration. Hydrochloric acid will be recovered in the condensed vapors.

5.3 Precipitation

The concentrated solution will be pumped to stirred tanks to be blended with twice its volume of ethanol to precipitate the pectin.

5.4 Filtration and washing

The precipitate will be separated from the solution in filter

presses and then sent to tanks for blending with water to make a suspension that will be re-precipitated with ethanol and filtered again. This operation will be repeated two times before a final washing with acetone.

5.5 Drying, milling and packaging

The wet pectin precipitate will be dried in a tunnel with air at 45-60 °C, milled in a stainless steel hammer mill and filled into polyethylene bags placed into fiber drums. The bulk density of the dry pectin powder was estimated as 759 Kg./m^3.

5.6 Ethanol and acetone recovery

It is necessary to recover as much acetone and ethanol as possible by distillation, for the process to be economical. A loss of 2.5 L. ethanol (95% v/v) and of 0.25 L. acetone/Kg. of pectin has been estimated.

6 INVESTMENT COST

Table I shows figures for a 350 t/year coffee pectin plant. The factors used for estimating the investment cost can be seen in Table III. Notice that the factor for installation is lower than the ones used in industrialized countries.

7. TOTAL PRODUCT COST

Table II contains some of the data used for estimating the total product cost for a 350 t/year coffee pectin plant, operating 110 days/year (during the coffee season).

Table III shows factors used to estimate some of the cost elements used in Table II.

A loan covering 70% of fixed and working capitals was assumed to calculate the interest costs.

It can be seen in Table II that interest on fixed capital is the dominating cost, followed by ethanol and acid costs. This means that if the capital investment could be reduced by building most of the equipment locally, a significant improvement in product cost may be achieved.

8. PROFITABILITY

Internal rates of return, defined as the interest that makes the net present value equal to zero (Figure 1), were calculated with a Lotus 1-2-3 spreadsheet program in an IBM PC microcomputer; using a sales price of US $ 7.27/Kg. for pectin (Anon., 1986), a plant life of 15 years, operating at 80% capacity for the first year, 95% capacity the second year and 100% for the rest.

9.REFERENCES

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TABLE I

INVESTMENT COST, US$ FOR 350 MT/YEAR COFFEE PECTIN PLANT

EQUIPMENT CIF	2943510.91			
INSTALLATION	735877.73			
LAND	---------			
PLANT BUILDINGS	115500.00			
OFFICE BUILDING	4000.00			
INSTRUMENTATION	264915.98			
ELECTRICAL INSTALL.	294351.09			
PHYSICAL COST		4358155.71		
ENGINEERING		653723.36		
DIRECT COST			5011879.07	
CONTRACTOR'S FEE			250593.95	
CONTINGENCY			501187.91	
FIXED CAPITAL INVESTMENT				5763660.93
PLANT STARTUP				172909.83
WORKING CAPITAL				381675.00
TOTAL INVESTMENT				$6,318,245.75

TABLE II

TOTAL PRODUCT COST FOR COFFEE PECTIN, 350 MT/YEAR

	UNIT/Kg.pec.	$/UNIT	$/YEAR	$/Kg.pec.	%
DIRECT COSTS					
ETHANOL, L	2.5	0.340	297500.00	0.850	19.34
HCl conc., L	0.1	5.800	203000.00	0.580	13.19
ACETONE, L	0.25	1.230	107625.00	0.308	6.99
PACKAGING		0.072	25305.00	0.072	1.64
STEAM	0.09	0.008	262.64	0.001	0.02
ELECTRICITY	0.70	0.057	13867.00	0.040	0.90
WATER	0.18	0.093	5859.00	0.017	0.38
DIRECT LABOR					
1st. shift		0.400	14080.00	0.040	0.92
2nd. shift		0.500	17600.00	0.050	1.14
3rd. shift		0.600	21120.00	0.060	1.37
SUPERVISION			10560.00	0.030	0.69
MAINTENANCE			44152.66	0.126	2.87
PLANT MATERIALS			883.05	0.003	0.06
INDIRECT COSTS					
FRINGE BENEFITS			8817.60	0.025	0.57
QUALITY CONTROL			10560.00	0.030	0.69
TRANSPORT		0.060	21000.00	0.060	1.36
FIXED COSTS					
DEPRECIATION:					
EQUIPMENT			98117.03	0.280	6.38
BUILDINGS			1991.67	0.006	0.13
INSURANCE			28818.30	0.082	1.87
ADMINISTRATION			7633.50	0.022	0.50
SALES COST			25445.00	0.073	1.65
INTEREST/FIX.CAPITAL			524493.14	1.499	34.09
INTEREST/WORK.CAPITAL			34732.43	0.099	2.26
CONTINGENCY			15234.23	0.044	0.99
TOTAL PRODUCT COST			$1538657.26	$4.396	100.00

TABLE III

FACTORS FOR COST ESTIMATION

CAPITAL INVESTMENT		
INSTALLATION	0.25	of equipment cost
INSTRUMENTATION	0.09	of equipment cost
ELECTRICAL INST.	0.10	of equipment cost
ENGINEERING	0.15	of physical cost
CONTRACTOR'S FEE	0.05	of direct cost
CONTINGENCY	0.10	of direct cost
PLANT STARTUP	0.03	of fixed capital investment
WORKING CAPITAL	0.15	of annual sales
TOTAL PRODUCT COST		
DIRECT COST		
SUPERVISION	0.20	of direct labor
MAINTENANCE	0.03	of equipment cost
PLANT MATERIALS	0.02	of maintenance cost
INDIRECT COST		
FRINGE BENEFITS	0.167	of direct labor + supervision
QUALITY CONTROL	0.20	of direct labor
FIXED INDIRECT COST		
INSURANCE	0.01	of fixed capital cost
ADMINISTRATION	0.003	of annual sales
SALES COST	0.01	of annual sales
INTEREST	0.13	of 70% fixed and working capital
CONTINGENCY	0.01	of total manufacturing cost

FIGURE N°3

PROCESS FOR PECTIN PRODUCTION FROM COFFEE

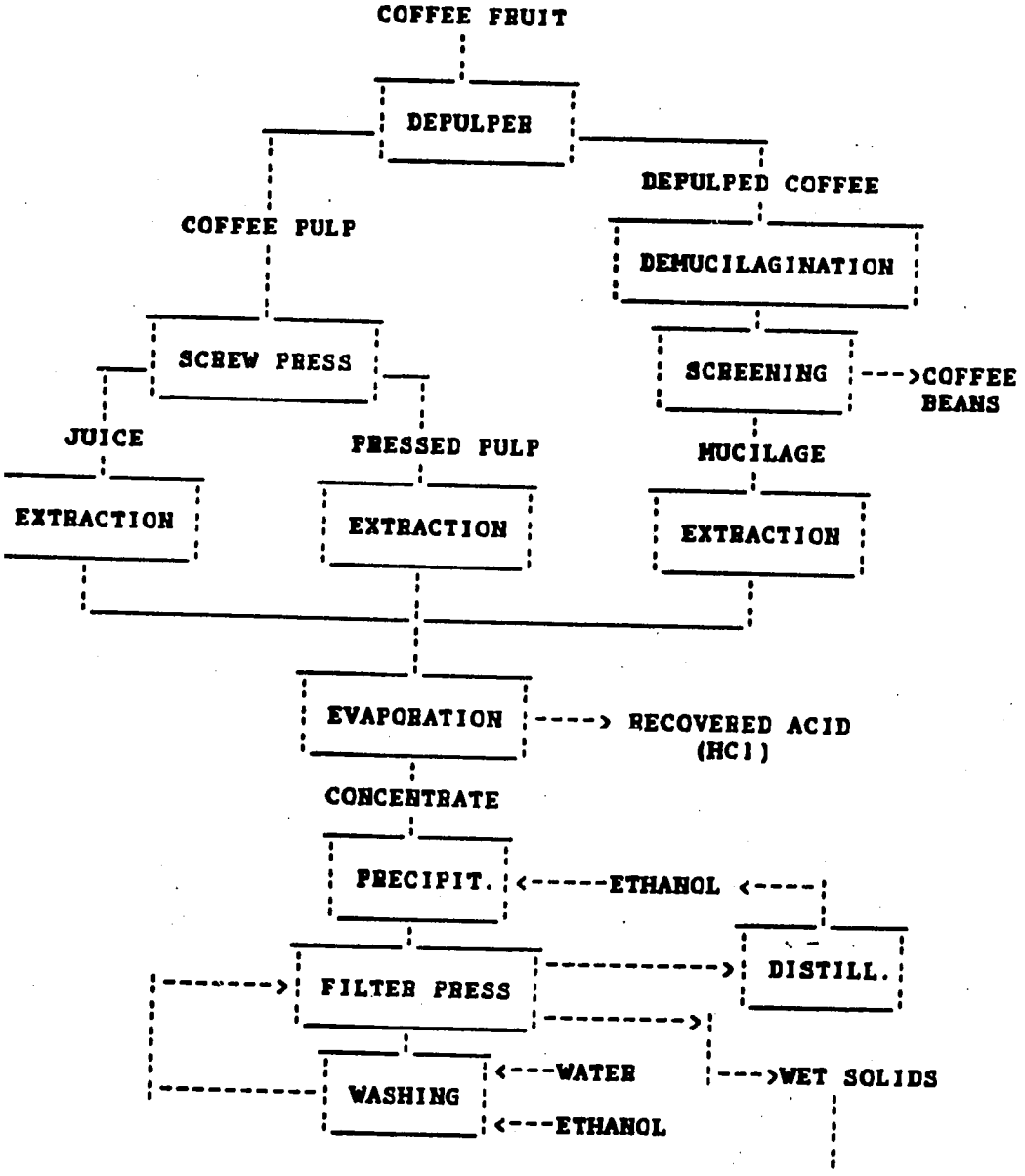
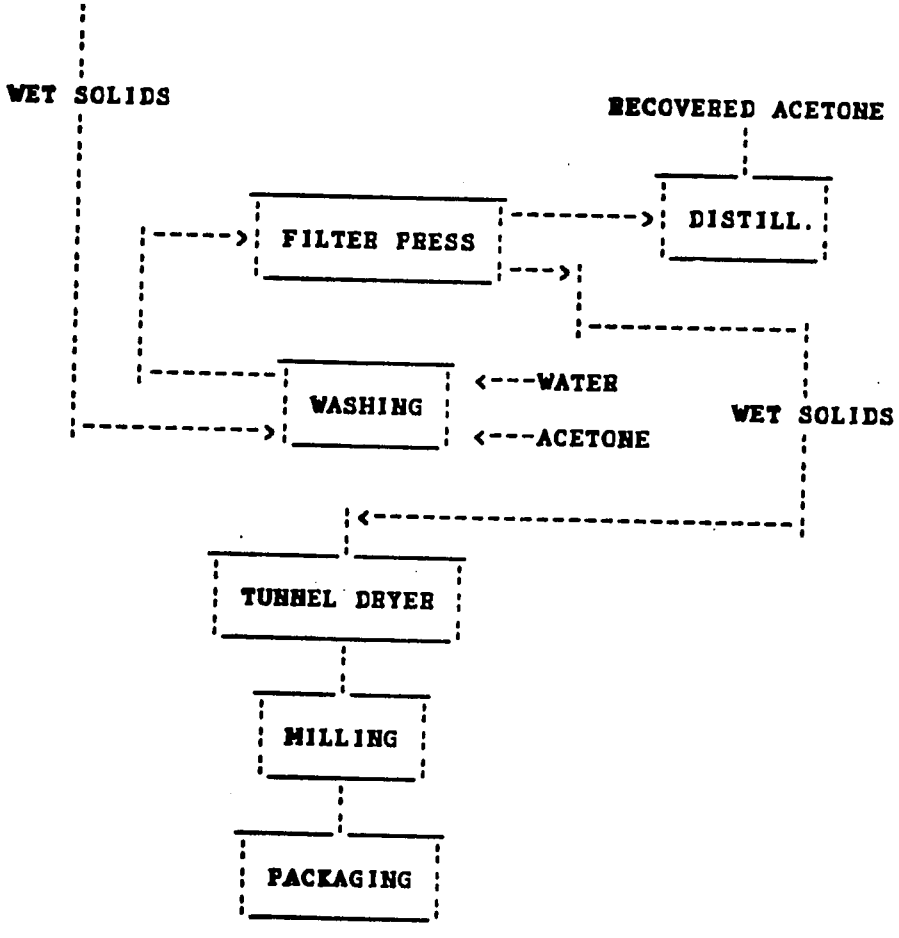


FIGURE N°3 (CONTINUED)



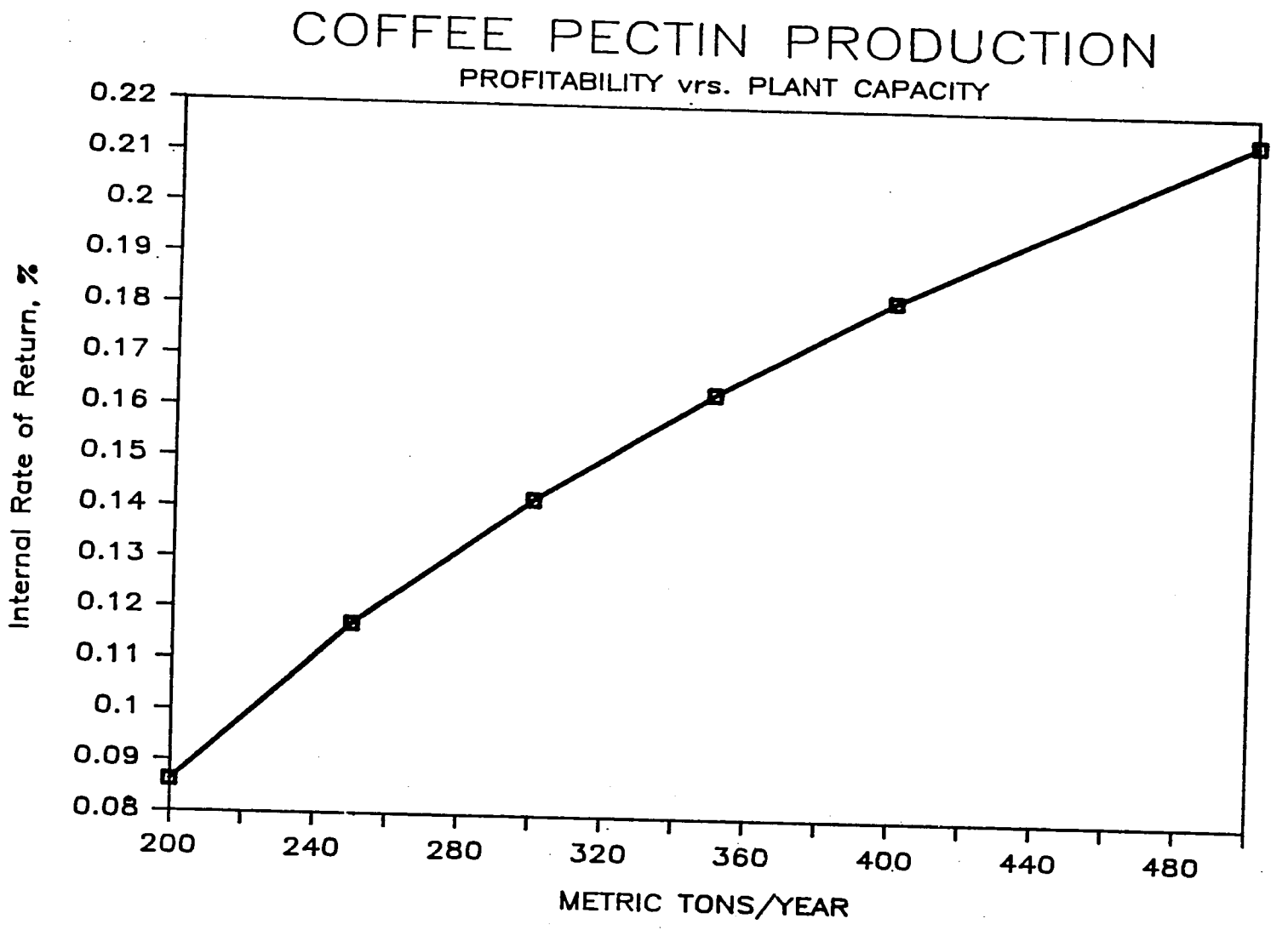

COFFEE PECTIN PRODUCTION
PROFITABILITY vrs. PLANT CAPACITY
Internal Rate of Return, %
0.22
0.21
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
200
240
280
320
360
400
440
480
METRIC TONS/YEAR

FIGURE 1

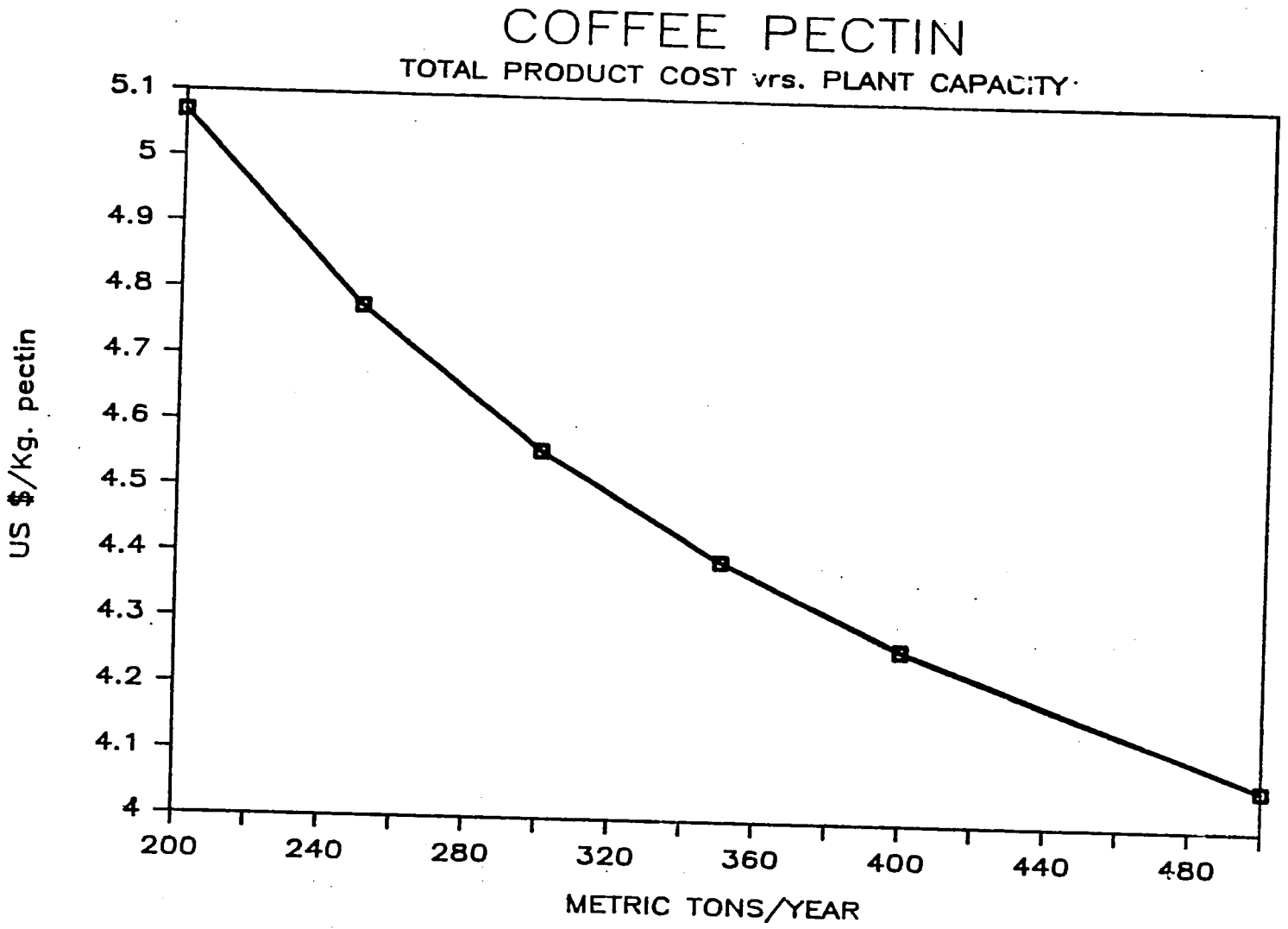

COFFEE PECTIN
TOTAL PRODUCT COST vrs. PLANT CAPACITY
US $/Kg. pectin
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
200
240
280
320
360
400
440
480
METRIC TONS/YEAR

FIGURE 2

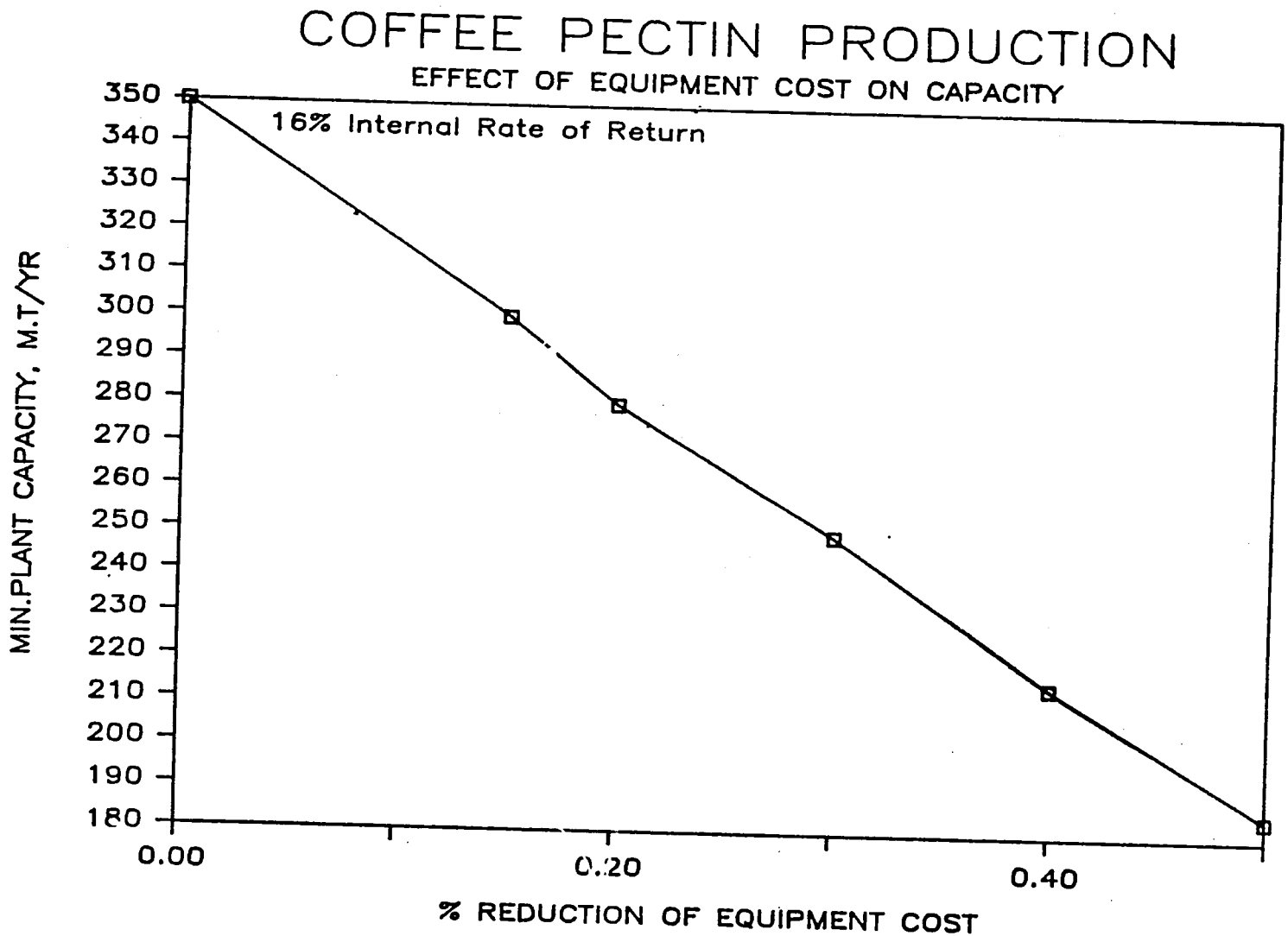

COFFEE PECTIN PRODUCTION
EFFECT OF EQUIPMENT COST ON CAPACITY
16% Internal Rate of Return
MIN.PLANT CAPACITY, M.T/YR
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
0.00
0.20
0.40
% REDUCTION OF EQUIPMENT COST

FIGURE 3

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FINAL PROGRESS REPORT

INDUSTRIALIZATION OF COFFEE PECTIN

Presented by ICAITI to:

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