Table II. Effect of Heat on Carotene Loss in Alfalfa Meal Sprayed with 0.2% Antioxidant and Wesson Oil at a Rate of 16 Pounds per Ton

(Storage at 25° C. for 6 months)

	Loss, %		
Antioxidant	*Unheated*	*Oil applied, then heated*	*Oil heated, then applied*
None (oil only)	79	76	78
Monomethylaniline	61	57	59
Diphenylhexamethylenediamine	45	35	42
2,5-Di-*tert*-butylhydroquinone	44	25	44
6-Ethoxy-1,2-dihydro-2,2,4-trimethylquinoline	40	30	39

some heating of the meal will occur during processing. Greater amounts of oil than now are used should be beneficial, although it appears from these data that 32 pounds per ton is not appreciably better than 16 pounds.

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SUGAR CANE PROCESSING

Clarification of New Varieties of Cane On a Pilot Plant Scale

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This research was undertaken to provide data on the suitability of new sugar-cane varieties for sugar production before they are grown on a commercial scale. Equipment and procedures were developed for grinding and processing individual 2-ton samples of cane on a pilot plant scale. The study of clarification of seven new varieties and a widely grown commercial standard on this scale provided information on the relative quantities of precipitate formed, filterability of the precipitates, and clarities of the juices, all of which are important factors in determining the efficiency of sugar recovery from the cane. Significant differences in the performance of these new varieties were established, and were considered together with the results of agronomic field testing in deciding to release two of them for commercial use. Further field testing of one of the less promising new varieties was discontinued when it was established that juice from this cane would be extremely difficult to clarify.

Almost every major sugar-producing area has come to rely upon the breeding of new varieties of sugar cane to maintain or improve the productivity of the crop. Breeding programs were initiated to combat diseases and have been continued for improving agronomic qualities, increasing the yields of sugar per acre, and maintaining disease resistance. In Louisiana, the new seedling varieties are evaluated agronomically during 6 to 8 years of multiplication before being cultivated commercially. Field tests establish the yields of sugar per acre, suitability for mechanical harvesting, early maturity, adaptability to climate and soils, and resistance to attack by diseases and insects.

Introduction of one new variety per year on the average results in complete change in predominant varieties in the crop about every 10 years. The continually changing composition of the crop alters the processing qualities of the juices obtained. New varieties that are satisfactory in field performance may yield juices that cannot be clarified readily to yield maximum recoveries of sugar. Work was initiated in 1949 to develop methods of evaluating the processing qualities of new varieties prior to commercial planting. Clarification characteristics of seven varieties of sugar cane have been determined on a pilot plant scale during four successive grinding seasons.

New varieties of sugar cane are available 2 or 3 years before they are eligible for commercial adoption, in quantities sufficient for experimental grinding and continuous processing on a pilot plant scale simulating factory conditions. The experimental Audubon Sugar Factory of Louisiana State University is equipped with a complete milling train 2 feet wide capable of grinding single bundles of approximately 2 tons of cane continuously through knives, crusher, and three three-roller mills in about an hour. Equipment for liming and clarification on a smaller scale was installed to obtain data on continuous clarification of the juice from this amount of cane in experiments of 4 to 6 hours' duration. Duplicate tests on both first-year plant cane and the stubble cane produced by a

Table I. Clarification Conditions and Resulting Clarities and Purities

Variety	Run No.	Heated Limed Juice Temp., ° F.	pH of Juice			Clarity of Clarif. Juice			Purity of Juice	
			Dilute	Limed	Clarif.	Low rate, 39 gal./hr.	High rate, 58 gal./hr.	Av. for run	Raw	Clarif.
C.P. 44-155 S[a]	1	215	5.55	7.02	6.8	39.6	36.8	38.1	77.0	78.1
	11	217	5.50	7.50	6.5	42.2	37.8	39.6	76.3	77.5
C.P. 44-155 P[b]	15	214	5.51	7.40	6.6	30.2	23.8	26.7	78.8	80.1
	26	216	5.37	7.35	6.6	27.8	37.8	32.8	79.7	82.0
C.P. 44-154 S	7	216	5.53	7.17	6.5	43.0	50.8	46.9	73.1	75.0
	14	214	5.29	7.88	6.8	57.5	51.2	47.1	71.7	73.4
C.P. 44-154 P	20	217	5.58	7.33	6.5	49.6	40.5	43.6	77.8	79.5
	27	216	5.46	7.36	6.7	28.4	27.1	27.7	74.8	76.1
C.P. 47-193 S	4	217	5.22	7.08	6.6	37.1	40.6	39.6	76.9	78.1
	10	216	5.57	7.05	6.5	38.0	44.5	43.1	76.7	78.7
C.P. 47-193 P	18	215	5.51	7.33	6.7	43.5	48.3	46.4	77.0	79.0
	24	216	5.50	7.30	6.5	35.3	44.0	40.8	74.9	78.0
C.P. 45-184 S.2[c]	6	213	5.37	7.27	6.6	48.5	49.0	48.8	78.2	79.8
	13	216	5.43	7.30	6.5	41.6	42.7	42.3	75.1	78.8
C.P. 45-184 P	21	214	5.50	7.26	6.6	60.3	53.1	55.5	75.0	76.3
	28	216	5.50	7.22	6.5	43.0	39.0	39.6	76.5	78.5
C.P. 48-103 S	3	212	5.55	7.14	6.5	40.0	38.0	38.6	82.0	82.6
	9	216	5.60	7.39	6.7	35.0	47.2	38.8	80.2	81.3
C.P. 48-103 P	17	215	5.53	7.18	6.6	43.7	29.8	35.4	82.1	82.3
	23	216	5.53	7.16	6.7	29.6	34.3	31.8	81.6	84.3
N.Co. 310 S	5	217	5.48	7.33	6.6	31.6	34.0	32.8	69.8	71.2
	8	217	5.54	7.19	6.5	32.6	42.3	34.8	77.9	79.8
N.Co. 310 P	19	216	5.55	7.40	6.5	...	36.3	36.3	75.9	78.4
	22	212	5.57	7.31	6.6	28.5	22.5	25.5	77.8	79.5
C.P. 44-101 S	2	213	5.59	7.38	6.6	46.6	45.0	45.8	75.3	77.3
	12	213	5.53	7.43	6.7	29.0	46.7	37.9	78.4	80.1
C.P. 44-101 P	16	214	5.53	7.45	6.7	24.2	40.0	31.0	73.4	76.0
	25	213	5.51	7.21	6.6	49.5	42.0	46.0	76.2	78.3
	29–30	216	5.47	7.30	6.4	37.5	33.8	34.8	77.9	81.1

[a] S, stubble cane, 1st year.
[b] P, plant cane.
[c] S.2, stubble cane, 2nd year.

second year's growth of each variety required a minimum of 8 tons.

Clarification

This critical step in raw sugar manufacture is carried out by addition of lime, followed by heating to effect as complete precipitation of impurities as possible. The insoluble calcium phosphates formed accelerate settling of suspended matter and of the colloids flocculated by neutralization. Completeness of reaction, and the density and settling rate of the precipitate, vary with differences in concentration of phosphates and other soluble constituents, precipitable nitrogenous impurities, and colloids in the juice. Removal of nonsugars increases the purity. The apparent purity, which is the sucrose content expressed as percentage of Brix solids, affords an approximate measure of the amount of sugar that can be crystallized.

It is important to form a dense precipitate that can be settled rapidly and removed in a minimum volume of discharge from the clarifiers. Large gravity settlers are universally employed, and the settling rate, total discharge volume, and ease of filtration of the precipitate determine the capacity at which most factories operate. Filtrate from the continuous, rotary filters is usually too turbid to be sent directly to the evaporators, so that capacity is greatly reduced when large volumes of this filtrate must be recirculated through the clarifiers. There are many variations of clarification procedure, but simple liming and heating of the whole, mixed juice is employed most widely. Details of the process are given in the handbook of Spencer and Meade (*8*) and numerous other texts. A standardized, simple liming method was used in all experiments to compare the results of its application to juices of different varieties of cane.

Pilot Plant Equipment

The clarification equipment is designed to operate at approximately 55 gallons of juice per hour. This is about 1/200 the capacity of commercial clarifiers, but is sufficiently large to permit continuous operation for 4 to 6 hours with juice produced from a 2-ton sample of cane. The capacity of the milling equipment (*5*) is much larger, so that all the juice can be collected and refrigerated to provide a uniform sample and to prevent its alteration during the time required to complete an experiment. Capacity is provided to hold up to 450 gallons of juice, with provision for reheating it as it is pumped to the clarification system. A general description of this equipment has been published and complete details of its construction with shop drawings are available (*4*).

Clarification Procedure

An individual sample of juice is pumped to the storage tank and cooled rapidly to approximately 36° F. to prevent spoilage or inversion. Processing is started by pumping the juice through a reheater to the liming tank, which it enters at between 70° and 80° F. Addition of lime is automatically controlled to bring the pH to between 7.1 and 7.8 as required to produce the same final pH in all juices after heating. The limed juice passes through tubular heaters under pressure to bring it to a temperature of 213° to 217° F. before discharge into the clarifier. Heating and settling result in a drop of all clarified juices to nearly the same pH of 6.5 to 6.7.

The first 2 hours of operation are required to fill the clarifier and bring the system into balanced operation. Data are recorded for at least an hour with a constant juice flow of approximately 55 gallons per hour. Sufficient juice was available from some samples, particularly in 1952, to permit reduction of the rate to about 40 gallons per hour, allowing balanced operation to be established, and recording data for an hour at this rate. Slurry is withdrawn at the rate necessary to maintain approximately the same level of precipitate in the body of the clarifier for each experiment. The discharged slurry is collected and weighed periodically. Varieties are com-

Table II. Trash, Weights, and Densities of Mud Produced

Cane Variety	Run. No.	Trash, % Cane	Av. for Low and High Rates, Lb./Ton Cane/Hr.	Wet Weight Lb./Ton Cane	Dry Weight, Lb./Ton Cane	Mud Composition, % Dry Wt. Mud: Mineral matl.	Organic matl.
C.P. 44-155 S[a]	1	1.47	146	116	4.83	23	77
	11	1.35	137	122	6.31	33	67
C.P. 44-155 P[b]	15	1.46	133	127	6.19	31	69
	26	0.49	150	125	9.92	51	49
C.P. 44-154 S	7	0.95	195	162	6.92	41	59
	14	0.98	253	194	8.43	44	56
C.P. 44-154 P	20	1.91	144	98	5.95	47	53
	27	0.99	121	106	6.55	51	49
C.P. 47-193 S	4	0.49	144	144	9.30	42	58
	10	1.45	218	178	9.52	47	53
C.P. 47-193 P	18	1.81	157	136	9.14	52	48
	24	1.98	181	157	12.92	56	44
C.P. 45-184 S[c]	6	0.99	185	172	8.67	42	58
	13	1.00	277	232	11.91	62	38
C.P. 45-184 P	21	1.90	155	130	7.82	46	54
	28	0.47	159	154	21.52	73	27
C.P. 48-103 S	3	0.97	133	92	3.73	30	70
	9	0.99	122	127	6.51	38	62
C.P. 48-103 P	17	8.00	268	258	33.70	80	20
	23	1.81	145	124	10.90	46	54
N.Co. 310 S	5	0.95	112	105	5.89	40	60
	8	0.94	142	132	7.97	35	65
N.Co. 310 P	19	0.00	122	144	11.29	29	71
	22	1.67	128	109	7.08	41	59
C.P. 44-101 S	2	0.48	170	165	6.29	26	74
	12	0.87	196	165	6.14	29	71
C.P. 44-101 P	16	3.26	123	130	8.92	59	41
	25	1.01	137	117	6.69	44	56
	29–30	0.89	141	123	15.27	66	34

[a] S, stubble cane.
[b] P, plant cane.
[c] 2nd year stubble cane.

pared on the basis of the rate at which slurry must be discharged to maintain the required level of precipitate while producing clear juice. The rate of discharge and the total collected during the entire experiment, in pounds per ton per hour and pounds per ton, respectively, are calculated to a common basis on the weight of cane ground. Laboratory determinations are made of the relative filterabilities of the slurries and of their densities, and total solids contents. Data are also obtained on the final clarity of the juice and on the rise in purity effected by clarification. The clarified juices are concentrated to sirups, which are analyzed to determine their quality and estimate recoverability of raw sugar.

Sugar-Cane Variety Samples

The American Sugar Cane League furnished samples of sugar cane from secondary test fields. New varieties that have reached this stage of agronomic evaluation are available in sufficient quantities for pilot plant processing. Material used during 1952 and 1953 was obtained from three different test fields in the eastern Louisiana area, two east of the Mississippi River, and one at Southdown near Houma, La. The varieties used had been produced by selective breeding at Canal Point, Fla., and are designated by C.P. numbers, with the exception of one introduced from Natal and designated as N.Co. 310. In order to relate performance of the new canes to that of a well-known standard variety, experiments were carried out with C.P. 44-101, which has increased to more than 20% of the total crop since its release in 1949. Variety C.P. 44-155, also released in 1949, and variety C.P. 44-154, planted commercially for the first time in the 1953 crop, were used in the experiments. Varieties C.P. 45-184, C.P. 47-193, and C.P. 48-103 are still being evaluated agronomically, while N.Co. 310 was released for planting in the 1955 crop on the basis of its satisfactory agronomic and clarification qualities.

Samples of both plant and stubble, or ratoon, cane of each variety were processed. Plant cane is that produced by an initial planting made in September or October for the succeeding year, while stubble canes are the second or third year regrowth from the initial plantings. Stubble cane samples were harvested and processed during the first half of the season, and plant cane samples during the latter half, following the usual commercial practice dictated by earlier maturation of stubble cane.

The experiments were designed to establish gross differences in the clarification results yielded by different varieties. Average results with samples grown at different localities under various weather and other cultural conditions proved significant for the purpose for which the tests are intended. While the samples were harvested by hand, they represented cane of a quality that should be obtainable commercially, containing 1 to 2% trash in most cases. They were ground 2 to 5 days after harvesting, and represent material that can be produced by improvements in mechanical harvesting equipment and practices.

Results

Clarification data obtained by pilot plant processing are illustrated by Tables I and II, in which the results of all individual experiments carried out during the 1952 season are assembled. Similar data on the same seven varieties of sugar cane were obtained during the 1953 grinding season, when growing and harvesting conditions were fairly good and generally similar to those of 1952. Additional data on four of the varieties—C.P. 44-101, C.P. 44-154, C.P. 44-155, and C.P. 45-184—were available from comparable sets of duplicate experiments carried out during 1950 and 1951. The 1950 harvesting season was characterized by very favorable weather during the early period when stubble cane was harvested, followed by severe freezes which killed much of the plant cane used during the second half of the season. Extremely adverse weather prevailed in 1951, when much of the crop was killed

Table III. Average Quantities of Clarifier Discharge

Variety	No. of Tests	Discharge, Av. Lb./Ton	Standard Deviation	Confidence Limits (95%)	Relative Precision: F	Critical F, 10% level
C.P. 48-103	7	121.9	18.0	104.4–139.4	3.89	4.03
C.P. 44-155	12	130.5	23.2	115.7–145.3	2.35	2.83
N.Co. 310	8	137.3	29.7	111.4–163.2	1.44	3.60
C.P. 44-101 (standard)	12	151.9	35.6	133.0–178.4	...	...
C.P. 44-154	13	155.7	32.8	131.9–171.9	1.17	2.73
C.P. 45-184	14	180.4	42.1	155.6–205.2	1.40	2.75
C.P. 47-193	8	192.2	51.0	147.7–236.7	2.06	3.01

by early freezes. All data have been used with equal weight in calculating average clarification results obtainable under the range of conditions that may be expected from season to season.

Clarifier Discharge The variability of the quantity of wet slurry that must be discharged from the clarifier to maintain satisfactory operation is apparent in Table II. This quantity depends upon density and settling rate of the floc formed as well as the amount of solid impurities precipitated, as is evident from the divergence of the weights of dry material and the total weights of the slurries. Some large differences are observed between pairs of duplicate experiments, but most of the duplicates checked reasonably well for this type and scale of operation. Duplicate experiments were not made on pairs of stubble or plant cane samples on consecutive days, and the period between harvesting and grinding or the condition of the cane could not be made exactly comparable. Some exceptionally high results are attributable to excessive amounts of soil and extraneous matter in the samples.

In general, the results for both stubble and plant samples taken together show that a variety such as C.P. 45-184 consistently produces larger amounts of clarifier discharge than one such as N.Co. 310. The same relationship among the varieties was found in the experiments carried out during the 1953 season and, in general, consistent results were obtained for those varieties that were tested during four consecutive seasons (*2*, *3*). The averages acquire greater significance as the number of individual determinations increases in repeated experiments during different seasons.

Average Results And Significance Twelve to fourteen determinations of the quantity of discharge had been made on the three varieties and the standard that had been processed during four successive seasons, and at least seven or eight individual determinations were available for the three varieties included only in the 1952 and 1953 experiments. Arithmetical averages of quantities obtained in all the experiments with each variety are given in Table III, listed in order of increasing quantities of discharge—i.e., from best to poorest in ease of clarification. On this basis variety C.P. 44-154 is practically equal to the standard C.P. 44-101 with respect to the quantity of precipitate to be handled, varieties C.P. 44-155 and N.Co. 310 are equal to each other and somewhat better than the standard, and variety C.P. 48-103 is much better than the standard. Clarification of varieties C.P. 45-184 and C.P. 47-193 produces such large quantities of precipitate that these canes would be of doubtful commercial value, regardless of high sugar productivity or other qualities. An increase of 25% in the quantity of precipitate to be handled with existing clarification equipment would reduce factory operating capacity by not less than 20%. Recirculation of the increased volume of filtrate would impose an additional limitation upon operating capacity that would reduce it to less than two thirds of that possible with standard cane. The use of a variety such as C.P. 48-103 would have the opposite effect of increasing factory operating capacity by at least 25%. Most of the factories now have adequate grinding and evaporative capacity to take advantage of such an increase in clarification rate.

Variations among the individual determinations were such that it was desirable to determine what significance might be attached to the average values. The standard deviation was calculated for each set of observations and from these the confidence limits at the 95% level were computed (*10*), with the results shown in Table III. These show the extreme limits that would be exceeded only once in 20 duplications of the experiment under comparable conditions. The least quantity of clarifier discharge that can be expected from the poorest variety, C.P. 47-193, is greater than the largest probable quantity that would be produced by the best variety, C.P. 48-103. The confidence limits would be narrower for larger numbers of experiments on each variety. Sufficient numbers of determinations have been made to yield averages that predict, within practical limits, results to be expected from the combined operation of all the Louisiana factories if one of these new varieties is substituted for C.P. 44-101 as the predominant variety in the crop.

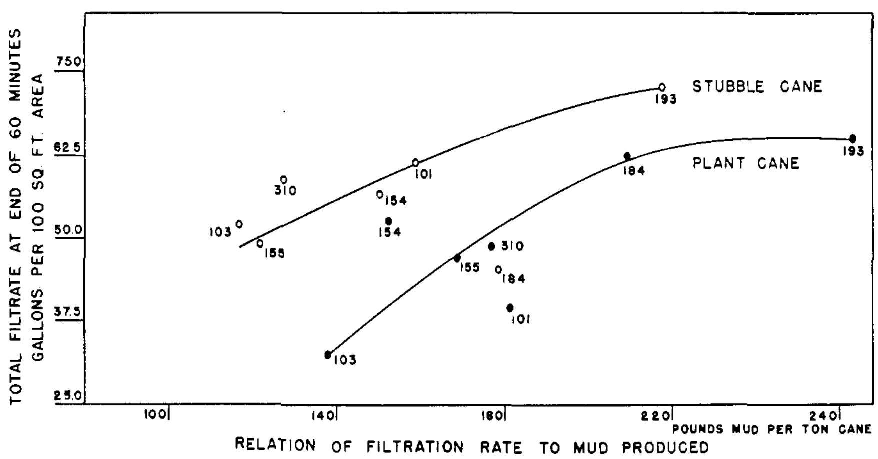
Table IV. Average Clarities of Treated Juices

Variety	No. of Tests	Average (% Trans.)	Standard Deviation	Confidence Limits (95%)	Relative Precision F	Relative Precision Critical, 10% level
C.P. 45-184	14	48.0	4.63	45.3–50.7	1.92	2.64
C.P. 47-193	8	47.1	5.60	42.2–52.0	1.32	3.60
C.P. 44-154	13	43.5	6.92	39.3–47.7	1.17	2.79
C.P. 44-101 (standard)	12	41.3	6.41	37.2–45.4	...	...
C.P. 48-103	7	39.6	9.35	30.5–48.7	2.13	3.09
N.Co. 310	8	35.9	7.40	29.4–42.4	1.33	3.01
C.P. 44-155	11	32.5	8.16	27.1–37.9	1.62	2.86

Juice Clarity Final clarities of the juice were averaged and the data treated in the same manner as those on the quantities of clarifier discharge. The results are arranged in Table IV in the order of decreasing clarity from the best to the poorest. With the exception of variety C.P. 48-103, which produced both the smallest quantity of discharge and juice, of fairly high clarity, this order is generally the inverse of that based upon quantities of discharge. This is not surprising, as the more voluminous, slower settling precipitates remove more suspended and colored impurities.

The economic importance of good clarity is not so well established as that of minimum quantities of clarifier discharge. Values determined by Luximeter as per cent transmittance relative to water are used in practice to establish the effectiveness of clarification. This instrument measures absorption by suspended and colloidal matter as well as color. The effect of suspended, colloidal, and colored impurities on sugar crystallization and quality will have to be investigated in the pilot plant to determine the importance of this quality of the juices. Information in the litera-

Figure 1. Typical filtration rate curves



ture (*1, 6, 7, 9*) on the melassigenic effect of various impurities that reduce sugar recoveries shows that some of the substances causing poor clarity may be responsible for economically important losses.

As the new varieties are rated relative to the standard C.P. 44-101, it is of interest to examine the relative precision of the data for different varieties. Established methods (*10*) were used to compute the *F* ratios given in Tables III and IV for the results on both the quantities of clarifier discharge and clarities of the treated juices. In both cases the values obtained for this ratio are well below the critical values for the 10% level. Comparison of the results to rate the different varieties is therefore justifiable, with only one chance in ten that repetition of the comparisons would yield higher precision for the standard than for any of the other varieties tested.

Purity Changes The juice samples varied widely in initial purity and the rises in purity bore no evident relationship to initial purity, clarities, or quantities of precipitate, or to the particular varieties processed. Purity is a practical index of the sugar that can be crystallized from juices or sirups, and the rise in purity is generally regarded as a measure of the effectiveness of clarification. Some individual samples that yielded large quantities of precipitate with a high solids content and juices of high clarity show relatively large increases in purity, but this is not always the case. The average results of all the experiments with each variety tend to approach a more or less constant purity rise for all the varieties. No analysis was made of the variations of sets of purity rise observations.

Filterability of Clarification Precipitates The standard Oliver vacuum filter procedure was used to obtain laboratory measurements of the filterability of slurry withdrawn periodically from the clarifier during intervals of uniform, continuous operation.

The filterability of the mud was determined with a filter disk of 0.1 sq. foot filtering area, clothed with a standard duck filter press cloth. It was submerged in a container holding approximately 4000 ml. of mud, and 23 inch vacuum was applied to the disk. Readings of the volume of filtrate collected in a calibrated vacuum receiver were taken at intervals of 10, 30, and 60 minutes. Results are only relative, and their relation to actual capacities of the continuous filters has not been established.

Typical filtration rate curves were obtained, from which the volumes of filtrate delivered in 60 minutes were used as a basis for comparison. The relation of this volume to the quantity of precipitate produced per ton of cane is shown by the curves in Figure 1. With the exception of the stubble cane test of C.P. 45-184 and possibly the plant cane samples of C.P. 44-154 and C.P. 44-101, there is a fairly consistent relationship of filterability to the total quantity of precipitate. Voluminous precipitates in general, although not invariably, have lower dry solids contents, which accounts partly for the observed results. Ease of filtration, together with the better clarities obtained, compensates to some extent for the difficulty of processing varieties that produce large quantities of precipitate in clarification.

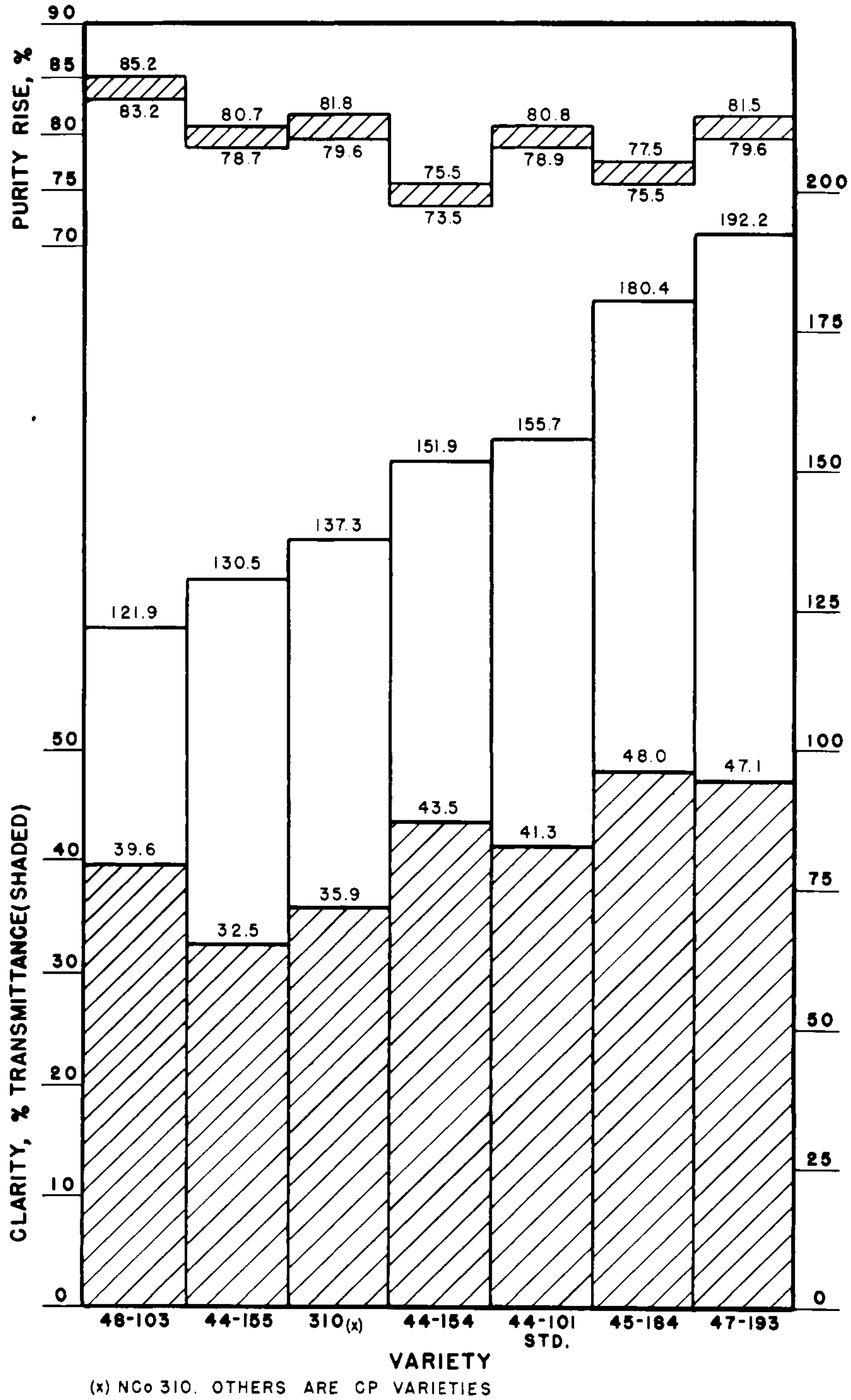


Figure 2. Composite results

Composite Results All the results obtained on each variety are summarized in Figure 2. It is possible to compare any two varieties with respect to all of the qualities desired in clarification by reference to the data represented by the bar graphs. This figure shows clearly the general trend of better clarity obtainable with increasing quantities of clarifier discharge. Weight must be given to both factors in determining the suitability of a new variety as a replacement for the standard or other equally good varieties. Results of these pilot plant experiments were considered in releasing varieties C.P. 44-154 and N.Co. 310 for commercial sugar production, after their productivity and agronomic qualities had been shown to be satisfactory by field testing. The processing data also contributed to the decision to discontinue further field testing of variety C.P. 45-184.

Summary

The clarification of six new varieties and of the widely grown commercial variety used as standard has been studied on a pilot plant scale to obtain information on the suitability of the new canes for commercial use. The results were considered, together with agronomic and other qualities, in releasing two new varieties for large scale planting and in discontinuing further field tests of a variety that yields juice that cannot be clarified efficiently.

Although the scale of operation is only $^1/_{200}$ that of an average Louisiana factory, effective clarification can be carried out continuously under conditions duplicating those of the large scale operation. Accurate control of operating conditions makes it possible to duplicate results on cane of the same variety and quality with reasonable accuracy. Sufficient numbers of individual experiments were carried out with each variety to yield average results that are significant in determining the important differences to be anticipated in the commercial clarification of juices from these canes.

The most important variable studied was the total quantity of clarifier discharge, which ranged from about 130 to over 190 pounds per ton for the best and the poorest cane varieties tested, respectively. A general relationship has been observed between the clarities of the juices and quantities of precipitate; better clarities are obtained in processing the varieties that yield larger quantities of more voluminous clarifier discharge. Increased quantities of precipitate are compensated to some extent by higher filtration rates as determined by laboratory filtration tests.

Methods developed in this research are applicable to the evaluation of new varieties in any areas in which the composition of the sugar-cane crop is being altered continually by the breeding and introduction of improved canes, and will be extended to the study of other sugar-cane processing operations.

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FISH PROCESSING

Expression of Oil from Dried Fish Meal

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Expression of oil from fatty fish has been a process of commercial importance for more than a century. The most common process, generally referred to as wet reduction (*2, 4, 24*), employs the wet press which separates the cooked fish into two fractions, press cake and press liquor. The press cake is dried and marketed as fish meal, whereas the press liquor is separated into two fractions, oil and stickwater. The fish oil is used for various industrial purposes. The stickwater is usually discarded, although in some instances in the United States it is concentrated and marketed as condensed fish solubles.

The wet-press method is well suited for large scale continuous operation and the production of fish oil, but there are disadvantages inherent in this process. The loss of water-soluble solids to the stickwater may amount to 20% of the dry weight of the fish (*13, 22*). Stickwater, when concentrated to 50% solids, is used as a vitamin supplement in animal and poultry feeding and is an excellent source of B vitamins and minerals. Its nutritive quality has been thoroughly investigated by Lassen and associates (*17, 18*), Deas and Tarr (*10, 11*), workers of the U. S. Fish and Wildlife Service (*7–9*), and those of Herring Oil and Herring Meal Industry's Research Institute in Bergen, Norway. Bakken (*3*) has demonstrated that stickwater contains 40 to 60% of the vitamins of the fish.

Fish meal and fish solubles are used extensively in the feeding of domestic animals and have been found especially valuable as a supplement in poultry feed. Discovery of vitamin B_{12} and other recent growth factors has been of special interest to fish meal manufacturers, as fish meal and fish solubles are good sources.

Realization of the high nutritive value of the stickwater as well as lowered demand for marine oils during recent years has enhanced the interest in recovering the stickwater solids. Concentration of stickwater is practiced to some extent, mostly using the Sharples Lassen process (*24*). However, feeders prefer to obtain stickwater nutrient included in the meal, and in some Norwegian plants the stickwater is returned to the press cake after wet-pressing of the fish to produce what is known as "whole meal." Einarsson (*6, 13*) has developed a method involving evaporation of water from the whole fish and subsequent solvent extraction of the oil. Levin and Lerman (*19*) and Smith (*23*) report a solvent extraction process known as the VioBin process.

Dry rendering is commonly used for the reduction of nonfatty fish. The wet press is eliminated and there is no stickwater; hence essentially all the constituents of the fish occur in the meal, with the exception of water. Anderson, Harrison, and Pottinger (*1*) investigated this method in 1935. The percentage of oil in the meal is approximately four times that of the original fish. Thus, in the case of oily or medium oily fish it becomes essential to lower the oil content of the

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