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The Manufacture of Rum

Part II

Mashing and Fermentation Methods . . After-Treatment of the Fermented Mash

*By Rafael Arroyo, Ch. S., S. E.**

FOR the average rum distiller mashing operations mean the dilution of the molasses with a stipulated amount of water, with the addition (in some cases) of certain fixed amounts of sulphate of ammonium and sulphuric acid. The author of this paper has had occasion to observe the disastrous results of this mental attitude, for in practically all cases when this *modus operandi* is followed the final results are fermentation efficiencies of from 55% to 70% of the theoretically attainable, with a proportionate recovery of commercial rum of very low quality. For rational molasses rum making the mashing operation should take into consideration the following factors: (1) the characteristics of the rum yeast strain in use; (2) the composition of the molasses to be mashed; (3) the quality of the water used in diluting the molasses.

Considering the first factor, we find that different strains of rum yeasts require differences in the setting of the mash so that they can perform their work during the fermenting stage under optimal conditions. Of special importance in this connection are the initial pH value and total sugar concentration of the mash. As regards optimum pH value no fixed rule can be given and every distiller should find out by experimentation the most suitable initial pH for his particular yeast strain. While in molasses mashes intended for industrial alcohol fermentation it is customary to set at such a pH value so that no further increase in acidity occurs during the subsequent fermentation, this does not hold for mashes intended for the production of rum, for in this case the formation of organic acids of as varied a nature as possible is very desirable for ester formation. In a general way, mashes for the production of high class rums should be set at pHs considerably higher than for industrial alcohol production; while a pH of around 5.0 is very commonly used in industrial alcohol distilleries, one around 5.8 has produced best results in our practice of rum making. Herein lies a fundamental difference between rum and alcohol manufacture. In the same way we can point out other great variations between these processes. Take, for instance, the matter of initial sugar concentration: for rum production the range of sugar concentration at mashing lies between 9 and 11 percent for most rum yeast strains, while yeasts employed in industrial alcohol manufacture are able, and are required to ferment mashes of 15% total sugars, and even higher.

A possible explanation of this difference of behavior between industrial alcohol and rum yeasts may be found in the fact that the products of their respective metabolisms are quite different, the ideal yeast for alcohol production being one capable of producing the largest amount of pure alcohol in the least possible time. A yeast breaking the sugar molecule with the production of ethyl alcohol and carbon dioxide as the only products of fermentation would be the ideal from the standpoint of the industrial alcohol distiller. This condition not being attainable, that yeast producing the least amounts of the congeners usually associated with alcoholic fermentation is the one required. On the other hand, in exactly opposite position, rum production requires the use of yeasts capable of producing, besides ethanol, appreciable quantities of these related substances of alcoholic fermentation, such as organic acids, aldehydes, esters and higher alcohols. Now, the toxicity of the metabolic products of the yeast cell during fermentation will increase in direct ratio as the production of the above mentioned congeners increases; hence, the tolerance of rum yeasts will be below that of distillery yeasts, with the result that inhibition of zymoganic power by the accumulation of metabolic products will take place sooner in the case of rum yeasts. Hence, fermentation will be arrested sooner than in the case of alcohol distillery yeasts, i.e., when less alcohol by volume has been actually produced. Such being the case, setting the mashes at higher concentrations of sugars than the yeast can utilize represents a great waste of sugars that are run out in the discarded slops. The writer has had occasion of analyzing slops running up to 3.4% residual sugars, due to a lack of proper understanding of the mashing operation.

The second factor, or the knowledge of the composition of the raw material, is fully as important as the one just discussed. The yeast, like any other plant, is dependent for its growth and development on certain elements furnished by the medium in which it lives. Among the elements most essential to the life of the yeast are carbon, nitrogen, phosphorus, and potassium, followed by iron, manganese, magnesium, sulphur and calcium. Fortunately, sugar cane final molasses contains most of these elements, in variable quantities; but cases of deficiency as to amounts are common, especially

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in nitrogen and phosphorus. These deficiencies, when existing, must be corrected at mashing time.

Dilution of the mash for rum production should be a function of the chemical composition of the raw material, as well as of the inherent characteristics of the yeast strain in use. The first point to bear in mind is that of total sugar concentration in the mash; any concentration of sugars above the optimum for the particular yeast in use will mean an unnecessary waste, for the yeast will stop using these sugars as soon as inhibited by the products of its own metabolism. We must, therefore, dilute our molasses to that sugar concentration at which our yeast can handle efficiently, and this cannot be done properly without accurate knowledge of the initial sugar concentration of the raw material. This means that, for a given yeast, high sugar test molasses must be diluted more than low sugar test molasses. This is simple enough as far as it goes; but we must remember that when diluting the molasses for right sugar concentration we are also diluting the concentration of the yeast nutrients in the molasses; hence, a high testing molasses will require much more heavy treatment than a low testing one with nutrients for the yeast. Another additional reason is that high test molasses is usually more deficient in nitrogenous and mineral constituents.

The third factor, or the quality of the dilution water, hardly needs comment, for it is well known that, for all biochemical industries, the chemical and microbiological characteristics of the water used are factors of paramount importance. We must mention the fact, however, that in the case of a product like rum, whose price depends mainly on taste and "bouquet," we must use especial precautions with the quality of water used for mashing operations. The quality of this water will influence both the fermentation and the distillation processes and if it is greatly contaminated from a microbiological standpoint, it will render useless and destroy the good effects of all the precautions, labor and expense involved in the pretreatment stage already described. Some of the members of the microbiological flora of dilution water may become responsible for side fermentations during or after the fermentation stage, that may generate ill-smelling impurities. These will pass together with the raw rum during the distillation stage, ruining both its taste and aroma. On the other hand, high mineral content in the water of dilution, specifically salts of sodium, calcium and magnesium, will raise the ratio of non-sugars to sugars in the mash, with detriment to the growth and zymogenic activities of the yeast. Especially during the last stages of fermentation will this increased amount of non-sugars exert its inhibitory influence. Later on, during the distillation of the fermented mash, the malefic effect of these mineral salts will be experienced further, for most probably they will make their appearance in the form of scale on the plates and feeding pipe of the still (if a continuous still is used), lowering its efficiency, giving rise to frequent stoppages for cleaning purposes, and sometimes preventing operations altogether.

From what has been stated we may realize the importance of the mashing operation and how it will influence the succeeding fermentation and distillation stages. As a rule, the properly mashed material will offer the following analysis:

Density, degrees Brix	15 to 17
pH	5.5 to 5.8
Titrable acidity (in ml. of 10/N alkali per 10 ml. mash)	1.5 to 2.0
Total sugars, grams per 100 ml. mash	10 to 12
Nitrogen, mg. per 100 ml. mash	200 to 250
Phosphoric acid, as P_2O_5, mg. per 100 ml. mash	60 to 75

Having thus prepared our mash, the next step will be its inoculation and fermentation. The seed used must possess certain characteristics for best results. The requirements are a maximum of young, active yeast cells in full vegetative vigor, and free of contaminants. To attain this condition of the seed, the best procedure is to cultivate it in a pure yeast culture apparatus, of which the Magné machine constitutes one of the foremost representatives. Care should be exercised always to have ready for use a vigorous, pure footing of yeast to start fermentation, and so measure the time that the mash, once ready for inoculation, will not have to wait for the preparation of the necessary footing. Here again we must think in terms of a fermentation for the production of a certain type of rum, and not in the sense of the ordinary methods employed in ethyl alcohol production for industrial purposes. The characteristics of the finished product will depend in a very large measure on the fermentation process followed at the rum distillery. A look at the comparative specifications required for successful practice in the fermentation of rum and industrial alcohol will show at a glance that the aims are altogether different, and even antagonistic, except for the production of ethanol as the main substance in both instances. Moreover, the methods used in rum fermentation will vary considerably with the type of rum desired, while for industrial alcohol standard specifications control the process. The following comparative scheme will bring out these points:

Industrial Alcohol Requirements

A highly efficient yeast capable of utilizing practically all of the sugars in the mash:

(1) In the least time.

(2) With maximum production of ethyl alcohol.

(3) With least production of:
- (a) Organic acids
- (b) Aldehydes
- (c) Esters
- (d) Higher alcohols
- (e) Essential oils

(4) Under standard fermentation: technic.

Rum Production Requirements

A fairly efficient yeast capable of utilizing most of the sugars in the mash:

(1) In a reasonable lapse of time.

(2) With comparatively large yields of ethyl alcohol.

(3) With adequate yields of the proper kind of:
- (a) Organic acids
- (b) Aldehydes
- (c) Esters

(d) Higher alcohols
(e) Essential oils, especially rum oil.

(4) Under variable fermentation technic according to end products desired.

Resuming, we find that the ideal fermentation for industrial alcohol will require that the largest possible amount of ethanol, and the least possible amount of congeners be formed in the fermenting mash in the shortest possible fermentation period; while in the ideal fermentation with rum production in view, yield of alcohol and rapidity of fermentation may be and usually are sacrificed (within certain limits of course) in behalf of quality of the finished product. This factor of quality will depend almost entirely on the quantity and nature of the other products formed during alcoholic fermentation, the nature of these products being far more important than the quantity. It is natural and logical that this should be the case, for the market has set specific requirements for industrial alcohol, and all the industrial alcohol is paid at the same price when these trade specifications are met; while in the case of rums, prices differ directly with quality.

Now, the different types of rums will vary in the quantity and kind of these by-products of alcoholic fermentation; hence, fermentation methods will vary in individual cases in: (1) yeast type selection, (2) fermentation temperature, (3) initial pH, (4) length of fermentation period, (5) after fermentation treatment. We can do no more than offer general lines of procedure in accordance with the type of rum to be manufactured. There are two large groups of yeasts that may be employed in rum manufacture: (1) the saccharomyces or budding yeast, and (2) the schizosaccharomyces, or fission yeast. Both types may be further divided according to their characteristic ways of inducing fermentation into: (1) top fermenting and (2) bottom fermenting. When a very heavy bodied, high ester, persistently aromatic rum is desired, a top-fermenting, fission type yeast should be selected; for the opposite type of rum, light bodied, comparatively low ester, not too highly aromatic, a bottom-fermenting budding yeast will be most adequate. Intermediate types of rum are easily secured through proper yeast selection or by the use of more than one fermenting organism during the process of fermentation.

Temperature of fermentation is one of the most important factors controlling its rate so it plays a very important role in rum making. Here again, the optimum temperature will not necessarily be that at which the yeast builds up the highest amount of ethanol in the most efficient way, as would be the case for industrial alcohol production; but rather that temperature at which pleasant aroma is best developed in the fermenting mash without sacrificing the alcoholic yield to unprofitable levels. In this respect subtropical temperatures are more recommendable than the extremely high temperatures of tropical countries, for it must be borne in mind that while high temperatures of fermentation greatly accelerate the rate of sugar destruction and alcohol formation, they also accelerate the rate of formation of undesirable (as against desirable) by-products and yeast autolysis. The author has found that for the better development of these aromatic and flavoring by-products in the mash, the average temperature of fermentation should not much exceed 27°C. This is proved by the fact that in tropical countries, rums produced in the mountainous regions are always more aromatic and superior in flavor to those produced at sea level.

When comparatively high fermentation temperatures (35° to 40° C.) are unavoidable, due to the prevailing temperature of the water used, poor results both in yields and qualities are generally to be expected, unless a specially adaptable yeast strain has been fortunately secured to work under these conditions. Very few rum yeasts will withstand the combined effects of high metabolic products concentration and high temperatures, occurring simultaneously. The author, working with the African yeast strain known as Pombe Lindner, has found that inhibitory signs during fermentation may be noticed after a temperature around 37° or 38° C. has been attained. Therefore, unless artificial temperature control is permissible or available, the choice of site for the distillery is a matter to which considerable care and attention should be given.

The initial pH value of the fermenting mash will have a great influence in the course of fermentation as well as in the amount and nature of the metabolic products other than ethyl alcohol. We have already stated that every rum distiller should determine by experiment the optimum setting pH for his particular yeast strain; but we have found that while low initial pH (about 5.0) will result in a more rapid fermentation and perhaps higher alcoholic yield, pH values between 5.5 and 5.8 will result in a rum with better flavor and bouquet. The esters produced during a given fermentation will be more varied in composition and larger in amount as the setting pH value increases above the value 5.0 and up to 5.8 pH, other factors of fermentation remaining constant. The development of the fine aroma inherent to the formation of rum oil is also greatly enhanced at the higher pH values mentioned above.

As to the lapse of the fermentation period, it will be determined mainly by the yeast cells concentration per unit volume of mash and by the temperature of fermentation, and also by the characteristics of the particular yeast strain used. Also the ratio of non-sugar to sugar soluble solids, and the amount of sugar concentration, as well as the character and amounts of yeast nutrients, will have their influence on the length of the fermentation period. But the distiller has some means at his disposal to alter at will this period of fermentation. In the first place he can shorten the time required for a

given fermentation by increasing the amount of seed yeast used at setting time; by adding the main mash to the seed and not vice-versa; by providing for agitation of the fermenting mash towards the final stages of fermentation; by using comparatively large fermenters; by incorporation of small amounts of activated carbon and even of inert material such as filter-cell and "bagacillo", etc. But while these practices may be recommended in special cases (as when an extraordinarily slow fermenting yeast is being used) usually it is much better to let fermentations intended for rum production, run their natural course.

While in industrial alcohol manufacture it is customary and convenient to distill the wort as soon as possible after fermentation is completed, this is not always the case in rum manufacture. It is customary in this case to allow a period of rest to the fermented mash before distillation. This practice, though not universally followed, results in most cases in a better raw distillate, in taste, mellowness and aroma. The slow, residual fermentation following the main one seems to be responsible for the formation of these valuable bodies that so greatly help in the betterment of the quality of the raw distillate. In some instances a further step may be taken during this after fermentation treatment of the wort. Reinoculation with pure cultures, and well measured amounts of certain micro-organisms becomes very beneficial when a high ester, heavy bodied, strongly scented rum of the Jamaica type is desired. Special factors to be considered when venturing into this practice are: (1) Assuredness that the activities of the newly inoculated micro-organism will not be arrested by the yeast metabolic products already present in the fermented mash. (2) Similar assuredness that the newly introduced organism will not attack and decompose or materially change the already existing products of metabolism; especially the ethyl alcohol already manufactured by the yeast, to such an extent as to greatly reduce the yield of rum. (3) The newly inoculated micro-organism should possess the power of acting upon the residual sugars of the fermented mash, using them in the building of the products of its own metabolism. (4) The metabolic products of the newly incorporated micro-organism should be of such character as will produce directly those bodies that are sought for in a good rum or else will generate such substances as may combine chemically with the already present products of the alcoholic fermentation. When knowledge of the foregoing conditions is obtained, and all affecting factors are well under control, this after fermentation practice may greatly benefit the quality of the resulting rum. In a future publication the author will enter more fully into this very interesting phase of rum production.

Before closing the subject of rum fermentation it is well to treat of certain phenomena that may occur during this stage of manufacture, especially in small distilleries where no chemical or biological control is practiced. To all outward appearance, fermentation is considered finished when the characteristic agitation coincident with gas generation within the fermenting liquid is no longer apparent; and in most cases this indication is sufficient. But there are cases in which this appearance of the fermenting vat only indicates that fermentative activity has been merely arrested; but it does not necessarily follow that fermentation has been completed in the sense that the optimum breakage of sugar molecules has taken place, with the subsequent formation of the corresponding amount of alcohol and other congeners of fermentation. Fermentation may, in fact, come to an apparent end while considerable available sugars are yet unconverted into alcohol and other products of the metabolism of the yeast cells. The causes of this quite common happening are many: premature exhaustion of the elements necessary to yeast nutrition; abnormal rise in temperature, resulting in the inhibition of the fermenting organism by the "alcohol-temperature" complex; inadequate ratio of non-sugars to sugars; weakening of the zymogenic power of the yeast through the effect of contaminations that may have gained access to the fermenting liquid and alterations of the pH of the substrate through the agency of these contaminants, etc. The most familiar and common causes of this phenomenon, however, are exhaustion of yeast nutrients in the fermenting mash, and the effect of the "alcohol-temperature" complex. In the first of these cases, addition of nutrients, especially ammonium salts and soluble phosphates, will cause fermentation to start anew; in the second case, some means of lowering the temperature of fermentation will greatly help the situation. The addition of some solid inert matter in a finely divided form will increase the good effect obtained from a lowering of the temperature alone.

A more rare phenomenon is sometimes met with: The liquid mass in the fermenter is apparently undergoing vigorous fermentation as shown by its agitation, gas generation, and foaming, but it is found that the readings of the Brix scale on samples taken at periodical intervals of time do not show appreciable attenuations. These cases are almost always originated by the presence of certain bacteria capable of maintaining the fermentation of the medium after they have inhibited alcoholic fermentation. As generally these contaminants produce chemical substances differing little in specific gravity from that of water, observations made for drops in density of the fermenting liquid no longer show the inherent and characteristic differences observed when large quantities of alcohol are being formed. In such cases, the first thing is to determine the nature and source of the contaminant, and proceed to its destruc, and reinoculation of the mash with a fresh yeast footing.