PART IV.

DISTILLERY EXPERIMENTS AT THE GOVERNMENT LABORATORY.

Since the results published in the previous report for 1905, pages 74-118, were obtained, we have continued our work in the small distillery attached to the Government Laboratory and a selection from a large number of Experiments is here presented.

The results obtained by the class of practical distillers who attended the courses in 1905, 1906, and 1907 are now given in a summarised form. Wash was set up in a great variety of ways and with very different materials. The figures are well worth a close study by those interested in the economic production of rum from the fermentable matter as sent to the distillery.

A summary is also given of some Experiments in 1907 in which the alcoholic production and its recovery in the commercial form of rum are set out in relation to the sugar fermented. The practical recovery of rum at 40 o. p. to be expected under ordinary conditions in a still-house in Jamaica, making common, clean rum and using a steam-heated pot still with double retorts may be set out as follows:—

First Class Management.

1 gallon 40 o. p. rum from 15 lbs. sugars sent to the distillery.

Good Management.

1 gallon 40 o. p. rum from 15 to 16 lbs. sugars.

Indifferent Management.

1 gallon 40 o. p. rum from 16 to 17 lbs. sugars.

With healthy yeasts and the most careful control a return of a gallon of rum from 15 lbs. sugars is quite attainable:

With common, clean rum, selling locally at 2/6 per gallon, the price obtained for our Laboratory rum, this equals 2d per pound for sugar or over £18 a ton.

It is apparent that the Distillery is a department that every sugar planter should study most closely and one that should well repay care and the best management obtainable.

DISTILLERS' EXPERIMENTS, 1905

EXPERIMENT 1.

MESSRS. MORRIS, NUGENT, SEWELL AND TAYLOR.

This was an Experiment in aiming at a higher quality of flavour by gradual additions to the liquor of prepared materials.

350 lbs. cane juice was allowed to ferment for 36 hours whereby it attenuated from 17.5 to 15.4 Brix.

450 lbs. of Dunder were then added and fermentation allowed for a further period of 36 hours, then 100 lbs. of molasses were added, the liquor then standing at 20.2 Brix. After 24 hours, 91 lbs. of acid cane-juice at 2.3 per cent acidity were added, so that the liquor as finally 'set up' stood at 19.8 Brix with an initial acidity of 1.25 per cent—after 6 days the liquor attenuated to 8.1 Brix with an acidity of 1.34 per cent.

The wash as finally set up contained 12.66 per cent. of sugars of which 11.87 per cent. subsequently fermented, 0.79 per cent. of sugar remaining in the dead liquor. The following results were recorded:—

Apparent attenuation	11.7 Brix
Sugars fermented	11.87 %
Proof spirit produced	12.43 %
Proof spirit per deg. attenuation	0.106
Unfermented sugars	0.79
Acidity developed	0.35
Proof spirit on sugars fermented	104.7 %

Results of Distillation.

Yield. .466 lbs. alcohol per gallon.
58.8 gals. alcohol per 1000 gallons.
103 gals. P. S. " " "
73.6 " Rum 40 o. p. " "
Charge on attenuation 100.2 gals. P. S. Return 3% over 'charge.'

Rum Produced.

Alcoholic Strength—	43.6 o. p.
Acidity	14.6
Ethers	135.0

EXPERIMENT 2.

MR. MUIRHEAD.

Object.

To test the effect of high setting and muddy dunder on common clean process.

Wash was set up as follows:—

277 lbs. cane juice at 14.5 Brix.
502 lbs. dunder (purposely stirred up and not clarified.)
137 lbs. water.

The wash as set up stood at 19.8 Brix, total sugars 12.35, acidity 0.99. After 2 days, no attenuation being observed, 35 lbs. water was added reducing the gravity to 19.0 Brix. On the 15th as the liquor had only attenuated 2 degrees, 10 lbs. Lime and 28 lbs. Cane juice were added. At the end of the 9th day the liquor attenuated to 7.7 Brix with an acidity of 0.64 per cent. Some acid liquor at 2.5 per cent. acidity was then added—150 lbs.—and left for three days.

The dead wash stood at 8.4 Brix, contained 0.82 of unfermented sugar and 1.12 per cent. of acidity.

The apparent attenuation was 10.6 Brix.

The liquor was distilled and the following result obtained:—

Yield.

77.94 gals. P. S. per 1000 gallons wash
55.7 gals. Rum 40 o.p. „ „
Charge on attenuation equals 90.6 gals. P. S.

The high wines used were etherised slightly with lees material by High Ether Process and the Rum obtained gave the following results:

Rum.

Alcoholic Strength	41.6 o.p.
Acidity	68.3
Ethers	355

The returns were therefore disappointing and the yield on sugars fermented very low. On the other hand, Rum of decidedly improved quality was obtained.

EXPERIMENT 3.

MR. WALCOTT.

Ordinary Setting and Process.

Materials were set up as follows:
308 lbs. cane juice at 14.8 Brix.
454 lbs. dunder.
172 lbs. water.
125 lbs. molasses.

This wash stood at 18.5 Brix with 12.4 per cent. of sugars and 0.81 acidity. In 8 days it attenuated to 6.2 Brix with 0.6 of unfermented sugar, 0.88 acidity and 11.1 per cent. of proof spirit. Proof spirit per degree of attenuation = 0.90

P. S. on sugars fermented = 93.2 per cent.

The results from the still were as follows:
469 lbs. alcohol per gallon.
59.09 gals. alcohol per 1000 gallons.
103.56 „ P. S. „ „
74.0 „ Rum 40 o. p. „
Charge on attenuation = 104.16 gals. P.S.

Rum Produced.

Alcoholic Strength	= 42.9 o. p.
Acidity	21
Ethers	111

EXPERIMENT 4.

MR. BELL.

Ordinary setting and process, but reduced proportion of Dunder.

Materials set up:

400 lbs. cane juice a 16.2 Brix.
200 lbs. dunder a 14.0 Brix.
200 lbs. water.
140 lbs. molasses.

The initial gravity was 19.5 Brix with an acidity of 0.55 per cent. In 7 days the wash died down to 6.1 Brix with an attenuation of 13.4 and an acidity of 1.14 per cent. The sugars were reduced from 13.2 to 1.4 per cent. and 13.3 per cent. P. S. was produced.

On distillation the following returns were obtained:

0.523 lbs. alcohol per gallon.
65.9 gals. alcohol per 1,000 gallons.
115.5 „ P. S. „ „
82.5 „ Rum 40 o. p.

Charge on attenuation = 113.8 P. S.

Yield = 1.5 per cent. over charge on attenuation.
P. S. per degree attenuation = 0.993.
P. S. on sugars fermented = 98 per cent.

The Rum produced was as follows:

Alcoholic Strength	= 38.9 o. p.
Acidity	17
Ethers	102

EXPERIMENT 5.

MR. FORBES.

Ordinary Process Medium Setting.

250 lbs. Water.
250 lbs. Dunder a 14.4 Brix.
400 lbs. Cane Juice a 17.5 Brix.
84 lbs. Molasses.

Wash as set up.	Brix	16.4
	Total sugars	12.7
	Acidity	0.6

After 6 days the liquor died down.

Brix	4.4
Sugars	0.6
Acidity	0.85
Proof Spirit	11.5

The attenuation was 12.0, P. S. per degree attenuation 0.953. P. S. per cent. on sugars fermented = 95 per cent.

On distillation the returns were:

64.64 gals. alcohol per 1000 gallons.
113.26 gals. P. S. „ „
80.9 gals Rum 40 o. p. „

The charge on attenuation amounts to 100.2 gallons Proof Spirit, so that a return of 13 per cent. over charge was obtained.

The Rum recovered amounted to 98.5 per cent. of that in the liquor, a very high return for a Pot Still.

The rum produced was as follows:

Alcoholic Strength	42.2 o. p.
Acids	14
Ethers	122

EXPERIMENT 6.

MR. PARKINSON.

Common Process High Setting: a little flavour added.

Materials used:

250 lbs. Dunder	14.4 Brix
400 lbs. Cane Juice	17.5 Brix
150 lbs. Molasses	
30 lbs. acid flavour	
230 lbs Water	

Wash as set up:

Brix	20.5
Sugars	17.54
Acidity	0.62

After 8 days the wash died down to 7.8 Brix with an acidity of 1.20. Unfermented sugar = 2.64, Proof Spirit 12.57 per cent., P. S. per degree attenuation 0.99, P. S. on sugars fermented 84 4 per cent.

On distillation Rum was obtained in the proportion of per 1,000 gallons wash 94.06 gs. P. S., = 67.2 gs. Rum 40 o. p. The rum was 40.9 o. p. with an acidity of 37 and Ethers 178. This experiment showed that the amount of sugars used was too high for economical production. The alcohol produced was only 71.6 per cent on the sugars in the wash calculating as Proof Spirit.

EXPERIMENT 7.

MR. TAYLOR.

Ordinary Process.

Materials set up.

315 lbs. Cane Juice	11.4 Brix
31 lbs. Water	
447 lbs. Dunder	11.5 Brix
96 lbs. Molasses	

Wash.

Brix	18.3
Sugars	11.24
Acidity	1.16

In 5 days the liquor died down at 8.5 Brix, showing 9.8 attenuation. The unfermented sugar was 1.69, acidity 1.42.

On distillation, the high wines were treated with Lees lime-salts by the High Ether Process and a rum of light body with something like a 'tea-rum' character was obtained.

Analysis of Rum Produced,

Alcoholic Strength	39.7 o. p.
Acidity	178
Ethers	1082

EXPERIMENT 8.

MR. STRICKER.

Wash was set up as follows:

125 lbs. Molasses	
426 lbs. Dunder	12.3 Brix
293 lbs. Cane Juice	14.8 Brix

The Cane Juice was diluted with 33 lbs. of water and allowed to stand for about 6 hours, then dunder and molasses added and finally 50 lbs of water to reduce the gravity of the setting.

The wash as set up was as follows :—Brix 20.0, Sugars 13.7, Acidity 0.7. In five days the liquor had attenuated to 7.5 Brix and after standing for two days whereby an acidity of 0.1 per cent developed, the wash was sent to the still. The dead wash contained 1 per cent. of unfermented sugar and 0.46 per cent of acidity had developed during the fermentation. On distillation rum was obtained equal to 98.7 gallons P.S. per 1000 gallons wash or 70.5 galls. rum at 40 o. p. This is 8 per cent. under the "charge" on attenuation. The rum produced gave the following factors :—

Alcoholic Strength	41.7 o. p.
Acidity	17.
Ethers	144.

EXPERIMENTS IN 1906 AND 1907.

The experiments in the distillery of the Station for 1906 were mainly on the same lines as those published in the previous Report and it is not considered necessary to set them out in detail.

In 1907 we carried out a series of experiments with Cane Juice and Dunder and with evaporated Cane Juice under various conditions. The results of 7 experiments with plain juice and Dunder at an average standard of 17 Brix. and 14 per cent. sugars with an initial acidity of ⅓ per cent. gave attenuations varying from 11 to 15 Brix. The production of alcohol on sugars fermented averaged 84.3 per cent. as Proof Spirit and varied from 65 to 97 per cent. The Recovery by the Still averaged

95 per cent. of the alcohol in the liquor. This must be regarded as a fine return and indicates that the Jamaica Pot Still with double retort and Steam Coil is a very efficient means of recovering alcohol from a fermented liquor.

There is no doubt a good deal attaching to the skill with which a Still is run, but with good condensation and efficient Can Pit arrangements it would appear that a liquor can be distilled in Jamaica with a loss of only 5 per cent. of the spirit in the fermented liquor.

The Rum produced, as would be expected from the materials employed, was very light and not up to the Jamaica Standard. The Ethers were as follows :

Experiment			Ethers per 100,000 volumes
1	—	—	88
2	—	—	45
3	—	—	91
4	—	—	44
5	—	—	88
7	—	—	95
8	—	—	134

Our crop of rum resulting from these experiments amounting to 2 puncheons was sold locally at the price of 2/6 per gallon. It was considered of good drinking quality.

CANE JUICE AND DUNDER EXPERIMENTS.—1907.

Ref. No.	Wash as Set up.				Wash as Distilled.				Attenuation.	Sugars Fermented.	Alcohol Produced.	Acid Produced.	Per Cent Proof Spirit on Liquor.	Proof Spirit % deg. attenuation.	Recovery.		
	Brix.	Sugar.	Alcohol as P.S.	Acids.	Brix.	Sugar.	Alcohol.	Acids.							gls. P.S. 1000 gls.	Efficiency of Still.	Percent. on Charge.
1907—1 -	16.6	14.3	0.23	0.35	2.4	0.81	12.97	0.65	14.2	13.49	12.74	.30	84.4	.896	121.45	93.7	103.0
1907—2 -	16.5	14.5	1.28	0.32	4.2	1.62	12.16	0.70	12.3	12.9	10.88	.38	84.3	.884	117.6	96.7	114.6
1907—3 -	17.0	13.9	1.16	0.40	2.7	0.51	12.97	0.68	14.3	13.4	11.80	.28	88.0	.825	122.5	94.4	103.0
1907—4 -	17.5	14.9	0.23	0.35	3.0	0.75	12.97	0.70	14.5	14.2	12.74	.35	90.0	.879	116.6	89.8	96.4
1907—5 -	16.5	14.1	nil	0.30	5.0	1.37	10.26	1.03	11.5	12.7	10.26	.73	80.8	.892	100.2	97.7	104.1
1907—7 -	16.8	13.7	0.46	0.32	5.9	1.42	8.51	1.15	10.9	12.3	8.05	.83	65.4	.738	83.9	98.6	91.6
1907—8 -	17.6	14.5	nil	0.33	2.7	0.7	13.42	0.65	14.9	13.8	13.42	.32	97.2	.900	123.9	92.3	99.8

PART V.

DISTILLERY EXPERIMENTS ON ESTATES.

Owing to certain commercial factors involved in the trade in Jamaica Rums I have decided not to publish for the present any of our experimental results on estates. The report on this work will be included in the next publication of the work of the Sugar Experiment Station.

PART VI.

REPORT ON THE STUDY OF FERMENTATIONS IN THE MANUFACTURE OF JAMAICA RUM, 1907.

BY—S. F. ASHBY, B.Sc., FERMENTATION CHEMIST.

It had been established during the three years that my predecessor Mr. Chas. Allan, B. Sc. had worked on the manufacture of Jamaica Rum, that flavour was mainly due to the compound ethers. These bodies were considered as produced by chemical combination of alcohol with various volatile fatty acids during and after fermentation of the wash, and particularly during distillation. The alcohol was the product of the action of yeasts on the sugar in the wash, but the acids were the work of bacteria, being partly preformed in the materials used for setting up the wash, and partly produced in the wash during and after the yeast fermentation. The following acids were found, acetic, propionic, butyric, capryllic, capric, lauric, all of which yielded ethers with alcohol capable of giving varied flavours to Rum. Acetic ether was shown to constitute about 98 per cent. of all ethers in Rum, but contributed little flavour and owing to its volatility was very transient. Butyric ether was found to be more valuable, but the ethers of the higher acids, capryllic, capric, and lauric, were held to be of special importance for giving both body and characteristic flavour.

As the yeasts were considered to be only alcohol producers attention was mainly directed to the study of bacteria producing the valuable acids. One such bacterium was isolated and the conditions under which it works determined (Report 1906, pages 136-137). A microscopical examination of washes showed the presence of two yeast types, distinguished by very different modes of multiplying; to the one type belonged, the oval and sausage shaped forms which multiplied by budding (Saccharomycetes) whereas the other type reproduced by division through the middle of the cell, that is by 'fission.' (Schizosaccharomycetes). The oval budding forms were alone seen in cane juice washes, but the fission type was found to be the characteristic fermenting yeast of both common, clean and flavoured rum washes. The latter kind could not be isolated, and indeed no systematic experiments appear to have been made with any of the yeasts.

Mr. Percival H. Greig of Westmoreland was the first to isolate a number of Jamaica Distillery yeasts, and to study their action on washes in a state of pure culture. In molasses and dunder which he took to Jorgensen's Laboratory in Copenhagen in 1893 the fission type of yeast was discovered and studied for the first time. Greig continued to work with these yeasts in Jamaica till 1896 and published reports of his results in the Bulletin of the Botanical Department (March, August, and September 1895 and January 1896). He observed marked differences in the time required for fermentation, amount of attenuation, and alcohol-yield with different yeast, and drew particular attention to a slow working top fermenting fission form which alone was able to produce an agreeable flavour in washes. He recognised the importance for flavouring of fruit ether in rum, but appeared to think that these bodies in so far as they were not contained in the original juice of the cane, could be produced at will by pitching the wash with a suitable flavour engendering yeast. On these grounds he strongly advocated the employment of pure yeast cultures in Jamaican Distilleries, and insisted that the distiller should strive to suppress the action of bacteria.

As previously indicated Mr. Allan took up the precisely opposite view, pushing the yeasts into a subordinate position and devoted his attention mainly to the search after flavour producing bacteria.

As the yeasts must always be the central factors in fermentations for the production of spirits, it appeared to me natural to devote first attention to them, and to observe in particular whether some are really able to engender flavours of value in Jamaica Rum.

I.—EXPERIMENTS SHOWING THE EFFECT OF ACIDS ON FERMENTATION WITH DISTILLERY BUDDING AND FISSION YEASTS.

Early in the year I isolated and obtained in pure culture a number of the oval budding yeasts from washes in the Laboratory distillery which were set up from a mixture of fresh cane juice and dunder, and about the same time some fission yeasts were secured from a dead wash sent in from the country. As the result of some preliminary fermentation experiments it was observed that the oval cane juice yeasts worked more rapidly in washes of low acidity, but with an acidity of nearly 1 per cent. the oval yeasts showed very sluggish fermentation, while the fission type worked as well at the high acidity as at the low.

It seemed desirable to study the effect of three common distillery acids, lactic, acetic, and butyric, on the two types of yeast, and accordingly a number of fermentations were set going in cane juice and dunder washes to which varying quantities of the single acids were added before putting in the yeast. The oval budding yeasts all showed bottom fermentation phenomena, but the fission yeasts all showed strong top fermentation with the production of an abundant fatty head. A vigorous yeast of each kind was selected for the experiment with the acids.

Data	Composition of Wash.
Cane Juice - -	300
Dunder - -	150
Water	100

Wash as set up.

Brix - -	15.0
Acidity - -	0.24 % as Sulphuric acid.

The amounts of the different pure acids added are expressed also as Sulphuric acid by weight per cent. of the wash by volume. The amount of the yeast added was as far as possible the same for both types, except in the butyric acid series, which was carried out at a later date with a larger amount of yeast. The results are set out in Table I. which shows the amounts of sugar fermented at the end of each day to the sixth day. The figures were obtained by daily weighings, multiplying the loss of weight by two and calculating the resulting numbers on the total amount of sugar originally present.

TABLE I.

Yeast.	Acid.	Amount, per cent.	Per centage of sugar fermented in days 1.	2.	3.	4.	5.	6.
Budding	Acetic	.2	11	26	40	49	55	64
"	"	.5	3	6	12	36	48	62
"	"	1.0		no fermentation.				
Fission	"	.2	6	21	40	54	64	78
"	"	.5	4	16	37	52	63	76
"	"	1.0	4	18	30	42	55	69
Budding	Lactic	.2	12	30	44	55	64	72
"	"	.5	12	29	43	53	64	72
"	"	.7	9	23	36	48	60	70
Fission	"	.2	7	21	37	51	67	85
"	"	.5	4	18	34	50	65	79
"	"	.7	6	24	40	56	72	89
"	"	1.4	3	20	36	52	66	80
Budding	Butyric	none	21	44	69	86	100	—
"	"	.1	15	31	54	69	81	93
"	"	.15		no fermentation.				
Fission	"	none	10	28	56	83	100	—
"	"	.15	5	14	37	60	83	100
"	"	.4	2	3	6	9	13	20
"	"	.5		no fermentation.				

With regard to acetic acid the results show that the budding yeast is much more susceptible to it than the fission yeast. In the presence of a half per cent. of this acid the budding yeast showed greatly reduced fermentation during the first three days, whereas the fission yeast was but slightly affected. One per cent. completely prevented the activity of the budding type, but again only slightly reduced the fission yeast fermentation. Both yeasts are very resistent against lactic acid, but even here .7 per cent. showed an injurious influence on the budding yeast, whereas 1.4 per cent. hardly reduced fermentation by the fission yeast. Butyric acid proved to be very poisonous for both yeasts, but whereas .15 per cent. wholly prevented the budding yeast from fermenting it caused the period of fermentation to be increased by only one day with the fission type. Even .4 per cent. did not completely suppress the latter's activity, but .5 per cent. prevented all fermentation. The conclusion to be drawn from these results is that the budding yeasts are suitable only for the fermentation of weakly acid washes, whereas the fission type is at home in washes of high acidity. A notable point which the figures bring out is that where the acidity is low the budding yeasts get to work greatly more rapidly than the fission yeast. This is particularly well shown in the case where no acid was added. Although both yeasts completed the fermentation in five days, the budding yeast multiplied and fermented much stronger in the two first days. The ability of the budding type to multiply and ferment more rapidly from the outset in the weeker acid liquors, like cane juice washes and fresh skimmings, explains why this is the only kind found in such liquors the acidity of which is generally under .5 per cent. In the usual estate washes containing dunder, molasses, acid skimmings, and frequently specially added acid, the budding yeast is largely suppressed, but the more slowly developing and very acid resistent fission type takes possession, and is practically the only form found in washes the acidity of which is 1.0 per cent. and over.

II.—EXPERIMENTS WITH VARIETIES OF FISSION YEAST: THEIR INFLUENCE ON THE FLAVOUR OF RUM.

In March I collected samples of fermenting washes, dead washes, skimmings, dunder, acid and rum, from several estates in Westmoreland and St. James, and from the washes was able to gain pure culture of many fission yeasts. These cultures were started from a single cell according to the method of Hansen in order to prevent the possibility of any of the growths consisting of mixtures. With ten of these derived from four estates a fermentation series was set going in a wash of the composition :—

Dunder	2,000	Molasses	1,500
Skimmings	500	Water	5,000

The Brix was 17.4, the Acidity .48 per cent, and the total sugar present 14.5 per cent.

The yeasts 3 and 9 although pure fission forms showed a totally different kind of fermentation to most of the others, the yeast gathering mostly into a coherent mass at the bottom of the vessels, the bubbles breaking on the surface being glassy clear and containing practically no cells. This fermentation was evidently strictly of the bottom kind. Yeast 5 showed mainly bottom fermentation phenomena, but produced also a slight yeasty head. All the other yeasts formed a strong glistening brownish white head at the surface and the bubbles were thickly cloudy, these yeasts were accordingly strongly top fermenting. Under the microscope the two forms could be distinguished easily, the bottom type showing isolated and paired cells, but never more than two together, whereas the top yeasts showed long chains of four or more cells interlaced and apparently branched. Yeast 5 showed no chains but the cells were often united mechanically into flocks.

TABLE II.

Yeast.	Acidity at start.	Acidity at end.	Wash dead in days.	Proof Spirit by volume.	Brix at end.	Attenuation.	Proof Spirit per degree attenuation.
1	.48	.57	10	15.42	1.8	15.6	.98
2	.48	.58	10	-	1.7	15.7	-
3	.49	.55	8	15.12	1.6	15.8	.96
4	.48	.58	10	15.12	1.7	15.7	.96
5	.48	.55	9	16.42	1.6	15.8	1.04
6	.48	.57	10	15.42	1.7	15.7	.98
7	.48	.58	10	15.42	1.6	15.8	.97
8	.48	.60	10	15.70	1.8	15.6	1.01
9	.48	.52	8	16.57	1.9	15.5	1.07
10	.48	.55	10	15.85	1.7	15.7	1.01

The bottom yeasts 3 and 9 completed the fermentation in two days less than the top forms, yeast 5 occupying an intermediate position. This character of the bottom yeast to ferment more vigorously than the top kind has preserved itself in all subsequent experiments. The increase of acidity due to the yeast alone, all bacteria having been excluded, amounts to only about .1 per cent. The attenuation was very much the same in all cases, but the highest amounts of proof spirit were obtained from the bottom yeast 9 and the mainly bottom yeast 5. The yield of proof spirit per degree attenuation was good, in four cases exceeding unity. The distillation was effected from glass apparatus with one retort, the liquor being divided into two parts, the first yielding high wines of 20 O.P. and the second portion giving rum of 40 O.P. with the high wines in the retort. The rum could hardly be called by that name, and it showed the same character for all ten yeasts; in no case was any characteristic flavour produced.

In another experiment with dunder, molasses, and water, a much larger amount of dunder was used, namely one half the bulk of the wash.

The Brix of the mixture was 18.6, Acidity .7 %.

TABLE III.

Yeast.	Acidity Increase.	Wash dead in days.	Proof Spirit by volume.	Brix at end.	Attenuation.	Proof Spirit per degree Attenuation.
2 Top	.09	9	13.57	6.0	12.6	1.08
3 Bottom	.12	6	13.88	6.3	12.3	1.13
7 Top	.12	8	13.88	6.0	12.6	1.10
9 Bottom	.14	6	13.27	6.0	12.6	1.05

The Bottom yeast here showed a gain of 2 to 3 days in the fermentation period. The yield of proof spirit was very high. The rum obtained was very light, and gave no difference in flavour with the different yeasts.

In another fermentation series with the yeasts 2 and 9 pure volatile acids were added to the molasses and dunder wash before pitching with the yeast. The Brix was 18.6, the natural acidity of the wash .46. Acetic acid was added equal to .5 acidity, and butyric acid equal to .1 acidity, so that the total acidity before fermentation amounted to 1.06.

Yeast.	Brix.	Time days	Attenuation.	Proof Spirit.	Ethers per 100,000 alcohol in Rum.
2 Top	18.6	16	12.0	12.3	302
9 Bottom	18.6	10	12.6	12.6	128

The large amount of volatile acid added had a marked effect in slowing fermentation, the time required as compared with the previous experiments, being 10 days as against 6 days with the bottom form, and 16 days as against 9 with top yeast. The rum showed an improvement in flavour, and with the top yeast contained more than twice as much ether. This was due to the much longer period during which alcohol and volatile acids could react chemically to produce ethers in the wash containing the top yeast.

The conclusion to be drawn from these experiments is that, whereas, none of the fission yeast isolated from the estate washes was able to produce flavour on its own account, the top yeast owing to its slower fermentation admitted a greater amount of chemical ether production in a wash originally high in volatile acids. The latter result is in accordance with distillers' experience as they consider that a wash showing a strong fatty head due to the top fermenting fission yeast yields the best flavoured rum.

III.—EXPERIMENTS ON THE MAXIMUM YIELD OF ALCOHOL BY FISSION YEASTS.

It is well known that the alcohol accumulating during fermentation has, beyond a certain concentration, different with different yeasts, a marked slowing effect on fermentation and finally stops it all together. In order to test the maximum amount of alcohol endured by the Jamaica fission yeasts, it was necessary to set up a wash of very high gravity. In a first experiment with the yeasts 2 and 9, a wash consisting of 4,000 dunder, 1,600 molasses, and 700 water was set up at 30° Brix. This was practically completely fermented, so that the alcohol formed was below the maximum which the yeasts could endure. In a second series a wash of 30° Brix was set up with molasses and an extract of yeast, and after some days a further quantity of molasses was added. In this case both yeasts stopped fermenting due to the action of the alcohol, while there was still abundant sugar left in the wash. The data and results of the Experiments are given in Table IV.

TABLE IV.

Yeast.	Brix.	Brix Attenuated.	Acidity at start.	Acidity at end.	Proof Spirit in 7 days.	Proof Spirit at end.	Time in days.	Attenuation.	Sugar at start.	Sugar at end.
1ST SERIES.										
2. Top	30.0	7.35	.78	.85	13.0	22.06	23	22.65	23.3	.45
9. Bottom	30.0	8.05	.78	.90	16.5	23.86	18	22.00	23.3	.52
2ND SERIES.										
2. Top	30.0	13.3	.23	.40	13.5	23.21	24	fresh molasses added after 10 days.		5.2
9. Bottom	30.0	11.8	.23	.43	17.0	24.70	19	do	do	7.5
2 & 9 Mixture	30.0	13.1	.23	.50	15.5	24.03	22	do	do	7.6

The first Experiments show a complete fermentation by both yeasts, the bottom form taking 5 days less than the top yeast. The bottom yeast also shows a higher yield of proof spirit. The influence of the accumulating alcohol on fermentation is very marked, for whereas the bottom yeast had produced 16.5 per cent. proof spirit in 7 days, only 7 per cent. more spirit was produced in the following 11 days.

In the second Experiment the maximum yield of alcohol which prevented all further fermentation was just under 25 per cent. with the bottom yeast and just over 23 per cent. with the top form; while the bottom yeast yielded 17 per cent. proof spirit in 7 days only 7.7 per cent. more was produced in the following 12 days. A similar effect of the alcohol is shown by the top yeast. The top yeast showed a rather sudden falling off in fermentation with about 18.5 per cent. proof spirit present, but the top yeast gave a more gradual falling off; it appeared, however, to be susceptible at about 16.5 per cent. proof spirit. The mixture of the two yeasts showed throughout intermediate results.

It is evident from these results that the fission yeasts which work the estate washes are capable of yielding very large amounts of alcohol in pure culture with abundant time at their disposal. Fermentation is rapid and uniform for 7-9 days, during which 16-18 per cent. of proof spirit is yielded. This means that a wash containing about 16 per cent. of sugar can be fermented in a reasonable time. Above this amount the loss often becomes serious owing to sluggish fermentation. This fact has been recognised in practical distillery work, so that estate washes are rarely set up with more than 16 per cent. of sugar and usually with less.

FERMENTATIONS WITH FISSION YEASTS IN WASHES OF DIFFERENT GRAVITY.

This Experiment was devised with a view to observing the effect of varying the amount of sugar in the wash, on time, attenuation and yield of proof spirit. The washes all contained the same proportion of dunder, namely, three-fifths, the gravity being varied by means of the molasses. The results were as follows:

TABLE V.

Yeast.	Brix	Sugar.	Acidity.	Acidity increase.	Time days.	Attenuation.	Proof spirit.	Proof spirit per deg. attenuation.	Sugar in dead wash
Bottom	25	16	.85	.10	9	16.6	17.58	1.06	1.5
Top	25	16	.85	.10	12	16.6	16.42	0.98	.96
Bottom	20	12	.87	.06	7	11.5	11.61	1.01	.97
Top	20	12	.87	.06	10	11.5	11.15	0.97	.55
Bottom	15	8	.80	.02	6	8.0	8.2	1.02	.71
Top	15	8	.80	.02	9	8.0	7.6	0.95	.44

Here as usual the bottom yeast is the most rapid worker, showing a gain of three days. The time required is least with the lowest gravity, but there is a difference of two days between the 25 and 20 settings and of only one day between the 20 and 15 settings. This difference hardly shows itself during the period of the main fermentation. After five days the relative amounts of sugar fermented by the bottom yeast were 35, 51, and 68.

As there was a half more sugar in the 20 setting as in the 15, and twice as much in the 25 setting, these figures indicate that the activity of fermentation was proportional to the amount of sugar present, *i.e.*, in a given time twice as much sugar was fermented in the 25 setting as in the 15 setting, the 20 setting coming half way between. The difference, however, was shown by the time taken by the wash to die off after the main fermentation was over. The 25 setting took 3 days to die, the 28 setting 1 day, and the 15 setting only a few hours. The yield of proof spirit was as high for the highest gravity as for the lowest, and the bottom yeast gave as usual the best results.

On the other hand there was markedly more sugar left unfermented in the highest setting than in the other two, and the bottom yeast in all three case left more than the top yeast. The dunder employed in this series was a light cane juice product having a Brix of 9 and an acidity of only 1.2. The amount which had to be used (3/5 of the wash) to secure a normal acidity was more than is usual in practical operations, where the dunder has an acidity of over 2 per cent. The result was that the relative amount of sugar in the wash was low, and the attenuation and yield of proof spirit low also.

IV.—AMOUNT OF YEAST PRODUCED BY FISSION YEAST.

The yeast produced in some of the fermentations of the last experiment was collected, dried in the air and weighed. The results are shown in pounds for 1,000 gallons of wash.

Yeast.	30 Brix.	25 Brix.	20 Brix.	15 Brix.
Bottom	18—19	—	—	—
Top	28	26	18	13

One pound of air dried yeast ferments sugar in pounds:—

Yeast.	30 Brix.	25 Brix.	20 Brix.	15 Brix.
Bottom	110	—	—	—
Top	75	65	66	65

The top yeast produces a half more yeast substance than the bottom yeast consequently a pound of the bottom yeast is able to ferment a much greater amount of sugar. The amount of yeast produced by the top variety falls away with the reduction in gravity of the wash, so that only one half as much yeast is produced in a 15 Brix setting as in one at 25 Brix. The amount of yeast produced is proportional to the amount of fermentable sugar present for washes from 25 to 15 Brix, but at 30 Brix relatively less yeast is produced, so that the ratio to sugar fermented is wider.

At first sight it seems inconsistent that the top yeast should often attenuate more than the bottom yeast and leave less sugar unfermented, yet give a lower yield of proof spirit. The above results, show however, that it removes no more sugar to build up its substance than the bottom yeast, and owing to its habit of gathering at the surface of the wash in intimate contact with the air, respiration is more active, causing a greater loss of sugar by conbustion into water and carbonic acid. The bottom yeast is consequently a more economical worker.

Stability of the two Varieties.

Distillers often observe that during the advance of the season their fermentations which were at first of the bottom type, tend more and more to top characters, suggesting either a conversion of the bottom yeast into the top or else a gradual displacement of the former by the latter due to some change in the composition of the wash which favours the top yeasts. That top and bottom fermentation may proceed in the same wash, was evident from the fact that both forms were in several cases isolated from the same material.

Some observations have made it seem probable to me that at any rate one of the varieties is not stable. The fission yeast No. 3 when freshly isolated showed wholly bottom-fermentation phenomena, and agreed entirely with the other bottom yeasts. It was allowed to lie for two months under a fermented cane juice wash, and was then freshened up again. I was surprised to find that it no longer showed bottom fermentation, but gave a strongly marked top fermentation. On comparing its behaviour with that of yeasts which had always been top fermentation, it was found that it gave quite similar results, *i. e.*, an equally slow fermentation and a lower yield of alcohol than the bottom yeasts. Under the microscope it also was identical with the top form. The view which remained for many years unchallenged in Europe was, that the top and bottom yeasts were distinct types, the one never passing into the other. Quite recently Hansen has shown however, that there is always a tendency to vary, and has actually obtained the one form from the other in the case of a number of brewery and wine budding yeasts. There appears to be a much greater tendency for bottom yeasts to go over into the top form than vice versa. Further observations must show whether the fission yeasts are particularly liable to vary in this way, and whether the change so often seen in distilleries in Jamaica from bottom to top fermentation is due to a variation of the yeast.

Conclusions with regard to the two varieties of Fission Yeast.

1—The bottom yeast is a characteristically more rapid worker than the top yeast giving a gain of 2 to 3 days in the fermentation period.

2—The bottom yeast forms less substance and consequently makes a smaller claim on the amount of food stuff in the wash.

3—The bottom yeast gives a rapid and uniform fermentation during the main period, but the wash dies slowly. The top yeast ferments very uniformly throughout, and shows no sharp transition to the final stage.

4—The yeasts attenuate about equally, but the bottom yeast gives a better yield of alcohol.

5—The top yeast leaves less unfermented sugar in the wash.

6—The bottom yeast gives a higher maximum yield of alcohol, namely 25 per cent., as against 23 per cent., with the top variety.

7—The bottom yeast shows the injurious effect of alcohol at a higher concentration than the top yeast, viz., 11 and 16 respectively.

8—Owing to its slower fermentation the top yeast admits of more ethers being produced in the wash than the bottom yeast where volatile acids are present. The rum is consequently better.

V.—THE "FOAMING" OF MOLASSES.

Owing to insufficient distillery space or small still capacity, it often happens that molasses have to be stored for weeks during which period they undergo a rather active fermentation. This involves a loss of sugar, so that it seemed desirable to make some experiments with a view to (1) determining the amount of loss arising from the cause. (2) separating and studying the properties of the yeast causing the trouble. (3) finding a remedy for it.

Three yeasts were secured in pure culture from a fermenting molasses, all of which were able to set up fermentation in a liquor of very high gravity.

YEAST (a)—This was a budding form of the pastorianus type which formed spores on the gypsum block at the air temperature in under 18 hours. Transfered to mixtures of molasses and water of increasing gravity it fermented actively at 45 Brix, feebly at 60 Brix, and showed no fermentation in molasses alone of 90 Brix. It was therefore not the kind active in the stored material.

YEAST (b)—This was a fruitether producing yeast forming a dry wrinkled friable skin on ordinary washes. It was a small budding yeast which formed hat shaped spores on the gypsum block in 24 hours. It fermented strongly in molasses and water of 45 Brix, more weakly at 60 Brix and not at all in molasses alone. It was also therefore not the form desired.

YEAST (c)—This was a small spherical or oval budding form characterised by the production of branched chains of cells in weakly acid washes, and a very abundant multiplication. It formed no spores and no skin on cane juice, but merely a yeast ring. It appeared therefore to be no true yeast, but a 'torula.' This kind fermented actively in molasses and water of 45 and 60 Brix, and also in pure molasses of 90 Brix. It corresponded to the form most abundantly present in the original material, and was evidently the true agent.

As an alkaline medium acts very unfavourably on yeast fermentation lime suggested itself as the first substance to try as a remedy. In one experiment the molasses were allowed to ferment spontaneously without the addition of lime, and with the additions of 6, 12, and 18 lbs. of dry lime to every 100 gallons of molasses, the lime being added as fresh milk of lime and well stirred in. The same experiment was repeated with sterile molasses into which a pure culture of yeast (c) had been introduced, but here only 3 and 6 lbs. of lime were used. The fresh molasses had a Brix of 90 and contained nearly 70 per cent. of sugars. After six weeks the Brix was determined and found to be as follows:—

	Spontaneous Fermentation.	Pure Yeast.
Molasses alone	80	75
Molasses 3 lbs. lime	—	77
Molasses 6 ,,	88	77
Molasses 12 ,,	89	—
Molasses 18 ,,	90	—

The molasses alone fermented strongly with crude and pure yeasts from the outset. With 6 lbs. of lime there was no fermentation for nearly three weeks, when it started, but was much stronger in the pure yeast culture. 3 lbs. of lime in the pure yeast culture did not prevent fermentation from starting within a few days. With 12 lbs. of lime in the crude culture fermentation had only just started between the 5th and 6th week. With 18 lbs. of lime there was no growth of yeast and no fermentation. In the crude there was a maximum loss equal to 15 per cent. of the total sugar, and in the pure culture this loss exceeded 21 per cent. Lime in small amount was therefore capable of checking this fermentation for a time, 6 lbs. to 100 gallons being sufficient to preserve the molasses for nearly three weeks. As the lime gradually losses its alkalimiand goes into the neutral carbonate the fermentation starts afresh As it is very undesirable to bring an alkaline molasses into a distillery wash as small an amount as possible should be used to check the foaming 6 lbs. of lime to 100 gallons molasses should be used at first, the lime being freshly stirred up into a milk with a few gallons of water, but only enough of the latter to admit of a thorough stirring into the molasses. If after a time foaming shows evidence of begining again a further smaller amount of lime milk must be stirred in.

The yeast or 'torula' (c) ferments very sluggishly in a dilute molasses wash, and hardly at all in cane juice. Judging from the Experiments with the molasses, it is able to produce about 14 per cent. of proof spirit. It cannot invert cane sugar, and hence the feeble fermentation in cane juice, but only attacks the ready formed invert sugar in molasses.

VI.—EXPERIMENTS WITH THE "FRUIT ETHER" YEAST FROM MOLASSES.

As this yeast in pure culture gave a very marked flavour to washes in which it was fermenting some preliminary Experiments were made with it in different media, the Rum distilled off and the Ethers determined therein. It was grown in three washes ;—

(1) Molasses and water Brix 15 Acidity .10

(2) Molasses, half dunder and water Brix 15 Acidity .34

(3) Tempered cane juice and one sixth dunder Brix 15 Acidity 20.

The yeast formed the dry wrinkled surface skin in a couple of days in all the washes, and multiplied abundantly, at the same time the fruity odour was very preceptible. Fermentation was very slow, the time required for the washes to die was ;—

(1) 24 days. (2) 27 days. (3) 17 days.

The Acidity of the washes was ;—

Number.	Acidity at start.	After 5 days.	After 15 days.	Final Acidity.
(1)	.10	.25	.32	.27
(2)	.34	.49	.43	.37
(3)	.20	.26	.35	.35

The Ethers found in the rum were for 100,000 alcohol by volume ;—

(1) 18,000 (2) 15,000 (3) 12,700

In spite of the very high ether content the rum had a pleasant fruity flavour with no trace of 'peperiness.' These result were obtained by a simple distillation without any treatment of lees. The ethers consisted mainly of acetic ether, so that the yeast is able to produce both alcohol and acetic acid. There was no increase of ether production during distillation as a portion of (1) was neutralised before distilling and gave the same amount of ether as the un-neutralised part, namely 18.000.

The increase of acidity during fermentation was inconsiderable, a result which taken from the preceeding one makes it highly probable that ether formation does not occur by a merely chemical reaction in the wash, but takes place in intimate relation with the actively working yeast cell.

Further work is being done on this yeast with a view to its introduction into distillery practice.

VII.—EXPERIMENTS WITH ACETIC ACID BACTERIA FROM JAMAICAN DISTILLERIES.

Two perfectly different species of Acetic Acid Bacteria were isolated from acid skimmings and dead washes.

I. A form which appears quickly on dead washes both of low and high acidity. At first a delicate blue dry friable film which becomes white when strongly developed, but is always easily broken up. In a glass vessel the film climbs up the sides high above the surface of the liquid. It consists of short rather plump rods which stain yellow or yellowish brown with iodine, but never blue, and forms only short chains. It resembles Bacterium Kutzeanum of Hansen except in its inability to turn blue with iodine.

II. A Bacterium which forms a very tenacious cartilaginous skin in skimmings and dead washes, consisting of long narrow rods. The skin turns blue with iodine and sulphuric acid, and is in all respects similar to Bacterium Xylinum of A. Brown.

In order to observe the highest concentration of alcohol which admits of a development of acetic bacteria a dead wash holding 23 per cent. of proof spirit was exposed to the air. For six weeks there was no sign of an acetic film, and there was no rise in the acidity. Between the sixth and seventh week a film began to form and at this stage the liquor contained 14 per cent. proof spirit, 9 per cent. having evaporated away from the wash.

In another experiment a dead wash containing 24.7 per cent. of proof spirit was diluted with water in varying amounts and seeded with a pure culture of acetic bacterium I. The progress of acidification is shown in the following table, the figures representing the increase of acidity expressed as Sulphuric acid per cent.

Proof Spirit at Start.	3 days	6 days	8 days	10 days	13 days	15 days	17 days	20 days
a. 24.7 per cent.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
b. 16.5 „	0.1	1.2	1.6		lost			
c. 12.3 „	0.74	2.14	3.0	3.8	4.14	4.3	4.4	4.6
d. 9.9 „	0.86	2.13	2.9	3.5	3.8	4.9	4.1	4.2
e. 8.2 „	0.80	2.9	2.5	2.9	3.2	3.5	3.6	3.8

More alcohol was added to c, d, and e, after three weeks, and the acid rose to 6.2, 5.8, and 5.3, respectively in another week, but showed no further increase. The greatest amount of acid produced was therefore equal to about 7.5 per cent. of pure acetic acid, the largest quantity which the bacterium could endure. The organism could not grow and work in 24.7 per cent of proof spirit, and showed only feeble activity in 16.5 per cent, but in 12.3 per cent. it worked strongly. The evidence shows therefore the amount of alcohol which can undergo vigorous acidification is between 12 and 16 per cent proof spirit, which agrees with the result of the first observation.

The theoretical maximum amount of acetic acid which could be formed from the alcohol in cultures c, d, and e, is 7.3, 5.9, and 4.9 per cent. The actual amounts formed in 20 days were 5.7, 5.2, and 4.6 so that

in	c	78 per cent of the possible was formed.	
„	d	89	„
„	e	94	„

The lower the amount of alcohol in a liquor, the more completely therefore is it oxidised to acetic acid. For practical purposes the highest acidity was reached in a fortnight at about 4 per cent. Bacterium II. proved to be unable to grow and produce acid in a dead wash containing 12 per cent proof spirit, but gave over three per cent acid in a liquor with 8 per cent proof spirit. This bacterium also makes greater claims upon the nitrogenous foodstuff in the liquor than bacterium I. Bacterium I. is therefore the characteristic acetic acid producer in all liquors containing 10 per cent and more of proof spirit, such as ordinary dead washes, while bacterium II. works best in liquors like fermented skimmings and fermented rum cane juice.

The following table shows the amounts of Total and Volatile acid (mostly acetic acid) and the relative amounts of volatile acid to total acid in some distillery liquors. Of special interest are the quantities of volatile acid in such materials as acid skimmings, and flavour, because in these liquors an attempt is made to produce as much volatile acid as possible. The volatile acid shows an average percentage of the total acid of from 22 to 27, or only about one quarter of the acid present is volatile. As the fresh skimmings which comes down from the boiling house are practically neutral the great part of the acid produced in the cisterns is the work of bacteria. Although the skimmings readily undergo fermentation, this is not entirely due to yeast, as the liquor is heavily contaminated by bacteria which produce fixed acids such as lactic from sugar. A number of such bacteria have been separated from the skimmings. They include the well known rice grain bacterium, which can nearly always be found in skimmings. It forms large rounded gelatinous masses when strongly developed consisting of enormous numbers of hand shaped colonies, the rod shaped bacteria being embeded at the ends of finger like processes of the jelly. This bacterium produces lactic acid and forms its jelly at the expense of the sugar present. Another rod shaped organism often developes in fresh cane juice contaminated by dirt from the mill or by soil, at a great rate, and converts the liquor in one day into a thick viscous mass in which yeast can only work very sluggishly. Gas and lactic acid are produced, the viscous substance being formed at the expense of the sugar. The presence of such objectionable organisms account for the poor yield of alcohol in skimmings, and the small amounts of volatile acid. Acetic acid bacteria are wholly dependant upon oxygen for their work of converting alcohol to acetic acid, and require therefore that the liquor in which they are working should expose as great a surface as possible to the air. This is only being imperfectly attained in distilleries even in the trash cisterns. It is proposed therefore to Experiment on a practical scale with a view to the more rapid and more abundant production of acetic acid from alcoholic liquors.

	Total Acid.	Volatile Acid.	Volatile to 100 Total Acid.
Wash freshly set up	1.37	.38	28
"	1.90	.15	8
"	1.13	.19	17 Average of 4—16
"	1.47	.15	10
Dead Wash	1.53	.24	16
"	1.27	.26	20
"	1.18	.22	19
"	3.09	.55	18 Average of 9—17
"	1.37	.27	20
"	1.57	.27	17
"	1.32	.27	20
"	2.60	.36	14
"	2.45	.30	12
Skimmings	1.03	.32	31
"	2.16	.54	25
"	2.45	.45	19 Average of 5—22
"	1.72	.30	17
"	2.74	.46	17
Acid	2.50	.49	20
"	4.50	.75	17 Average of 4—20
"	2.60	.36	14
"	2.45	.68	28
Flavour	2.25	.51	23 Average of 2—27
"	2.70	.80	30

APPENDIX.

LECTURES ON FERMENTATION

IN RELATION TO

JAMAICA RUM.

As delivered at the Course for Distillers

—AT THE—

Government Laboratory in 1906

—BY—

CHARLES ALLAN, B.Sc.,

Late Fermentation Chemist, Sugar Experiment Station.

LECTURE I.—THE PHENOMENON OF FERMENTATION.

You are all familiar with the phenomenon of fermentation as manifested in the manufacture of rum. You know, from your everyday experience the visible signs of the phenomenon, namely: the boiling appearance of the surface of the liquid in which a vigorous fermentation is taking place and the consequent increase of temperature. You also are aware, I have little doubt, that this boiling appearance is due to the copious evolution of gas, and that although the temperature of the liquid increases, no boiling really takes place. The name fermentation, however, probably arose from the fact that this boiling appearance always accompanied the formation of alcohol, the knowledge of which goes back to very remote antiquity.

Mistaken ideas arose as to the nature of the process based upon this appearance such as the evolution of gas from other causes. If I add a little acid to this chalk you will see that a similar boiling appearance is produced as in the case of fermentation and moreover a similar gas is given off but there is no similarity in the causes. A process, which was of very early date, was correctly associated with fermentation. This was the action of leaven in the preparation of bread. The evolutions of gas was observed in connections with the raising of the dough, though no further resemblance to the alcoholic fermentation was recognised. We know of course now that the processes are identical. The evolution of gas accompanies the formation of alcohol in the leavening of bread as it does in cases where the production of spirit is the object aimed at, only in the former instance the production of alcohol is very small.

The term fermentation first applied to the process which leads to the formation of alcohol has now a very much wider application. It includes such processes as putrefaction, the production of various acids such as Acetic. Buryric, Lactic, &c., besides many other substances. The active agents in bringing about the changes which we have described are what are called FERMENTS. There are two classes of ferments the organised and unorganised ferment. We will deal only with what are called organised ferments, that is living organisms such as yeasts and bacteria of various kinds. To go back to the fermenting vats in the distillery. When you see a liquor in a state of active fermentation you know that what is taking place is that the sugar in the liquor is being acted on by yeast with the result that the sugar is being replaced by alcohol and that gas is being sent off into the atmosphere. While this is going on the yeasts are multiplying, growing and feeding just as another plant would do.

The necessary conditions for the development of yeasts are *first* that there must be seed, that is, there must be some yeast cells present in the liquid before any development can take place. In the second place the liquid must be composed of such material and be in such a state as will form a suitable medium for these yeasts to thrive in, just as the soil must contain such substances and lie in such suitable condition as will allow of the growth of a plant when its seed is sown, otherwise the seed will not develop into a plant. As we will have a good deal to say about the best conditions for the develpment of yeasts in subsequent lectures we will leave the subject for the present. The point I wish to emphasise at present is, that there can be no development of yeast or any other living organisms without the seed or germ of such organisms being originally present. Up to the present time, at least, no single case of spontaneous generation has been experimentally proved.

This is of practical importance as you may be assured that try as you will, you will never start a fermentation unless you have living yeast cells in the liquor which you wish to ferment. On the other hand you will not have your liquors getting bad such as becoming sour or ropy unless you get them contaminated with the organisms which give rise to these conditions.

Sterilisation, as the process is termed by which a liquid may be freed from all germs, is very largely practised in fermentation industries. In the manufacture of beer, great importance is placed upon all vessels and liquids being freed from all germs other than those which are desired to be present. In the manufacture of alcohol for the spirit only, many precautions are taken to prevent the access of undesirable germs from the fermenting vessels and the wash.

In the case of Jamaica rum practically no precations are taken. Indeed on the other hand the distiller depends for his fermentation to start on germs which find access into the wash, accidentally. Thanks to bountiful nature and a favourable atmospheric temperature, yeasts are always about in large numbers, but it must be remembered that so are other organisms which are often of a kind which the distiller does not want.

You will readily become aware of this if you leave exposed to the air a vessel with such a substance as freshly ground cane juice, and, if you closely watch the changes which take place in the juice you will see that these changes take place in a certain order which will generally be followed in the cases where cane juice is left exposed to the air. The first change will be the familiar one of alcoholic fermentation. That is the sugar in the juice will be broken up into alcohol and carbondioxide gas with a very small quantity of other substances such as glycerine and succinic acid. The organisms exciting alcoholic fermentation are the first to develop, because the constitution of the cane juice favours them the most. There is also generally an abundance of yeast in freshly ground cane juice from the rind of the cane. When the sugar is split up into alcohol and carbondioxide, the character of the liquid has become changed and now a new species exciting acetic fermentation comes into play. This organism was already present in the juice, but could not make headway against the predominant yeast, because in the first place, the alcohol on which it feeds was lacking. Secondly, even had this substance been present, it could not have been utilised, because of the atmosphere of carbondioxide immediately above the liquid preventing the free access of a copious supply of oxygen without which the oxidation of the alcohol cannot proceed. Now, however, that both substances are present, the liquid commences to undergo a second alteration, and turns sour; the acetic acid bacteria being now on the surface, and this condition endures so long as there is any alcohol left. When this is exhausted, a third group of organisms comes to the front and establishing themselves in the strongly acid liquid consume the acetic acid, carbondioxide and water being formed. This accomplished, the once again altered nutrient medium is attacked by putrefactive bacteria which have been carried into the vessel along with the dust in the atmosphere, but can only develop now that the alcohol and acid which are poisonous to them are wanting. The putrefactive bacteria attack whatever albuminous substances may be left and convert them into acids and other substances. More complications would in all probability take place. The lactic ferment which is always present in cane juice would succeed in developing to some extent and this would ultimately give rise to butyric fermentation, but in the end the same point would be reached. All the substances would in turn be attacked and reduced to carbonic acid and water. The distiller however, does not wish the process carried quite so far as this so he steps in on the completion of the first stage and interrupts the course of nature and separates by distillation the alcohol from the rest of the wash. The best methods of making up washes to ensure the most efficient accomplishment of the first stage, namely, alcoholic fermentation with the least, or just as much as may be desired, interference from the subsequent stages are what we wish to attain. Evidently the best and surest methods of attaining a vigorous alcoholic fermentation would be to rigidly exclude all other organisms from the wash and this would be the course we would adopt if the production of alcohol was the only consideration. Nor would this be at all difficult as the wash and vessels could be sterilised by means of steam. Unfortunately for this method, rum, and Jamaica rum, in particular, is composed of other substances than alcohol and water. The amount of the other substances are indeed very small when compared with the alcohol and water but on these other substances, small in amount as they are, depends the value of Jamaica rum and their production must not be interfered with if the high standard of this Island's rum is to be maintained. Secondary products in Jamaica rum vary, but compared with alcohol and water would be roughly:—

Alcohol by Vol.	Water	Secondary products
78 to 80%	19 to 20%	⅓ to 2%

As the matter of secondary products is of importance let us consider it more fully.

Suppose we take 100 gallons of rum and break it up as nearly as we can into alcohol water and secondary products.

What we are to term secondary products is composed of all the substances found in rum other than alcohol and water i.e. white rum before caramel is added.

Let us take first an average common clean rum worth about 2/1 per gallon.

In the 100 gallons rum there would be 80.4 gallons pure alcohol.

Of secondary products there would be .43 gallons or 3½ pints.

Of water there would be very nearly 19 gallons.

Let us now take a good flavoured rum worth a'.out 4/3 per gallon.

Of the 100 gallons rum there would be 78.2 gallons of alcohol.

Secondary products	„	1.1 gallon.
Water „	„	21.1 gallons.

These two examples are taken from actual analysis of rums and the prices given per gallon were what the rums actually fetched in London.

You will observe that the difference in the analysis is mainly on the secondary products. The slight difference in the amount of alcohol is of no account.

In subsequent lectures I will show you that the chief constituent of the secondary products are ethers and will discuss with you how far a chemical analysis of a rum may be trusted as an indication of the value of the rum.

The point I wish to emphasise at present is that the value of rum depends mainly on the secondary products it contains.

I will show you by means of experiments in the laboratory that cane juice or molasses fermented by yeasts alone produce but very little of the secondary products. These, therefore, must be formed by other organisms, chiefly bacteria which swarm in the washes of Jamaican distilleries.

You will naturally conclude that it is good to have the wash infested with bacteria. To some extent it is but unfortunately bacteria and yeasts do not thrive well in each others company, yeasts work best in liquids which are free from bacteria. It is not the bacteria themselves that the yeasts object to but the products which they form.

It must not be forgotten that alcohol is the main constituent of rum, that every gallon of rum must contain 4-5th of a gallon of pure alcohol, so that in making rum the first consideration is to produce alcohol. This can be done by encouraging the development of yeasts but in so doing you are discouraging the growth of bacteria and again if you encourage the development of bacteria you are setting up conditions which are against the interests of the yeasts. You must choose a middle course and it is just here where our greatest difficulty arises.

Such middle courses are always difficult to run. At times one or other of the sets of organisms will get the upper hand no matter what you do, and hence arises the difficulty of obtaining a uniform product, under such conditions the quality of your product must vary.

The difficulty in obtaining a uniform product has led to the reform in Beer-brewing. Under the old system the brewer found that it was impossible for him to be sure of making the same quality of beer.

In the most up-to-date breweries now not only are all bacteria excluded but yeast which has been carefully cultivated from selected seed are only used. The effect of this on the article produced was to alter to an appreciable extent its flavour but it ensured its stability in character and in a short time the newly acquired flavour got to be appreciated.

In the case of Jamaica rum however we have an article of a very different nature to deal with. The flavour is of a very pronounced character and is one of its chief assets. The flavour of beer is very delicate and is produced by the yeast itself whereas I am of the opinion that the yeasts contribute but a small amount of the flavour of rum.

There is nothing left for us then but to try the middle course and to keep in hand the various species of organisms as well as we can.

The extent to which bacteria are to be allowed to develope must depend to a considerable extent on the nature of the rum which it is desired to make. There can be nothing more disastrous to the working of a distillery than for the distiller not to know exactly what style of rum he wants to make. If common clean rum is being made stick to common clean and never allow things to drift in the direction of making flavoured rum in the pious hope that you may wake up some day to find that you have become famous by making flavoured rum where it was never been made before. You are much more likely to find an enfuriated Busha awaiting to tell you that your services are no longer required on that estate.

There are certain essential differences between the manufacture of flavoured rum and common clean which if the distiller does not understand, any attempt by him to make flavoured rum on a common clean estate is almost certain to entail very serious loss in production.

Loss in production is a much more serious thing than most distillers and even managers seem to think. A penny or twopence a gallon advance in price is much more highly esteemed than an increase in production which would in the end be a greater gain to the estate.

Let us suppose you are getting a fairly good yield of rum but the price is only moderate say 2/- per gallon. If you want to increase the price of your rum you try to increase the flavour. Any attempt in this direction generally means decrease of yield but suppose you increase the price by this means to 2/2.

Then how much loss will be required to counterbalance the gain.

Take 100 gallons at 2/- = £10. How many gallons at 2/2 will you require to give you £10, result is 92 gallons. That is to say, if you increase the price by 2d a gallon but lose 8 gallons per 100 gallons in yield you are no better off than before. I do not wish to discourage you from trying to make better rum but I want to point out to you the danger you run in following the methods generally adopted for that purpose. What you want is to get to know how you can arrive at a satisfactory yield from your materials. If you can do that accurately then you could proceed to try to improve your rum without running the risk of the serious consequences of loss in production.

In this course I would advise you to give particular attention to making yourselves proficient in estimating what is a satisfactory return of rum from your washes, because without this knowledge you are not likely to make the most of your materials.

LECTURE II.—THE CONSTITUENTS OF JAMAICA RUM.

Before proceeding to speak of the manufacture of Jamaica rum let us first see what are its chief constituents. In my last lecture I pointed out to you that in the chemical analysis of rum the results were returned under three main heads, viz., Alcohol, Water, and Secondary Products or impurities. Alcohol, of course, is the chief constituent. Secondary products although insignificant in volume, are of prime importance to the value of the article. Under this head many substances are included some of which exist in fair amounts, while others only in almost intangible traces. Before going on to explain the nature of these substances we will endeavour to get a clear idea of the meaning of the term per 100,000 parts absolute alcohol which you will always find mentioned in a Chemist's report on the analysis of a potable spirit.

Absolute alcohol means alcohol without any water. In other words pure alcohol. It is extremely difficult to obtain absolute alcohol. The article which is sold as absolute alcohol is not really absolute alcohol at all, but contains water to the extent of 1 % or more.

I will endeavour to illustrate to you the composition of rum by means of accurately measured volumes. Cylinder No. I. contains 1,000 cubic centimeters of rum taking the 17 bead. Cylinder No. II. contains the amount of water representing the quantity of absolute alcohol contained in Cylinder No. I.

It is on the absolute alcohol the Chemist calculates his results and he takes as his unit 100,000 parts by volume.

Now No. 1. Cylinder contains the rum which we wish to analyse.

No. 2. represents absolute alcohol contained in No. 1.

No. 3. „ water „ „

No. 4. „ secondary products „ „

We may pass over the alcohol and water without comment, as pure alcohol, from whatever source obtained is the same. No chemical difference exists between alcohol from the potato and that obtained from the sugar in the cane. Pure water is also the same, from whatever source obtained.

We are left with the secondary products, and I will endeavour to illustrate by means of these small cylinders the relative amounts of the various constituents as determined in the particular sample which I have chosen.

No. 1. Cylinder represents the total amount of secondary products, 10 c.c.

No. 2. " " " Compound Ethers, 7.9 c.c.

No. 3. " " " Higher Alcohols, 1.3 c.c.

No. 4. " " " Acid, 1.4 c.c.

No. 5. " " " Aldehydes, 0.24 c.c.

No. 6. " " " Furfurol, 0.02 c.c.

The contents of these cylinders are not single substances in the sense that absolute alcohol is a single substance. Each of these cylinders contain substances which are very nearly related to one another as far as their chemical constitution is concerned, but they might be again divided up into several substances, each with its own characteristic properties. This will give you some idea of the complicated nature of the secondary products of rum. I am not going to speak of the chemical properties of the substances which form the constituents of the secondary products, but you have already seen that their volume is insignificant, so it is only as flavouring agents that they are of value.

First in importance, at least in quantity, are the compound ethers. The sum total of ethers is made up of acetic, butyric, propionic ether and other ethers of acids of higher molecular weight. The proportions in which they exist in rum is in the order which I have given them. Of the total amount of ether in rum, acetic ether composes at least 95 per cent. or 95 parts out of every hundred are acetic ether. Of the remaining five parts by far the larger portion is made up of butyric and propionic ethers. A small, but important part of the whole is composed of ethers of higher acids which have not been separated out and identified. The minuteness of the amount makes it almost impossible to identify those substances.

Judging from the flavour imparted by various ethers in the pure state, acetic ether gives very little flavour. It must not, however, be assumed that this ether is on that account quite useless. On the contrary, it would appear to be an essential ingredient in a good rum. It seems to act in some way as a carrier for the other ethers. At any rate a rum without a fair amount of acetic ether is flat and lacks the sharpness which is required in good rums.

Butyric ether on the other hand has a good deal of flavour. It has a heavy, fruity smell which has been described as that of pine-apples. There can be little doubt but that this substance contributes a fair quota of the flavour of rum. Propionic ether is also present in rums, and as a flavour or smell similar to what a mixture of acetic and butyric ethers would produce. Of the other ethers little can be said. That they exist in rums there is no doubt, but they are only in traces, and it is impossible to say what is the effect of each one taken separately or for that matter all taken collectively.

ACIDITY, under this term is included the acids found in rum. The acidity of a rum generally bears some relation to the amount of ethers. That is to say, that as the amount of ethers increase so does the acidity. As an ether is a compound body formed by the combination of an acid with an alcohol, you will readily understand that there is also a close relationship between the nature of the acids present and that of the ethers. The acids therefore are acetic, butyric, propionic and traces of others higher in the scale of molecular weights.

The remaining bodies, Higher Alcohols, Furfurol, and Aldehydes are usually considered under the head of 'fusel oil,' and looked upon as noxious. They are only found in very small quantities in rum, and although they vary in amount in different rums, yet there is no evidence to show that the variation of these substances has any appreciable effect on the value of the rum.

As far as our analysis of rums have gone the only substances which affect their value are the compound ethers. I think now planters and others interested in rum are convinced that the presence or absence of compound ethers does affect the value of a rum very considerably. On the other hand most of them are also convinced that the value does not depend entirely on ethers. The sum total of other substances contained in rum has undoubtedly some influence on the flavour. I am of the opinion that there are some substances in rum of which at present little is known. I am not speaking merely as a matter of speculation. I have observed the presence of substances other than any of those mentioned. In very small quantities indeed, but of such powerful aromatic flavour as would certainly affect to some extent the aroma of rum.

I have made no distinction as yet between flavoured rums and common clean rum. I have done this advisedly as the only marked distinction which has been found is in the quantity of the compound ethers, so that so far as the chemical analysis are concerned, the difference is one of degree, not of kind.

That a chemical analysis falls very far short of affording sure indication of the value of a rum will be readily admitted. In fact the rum merchant ridicules the idea of the chemist being able to give information worthy of serious consideration concerning the article. This is not to be wondered at when the chemical data themselves mean next to nothing. Take the amount of ethers contained in a large number of rums and let us see if we can arrive at any conclusion as to their value. The first thing that strikes one is the enormous varations in the ether figure. It varies from 80 parts to 1,800 parts per 100,000, and if we include some rums which have been made during last crop, we have a still greater range, the upper limit being 3,500. But this figure is unimportant regarded as a limit, as a much higher figure could be obtained without any difficulty if there was any object in doing so. I could easily select a list of samples which would show you a regular gradient in the amount of ethers and at the same time a corresponding rise in value, but on the other hand I could select a list which would go to prove that the amount of ethers had no effect on the price.

For instance we find that rum with an ether figure below 100 parts bringing as good a price as a rum with from 300 to 400 parts ether. We have authenticated reports of rums with 500 parts ethers selling at 2/3 per gallon. The same rum last year brought 2/2 with an ether content of 360 parts ethers. We have, however, to take into consideration the rise and fall of the market, and I do not think that we can draw any conclusion from this case.

In another instance the increase of the ethers seemed to have a prejudicial effect on the value of the rum. For common clean rum with ethers from 80 to 500 parts per 100,000 I do not think that the ether figure can be relied upon as an indication of the value. Other things seem to have just as great effect as the ethers. So far then as common clean rums are concerned chemical analysis can tell but little as to the value.

When we come to the distinguishing feature between common clean rum and flavoured rums analysis gives us material assistance. Without exception all flavoured rums are high in ethers. These rums vary in their ether contents just as common clean rums do, flavoured rums stand as it were on a higher plain as far as their ether contents are concerned. As in the case of common clean rums, the price of flavoured rums cannot be guaged by the ethers. Here again other things come in. These "other things" are difficult to define. They include body and what may be called the general character of the flavour,—what the Germans call I think, "Rasse." These things can only be judged by one with considerable experience, but I am of the opinion that if the chemist acquired this experience he would be in a very favourable position not merely to give an idea of the value, but to render very material assistance to the manufacturer, especially in the way of assisting him to maintain a uniform standard in the article which he manufactures.

LECTURE III.—METHODS OF MANUFACTURE.

In my last lecture I spoke of the chemical analysis of rums, and what we could learn from such an analysis. We will now consider the methods of manufacture and see what we can deduce from them concerning the composition of rum.

As you know the basis of rum is alcohol, and the object of the distiller is to produce as much alcohol from his materials as he can consistent with maintaining the quality of the rum. There are therefore the factors, (let us call them) quantity and quality to be considered. For the present let us leave out of account the factor quality, and consider the manufacture of rum from the view of quantity only.

It is a well known fact that the breed of yeasts have much to do with the quantity of alcohol which they can produce. Some breeds will produce only a small quantity and then cease to act on the sugar.

They do not necessarily die, but they get into a state of suspended animation. Others again produce much more alcohol before their vital activities become suspended.

The yeasts which you have to deal with are very far from being of one breed. They are many breeds, some good, some bad. I will describe some of these later, but in the meanwhile let us consider how this mixed breed acts.

The following experiment, which was carried out to see how much alcohol a mixture of yeasts such as one finds in any distiliery in Jamaica would produce. In the first place it was necessary to remove all the influences which would hinder the yeasts in doing their work. A wash was made up of one part of molasses to five parts of water. This wash was thoroughly sterilised by heating it to 120° C., that is 20°, higher than the boiling point of water. A small quantity of yeasts from which all other organisms had been eliminated was then put into the wash. The wash was allowed to stand at the room temperature. The gravity of the wash was taken when the yeasts were put in. It stood at 18° Brix or 27° Arnaboldi.

YEAST A.

18/7/06	Brix	18.0		COMPOSITION OF WASH.
21/7/06	Brix	14.75	3 days.	
24/7/06	Brix	11.3	5 days.	1 part molasses to 5 of water.
27/7/06	Brix	5.1	10 days.	
2/8/06	Brix	1.05	15 days.	
3/8/06	Brix	.4	16 days.	
9/8/06	Brix	.5	22 days.	

When this point was reached an analysis was made of the fermented wash, giving the following results:—

Alcohol — 19.58 per cent. P.S. or 14 per cent of rum at 40 O.P.

Acidity — 0.28 per cent.

Sugar left unfermented — 0.8 per cent.

Proof Spirit per degree of attenuation — 1.08.

In another experiment made on similar lines, the gravity of the wash when the yeasts were added was 15.4° Brix. In ten days the gravity had gone down 9.5° Brix.

YEAST B.

6/8/06	Brix	15.4		COMPOSITION OF WASH.
8/8/06	Brix	12.8	2 days.	
9/8/06	Brix	10.95	3 days.	1 part molasses to 5 parts water.
10/8/06	Brix	8.4	4 days.	
11/8/06	Brix	6.2	5 days.	
13/8/06	Brix	3.0	7 days.	
14/8/06	Brix	1.6	8 days.	
16/8/06	Brix	0.5	10 days.	

From these experiments you will see that these yeasts are capable of producing a very large quantity of alcohol, provided they are given sufficient time. You will note particularly that it took a longer time in the first experiment for the gravity to reach water mark than in the second. You will also observe that in the second experiment the gravity decreased much more rapidly. There is another important point which I wish you to note; that is, that in cases where yeasts freed from bacteria are used, very little acidity is formed in the wash. These experiments were carried out under what may be called 'ideal' conditions, but nevertheless they show how the tendency lies.

We will now take some experiments which were carried out in the Experimental distillery, which approach more nearly the actual working on Estates.

EXPERIMENT 12.

11/2/05	Brix	19.1	
13/2/05	Brix	18.1	2 days.
15/2/05	Brix	17.6	4 days.
17/2/05	Brix	14.9	6 days.
19/2/05	Brix	10.2	8 days.
22/2/05	Brix	8.6	11 days.
24/2/05	Brix	8.0	13 days.

COMPOSITION OF WASH.

40 gallons Dunder.
24 gallons Skimmings.
16 gallons Molasses.

WASH AS SET UP.

Brix	31.6°
Total Sugars	25.0
Acidity	0.78.

The wash was set up at 31.6° Brix on the 6th February, 1905. It was found that at this concentration no change whatever took place and the wash remained unchanged for four days. On the fifth day the wash was diluted with water to 19.1 Brix and a content of 15.6 % Sugars, with an acidity of 0.49 13 days after the wash was diluted fermentation ceased. An analysis of the 'dead wash' gave the following results:—

Brix—8.0

Sugars—0.48

Alcohol—9.18% P.S.

Acidity—1.08

Proof Spirit per degree of attenuation—0.827

The experiments which were carried out in the Experimental Distillery and which are given in the Report for 1905 show clearly that fermentation carried on under the conditions usually found in Jamaica must yield very irregular results. From my own experience of what I have seen in the distilleries, I am convinced that the yields of rum must be very far indeed from what they might be.

I have shown you that from a wash fermented in such a way as would prevent the admission of organisms other than yeasts, a much better yield of alcohol can be got. By so doing, however, a very poor quality rum is obtained, so it is advisable to admit bacteria to a certain extent. The point is where are you to draw the line! Is there any means of knowing when the bacteria are getting too great a hold on the wash? There are certain signs which should tell a practical distiller when this is happening. The wash gets acid, the fermentation sluggish, and ultimately if things are not remedied fermentation ceases altogether. I have been on several cases asked for a remedy for sluggish fermentation, and consequent loss of yield. I have found in one or two cases the yield reduced down to less than one half what it should be. On examining the materials I always found them swarming with bacteria of all sorts. Sometimes the acidity of the wash was by no means too high, but other bacterial products were having a very prejudicial effect on the yeast. My remedy has invariably been successful, and it is simple enough,—Lime and water; lime to conteract the acidity, and water to remove the dirt. I have generally also found it advisable to recommend a reduction of the gravity at which the wash was set up.

I know there is a strong prejudice against the use of lime in Jamaican distilleries, and also a considerable reluctance to the use of water The contention is that lime kills the flavour. I do not deny but that it does. If used in excess it will certainly kill flavour and also kill the yeast, but just as in the case of all medicines, it must be administered in proper doses if it is to be beneficial. If vats are well washed out frequently, and then washed with a thin lime wash, nothing but good will result, especially in common clean estates. Wood-ashes (I have found) are very frequently used. There action is something similar to lime, though not so effective in checking bacterial development. It is, however safer, as you may heave in a half vat full with not much effect. Lime must not be used in such large quantities as will make the wash alkaline as then it will prevent the development of the yeast, and it will also prevent the development of certain bacteria which are essential in the production of flavour. Use lime as a wash, and I do not think you will find it doing any harm. If you are to maintain a good yield you must aim at getting a regular fermentation and attenuation, and to do this you must check and keep within limits the development of bacteria.

I am of the opinion that in common clean distilleries the yield should be the first consideration. To get a good yield there are two important points to attend to. First the setting up gravity. Speaking generally, this is far too high in Jamaica. The initial gravity in common clean estates should not exceed 15° to 16° Brix or 22° to 24° Arnaboldi. The amount of alcohol from a given quantity of wash will of course be less, but you will get more rum out of a given weight of sugar. The reasons for this are not far to seek. If you set up high you place the yeasts in an unfavourable medium, for they work slower in heavy liquids than in light ones. Bacteria are not so particular, they find heavy liquids as congenial as light. Secondly the time taken for completing the fermentation is prolonged, the yeasts get more and more sluggish and the bacteria get stronger and stronger. In distilling you get a comparatively better return from a weak alcoholic solution than from a strong.

The distiller's reply to these arguments are that low gravities produce a low grade rum. They say that rums made from washes set up at low gravities are light in body. I have no doubt but that this is perfectly true. The reason is, that with a low gravity the yeasts work better and faster, and so do not allow the bacteria to get a chance

With high gravities on the other hand, the yeasts work more slowly, a longer time is required for the wash to attenuate, and hence there will be a greater development of bacteria. Again you always run the risk of leaving unfermented sugar in the wash. Indeed we have found from analysis that very few dunders are free from sugar. As this goes on sugar is allowed to accumulate in the dunder until it gets too heavy. A good deal of this sugar which is left in the dunder becomes converted into caramel, and so is lost, as caramel is unfermentable by yeasts.

In this case, as in others, you have to consider how far you can go in pursuit of flavour at the expense of yield. You must always bear in mind that it is not in the interest of the estate to produce flavour if by so doing the output is so lessened as to mean a nett loss as against a poorer quality but a better yield. The usual method of guaging a distillers' capabilities by the yield from a still, without taking anything else into account is a very objectionable one. It leads to the practice of many tricks. It has certainly been productive of many wonderful yields, and also many remarkable stills. These I believe, get less and less as the number of changes of distillers increase.

Another plea is often put forward for high gravities, that is, that sometimes materials increase so that they must be got rid of anyhow. This is what I would call wanton waste, and extra receivers should be provided for emergencies of this kind. Again, more time may be lost by sluggish fermentation than would be taken up in a few extra vats working off.

I cannot impress too much on you the necessity of some intelligent and fairly accurate method of calculating what amount of rum should be obtained from each vat. Without being able to do this, you are working in the dark, and you can never make such a good use of experience and observation to improve.

In the first place it is essential to have all your vats, receivers, and stills accurately guaged. It is worse than useless to guess about the capacity. A difference of 50 to 100 gallons in capacity just decides whether your yield is good or bad. I can recommed no other methods than either by measuring the contents or by weighing them. Select a vat, fill it with water, then run it into a 4 or 5 gallon measure and count the number of times the contents of the vat fills the measure. This is a laborous method, but the vats and receivers are generally so irregular in shape that they require very intricate calculations to get at their capacities, even approximately.

To calculate the approximate yield of spirit from a wash from attenuation. This is very simple indeed if you use a Brix Hydrometer which I recommend as being vastly superior to the Arnaboldi. The Brix instruments can be had from the Laboratory, and there is no reason why they should not be adopted on every Estate.

In the experiments carried out in the Experimental Distillery the amount of Proof Spirit per degree of attenuation was found to vary somewhat. It will always be found to do so, but within limits, if the fermentation is good and healthy. The limit should be .8% of proof spirit for every degree of attenuation per 100 gallons of wash. To take an example:—

A wash set up at	18° Brix
Attenuates down to	6° „
Attenuation —	12° Brix.

The yield of spirit of that wash should not be less than .8° × 12° = 9.6 gallons proof spirit per 100 gallons of wash, or 96 gallons proof spirit from a 1,000 gallons wash. To convert 96 gallons proof spirit to strength of rum:—

96 × 5.7 = 68.5 = 68½ gallons of rum at 40 over proof.

This is the lowest limit, and you should not be satisfied with it. You should aim at least at getting .9% P. S. for every degree of attenuation. Yield of spirit per 100 gallons wash—

.9 × 12° = 10.8 P. S. or 10.8 × 5.7 = 77 gallons per 1,000.

It may go as high as 1 gallon for every degree, then;—

1 × 12° = 12 P.S. = 12 × 5.7 = 85 gallons per 1,000.

One gallon for every degree of attenuation is I think the highest you are ever likely to reach. In fact you will be much more likely to fall very short of it. You should, however, not be content with anything short of .9% for every degree of attenuation.

One other point I wish to emphasise, and that is you must know accurately the capacity of your still, otherwise any calculation you may make is useless, and you will only deceive yourselves by those calculations.

LECTURE IV.—THE PRODUCTION OF FLAVOUR.

In my last lecture I dealt with the yield of rum purely from the point of view of quantity and therefore confined myself to the production of alcohol. Now I propose dealing with the production of flavours in rum, and the various experiments which have been carried out in the laboratory and on estates with a view to the investigation of the development of these flavours.

Analyses of rums made in the laboratory established the fact that the compound ethers contained in the rum was closely connected with the flavour. Now these ethers are compound bodies formed by the combination of alcohol with an acid. If an organic acid such as acetic acid is allowed to remain in contact with alcohol, a certain amount of the alcohol and acid will combine and form acetic ether. If the mixture is distilled a larger proportion will combine.

We already know how the alcohol is formed so we have to find out how the acids are formed.

The organic acids found in rum are produced by fermentation in a similar way to that in which alcohol is produced. The organisms causing this fermentation are different and are of many kinds. When dilute alcohol is exposed to the air, it is attacked by a ferment known as the acetic ferment and is turned into acetic acid. In order that the formation of acetic acid may go on a supply of air must be accessible as, oxygen which is obtained from the air is indispensable to the life of the acetic ferment. Thus the formation of acetic acid takes place for the most part at the surface of the liquid and when the ferment has developed sufficiently it forms a thin pelicle over the surface of the liquid. Acetic acid forms a very large proportion of the acid found in rum.

Acetic acid is the acid of vinegar. The method in which vinegar is made is interesting as, in some measure, the same process is followed in making acid on estates making flavoured rum. The wine which is to be converted into vinegar is placed in casks, half filled, at about 30 degrees C. to which air has moderately free access. The formation of acetic acid takes place in consequence of the liquid being gradually covered with a film consisting of the mother of vinegar. In other countries the German quick "vinegar process" is employed in which the growth of bacteria suspended in dilute spirit mixed with vinegar, is accelerated by coming into intimate contact with the air. This is brought about by allowing free access of air, by dividing the liquid into small drops and distributing these over a large surface (such as beech shavings.)

Acetic acid must be produced in large quantities in the distilleries of this island but especially in those making flavoured rum. Indeed in them special processes have been evolved to produce this acid as well as others. The part of the process which is mostly concerned in the production of acetic acid is the fermentation of what is called rum cane juice. This juice is generally poor in sugar and what sugar there is, is mostly glucose which would not crystallise out even the juice. It is however, in a suitable state for being fermented. A weak alcoholic solution is formed. This liquor is thrown over cane trash and allowed to stand. The result is that the alcohol is turned into acetic acid. You will note how closely this process corresponds to that of making vinegar. Only in the case of vinegar-making a freer access to air is given.

Next to acetic acid in point of quantity as found in rum is butyric acid. This acid is formed by fermentation excited by many forms of bacteria. The one which perhaps forms it most readily is known as Bacillus butyricus. I have given a considerable amount of study to this organism as I found to be very prevalent in washes and materials about distilleries and especially those making flavoured rum. I have isolated this organism and grown it on a fairly large scale. In order to isolate organisms of this class they must be cultivated out of contact with air as the oxygen is fatal to them. After having cultivated them to some extent by this means I inoculated them into a 5 gallon tube and having succeeded in getting them to grow there I transferred them to puncheons. From these they could be grown in any quantity for estate experiments with butyricus. A five gallon keg of liquid was taken to an estate. The contents was emptied into a cistern of 1,000 gallons capacity. Dunder which had been made almost neutral with lime was added and about two gallons of molasses. A vigorous fermentation started. After a few days the contents of this cistern was used as dunder in getting up a wash. When the wash was distilled a heavy fruity smell was the result. On a second trial it was found that the presence of this organism had a very detrimental effect on the attenuation.

On another estate the effect of this organism was tried and it was found that it had a very marked effect on the rum. The retardation of the alcoholic fermentation was prevented by making the liquid in which the organism was cultivated much stronger in butyric acid. This can always be done by neutralising the acid formed.

By this means a flavour was undoubtedly imparted to the rum but in my opinion it is somewhat harsh and suggests too much one ingredient. It requires to be blended with something else to make it a desirable flavour. Reports on the rum are expected soon. In another experiment carried out on an estate where the butyric fermentation was stimulated by special materials a rum was produced by the High Ether process which brought 5/6 per gallon. Of course there were other organisms at work here but there was a large amount of butyric acid produced by organisms of this nature.

In putrefaction butyric acid is produced as well as other higher acids.

Putrefactive bacteria require nitrogenous substances to feed on. The albuminous matter of the cane supplies this but a more important source is the dead yeast cells which remain in the dunder. The dunder muck as it is called is almost wholly composed of yeast cells. In the dunder itself there is also a large amount of aluminous matter which has been made soluble by boiling in the still. The soluble portion goes back into the wash and assists to feed the yeasts and bacteria there. The solid dunder is used in the flavour making process on estates making flavoured rum.

As far as our analytical investigations have taken us the only result of adding flavour and acid to the wash as is the practice on flavoured estates is the addition of acids. The acidity of the wash making flavoured rum is always much higher than in washes making common clean rum.

Common Clean Rums.			German Flavoured Rums.		
Description.	Acidity as Sulphuric Acid.		Description.	Acidity as Sulphuric Acid.	
	Total	Volatile		Total	Volatile
SERIES I.			SERIES II. B.		
				3.09	0.55
Wash set up	1.37	0.38	Dead Wash	2.50	0.49
Skimmings	1.03	0.32	Acid	2.06	0.54
Dunder A	2.21	0.49	Skimmings	2.25	0.51
Dunder B	2.07	0.30	Flavour	3.33	0.68
Dead Wash	1.53	0.235	Dead Wash Cotton		
SERIES I. B.			SERIES II. C.	2.40	0.98
Unfermented Wash	1.90	0.15	Dunder	4.50	0.75
Fermented Wash	1.27	0.26	Acid	2.70	0.80
Dunder	1.62	0.27	Flavour	2.45	0.45
SERIES I. C.			Skimmings		
Unfermented Wash	1.13	0.19			
Dead Wash	1.18	0.22			
Dunder	1.67	0.22			

From these data you will see that the amount of acid and especially the amount of volatile acid, which is the chief point, is very much greater in the materials which go to make flavoured rum than in common clean.

The point I wish to emphasise is that the chief difference and the only one which is measurable by chemical analysis between common clean rum and flavoured rum is the ethers and we know that other things being equal the amount of ethers increases with the amount of volatile acid in the wash. The essential difference then between the manufacture of Common Clean Rum and Flavoured rum is in the production of acids. These volatile organic acids are produced by fermentation under certain conditions and the object of the distiller is to get at those conditions which favour the production of acids which he wants.

Different organisms require different conditions these I will discuss when I speak of these organisms.

LEES.—The virtue of lees in producing flavour has been partially recognised for long but not I think to its full value. The lees from the Retorts contain a good deal of acid. On flavoured estates as much as. 7 % of acid has been found. Now this acid is all volatile otherwise it would not have gone over into the retort. What happens is this, the acid distills over along with the alcohol but being much less volatile gets condensed in the retort. These lees have been made use off but I am sure much of them is wasted for want of proper storage. The process known as the high ether process has for its aim the utilisation of the acid in the lees.

I have here a sample of rum made on an estate by using the lees directly in the wash instead of acid. The rum when made had a somewhat greenish smell but otherwise it was good and sold readily enough at 3/9, this being the price which the rums made on the estate were fetching at the time.

Lees have also been used I believe in the retort in small quantities. I may also add that flavour has also been used in this way. Its use seemed to have a slight beneficial effect. Lees ought to be stored for some time before use. What exactly takes place I cannot say but ripened lees as they are called have a much better effect than fresh lees.

Lees however should not be mixed with the solid dunder for some time as the lees will prevent it from decomposing. On the other hand when the fermentation of the dunder solids has gone so far the lees should be added to stop further decomposition, otherwise if the putrefactive organisms are allowed to complete there work you will have nothing at all left, as you must bear in mind the work of putrefactive germs is to reduce all the substances on which they act to water and certain gases such as Carbonic acid, Hydrogen sulphide and Ammonia. By adding the lees at the right time you stop this action and utilise the acids formed.

The only method of guaging this is by carefully observing the acidity of the material. For a time it will gradually increase, then it will cease and if left alone will begin to get less and less again. The amount of acid formed is very small but if carefully neutralised with lime the action will again start, as in the experiment I have already described. You will see how important it is that you should make yourselves thoroughly acquainted with the methods of determining acidities and alkalinity.

LECTURE V.—MICRO-ORGANISMS OF RUM.

In my previous lectures I have showed you that the active agents in producing alcohol from sugar are yeasts, and I have also stated that the flavour of rum was due in most part to the action of bacteria. I will now describe (in more detail) to you, some of those ferments, as a knowledge of how those organisms develop and the conditions under which they thrive best, will assist you to some extent in controlling your fermentations. Let us consider (first) the yeasts:—Yeasts are living plants. Just as much plant as the sugar cane is a plant. The differences are great, but are only in structure and size. When you look at yeasts under the microscope you may see many forms, but the essential characteristic is, that they are single cells. What you see is a thin membrane enveloping a clear transparent substance. This substance is the living matter of the plant and is called the plasma. All plants and animals are built up of cells but in the case for instance of the sugar-cane, many cells are required to form one plant. Some of these cells are specialised in such a way as to suit them for absorbing nourishment from the soil, others go to build up the complicated structure known as the stem, others form leaves and others (again) go to reproduce the plant. Yeasts and all one-celled plants include all their vital functions in the one cell. They feed, grow, and multiply just as other plants do but very simply. If you watch a yeast cell under such conditions, as will allow it to grow and multiply, you will see it throw out a small bud from its membrane. This bud grows larger and larger, and in time it will break off and free itself from the parent cell. This process goes on and on as long as the conditions in which the cells are placed will allow it.

When the yeast cell is young and vigorous, the contents of the cell are clear and transparent, but when it gets old or gets starved for want of food its contents become granular, and empty spaces appears called vacuoles. In coloured liquids, such as washes, living cells can easily be distinguished from dead ones. The dead cells get coloured with the liquid while the living ones remain quite clear.

There are many kinds or species of yeasts. Some of them can be recognised under the microspe by their forms, others cannot.

We often speak of wild yeasts and cultivated yeasts. The distinction has something of the same significance as when we speak of wild cattle and domesticated cattle. There is another broad division of the yeasts depending on the way they ferment a liquor. Some yeasts work at the bottom of the liquor while others work at the top.

They are thus called top fermentation yeasts or bottom fermentation yeasts. For the most part Jamaica yeasts are bottom fermentation yeasts. In beer brewing both kinds of yeasts are used. In England the top kind is invariably used, while on the continent the bottom is used. In the case of top fermentation a very heavy foaming head is formed, while when bottom fermentation is taking place very little head is formed.

A few of the more important groups have the following characters:

Cerevisiae group.—These are the yeasts producing the normal fermentations resulting in beer, etc. They are round slightly ovoid cells.

Pastorianus group—These are wild yeasts. The cells are elongated or sausage shaped.

Ellipsoideus group.—These are also wild yeasts. The cells are usually ovoid or pear shaped. Sometimes they are round.

All these forms are found in Jamaican distilleries.

There is also another type of yeast found very largely in Jamaican distilleries. I have found it in all the distilleries but it is specially plentiful in north-side estates where flavoured rum is made. This yeast can be easily recognised under the microscope by its shape. It is a long rod-shaped cell. Its method of multiplying is quite distinct from other types of yeasts.

It does not form buds but first grows into a long rod then a division is formed across the rod and what was one cell becomes two cells and ultimately the two cells separate and form two organisms. The difference is that round forms multiply by budding while the rod-shaped forms multiply by division.

It is remarkable that this form should thrive best on those estates using very acid washes. I have not had sufficient time to devote to these forms but they seem to me to be in some way connected with the production of flavoured rum. I have made various attempts to isolate these but have not yet been successful in getting them to develop in the laboratory. What happens is that the round forms which are always mixed with the rod forms readily develop in the laboratory and swamp the others. In establishing a fermentation for flavoured rum, it is just possible that such conditions as will permit of this kind of yeasts developing will have to be obtained. This is a point which will require further study but will in time be elucidated.

Yeasts are found in the air but for the most part yeasts find their way into the wash from the rind of the cane. Large numbers are found on the rind of the cane. From the rind they get into the juice and hence into the skimmings. They are also found in the molasses but this must be by contamination from vessels as they cannot survive boiling.

To start a fermentation, cane juice slightly warmed should be used. If however, the juice has sulphur dioxide added to it for the purposes of clarification, juice should be taken to which no sulphur dioxide has been added. Sulphurous acid is poisonous to organisms, but after the juice has been boiled the sulphurous acid becomes converted to sulphuric acid which in small amount has not an inhibiting effect on yeasts.

Yeasts thrive very well in all sugar solutions and cane juice seems to be a very favourable medium for them. The action of the yeast on cane sugar is first to convert it into glucose or uncrystallisable sugar, then to break this up into alcohol, and small quantities of other bodies such as succinic acid and glycerine. The fermentation of sugars by yeasts is a function of the living cell and everything that affects the life of the latter has a certain influence on its fermentative power. Substances which serve as food for the yeast promote fermentation. Generally speaking acids are deleterious to the cell, their influence being the more marked as their concentration is increased.

Different acids have different effects. In some cases yeasts seem to thrive in fair amounts of acid while in others a very small amount seems to influence them unfavourably.

It is stated that .1 per cent. of sulphuric acid reduced the energy of fermentation while .7 per cent. inhibited it altogether. The development of the yeast-plant was promoted by .02 per cent. of sulphuric or by .1 to .5 per cent. of lactic acid, but unfavourably influenced by .07 per cent. of the former or 1.5 per cent of the latter. The volatile organic acids such as acetic butyric, etc., affect fermentation unfavourably when present in large amounts.

It is difficult to say what acidity is really the limit where fermentation is seriously retarded, it depends so much on the nature of the acids present. For common clean rum, 1 per cent. is high enough at the start of fermentation and it may go up to 1½ per cent. without doing much harm. In the manufacture of flavoured rum much higher acidities are used, but in these cases fermentation is undoubtedly retarded. The best temperature for yeast development is from 80°F to 90°F. Above this temperature yeasts are less vigorous. Higher temperatures favour the development of bacteria and hence of acids.

Bacteria.—Bacteria are the busiest forms of organic life. They are single cells belonging to the lowest forms of plant life. They vary in form and there is considerable difference in size, but species cannot be readily distinguished by their form and shape. To give you some idea of the size of these minute germs, the lactic acid ferment is 3-25,000 of an inch long and 1-25,000 of an inch wide. That is, it would require 25,000 placed side by side to measure one inch. Something over 900 billions weigh 1 grain or 1-28 of an oz. Bacteria are found every where, in air, soil, water, dust, clothes, skin alimentary canal of man and animals, and in our food. Very small quantities of organic matter are sufficient for their support, and the nature of this organic matter is very varied—carbohydrates, such as sugar and starch, all kinds of organic matter and mineral matter. Moisture is necessary; without it bacteria will not develop. The majority of bacteria like warmth, but some of them grow at low temperature. Bacteria live in temperatures between 39 degree F. and 122 degree F. Some will survive at still higher temperatures. These minute organisms are extremely retentive of life. They never die a natural death. They may be killed by various means, such as by heat, by poison, by starvation, by exposure to sunlight. It is a fact worth noting, that direct sunlight is a powerful germicide. Disease germs

These are the chief factors which determine the development of bacteria, food, temperature and absence of sunlight.

No useful purpose would be served by my going into the biological characters of the various bacteria found in distilleries. Their numbers are legion and the species numerous. The chief ferments I have already described viz:—the acetic and butyric ferments. The latter is what is called an anaerobic organism that is, it cannot set up fermentation in the presence of oxygen, but I have found that it works well in liquids in which aerobic, that is air-loving organisms, have been first estabilshed. This is how it is able to work in liquors exposed to the air. There is a type of bacterial action known as viscous fermentation, which often gives trouble in distilleries. Lumps of a jelly-like substance are often seen floating in liquors. This viscous fermentation is caused by a particular organism which acts upon glucose, and transforms it into a kind of dextrin or gum. A similar organism causes ropiness in skimmings. The same phenomenon is often met with in the manufacture of sugar, masses of gelatinous consistency being formed. These masses are composed of microbes with extraordinarily swollen and gelatinised cell-walls which appeared as masses of jelly in which the organisms were embedded.

Another phenomenon sometimes makes its appearance in distilleries and goes under the name of rice grain. These masses which resemble grains of boiled rice are composed of yeasts closely packed together. In the liquor is found an animalcule called the vinegar eel. This eel which resembles a very small worm gets into the skimmings by means of rain-water which washes it from roofs and gutters.

As far as acetic and butyric acid fermentations are concerned, these can be controlled in a similar manner to alcoholic fermentation by yeasts. The conditions for these types of fermentation are well ascertained. It is very different when we come to consider the putrefactive process. The changes which albuminous matter undergoes when attacked by various micro-organisms are not completely ascertained at present. We know when putrefaction is taking place by the development of a peculiar and characteristic odour, partly due to certain gases such as Sulphuretted Hydrogen, Ammonia, and other gases being disengaged. This feature is especially noticeable when the microbes carry out their work in the absence of air, the process being comparatively inodourous when a free access of air is permitted. Many microbes take part in these changes but it is not known whether a particular series of changes is due entirely to one kind of organism or whether the process is started by and carried further by another; whether the decompositions take place simultaneously or successively. We know that during these changes among other substances volatile acids are produced and that these acids are among the ingredients which goto produce the flavour in rum but we do not know what other substances produced in this process enter into the composition of flavour. Moreover we can do little to control the putrefactive process. You must put down the materials and trust to nature to do the rest. We may assist putrefaction to start and we may arrest it when we think it has gone far enough but we cannot inoculate a wash for instance with cultures with any hope of producing a desired result. For this part of the manufacture of flavoured rum you must experiment with your materials until you obtain what you want. I do not claim more as the result of my investigations than that I have established the fact that the flavour of Jamaica rum is mainly produced by bacterial action and in a general way indicated the nature of the organisms at work. I have also indicated certain lines by following which you are likely to obtain flavour. From my remarks on the idiosyncrasies of these tiny forms of life which you have to coax into working for you, you will easily understand how perplexing it would be for one, who has no knowledge of them to comprehend their ways.