THE

MANUFACTURE OF SUGAR

IN THE

COLONIES AND AT HOME,

CHEMICALLY CONSIDERED

BY

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ANGEL COURT, SKINNER STREET.

Whilst this TREATISE was still in sheets, Mr. Shute Barrington Moody,—a gentleman whose long residence in the West Indies renders his remarks on the Colonial Sugar Manufacture of great value,—did me the kindness to look over the pages, and append certain remarks. They will be seen in the form of footnotes, to which the name of "*Moody*" is attached.

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PREFACE.

If we take a survey of the numerous branches of manufacture which are now so generally followed in civilized countries, it will be found that the most recondite and elaborate suggestions of the philosopher have been applied to the actual necessities of commercial utility with a remarkable amount of practical success. It will be found that results, which first originated in abstract thought, great inventive tact, or acute power of observation, have at length become developed into operations of commercial no less than scientific magnitude—operations in the accomplishment of which the reasoning powers of the philosopher have been superseded by the tactile instinct of the artisan; and this with less sacrifice of accuracy than any one unacquainted with the routine of manufactures on the large scale could have ventured to suspect.

The whole theory of calico printing is but the theory of chemical tests—its whole practice but their application on a gigantic scale; and here, as in numerous other instances, the laboratory chemist who suggested, is at length surpassed in his art by the practical tact, the elaborate mechanism, and, more than all, by the well-organized division of labour which subsists in a manufactory. It would be easy, were it necessary, to prove the intimate connection which subsists between chemistry, and at least nine-tenths of our arts and manufactures. Whenever a regulation of temperature is required, whenever crystallization, evaporation, change of colour, of aggregation, or other readjustment of atomic constitution is effected, then there exists a process or series of processes, guided by the operation of certain immutable laws, the investigation of which constitutes a science; and this science is chemistry. No matter what the art or manufacture be called, nor where followed; still, if the principles of such art or manufacture be chemical, they can only be elucidated by chemistry.

It is proverbially urged that the performance of an operation in the laboratory, and on a small scale, is *one* thing; in a manufactory, and on a large scale, another; hence, that laboratory operations are not even suggestive of manufacturing ones. That a difference between the two does exist is certain; but it is no less certain that, for a very large class of chemical operations, this difference is merely one of facility on the side of the manufacturer over the chemist. A great number of chemical operations depend on the exercise of either a large amount of mechanical resources, or on an equivalent amount of manual and mental dexterity. Thus the practice of calico printing, when reduced to a system, and prosecuted with the aid of ingenious mechanical appliances, becomes a matter of the merest routine; yet the results are so perfect, that to imitate them, and but inefficiently too, would require all the resources, mental and tactile, which the laboratory chemist could bring to bear on the subject. To take another instance of similar purport, but from another class of manufactures, I may cite that of soda from sea-salt; a manufacture which is known to have been suggested in the laboratory, and which, owing to the application of mechanical aids and divisions of labour, is certainly now conducted with far greater ease on the large than it can be on the small scale.

True it is that many so-called successful operations on the small scale are productive of disappointment when reduced to practice; but the failures of this kind are, after all, frequently more nominal than real; and result from the want of proper understanding between manufacturer and chemist. The former, in proposing to a chemist whether any particular thing can be done, embodies two propositions of essentially different elements. The first is,—can the thing *be* done? The second,—will it pay for *being* done?

This latter proposition the chemist usually does not heed: indeed, it involves considerations about which a chemist is not very likely to have any adequate knowledge.

Some chemical appliances on the large scale are so elaborate, that a mere laboratory chemist would hesitate to have suggested their possibility. As an example of these may be cited one of the many triumphs accomplished by the calico printer. It is in relation to the substance indigo; which, by the aid of chemical science, is rendered capable of being employed as a beautiful dye. This desideratum was not attained without much chemical investigation, leading to an intimate knowledge of the habitudes and qualities of the substance.

A dye must possess the following qualities:—*It must be soluble*:—else the fabric to be dyed cannot be dipped into it. When imparted to the fabric, *it must become naturally, or must be rendered artificially insoluble*:—so that no washing to which the fabric will have to be subjected shall be able to dissolve it away. Such are the indications to be followed out, and to attain which the most elaborate chemical resources are frequently brought into operation.

As it regards the solubility of indigo the case is this:—Indigo, in its blue or commercial state, is perfectly insoluble in water or alkaline solutions: hence it cannot, without preparation, be used as a dye. Chemistry was called into requisition to investigate the composition and general qualities of indigo, and with this successful result. It was proved that blue or insoluble indigo was composed of $N\,C_{16}\,H_5O_2$—that is to say, one atom or equivalent of nitrogen, sixteen of carbon, five of hydrogen, and two of oxygen. It was furthermore proved that, by certain easy means, one atom of hydrogen could be added; that, when added, blue indigo became changed into a white *matter*, *soluble in alkaline solutions*, which has been termed white indigo. That moreover this white indigo had such a tendency to resume its former condition, that an exposure of it, on a fabric dipped into it, to the atmosphere (containing oxygen), sufficed for the removal of hydrogen, and the reconversion of white and soluble indigo into that which was blue and insoluble*.

To apply this chemical principle to the dyeing of entire pieces of tissue was henceforth a most easy operation; and inasmuch as patches of blue thus produced could be removed by chlorine with the greatest ease, leaving the white fabric exposed, the imprinting of white figures on a blue ground became a matter of facility. It was otherwise with blue figures on a white ground. In this case difficulties presented themselves, which required the most intimate combination of chemistry and mechanics to remove. It is obvious that the entire dipping of a fabric into a bath of white indigo solution presented the facilities necessary for enabling the latter to sink deeply into the fibres of the tissue; so that, on exposing the dipped fabric to the air, the blue colour

* Blue indigo is converted into white indigo by the operation of deoxydizing agents, as protochloride of tin, protoxide of iron, or sulphurous acid. This white indigo is soluble in alkaline solutions, and speedily becomes blue by exposure to the air. The circumstances under which blue indigo is changed into white indigo are most easily explained on the supposition that the former is a compound of oxygen plus the latter; hence the names of *deoxydized indigo* and *indigogene* were given to the white substance; but the investigations of Dumas have proved that the white indigo is a compound of hydrogen with the blue indigo. Hence deoxydizing agents effect the change of white to blue indigo by the decomposition of water, of which liquid they appropriate to themselves the oxygen, and yield up the hydrogen to the indigo.

would be developed within the substance of the cloth. The imprinting of a figured blue design, however, is incompatible with the former conditions; as the white indigo, being at once exposed to the air, loses hydrogen and becomes blue, not on the *inside* of the tissue of the fabric, but on the *outside**; hence the dyeing is not permanent. The desideratum was to give the necessary time for penetration, without the contact of air or any gas containing oxygen. Coal gas answers to these conditions; and the method of using it for this purpose is a lasting triumph of mechanico-chemical alliance. By means of most elaborate machinery the tissue, with its imprint of white indigo, is drawn by means of a roller, through an air-tight slit formed of two approximating lips of india rubber, *into* a chamber containing coal gas; then *through* the same, and lastly *out* of it through another slit of the same kind. Thus whilst in transitu, unexposed to the influence of atmospheric air, the white indigo finds the necessary time to penetrate into the fibres of the tissue, before being rendered insoluble and blue by contact with oxygen! Surely the contemplation of this wonderful triumph should render any one slow to predict the impossibility (expense of material not being the cause) of introducing refinements of manipulation into a ma-

* If a portion of cotton fibres be viewed under a microscope, they will be seen to consist of a congeries of minute and semitransparent tubes. It is the object of the dyer and printer to introduce dye colours *into* these tubes, through which the tints are easily seen, but are beyond the reach of liquids, and hence cannot be removed by washing.

nufactory. As an instance of a chemical refinement reducible, though not reduced, to practice, the slow combustion of alcohol in contact with platinum black may be adverted to. Chemists know that if alcohol be dropped into a pan containing platinum, in its finest state of mechanical division *, the latter becomes red hot, and the alcohol is immediately changed into three new substances †, of which vinegar (acetic acid) is one. I am informed by a large manufacturer of vinegar, himself a good chemist, that, were it not for the Excise duty on alcohol, this most beautiful and refined chemical means of making vinegar would be the cheapest in practice.

Thus, it is obvious, that a most material alliance does subsist between the chemical philosopher and chemical manufacturer; that the laboratory operations of the one do, when duly interpreted, afford valid evidence for the other; that the much complained of discrepancy between laboratory and manufacturing results, is rather one of words than of fact; and lastly, that he must be bold indeed who shall predict the inapplicability of laboratory refinements to manufactures merely from difficulties to be encountered.

* This powder is known to chemists as *platinum black*, and may be best prepared by dissolving protochloride of platinum in a boiling solution of potash, then adding alcohol by small quantities at a time, until all effervescence ceases, and a black precipitate falls. The latter, after being boiled successively with alcohol, hydrochloric acid, potash, and water, is platinum black, or pure metallic platinum in a state of impalpable powder.

† To be precise, these three substances are aldehyd, acetal, and *acetic acid*.

It will be the object of this treatise to set forth a process of sugar manufacture which depends on the application of a chemical principle; and one involving no appliances, save of the simplest kind. Indeed, the colonial sugar producers have expected too much from machinery, and too little from chemistry.

The two operations of calico printing and the production of soda from sea salt, furnish instances respectively of two well-marked kinds of chemical manufacture—the qualitative, and the quantitative. In the former, mere chemical agencies are brought into play without reference to any weighed chemical results. In the latter, the object, on the contrary, is to produce the practical maximum of some particular substance.

In all manufactures of the latter class, it is evident that some amount of waste *will* take place. Nay, even in the laboratory, when engaged in analytic researches, when the appreciations of the minutest fraction of a grain is a desideratum, the chemist almost suspects the truth of his own experiments if he do not encounter some trifling loss.

None, however, but practical men, well conversant with laboratory and manufacturing observations, can attain to a just estimate of the usually small amount of this loss. The chemist will not expect to encounter more than one or two hundredths of a grain at most in a quantity of 1000 grains; and if one per cent. be set down as the average amount of loss encountered in a chemical manufacture, this statement will be assuredly an extreme one. In proportion, then, as any chemical manufacture should happen to present a greater loss than the above, so would it challenge our suspicion in regard to the correctness of the principles on which it depended.

If, then, after those preliminaries, the reader were to be told of the existence of a manufacture in which some sixty-six per cent. of the material desired to be separated from only $\frac{1}{1000}$th of impurities were destroyed in effecting that separation, and that in being destroyed were converted into a foreign impurity, contaminating the remaining thirty-four per cent. ultimately obtained—his credulity would be largely drawn upon.

If, moreover, he were told that the aspirations and endeavours of the largest bulk of individuals engaged in this manufacture lay in the direction—not of saving the sixty-six per cent. lost; an endeavour considered by them as hopeless—but of producing economically a large excess of raw material, so that they might be able to *afford* this loss of sixty-six per cent., then the reader's incredulity would increase. Nevertheless, it is too true that such a manufacture does exist, and marked by the peculiarities indicated.—It is the manufacture of sugar.

The juice of the sugar-cane, containing as it does merely $\frac{1}{1000}$th of its weight of impurities, may be considered in relation to its specific gravity as a solution of sugar in pure water. Hence any of the available methods of taking the specific gravity of fluids may be employed as indicative of the amount of sugar in this material. That the test in question, *i. e.* of specific gravity, may be trusted as giving precise indications, has been demonstrated by frequently repeated chemical experiments.

Both these methods of inquiry assure us that the amount of sugar in sugar-cane juice varies from about seventeen to twenty-three per cent.; whilst, according to the almost united testimony of all observers, seven per cent. of sugar (about one-third) is something more than the average quantity obtained: and this, too, not in a condition of chemical purity, but admixed with numerous foreign matters.

The only sugar contained in the sugar-cane is that which alone is (at least in England) a mercantile commodity, and is composed of $C_{12} H_{10} O_{10}$ + Aq., or in other words twelve atoms or equivalents of carbon, ten of hydrogen, ten of oxygen, and one of water; that such are the elements composing crystallized or (aqueous?) cane-sugar there can be no doubt, and chemists are now pretty well agreed that the elements of one atom of water in crystallized sugar exist *as water*, with which the sugar combines in the manner of acid and base. The compound ($C_{12} H_{10} O_{10}$ + Aq.) − Aq., or crystallized sugar minus its basic water, has never been obtained, and is only indirectly proved to exist by the fact that the water may be removed and some other base substituted in its place. Thus, in general terms, sugar is *an acid*, (see Definitions, p. 17,) because it combines with bases and forms salts. Of these bases water may be one; but there are others. For example—If crystallized sugar (*saccharate of water*) be placed in contact with lime or baryta, under proper conditions, water is evolved, and baryta or lime takes its place, yielding respectively *saccharate of baryta* and *of lime.* Many bodies are situated like sugar in the above respect. Thus crystallized oxalic acid, as it is termed, is a compound of real oxalic acid and water. Oxalic acid *minus* its water has never been obtained; but is inferred to exist by the fact that it may be shifted from one base to another, as is the case with sugar. The reader will by this time recognise the propriety of the terms *hypothetical* and *practical*, as applied to sugar and to oxalic acid. Henceforth the term pure sugar will refer, throughout these pages, to the crystallized compound of sugar and water. Specimens of sugar, whether obtained from the cane or beet root, the date or sugar maple, are invariably of this composition; are, in other words, perfectly identical. Hence, chemists using the term—*cane-sugar*—as typical of a class, understand by this term *all* sugar, no matter whence procured, which presents the composition of $(C_{12}\ H_{10}\ O^{10}) + Aq.$ This fact, so well known to chemists, is somewhat foreign to the notions, and at variance with the conventional language, of the major part of the sugar community.

According to the technical phrases prevalent among individuals practically conversant with sugar, the idea would be created that certain occult and intrinsic differences of quality subsisted between sugar of the cane, the date, the maple-tree, and the beet-root; nay, further, that sugar acquired essential characteristic differences, as it was the produce of various climates, various canes, or various soils. The prevalence of this idea has exerted a fatal influence over the sugar manufacture, and has been subversive of every fixed principle of operation.

Practical men, I am aware, will not admit this identity of sugars from the various sources just indicated. They will say that there exist low sugars and high sugars, and weak and strong sugars. That sugar produced in the East Indies is different from sugar produced in the West; that Demerara sugar is different from sugar from Jamaica; that Havana sugars differ from both, and that the assertion of cane-sugar being identical with beet-root sugar is not reasonable. To all this there is but one answer. Either such perfect identity *does* exist, or the science of chemistry *does not*.

True it is that sugar in the beet-root, the maple-tree, and the date, is associated with impurities, varying for each particular vegetable; true even that quantity as well as quality of impurities varies in different plants of the same kind, but growing in different climates and different soils; which several impurities it should be the object of a sugar-manufacturing operation to separate, and to leave the sugar pure.

In this sense, and with these reservations, the colonial saccharine produce of the sugar-cane (improperly termed sugar) differs for different regions. Such produce, it must never be forgotten, is not sugar alone, but sugar *plus—certain impurities*; the latter may and do vary, but the sugar is absolutely and in all respects identical.

Circumstances induced me, in the summer of

1847, to turn my attention to the colonial sugar manufacture. That there should exist any necessity for the loss of two-thirds of any material in producing, combined with a host of impurities, the remaining third—I could not believe:—so opposed did the notion appear to every analogous case—so inconsistent with all chemical harmony. I have, since that time, given the subject my almost undivided attention; and to prosecute with the greatest efficiency my experiments, I have spent the greater portion of this subsequent period in a refinery. Thus circumstanced, I have had opportunities of working out a new process, modified to suit refineries, on a large scale, and with the most satisfactory results. With regard to cane-juice, I at length succeeded in obtaining some from the Island of Barbadoes: the first, I believe, ever brought in an unfermented state to England*.

Being aware that sulphurous acid possessed a remarkable anti-fermentive quality, I was induced to have the full powers of this substance tested on cane-juice; and by the politeness of Messrs. Hardy, of Cork, I was supplied with some cane-juice thus prepared from one of their estates. From this cane-juice I succeeded in extracting, by the process in question, more than twenty per cent. of crystalline sugar.

It is distinctly to be understood that the new operation, which it is the object of this treatise to

* A material under the name of cane-juice has frequently been brought from the colonies; but it is merely an extract made by boiling down the real juice to the consistence of a syrup.

develop, is not a mere laboratory process; or, in other words, is not one in which a certain maximum produce is aimed at, irrespective of expense. The mere chemical problem of obtaining the whole of sugar present in any given juice containing it, had long been perfectly solved and reduced to laboratory operation; but, unfortunately, it was totally inapplicable to practice on the manufacturing scale. My investigations have run in the direction of the sugar *manufacture*, and that alone. I have, in all my experiments, studiously avoided chemical refinements; have used common rather than distilled water; sugar contaminated with an exaggerated quantity of impurities, and, in short, I have, by preference, availed myself, by way of exercise, of many conditions involving a considerable amount of extraneous difficulty. I have tried the refining process on the refining scale, with the most perfect success; and have demonstrated that, in the refinery, it is more easy of management than when prosecuted in the laboratory. If to this I add, as the result of actual experience, that the operation of extracting sugar from recent juice is by far more easy to conduct by the new process than by the present most destructive operation followed in the colonies; and is, at the same time, more absolutely inexpensive, whilst the cane-juice is made to yield considerably more than double its present amount of sugar of purer quality—even white, if desired; surely I shall have said enough to interest the attention of the sugar-producing world.

Throughout the following pages I desire to avoid, as far as may be possible, all that ambiguity of language which has unfortunately so confused the meaning of several sugar treatises*, and with this view, I shall append a glossary, for the definition of certain terms which will occur throughout the volume.

* To the above remark the treatise of Dr. Evans is an almost unique exception. This gentleman's long residence in the colonies has enabled him to combine all his practical experience of tropical agriculture and manufactures with a refined application of chemical resources. I have derived great pleasure and information from his admirable volume, which should be found in every sugar manufacturer's library.

CHAPTER I.

DEFINITIONS.

ACIDS.—Bodies, invariably compound; which manifest great tendency to unite with another class of bodies termed *Bases*, and to form, when thus combined, a third class of compound bodies termed *Salts*. Generally acids are sour, though not invariably. Thus, prussic acid is bitter, silica (flint), termed by chemists *Silicic Acid*, is tasteless; and sugar (which combines with bases, and therefore is an acid), sweet. Nearly all soluble acids have the property of reddening blue litmus paper; to this rule, however, sugar is an exception.

GLUCIC ACID.—A compound of $C_8H_5O_5$, formed when sugar* is boiled in contact with lime. By longer boiling glucic acid becomes changed into

MELASINIC ACID, ($C_{12}H_6O_5$,) Sacchulmic, and Sacchumic Acids, Sacchulmine and Sacchumine.

N.B.—It is to the presence of the latter bodies that the dark colour of treacle is owing.

ALKALIES.—The most potent of all bases. Some alkalies withstand the action of fire without volatilization, and are hence called *fixed;* whilst others, similarly treated, are driven off,

* Whether cane-sugar or grape-sugar (*glucose*), glucic acid results; but, if cane-sugar, it is invariably changed into glucose before glucic acid appears.

and are hence termed *volatile*. The fixed alkalies are potash, soda, and lithia; the oxides of potassium, sodium, and lithium respectively. The term alkali is usually applied in sugar treatises to lime, although this substance is in reality an alkaline earth.

Bases.—Bodies, invariably compound, *generally* composed of oxygen and a metal*: having a great tendency to unite with acids, and to form, when thus united, another class of compound bodies termed salts.

Bastards.—A very dark and impure description of pieces made up of cane-sugar, grape-sugar, and the dark compounds of malasinic and other acids generated by the destruction of sugar. (*See* Pieces.)

Claying (operation of).—A process of removing a portion of the coloured impurities from Muscovado sugar by means of a clay-magma; and is thus conducted:—The Muscovado sugar being put, whilst hot and liquid, into cones with perforated apices (each perforation being stopped by a plug), crystallizes on cooling. The plug now being removed, the sugar drains to a certain extent spontaneously. A layer of clay-pap or magma is now superimposed upon the base of each cone. From this clay-magma small portions of water are continuously given off for a considerable time, and, sinking through the sugar, wash away a portion of the yellow im-

* Thus lime (a base) is composed of oxygen and the metal *calcium*.

purities through the aperture in the apex of the cone.

The operation of claying is chiefly followed by the Spanish and Brazilians, and is very wasteful—one-third of the original Muscovado sugar being lost in conducting the process*.

LIQUORING (process of).—The operation of washing yellow sugar white by the percolation of a concentrated aqueous solution of pure sugar. The rationale of this operation is as follows:—All the colouring matter, of whatever kind, to which brown or yellow sugar owes its peculiarities, is not deposited within the crystals, but on their outer surface; and hence may be washed away by any liquid which possesses the property of dissolving those impurities, though not the sugar. In practice, the most convenient liquid for effecting this is a saturated aqueous solution of pure sugar. Being saturated as regards sugar, it can dissolve no more of that substance, although it is a perfect solvent for all the chemical colouring impurities which are present in yellow sugar.

However colourless a solution of sugar may be before the application of heat, yet after that application, in the evaporative process, it always yields a crystalline product of more or less yellow colour, and which, therefore, requires

* The process here described now no longer prevails in refineries; where, instead of clay-pap, a magma of sugar and water is employed. This process, however, having been substituted for the use of actual clay, is still termed *claying*.

the final cleansing process of liquoring before absolutely white sugar results. The process of liquoring is, in modern refinery practice, always preceded by that of *claying*, (see Def., p. 18). If the colouring matter of muscovado or colonial brown sugar were altogether chemical, and not mechanical, white sugar might be made from it by the processes of claying and liquoring alone without previous solution and reboiling.

MOLASSES.—A liquid product of the colonial sugar manufacture, being a solution in water, of a variable amount of cane-sugar admixed with a large amount of impurities. Some of the latter originally existed in the cane-juice, but a greater amount results from the destruction by heat, lime, and improprieties of manipulation of a portion of the original sugar. Molasses cannot be converted into sugar*, but the sugar which it contains can be extracted from it.

PIECES.—A refinery product, consisting of sugar mixed with so many impurities (chiefly grape-sugar, (*glucose*,) glucate of lime, and animal matter), that the impurities cannot be remuneratively separated by the present refinery process †. (*See* BASTARDS.)

SUGAR.—A sweet substance, invariably the product

* Hereafter the term *sugar* will be used to indicate cane-sugar, *i.e.* (C_{12} H_{10} O_{10}) + Aq.

† This product of refineries might seem, to an ordinary observer, to be the colonial moist or Muscovado sugar; for which, indeed, it is now generally sold by grocers, but from which it may be known by the smell of blood used in the refinery operation.

of organic life, and composed of the three chemical principles, carbon, hydrogen, and oxygen*.

CANE SUGAR.—A sweet white semitransparent substance, composed of $(C_{12}H_{10}O_{10})$ + Aq.† Slightly acid, very soluble in water, hot or cold. Scarcely soluble in cold, but readily in hot alcohol. Crystallizable: form of crystals—the oblique rhombic prism; being, therefore, referable to the oblique prismatic system of Weiss and Mohs‡.

GRAPE SUGAR.—Synonyms, *sugar of fruits*, *glucose*, and sometimes but improperly *uncrystallizable sugar*.

A sweet principle, composed of $(C_{12}H_{12}O_{12})$ + 2 Aq., soluble in water, hot or cold; also in cold alcohol; slightly acid; crystallizable. Its crystalline form being that of minute needles radiating from a centre, and thus giving rise to an appearance of granulation. Grape-sugar

* Mere sweetness is not considered by chemists sufficient to constitute a sugar. Thus various salts of the metal glucinum are sweet, and so is acetate of lead; neither of these, however, is, chemically speaking, a sugar. Popular language, nevertheless, being less precise, has given the term *sugar of lead* to the lead compound.

† The symbols Aq. (the initials of aqua) and HO, the initials of hydrogen and oxygen, are both used by chemists to signify water. In a practical treatise the two symbols may be regarded as convertible in all respects; chemists, however, make a slight distinction.

‡ Cane-sugar, *i.e.* $(C_{12}\ H_{10}\ O_{10})$ + Aq., is not merely obtained from the sugar-cane, but from beet-root, various of the palm-tube, the sugar-maple, &c. The chemical term *cane-sugar*, or *sugar of the cane*, is used in a typical sense, and refers to identity of composition, not of origin. (*See* Preface, p. 11.)

may be made artificially by boiling starch, or cane-sugar, or woody fibre, with dilute sulphuric acid. A portion of cane-sugar is invariably converted into grape-sugar by the agency of heat alone. The presence of almost any foreign matter greatly facilitates this change. Hence the importance of purifying cane-juice before endeavouring to obtain the sugar by evaporation.

SUGAR OF MILK.—A sweetish principle, composed of $C_{12}H_{12}O_{12}$, extracted from the whey of milk: crystallizable; less soluble in water than sugar of cane or of grape; gritty between the teeth.

SUGAR OF MANNA.—Syn. *Mannite*, a sweet principle, composed of $C_{15}H_{16}O_{16}$ (*Prout*), naturally existing in manna, and artificially produceable from cane-juice. Crystallizes in minute silky filaments.

MUSCOVADO SUGAR.—The imperfectly crystallized product from cane-juice, before the operation of claying.

N.B.—Muscovado sugar is to be regarded as sugar,—plus impurities.

LOW SUGAR.—This term is used by the sugar community in a most indefinite sense. It would seem to indicate cane-sugar, somewhat altered from its normal type; but the kind of alteration not known. Chemists are ignorant of such alteration. Generally, the term low sugar may be translated *impure sugar*; occasionally, however, the term is applied to sugars of considerable purity, but of small soft crystals.

WEAK SUGAR.—An indefinite conventional term, usually applied to sugar in very soft* small crystals, but occasionally to sugar in very large crystals—the produce of the Demerara vacuum pans for instance.

REFINED SUGAR.—A term used as synonymous with pure sugar, and expressive of the common belief that such must necessarily be the result of a second operation.

TREACLE.—The molasses of refineries. A dark semi-fluid material, usually containing none, or but little of cane-sugar; but made up of grape-sugar (*glucose*), lime, animal matter (from blood employed in the operation), and certain dark bodies arising from the destruction of sugar. (*See* ACIDS, MELASINIC.) Treacle cannot be converted into sugar, but any sugar it may contain can be extracted from it.

* This soft or pasty condition usually depends on the presence of grape-sugar.

CHAPTER II.

CRYSTALLIZATION.

INASMUCH as the phenomena of crystallization are intimately associated with the production of sugar in the mercantile form, it has been considered desirable to offer a slight outline of that branch of science.

As a preliminary to a proper appreciation of the operation of that force, on which the formation of a crystal depends, it will be necessary to acquire a well-defined idea of the atomic and molecular constitution of matter.

Let it be assumed that matter, though immediately presented to our senses under the form of masses, is in reality but an aggregate of molecules; and that the latter are in their turn composed of particles of matter, which no human agency or law of nature, as nature now exists, can divide, and which, on account of this indivisibility, are called atoms.

The above-mentioned assumption is in accordance with all chemical testimony: not one valid experiment can be brought against it; so that the only proof necessary to establish the fact of the existence of these atoms is the direct visual proof of their existence—a proof which never can be attained, inasmuch as chemical experiment of a kind to be universally assented to has demonstrated that these atoms must be smaller than a certain determined bulk, in the contemplation of which the human intellect is lost. Thus it can be demonstrated by *the naked eye*, that an atom of lead must be smaller than the billionth of a cubic line*, how much smaller no one can tell, smaller, for aught we know, than there is space on the earth's surface for numerals to record†. Yet, despite this inconceivable minuteness of atoms, the science of chemistry has been equal to the task of discovering their relative weights, and in many cases their relative bulks; has been able to demonstrate that the atom of oxygen weighs eight times as much as the atom of hydrogen, yet is only half the size; that an atom of lead weighs 104 times as much as one of hydrogen; of silver, 110; and so on for every elementary body, and the greater number of compound ones, of which the earth and its inhabitants are composed. The *actual* weight and *actual* size of these atoms it is evident must ever remain unknown, inasmuch as the means of measuring, and weighing, objects so inconceivably minute involves an impossibility.

* This may be demonstrated as follows:—Dissolve in nitric acid a fragment of lead, 0·01, of a cubic line in size, and add the solution to 506 cubic inches of a clear solution of hydrosulphate of ammonia in water. A distinct blackness will be observed. Hence the magnitude of each particle of lead *cannot* exceed, but must rather fall short of *a billionth of a cubic line.*

† To render the idea of this degree of division more distinct than the mere mention of so imperfectly conceivable a number as a billion could effect, it may be added, that a man, to reckon with a watch, counting day and night, a single billion of seconds, should require 31,675 years!—*Kane.*

Much gratuitous difficulty has opposed itself to the contemplation of the atomic constitution of matter, by confounding two propositions, which are in themselves distinct: the proposition of the divisibility or non-divisibility of matter, with that of the divisibility or non-divisibility of space. To conceive space not to be infinitely divisible is irrational; but to conceive that matter filling such space is not infinitely indivisible does violence to no reasoning process whatever. For let it be granted that the matter filling such space is so hard, and so coherent, that no force now existent can cause its division or dismemberment,—then we have an atom according to the definition,—viz., a body which cannot be divided. Thus we learn that the term atom has no reference whatever to the smallness of a particle, but merely to the fact, of its indivisibility; inasmuch, however, as practice demonstates that the quality of indivisibility is alone confined to particles of incomprehensible smallness, this latter quality is always associated with the term atom.

Henceforth, then, the reader will assume the existence of atoms; and of aggregates of atoms, termed molecules; these molecules tending to unite again, and form masses.

It will be unnecessary for me here minutely to discuss the nature of those forces on which the formation of masses by the union of molecules depends. Suffice it to state, that these molecules are not only impressed with tendencies to combine, but to combine according to certain fixed and unvarying laws; as is best evinced by consideration of the fact, that, if the result of such combination be a solid, the latter has always a tendency to assume a definite geometrical form—to become, in fact, a crystal. Thus we may regard the crystalline condition the natural one of all solid bodies, and we may consider its absence due to the operation of some extraneous cause.

To illustrate the above proposition by immediate reference to sugar:—The smallest possible molecule of sugar is composed of $(C_{12} H_{10} O_{10}) + Aq$. What the form of such molecules may be, we cannot tell; but experiment demonstrates to us that, when several of them combine to form a mass, their tendency is not to effect a compound of indeterminate or irregular form, but one possessed of well-defined geometric boundaries; constituting a form which, although subject to slight variations, is always referable to the geometric figure called an oblique rhombic prism. Hence sugar is said by chemists to belong to the oblique prismatic system.

It is highly important to observe that, although sugar crystallizes in certain well-defined geometric shapes, all referable to the oblique prismatic system, and therefore invariable; yet the *size* of those crystals may be varied almost at the will of the operator; just as a bricklayer, with materials of the same form, may be conceived to build an oblique prism of any stated size. Nay, more, by a very easy modification of the treatment of two sugar solutions, both precisely equal in all respects, one shall be made to yield crystals, and the other a confused mass, devoid of all crystalline form, and hence called by chemists amorphous. A slight consideration of the operation of cohesive affinity between molecules will explain all that seems difficult here; and, as the subject is somewhat recondite, perhaps an analogy from ordinary matters will not be devoid of value:—Suppose, then, a legion of soldiers standing in an ample space, and ordered by sudden word of command to form a square; it is clear that the element of time is necessary to the success of their evolution. Give them time enough, and the evolution will be made,—the square will be formed. Give them less time and the evolution will be incomplete: either no vestige of the square will be recognisable, or its formation will be imperfect. The former is the exact condition of sugar solutions which have been exposed to slow evaporation; the latter the condition of such as have been exposed to a more rapid system of evaporation; and these remarks are applicable to all instances of crystallization whatever.

Thus we see that, theoretically speaking, the process of effecting the crystallization of sugar *should* be entirely under the operator's control; and practice has rigidly demonstrated the correctness of the theory. Hence the sugar producer has certain well-known indications to follow out, provided he desire to obtain his staple in the form of crystals. He should evaporate by the slowest temperature consistent with economy of time and fuel, and thus retain his concentrated syrup in a fluid state by the application of heat, until the crystals shall have accreted to the size desired.

In actual practice the sugar manufacturer is obliged to rely alone on the latter expedient, the process of slow evaporation being incompatible with the necessities of general commerce. The process would occupy too much time, and the result would necessarily be increased in price, without offering any adequate advantage. It would be in fact *sugar candy*, a material which is made by the process of slow evaporation here indicated, and which only differs from lump sugar in possessing larger crystals.

CHAPTER III.

PRELIMINARY REMARKS, GENERAL AND SPECIAL, ON SUGARS.

THE principal bodies which come under the chemical definition of sugars are—Sugar of the Cane, of the Grape, of Milk, and of Manna. They have respectively the following compositions:—

	Carbon.	Hydrogen.	Oxygen.	Water.
Cane-Sugar	12	10	10 +	1
Grape-Sugar, or Glucose	12	12	12 +	2
Mannite	15	16	16	
Of Milk	12	12	12	

Of these the latter may be entirely dismissed from our consideration, and few remarks will suffice for all but the first.

On Sugars.—General Remarks.

Cane-sugar is the only one which involves commercial interests on the large scale; being alone that which is employed in any considerable amount as a sweetening agent. For although manufactories of grape-sugar do exist on the Continent, with the object of producing the material for admixture with such wines as are naturally deficient in it, and thus furnishing the means of supplying alcoholic strength; yet the commercial interests involved are, comparatively speaking, small; and the clandestine manufacture of grape-sugar for the purpose of adulterating the West-India staple, a manufacture which *was* extensively carried on in and near London, is without the precincts of any commercial speculation in its true sense.

The sugar called Mannite is a mere chemical curiosity, and need not be farther adverted to in these pages, were it not for the circumstance that a portion of the juice of the cane is liable, under improper treatment, to be converted into this substance.

Sugar of milk is obtained, by a process unnecessary here to describe, from the whey of milk. Hence in certain cheese-making localities, considerable portions of this substance are prepared. In some parts of Switzerland this is done, and the resulting sugar of milk is employed as a sweetening agent.

On Sugars.—Special Remarks.

Cane-Sugar.—Under the definition sugar (cane, p. 20) the *distinctive* chemical characteristics of the substance have been so fully given that nothing further in that respect need be stated here.

Henceforth I purpose devoting the term *Sugar* exclusively to sugar of the cane; appropriating the terms *Mannite* and *Glucose* to the sugar of manna and the sugar of grapes respectively.

Perhaps sugar more than any other substance has been mystified by a variety of appellatives. According to some it has been termed a salt; by others an essential salt; whilst the conventional mode of using the terms saccharine matter and crystalline matter as applied to sugar, terms now legalized by Act of Parliament, imply that sugars may possess the former matter without the latter, the two being distinctively indicated as capable of existing separately, and as constituting, when united, the substance *Sugar*.

It seems unnecessary to point out how totally irreconcilable is the commercial and legislative definition of sugar, when compared with the chemical one.

Perhaps, however, the following parallel statement will place the discrepancy adverted to before the reader in its most powerful light:—

Chemical Doctrine of Sugar.	*Commercial and Legislative Doctrine of Sugar.*
Sugar is a compound of Carbon, Hydrogen, and Oxygen, united in known, exact, and unvarying proportions.	Sugar is composed of { Saccharine matter. Crystalline matter.
Its taste is sweet; and inasmuch as taste depends on rapidity of solution in the mouth, and inasmuch as large crystals dissolve less rapidly than small ones, sugar imparts less sweetness for equal time in proportion as its crystals are large.	Sugar is not invariably alike, but different according to region, climate, or plant; may have more or less saccharine, more or less crystalline matter. Its smell, too, may vary; so may its taste, and also its colour. Sugars may be weak, or strong; beet-root sugar, for instance, is a weak sugar.
Size of a crystal is not defined by nature, but shape is defined. Sugars may be obtained in crystals of any size, may be even made to measure.	Weak sugars possess small grains (*i. e.* small crystals). Some weak sugars have large grains (*i. e.* crystals): these are weak, because they do not sweeten well.

The reader will form his own conclusions as to the comparative rationality of the two varying statements concerning sugar. According to the chemical doctrine, all is lucid and precise; according to the other, sugar is a kind of organic anomaly.

If sugar be a compound of saccharine and crystalline matter, surely an inquirer would infer that either of these matters had been separately obtained, and would, with great justice, expect the sugar community to be able to state the composition, properties, and general nature of sugar, *after having been deprived of its saccharine matter.*

In selecting the purest specimen of a crystallizable body, chemists invariably seek for the largest and best developed crystal, experience having proved that nature avoids admixture of impurities with the substance of a crystal, but extrudes them to the outside, where they form a mere mechanical coating. In conformity with this rule of proceeding, pure specimens of white sugar-candy have been the staple material of analytical researches, prosecuted with the result of demonstrating that the composition of sugar is $(C_{12}\ H_{10}\ O_{10}) + Aq.$; and here we must interpose a chemical theory relative to this composition and the reasoning on which it is based. It will be observed, that the eleven* parts (atoms or equivalents) of hydrogen and the eleven of oxygen,—would, if combined, constitute eleven atoms or equivalents of water; hence the following question arises:—Does this amount of hydrogen and oxygen, or any

* That is to say, ten of each, as represented in the formula $(C_{12}\ H_{10}\ O_{10})$, and one in the Aq.

part of the same, exist in sugar *as* water or not? On this point chemists are agreed to consider that one part (equivalent or atom) of hydrogen and one of oxygen really do exist in the sugar-candy as water, without which water, or some equivalent for it, the remaining elements $C_{12}\ H_{10}\ O_{10}$ could not exist in combination.

The rationale of this opinion is as follows:— If sugar be brought in contact under favourable circumstances with certain bases,—oxide of lead, for instance, an equivalent of water is evolved, and the remaining elements of the sugar ($C_{12}\ H_{10}\ O_{10}$) combine with the oxide of lead. In this way the sugar, less one atom of water, may be shifted from one base to another, and its existence inferred. These bases, however, being separated, the $C_{12}\ H_{10}\ O_{10}$ immediately resolves itself into other forms of combination; that is to say, provided it have not the means of recombining with the necessary amount of water to form crystalline sugar. Thus water serves as a base, and hence is termed by chemists *basic water*.

Instead, therefore, of stating crystallized sugar to be composed of twelve atoms of carbon, eleven of hydrogen, and eleven of oxygen, or in chemical algebra $C_{12}\ H_{11}\ O_{11}$, it is more usual for chemists to represent it as composed of twelve of carbon, ten of oxygen, ten of hydrogen, *plus one atom of basic water;* or, in chemical algebra, thus:—$C_{12}\ H_{10}\ O_{10} + Aq$. These observations explain the meaning of the term *hypothetical,* in contradistinction to *practical* sugar. The former indicates crystallized sugar *minus one atom of water,* or $(C_{12}\ H_{11}\ O_{11}) - H\ O = C_{12}\ H_{10}\ O_{10}$, the compound which unites with bases. The latter, this compound plus one atom of water.

The non-chemical reader will save himself much trouble and error by remembering this explanation. Otherwise he might hereafter confound the *one atom* of combined water, with some indefinite quantity of that fluid, in an uncombined state, as constituting moisture.

Sugar has a sweet taste, but no smell. Its colour is white. When crystallized, it is semi-transparent. It is brittle, and may be easily reduced to powder. Exposed to the atmosphere, it attracts a little water, but incurs no chemical change. Sugar is very soluble in water, which, at a temperature of 48°, dissolves its own weight of that substance*.

With increase of temperature, the solvent power of water for sugar increases also; when nearly at the boiling point, it is capable of dissolving any quantity of sugar whatever.

On evaporating the water from a solution of sugar, the latter is obtained in the form of crystals, the primitive form of which is a four-sided prism, whose base is a rhomb. The crystals are usually four or six-sided prisms, terminated by two-sided and sometimes by three-sided summits†.

Sugar, like all other organic bodies, is very delicately constituted, and the laws or forces which hold its elements in combination are overcome by the operation of numerous disturbing causes. The action of heat; that of the alkalis—i. e. of all

* Wenzel Verwandtschaft, p. 308.

† Gillat Ann de Chim., xviii. 317.

proper alkalies, (the action of alkaloids on sugar has not been investigated;) of a considerable number of non-alkaline bases; and of most acids,—tend to the destruction of sugar, by causing its ultimate elements to fall into a number of new combinations, the major part of which are still but imperfectly known.

The following experiment of M. Soubeiran affords a remarkable illustration of the effects produced on sugar solutions by the agency of heat alone. This chemist, having dissolved a given quantity of sugar in a given quantity of water, applied heat to the solution for thirty-six hours. The apparatus was so constructed, that the water given off by evaporation was continually returned to the original solution; by which contrivance the latter was always composed of the same quantity of sugar or its derivatives, and the same quantity of water as when the experiment commenced. Gradually the solution acquired darkness of colour, and, at the end of thirty-six hours, it had become black*.

Hence this experiment teaches us that, even by the application of heat alone to sugar solutions, sugar is destroyed and treacle is formed.

Chemists have demonstrated that there scarcely exists a foreign body which, if admixed with sugar solutions, and the latter boiled, does not increase the rapidity of destruction. The alkalis, lithia,

* Journal de Pharmacie, Février 1842. The first change effected is the conversion of a portion of sugar (*cane sugar*) into a portion of glucose (*grape sugar*), which latter is rapidly converted into melasinic, sacchulmic, and sacchumic acids, sacchulmine, and sacchumine. (*E. Soubeiran. Des changements moléculaires que le sucre éprouve sous l'influence de l'eau et de la chaleur.*)

potash, soda, and ammonia act with such energy, that a very inconsiderable portion of either, added to a boiling sugar solution, produces an immediate and visible destruction of a large amount of the latter substance. This destructive agency is also participated in by the alkaline earths, baryta, strontia, and lime. The latter agent is almost universally employed in the manufacture of sugar from cane-juice, and hence arises great destruction of material.

Acids, as a class, are equally injurious with alkalis to the constitution of sugar. Sulphuric, and hydrochloric acids, convert it rapidly into other compounds, several of which are as yet imperfectly investigated. It would appear, however, that the changes effected by these agents are,—first the conversion of sugar into glucose, then the change of the latter into a series of dark-coloured bodies, many of them of an acid nature; amongst which are bodies termed glucic, melasinic, sacchumic, and sacchulmic acids, also sacchulmine, and sacchumine.

The action of nitric acid on sugar is peculiar; converting it into oxalic acid. There are certain acids, however, which, under no circumstances that I have been able to recognise, are injurious to the constitution of sugar. Of these, the carbonic and sulphurous acids may be cited. The latter has long been known as a powerful anti-ferment; and, taking advantage of this property, I was enabled to obtain a specimen of cane-juice from the Island of Barbadoes, in a state of such complete conservation that I extracted from it upwards of 20 per cent. of sugar.

Grape sugar.—Synonyms, *sugar of fruit*—*uncrystallizable sugar** (improperly so called)—*glucose.*

The last synonym, i.e. glucose, is that by which grape-sugar will in future be designated throughout these pages.

Glucose, so called from γλυκὺς, sweet, is that form of sugar, to the presence of which ripe grapes, plums, peaches,—and, indeed, the greater number of fruits, owe their sweetness. Glucose, moreover, is the sweet principle of honey, and of malt; hence, it is to its presence that brewers' wort owes its luscious taste, from which liquid it may be procured. The readiest method of obtaining this variety of sugar, in large quantities, is by boiling starch, or lignine, with water containing a minute portion of sulphuric acid. The best proportions for effecting this are—starch one part, water four parts, and of sulphuric acid $\frac{1}{100}$th of the weight of the starch. The ebullition should be continued for thirty-six hours, the water being returned as fast as it evaporates. At the expiration of this time the conversion of the starch into sugar will be complete; lime now is to

* I know not why glucose should be termed by some authors uncrystallizable. It crystallizes with great facility in slender needles, diverging from a centre, forming in the aggregate little masses of nodular or granular appearance. It certainly does not form hard crystals, and, in this respect, is very unlike cane-sugar. The term uncrystallizable sugar, as applied to it, is not only improper, but productive of confusion; that term having been applied by Proust, Ann. de Chim. lvii. 131, to a sugar supposed to be liquid under all circumstances and uncrystallizable by any means, to be associated with both sugar of cane and glucose, and accounting, as he thought, for the existence of molasses and treacle.

be added, which separates all the sulphuric acid in the form of sulphate of lime, and the remaining sugar may be obtained by evaporation.

In this operation none of the sulphuric acid used is appropriated by the starch, or enters into any form of combination, its effect being of the kind known to chemists as *catalytic*, or attributable to contact without combination.

This method of forming glucose artificially was accidentally discovered by the Russian chemist Kirchoff, during an attempt to convert sugar into gum. He set out with the idea of dissolving the starch merely in dilute sulphuric acid, but, on continuing the boiling, he noticed the production of sugar.

If, instead of starch, cane sugar be used, a similar result is obtained. Cane sugar is also partially changed into glucose by heat alone; and still more rapidly by the united agency of heat and alkalis or alkaline earths *.

Vogel demonstrated that no gas was eliminated during this transmutation; and Mr. Moore † and De Saussure ‡ proved that the quantity of sulphuric acid used was not diminished in the process. Saussure, moreover, ascertained that 100 parts of starch, when converted into sugar, became 110·14 parts. Hence he inferred, that glucose was merely a solid compound of starch and water §, or, more

* See Note, p. 36, also Glucic Acid, p. 17.

† Phil. Mag., xl. 134.

‡ Annals of Philosophy, vi. 424.

§ Ann. de Chim. et de Phys., xii. 181.

correctly speaking, of the *elements* of starch and the *elements* of water.

Glucose was, a few years since, largely prepared in the neighbourhood of London for the purpose of adulterating colonial sugar, the amylaceous material used in the process being potato farina, of which the chief part was imported from Ireland. It might have been still more economically made, by substituting certain kinds of saw-dust for starch.

Glucose, when quite pure, is nearly white, and crystallizes in little needles, radiating from a centre, offering, in the aggregate, the appearance of little tubercular masses.

Unlike cane sugar, glucose is soft and clammy to the feel: it may also be distinguished from the former by certain chemical tests*.

* It will be seen, by reference to the formulæ given at p. 30, that glucose is made up of the elements of (practical) cane sugar, plus the elements of three equivalents of water; hence a rationàle is obtained of the facility with which the latter is changed into the former. Indeed this conversion into glucose, which sugar experiences from slightly disturbing causes, is the first of a long series of destructive readjustments of elements to which sugar is subjected.—(See *Glucic Acid*; also *Melasinic Acid*, in the Chapter of Definitions, p. 17; also Soubeiran's Experiment, p. 36.) Any approach to the boiling temperature of a solution of sugar instantly converts a portion of the latter into glucose; a change which is usually expedited by the presence of foreign matters in general, and by none more powerfully than alkalis and alkaline earths. This fact leads to a just appreciation of the great loss incurred by the present mode of colonial sugar manufacture.

Mannite.—Various species of the ash yield, when incisions are made into their bark, an exudation of glutinous feel and sweet taste. When its fluid portion has been evaporated by the sun, it finds its way into commerce under the name of manna.

The bulk of manna consists of a peculiar sugar, which chemists term mannite; and to obtain which from manna, the latter is digested with hot alcohol, which dissolves the mannite. On evaporating away the alcohol, mannite crystallizes in slender acicular tufts.

The consideration of mannite would not belong to this treatise, were it not for the circumstance of its occasional artificial production from solutions containing sugar of the cane. Thus Fourcroy and Vauquelin demonstrated the existence of mannite in the fermented juice of onions and of melons—vegetables which naturally contain sugar of the cane—and, under certain conditions hereafter to be detailed, a portion of sugar in juice of the cane is converted into the same substance. Lactic acid is also a result of the fermentation of sugar under certain circumstances; which seem to be these—the presence of nitrogenous bodies, and the due fermentive temperature. Liebig imagines that the formation of both mannite and lactic acid may be due to the deoxidizing effect of these nitrogenous matters. An examination of the formulæ of the bodies involved in the supposition bespeaks the probability of this view; as also do the circumstances under which saccharine liquids undergo the change; namely, whilst they are still *raw*, or unpurified from the foreign matters which are derived from their native sources. Thus the juices of the beet and the cane rapidly undergo the change adverted to, but solutions of sugar and water probably never. With the juice of the white beet—(betula alba),—the rapidity of the transformation has often been to me a matter of surprise.

CHAPTER IV.

HISTORY—CHRONOLOGICAL AND NATURAL—OF THE SUGAR-CANE, AND OF SUGAR.

In a practical treatise on the sugar manufacture, such as this is intended to be, any extended history, either chronological or natural, of the sugar-cane, and its crystalline product would be out of place. On these subjects a few general remarks will suffice.

Of all eastern products sugar appears to have been the latest known, out of the regions wherein it was produced. The chroniclers of ancient Egypt, Phœnicia, and India make no mention of it; and it did not find its way into Arabia as a commercial article until the eleventh century: soon after which some adventurous Venetian travellers achieved the introduction of sugar as a commercial article into their metropolis. In Venice the first refineries were established; and hence the name, long prevalent, of *pains de Venise* as referring to loaves of sugar.

Even as regards the sugar-cane, the testimony of ancient authors is exceedingly devoid of precision. The most ancient writer by whom we find the sugar-cane recorded is Theophrastus (B. C. 321), who, in his chapter on honey, states as follows:—

*ὅτι αἱ τοῦ μέλιτος γενέσεις τριτταί· ἡ ἀπὸ τῶν ἄνθων καὶ ἐν οἷς ἄλλοις ἐστιν ἡ γλυκύτης, ἄλλη δὲ ἐκ τοῦ ἀέρος, ὅταν ἀναχυθὲν, ὑγρὸν ἀπὸ τοῦ ἡλίου συνεψηθὲν πέσῃ, γίνεται δὲ τοῦτο μάλιστα ὑπὸ πυραμητὸν, ἄλλη δὲ ἐν τοῖς καλάμοις**.

"The generation of honey is threefold: the first is from flowers or other things in which there is sweetness; the second from the air, which when there are dews is concocted by the heat of the sun, and falls, particularly in harvest time; the third sort is from canes or reeds."

Theophrastus, in another place†, mentions a sort of reed, or cane, growing in marshy localities in Egypt, and possessing sweet roots. The passage in question has been understood by some to refer to the sugar-cane; but there are many objections to the correctness of this assumption. The sugar-cane is not an aquatic plant, neither are its roots so sweet as its stem. Moreover, if it really had existed in Egypt, there were certainly those who would have chronicled the circumstance with more precision than we find in the above vague expression of Theophrastus.

If we are to rely upon the testimony of Strabo, in his history of India, written about the nineteenth year of the Christian era, Nearchus, the admiral of Alexander the Great, about 300 years before Christ, not only saw the sugar-cane in India, but was aware that a substance resembling honey (sugar) could be

* De Causis Plant., ed. Heinsii, 1613, p. 475.

† De Causis Plant., lib. vi. c. 16, ed. Heinsii.

extracted from it. But, if the statement were true, the sugar-cane would seem to have remained very uncommon, and sugar still more so, seeing that Seneca and Lucan, who lived in the time of Nero (A.D. 62), adverted to the sugar-cane and to sugar in language so ambiguous, and obscure—that some authorities have even doubted whether another plant and another substance might not have been intended. Seneca, in his 84th Epistle, has the following passage:—

"Aiunt inveniri apud Indos, mel in harundinarum foliis, quod aut ros illius cœli aut ipsius harundinis humor dulcis, et pignior gignat. In nostris quoque herbis, vim eandam, sed minus manifestam et notabilem, poni quam prosequatur et contrahat animal huic rei genitum."

Lucan*, treating of the Indians near the Ganges, writes:—

"Quique bibunt tenera dulces ab arundine succos."

After Seneca and Lucan, Pliny is the next author of repute who adverted to the sugar-cane. This was about the year 78 A.D. Subsequently to which period, and until the latter end of the dark ages, such little testimony as can be found relative to the sugar-cane and sugar is far too vague and unsatisfactory to merit attention.

To the crusades we probably are indebted for disseminating in Europe such a knowledge of the sugar-cane, and its crystallized product, as caused the

* Book iii. verse 237.

speedy introduction of both into this quarter of the globe. The sturdy warriors of the cross, on their return to the west, began to desire many oriental luxuries for which they had acquired a taste. An oriental commerce was speedily established, and Venice became the great emporium of the riches of the east:—Of these sugar was one.

Between the twelfth and the fifteenth centuries the sugar-cane was cultivated in Sicily, the south of Spain, and indeed in many other Mediterranean regions. In the south of France, also, the culture of this plant was tried, but without success; the climate proving too uncertain, or too cold. In the Canary Isles, however, the cane culture was most productive, as was also the manufacture of sugar. These islands, in fact, continued to supply civilized Europe with the greater portion of her saccharine produce until the discovery of the West India Islands by the Spaniards in 1492, and the maritime discovery of India by the Portuguese, opened newer, and more congenial soils to the production of the tender crop.

Much controversy has existed on the question, whether the sugar-cane were, or were not, indigenous to the new world. At the present epoch it would be impossible to determine this point, so much has the subject been involved by lapse of time and incapacity of the earlier historians. Fortunately the matter, so far as concerns practice, is of no importance whatsoever. Suffice it to know that the West India Islands, almost immediately subsequent to their discovery, began to supply civilized Europe with large quantities of sugar, and the less fertile fields of southern Europe soon fell into desuetude.

During a long series of years, the West India Islands produced sugar for the greater portion of the civilized world, and created large stores of wealth to the proprietors of their soil. At present, unfortunately, this condition of things exists no longer. The culture of the sugar-cane has now become extended over most tropical, and some temperate regions. To oriental nations, sugar—generally in its impure condition—is an article of daily food. The Chinese use it in profusion; so do the natives of Siam,—a country which, perhaps better than any other, is adapted to the successful produce of the sugar-cane. Throughout the whole of India, sugar is not only a common food for man, but immense quantities of the impure varieties of produce, called *Jaggery*,—are given to elephants. The amount of sugar capable of being produced by scientific processes of manufacture, from the canes and the palm tribe of India, may be so vastly increased, that it would be difficult to assign any limitation. The native processes of sugar extraction in India are so rude, and so destructive, that it may safely be asserted that 75 per cent. of the sugar existing in the juice operated upon is entirely destroyed in obtaining the remainder!

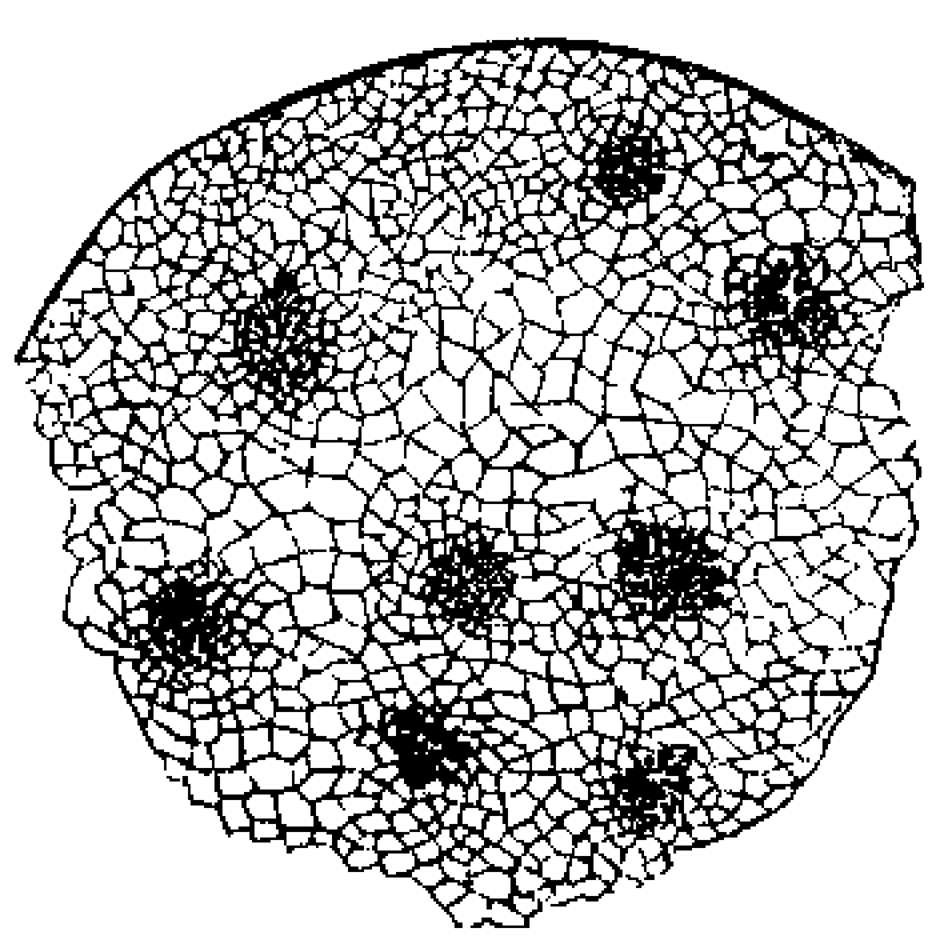
With regard to the natural history of the sugar-cane, very few remarks will suffice.

Botanists divide the vegetable world into phanerogamous or flowering, and cryptogamic or flowerless plants. With the latter we have no concern.

Flowering plants are again divided into *exogenous plants*, or such as acquire increase of structure during growth by the deposition of external layers of tissue; and *endogenous plants*, or those which grow by depositions of tissue within the substance of their stem.

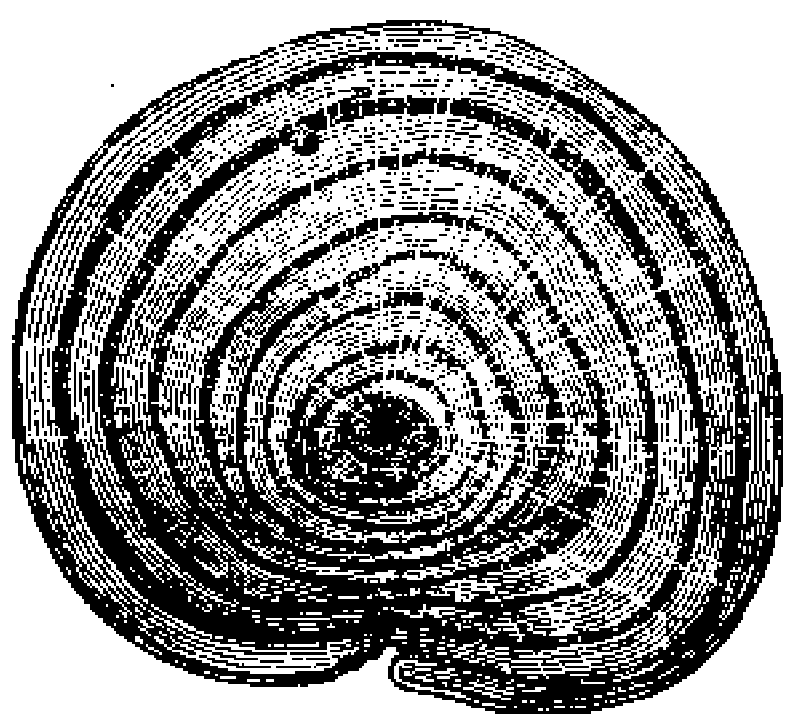
In temperate climes there are no large productions of the vegetable kingdom which belong to the endogenous class, all its representatives being of most humble growth. The grasses, for instance, are endogenous; and some of our larger grasses, as the wheat or barley, may be taken as the type of the endogenous vegetable produce in temperate regions.

It is in vain, however, to examine in the stem of our humble grasses, for palpable indications of the endogenous mode of growth. For this purpose a section of some tropical endogen,—the bamboo, or sugar-cane, for example,—should be made. This section, if carefully examined, will clearly indicate the prominent feature in the structure of an endogenous plant.



It will be seen that there is no appearance of concentric rings, indicative each of a year's growth, but the whole cellular and vascular structure forms one confused mass.

For the purpose of fully appreciating the difference between an exogenous and an endogenous stem, the cane section may be compared with another of oak or hazel.



The difference between the two will be now marked; here the indications of peripheral depositions of tissue are so clear, each deposition corresponding with one summer, that, by counting the number of existing rings, the age of the exogenous plant may frequently be told. Besides the difference of the mode of growth between endogenous and exogenous grasses, a difference on which are founded the distinctive terms of botanical arrangement, there exist others no less invariable, and well marked. All exogenous plants are provided with reticulated leaves, whilst the leaves of all endogenous plants are merely traversed by straight veins; this distinction will be well appreciated on making a comparison between an oak leaf and a leaf of barley or wheat.

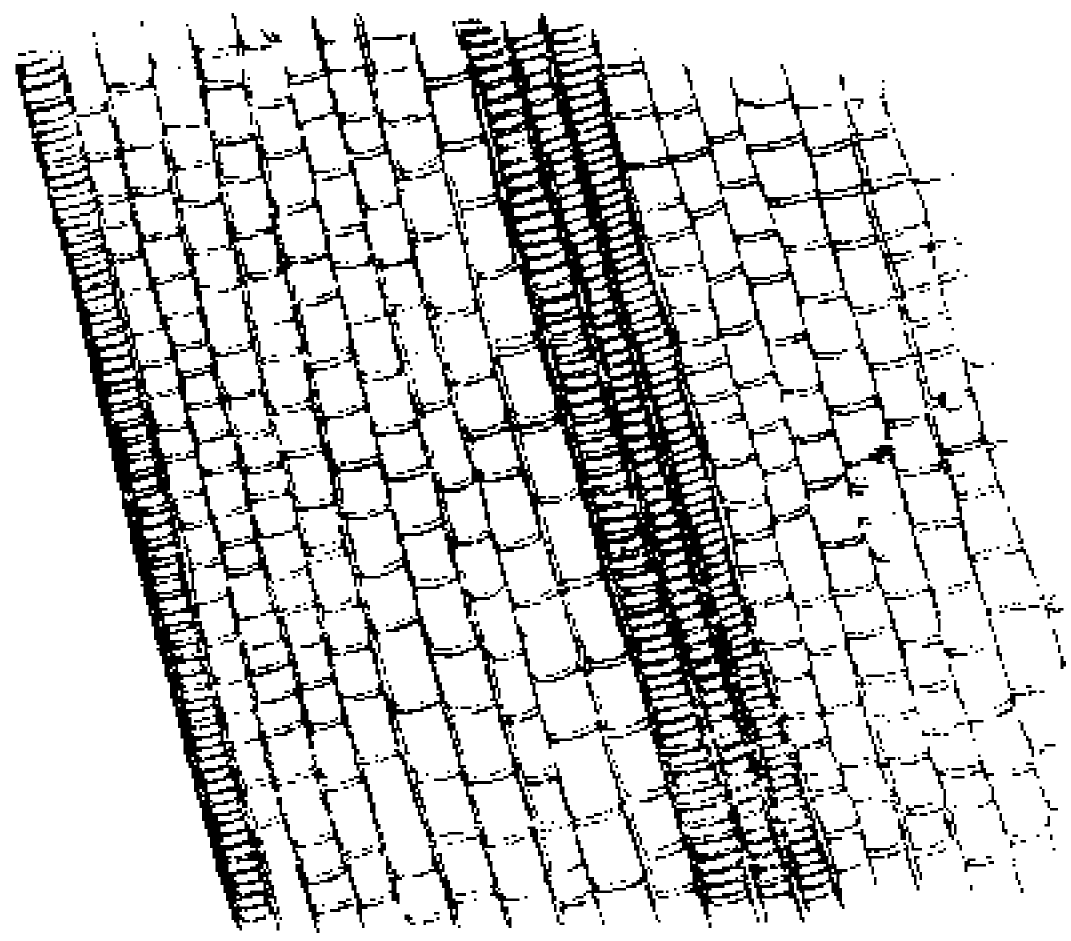
Again, all exogenous plants possess a well-defined bark, wood, and pith; whilst in endogenous plants no such defined arrangement exists;—one part merging into the other by insensible gradations. Other distinctions between endogenous and exogenous plants there are, but they belong exclusively to the province of the botanist. If the stem of any of our larger grasses be examined, it will be found incrusted with a hard brilliant coating. This is no less than silica or flint, as may easily be demonstrated by various means. If, for example, a straw be dexterously acted upon by the flame of a blowpipe,—the silica fusing with the potash naturally existing in all land vegetables,—there will result a beautifully transparent bead of glass. On a larger scale this production of glass from the same source is occasionally found amongst the debris of burnt hay or corn stacks. I have seen a lump of glass produced in this way, and weighing several pounds.

The sugar-cane is—botanically considered—a gigantic grass; and the siliceous covering so sparingly developed in grasses of the temperate zone, here acquires so palpable a thickness, that small portions of such can easily be chipped off, either from the sugar-cane or the bamboo.

A horizontal, or transverse section, of the stem of the sugar-cane, if examined under the microscope, is seen to consist of a series of hexagonal cells in close juxtaposition. They are formed of a delicate tissue, which incloses them on all sides, in such a manner that each cell is altogether separated from the others to which it is contiguous. This structure is called the cellular structure, and is intermixed with another structure called the vascular, by which the nourishment for the plant's support is absorbed and circulated. (See cut, p. 48.)

Although it has been said that endogenous plants possess no *defined* bark, and the sugar-cane is no exception to the rule, yet this plant has a kind of pellicle, or rind; not separable, it is true, from the trunk, but indicated by its greenish colour, which depends on a portion of the general colouring matter of leaves, to which chemists apply the denomination *chlorophylle*.

The arrangement of vessels and cells already described, as observed in a transverse section of the cane, will be still more fully comprehended by reference to a longitudinal section, a diagram of which is annexed. By reference to this diagram, which represents a longitudinal section of the cane at the point where a knot is formed, it will be seen that, in addition to the cellular structure already described, there is another structure—the vascular. The use of the latter is to minister to the circulation of the plant, hence the vessels contain the crude sap of the



cane, which may be assumed to resemble very nearly the sap of plants in general, and which is, therefore, a very complex fluid: a circumstance very necessary to be borne in mind, as will hereafter be recognised.

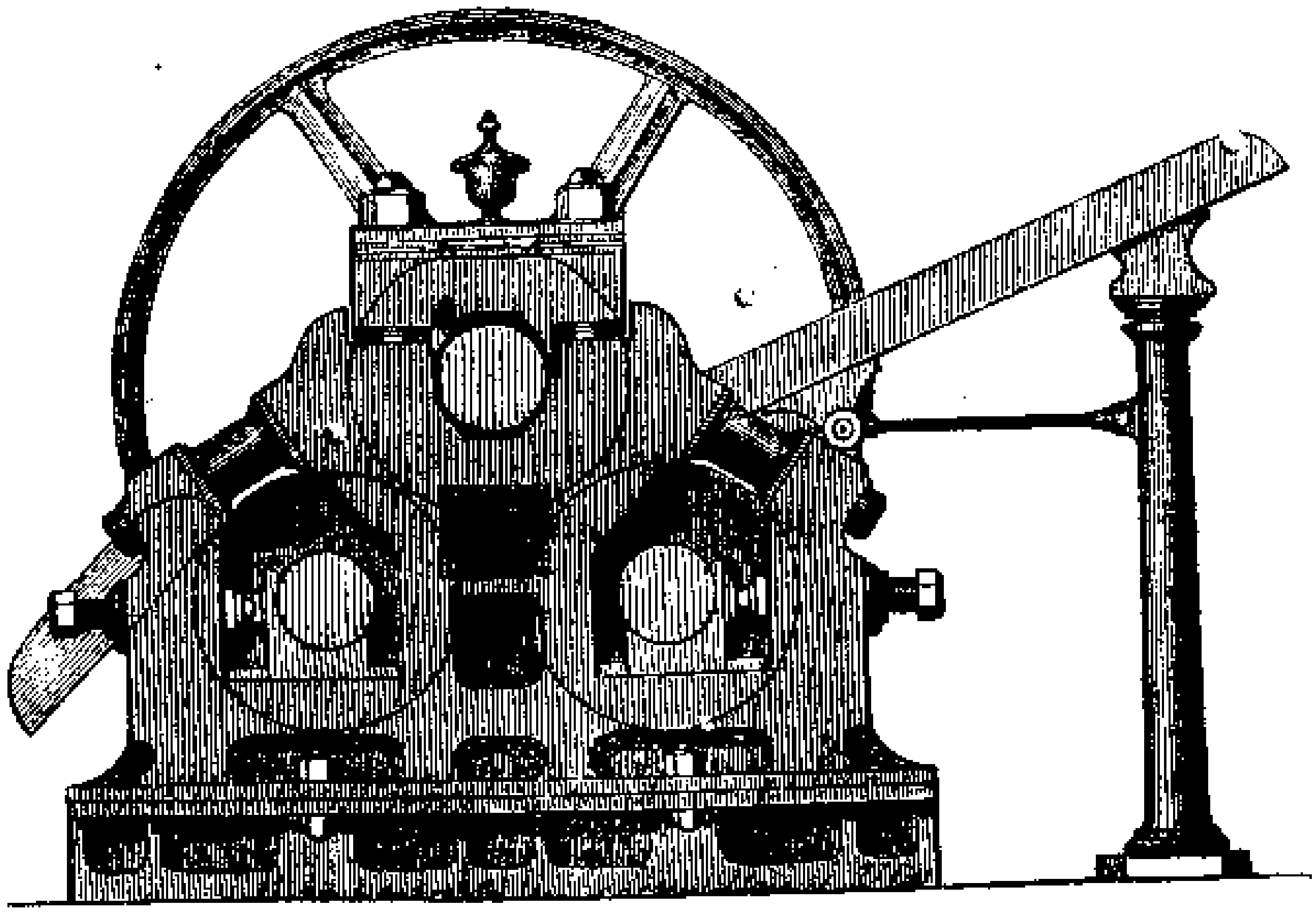
With respect to the hexagonal cells,—microscopic experiments have demonstrated that they contain a fluid which is little else than pure sugar dissolved in pure water. The problems to be solved, therefore, are either to extract the matter of the cells alone; or to express all succulent matter from the canes, and afterwards to effect a separation between the sugar and its accompanying impurities. The first indication seems most philosophical, and it is one which a chemist in his laboratory would prefer to follow out. Taking advantage of the property which albuminous matters possess of coagulating on the application of heat, and remembering that such matters constitute the larger portion of the crude sap of the sugar-cane, the laboratory chemist would proceed by slicing his cane, drying the slices in a proper stove, and washing out the contained sugar by means of alcohol. Even without alcohol he could succeed in obtaining a good result, hot water being a menstruum scarcely less eligible for effecting the solution; for albumen, when coagulated by heat, is no longer soluble in water.

Thus, at a first glance, the problem appears solved, even as regards the large scale; but a slight analysis of facts soon demonstrates the contrary. The first difficulty is one that would scarcely be imagined *à priori*. It is difficult, if not impossible, to use any slicing machine that shall not very speedily become blunted by the hard siliceous covering of the canes. Once blunted, the first object of the operation is lost; instead of a clean cut we have a bruise, and the saccharine cellular juice mingles with the sap: the grand objection to the usual squeezing of the mill obtains, without any of the mill's advantages. Then, how are sliced canes to be stove-dried in large quantities? Where is the necessary amount of hot water to come from? Where the fuel necessary to evaporate so dilute a solution as must result if the sugar be thoroughly washed out?

All these are practical questions, which the planter would do well to answer to himself, before making arrangements for the carrying out of this very philosophical, but impracticable, scheme.

Discarding the first of the two problems as incapable of a practicable solution, the second presents itself to our consideration; but as a preliminary, a few words concerning the mill and its operation will be desirable.

The sugar mill consists of a series of cylindrical rollers, usually three, between which the canes are pressed; the result of this operation is obviously to extrude not only the sugar—containing liquid, in the hexagonal cells—but also the complex vegetable juice of the vascular tissue, and also a portion of wax, which is secreted by certain little glands on the periphery of the cane nodules.



Hence, cane juice, or the fluid of expression, is a fluid of very complex nature; being made up of a great number of mineral salts, and of so many vegetable principles, that no perfectly trustworthy analysis of it is as yet recorded.

In a treatise which aims solely at being a guide to practice, it would savour of pedantry to expatiate on analyses which do not further the object to be kept in view. Without, therefore, entering minutely into the chemistry of cane juice, it will be sufficient for all practical purposes to consider, first, that it is made up of sugar, water, and impurities; and, secondly, that the prevailing or typical impurity is albumen.

Such is the fluid on which practical necessities oblige us to operate: and now the second problem is fairly before us for solution;—namely, to extract all succulent matter from the canes, and to effect a separation between the sugar and its accompanying impurities.

This separation must be effected beyond a certain extent, or the sugar existing in the cane juice obstinately refuses to crystallize on being evaporated; a circumstance not peculiar to sugar alone, but of almost universal occurrence in all parallel cases.

Thus the juice of limes, and lemons, contains a large amount of citric acid; a body which, though easily crystallizable out of an aqueous solution, obstinately refuses to crystallize until a great part of its associated vegetable impurities is removed. The method of this removal I need not describe, as it does not in the least resemble any of the processes which will effect the purification of cane juice. The object to be gained, however, in either case, is identical.

Considering that the leading impurity in cane juice is albumen, and considering that albumen coagulates by heat—it might have been theoretically inferred that a mere heating of the cane juice to a temperature sufficiently elevated to coagulate the albumen, would have left the sugar in a solution of sufficient purity to admit of crystallization: experiments, however, have demonstrated that such is not the fact, and have proved the necessity of adding to the juice some material, endowed with a chemical potency of effecting a greater separation of impurities than is possible by heat alone. The usual agent employed for this purpose is lime,—the mode of operation of which will be fully detailed hereafter.

We now arrive at a most important division of our subject; we have to examine closely into the changes which sugar is made to undergo by the combined agency of—heat, impurities, and lime.

This will best be accomplished by leaving for a period the consideration of cane juice, and by substituting for it a solution of pure sugar and pure water. This pure solution will be the starting point of all remarks on the more complex case, and will enable the following important agencies to be contemplated in detail; whereas in the actual colonial operation on cane juice they operate simultaneously. We shall have to study—

1. The changes effected on solutions of sugar in water by heat alone.

2. The changes effected on the same by the united agencies of heat and lime.

3. The changes effected on solutions of sugar, water, and impurities, by heat and lime (the colonial operation).

These considerations will form the subject of the next chapter.

CHAPTER V.

CHANGES PRODUCED ON SOLUTIONS OF SUGAR BY THE AGENCIES OF HEAT, LIME, AND IMPURITIES.

THIS important investigation will be approached with the greatest advantage, by an examination of the phenomena attendant on the crystallization, from a menstruum, of some body, which is not capable of decomposition by the agency of heat.

For this purpose no substance is better than common nitre. If a portion of this substance dissolved in water were given to an operator with the object of evaporating away all the water of solution, and leaving the whole of the salt unchanged—this could easily be effected:—The operator would simply have to apply heat to the solution, and the desired result would speedily be achieved. Whatever the amount of heat applied, no injury would occur to the salt, which would be found gradually incrusting the evaporating dish; and, by carrying on the process of evaporation to a sufficient extent, the whole of the nitre would be left dry. Under the circumstances, however, of rapid evaporation detailed, the salt would assume an imperfectly crystalline state; indeed, the chances are that no crystals would be visible.

Were the object to obtain the nitre in perfect crystals, the evaporation should be modified thus:—The evaporation should be stopped short at a certain point, and the hot liquid allowed to cool—the result of which cooling would be the formation of well-defined crystals. A portion of the liquor of solution, however, would still remain uncrystallized, until drawn off and subjected to a process of re-evaporation; when another crop of crystals would be formed, and another quantity of uncrystallized but crystallizable liquor would remain.

Upon the latter, the processes of reboiling and crystallizing might be repeated, until the total expenditure of the liquor of drainage; and with the result of obtaining literally the whole of the nitre employed—and crystallized, too; up to the period when the diminished amount of liquid to be evaporated and drained, furnished so small a mass, that the gradual cooling and perfect drainage, so essential to the production of good crystals, were conditions no longer under control.

The reader will have anticipated my coming remark, that this liquor of drainage stands in the same *mechanical* relation to nitre, that molasses does to sugar. Beyond this mechanical relation, however, the analogy ends,—as will be presently made known. If, instead of nitre and water, a solution of pure sugar in pure water be taken, and treated according to the scheme just indicated,—the results are as follow.

A portion of sugar crystallizes; but, instead of being white, as it was when dissolved, the crystals will have assumed a yellow tint, and the syrup of drainage will be more or less coloured. If this syrup be collected and evaporated there will result another produce of crystalline sugar still more yellow than the first, and the liquor of drainage from this second product will also have acquired a much darker colour than its parallel in the first operation. Proceeding in this way, there is at length a period arrived at, when the liquor of drainage becomes a dark-coloured viscid mass,—incapable of crystallizing at all.

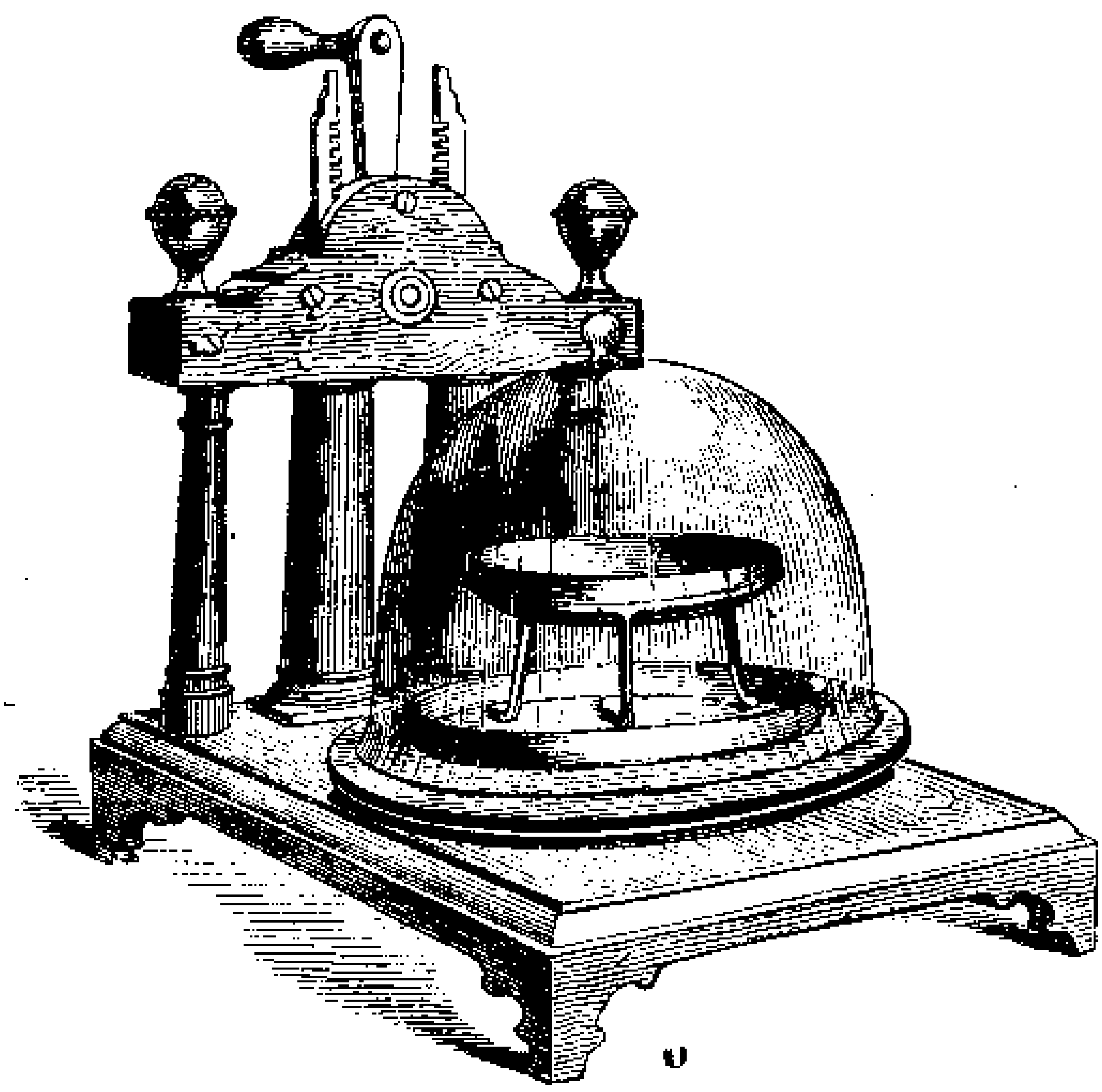
Thus, according to testimony of this experiment, it is impossible to extract, by the evaporative process (at least when heat is applied), the total amount of pure sugar dissolved in a quantity of pure water; a portion of such sugar being destroyed, and converted into a dark product.

If this operation had been conducted on a solution of sugar—not in pure water, but admixed with impurities of various kinds, such as coexist with the sugar in cane-juice; had the case been still more involved by the addition of a foreign agent, such as lime,—the experimentalist might have imagined the destruction of sugar just indicated to be exclusively due to the agency of the collateral bodies: an explanation which is obviously inapplicable to the conditions just detailed. Indeed, the experiment of Professor Soubeiran, mentioned at page 36, sets all doubt at rest on this point.

The agency of heat alone, being proved sufficient to effect a certain destruction upon a solution of pure sugar in water, it is an important point to determine the lowest amount of heat which is thus injurious; and whether a process of evaporation can be devised which shall not overstep that limit of temperature where the injury first commences.

In the laboratory, a chemist easily solves the problem; indeed, it involves a process which he very constantly applies to effect the evaporation or desiccation of many bodies,—so delicate in their nature, that a slight artificial temperature would subject them to decomposition.

The chemist would proceed by taking advantage of the fact, that to produce evaporation the removal of atmospheric pressure is equivalent in effect to the application of artificial heat. He, therefore, would put under the receiver of an air-pump a shallow saucer, containing oil of vitriol; over which he would place, on a convenient support, a dish containing the



sugar solution. A vacuum being now produced, the water of the solution would commence to be evolved as vapour; and this vapour would be immediately absorbed by the oil of vitriol. Thus, without any further working of the pump, a tendency to a vacuum would be kept up, until the sugar would have become dry, crystallized, and chemically unchanged.

I need not say that this process of evaporation is totally unadapted to any commercial case of sugar manufacture. A compromise, however, between two conditions, has been effected by the vacuum pan (an instrument hereafter to be described), which enables sugar solutions to be boiled in commercial quantities, under the joint circumstances of a partial vacuum, and a great diminution of temperature. The lowest practical temperature at which I have ever seen a vacuum pan worked is 135°; a temperature which I would, therefore, consider the practical minimum, but which is sufficient to effect a certain amount of destruction on sugar solutions.

Having recognised the fact, that the lowest practicable degree of heat for effecting the evaporation of sugar solutions, is sufficient in itself to produce a certain amount of destruction—it now remains to be shown how much this amount of destruction is increased, by the concomitant agency of lime, and impurities.

Proceeding in the demonstration systematically, I will assume a portion of white sugar to be dissolved in water, admixed with lime, and then boiled. If this operation be performed, the eye alone will recognise the fact, that a destructive process supervenes to a far greater extent than when a mere solution of sugar and water, without the addition of lime, was employed. Not only does the fluid become dark with increased rapidity, but it exhales a newly developed smell, indicative of some process of decomposition effected upon the sugar. If, moreover, the crystallization of the limed liquid be attempted, a further proof of destruction will be manifest in the increased amount of non-crystallizable material, which leaks away from the crystallized mass.

These are but rough indications of the injury to which sugar is exposed when solutions containing it are heated in combination with lime—indications which are so visible to all who have seen the operation performed, that there exists not a sugar producer, so far as my experience goes, who does not fully recognise the powerfully destructive agency of this alkaline earth. Nay, in the absence of other testimony, the multitude of contrivances which have, from time to time, been introduced to public notice, with the express intention of either diminishing indefinitely the amount of lime to be used, or of reducing the quantity to some definite standard—would be ample evidence in support of the position, that lime is commonly recognised to be a most destructive agent on sugar.

The minute chemistry of the agency of lime on sugar solutions, would be somewhat out of place here. So much of this agency as is necessary for the guidance of a practical sugar manufacturer has already been given in other parts of this treatise*.

* See *Glucic Acid*, p. 17, also p. 36, and foot note, p. 40;—also Preface.

Having successively examined the agency of heat on a pure solution of sugar and water,—and on the same with admixture of lime; we have next to investigate the complex changes which occur during the treatment by heat of sugar solutions mixed with vegetable impurities and lime.

That the cases selected may be consecutively demonstrative, I will suppose the experimentalist to contaminate a portion of pure sugar and water with some raw vegetable juice—that of raw parsnips, for example. Thus contaminated, the solution will be amenable to a new series of chemical decompositions of greatly increased complexity; of which the following are the most remarkable, and of greatest practical value, to be well understood, and remembered.

The first great influence exerted on sugar solutions by the presence of raw vegetable juices generally, is that of causing various fermentations. Thus, although solutions of pure sugar in water may be allowed to remain exposed to temperatures most conducive to fermentation for days, and even weeks, without any perceptible effect of this kind, yet the addition of very small quantities of these raw vegetable juices causes them, under the same circumstances, readily to assume fermentations accompanied by the destruction of sugar, and the formation of lactic acid, mannite, glucose, alcohol, acetic acid, and many other derivative bodies.

This factitious juice, made up of sugar, water, and the juice of raw parsnips, presents a very near analogy to the juice of beetroots, from which sugar may be extracted—and offers no very remote resemblance to sugar-cane juice itself; many chemical properties of which liquid may be correctly studied on this factitious compound.

If a portion of this compound saccharine juice be evaporated with all care, and with the view of effecting its crystallization,—the labour will be in vain. Until some of the impurities, at least, are separated, no crystallization will ensue.

If this factitious juice be a true practical representation of cane and other sugar-containing juices, it is quite evident, that the experiments cited have demonstrated the positive necessity of separating a considerable portion, at least, of the accompanying vegetable impurities, as a preliminary to obtaining the sugar in a crystalline form. Hence the following proposition is at once brought before us:—*Given, a mixed solution, of sugar, water, and impurities—how practically to separate all but the sugar, with the least expense and the least delay.*

This is the grand problem, upon the perfect solution of which every advance towards perfection in the manufacture of sugar hinges.

As the usual agent employed in sugar-growing countries, for effecting this separation of impurities from raw sugar-containing juices—is lime, employed in some manner or other, it will be proper, in this place, to examine its agency on the factitious juice.

If, then, a portion of the juice be admixed with a portion of lime, (rubbed with water into the condition of cream, for convenience of employment,) and then heated, the following changes will be seen to occur.

When the heat has been pushed to the extent of 180° Fahr., a black crust of impurities will be seen to have collected on the surface of the juice, from which it may be skimmed off,—leaving the subnatant liquid comparatively clear and bright, but much deeper coloured than it was originally.

If this fluid, thus freed from the scum thrown up by the agency of lime, be now evaporated down to the proper degree, crystallization will be effected;—and substituting cane juice for the factitious juice, here assumed to have been employed, the reader will have had brought before his notice the exact conditions of sugar boiling in the colonies.

Although in the preceding experiment the scum might have been removed from the juice treated with lime, so soon as the temperature arrived at 180° Fahr.;—although the subnatant liquor might then appear to the eye perfectly clear and bright,—yet it is not difficult to prove, by many different kinds of evidence, that this brightness or clearness of the liquor is a most fallacious sign of its purity. The first evidence to this effect, is the very strong one, that fresh coats of scum continually arise as the evaporative process goes on,—a result which never happens in solutions of pure sugar and water. A second testimony to the same effect is afforded, by the action of certain chemical tests, which are known to be endowed with the power of throwing down vegetable impurities. The acetates of lead are agents of this kind.

Thus far, the agency of lime has been demonstrated to be defective,—but the worst has yet to be told. Even conceding, for the sake of argument, that there is a certain theoretical relation, between a definite amount of vegetable impurities and the quantity of lime necessary for effecting its removal (which is not the case), still this relation would vary for almost every sample of juice; and no amount of care, or talent, or appliances, could accomplish this exact apportionment. The manufacturer would, therefore, even under this assumption,—the one most favourable to the employment of lime,—be continually obliged either to choose between adding too little of that agent, or too much; actual neutralization by apportionment being amongst the most difficult of laboratory operations, and one totally impracticable on a large scale.

A few remarks will be necessary here, relative to the assertion, that no theoretical relation *does* exist between the quantity of lime and the quantity of impurities to be separated. It will be intelligible when we consider that the removal of impurities effected by lime is not one of *combination*, but one of *determination*, and hence is influenced by such varying conditions of heat, density, solution, and other circumstances, that to calculate the chemical resultant of so many conflicting forces would be an impossibility. On this point the following may be taken as a practical exemplification. If a pint of cane juice, under the proper conditions of temperature, be treated with ten grains of lime, a scum will form; which, if separated by filtration, or otherwise, a clear, though high coloured, fluid will result. If this fluid be now examined for lime, considerable quantities of it will be discovered by the proper chemical tests for that alkaline earth;—a fact which might lead to the inference, if not checked by other observations, that more lime had been employed than was absolutely necessary, for the separation of the impurities present.

Nevertheless, it can be proved most unequivocally by chemical tests (the acetates of lead, for example), that not merely a large amount, but the *greatest amount,* of the original impurities still remains. This testing operation demonstrates, that there is not even a theoretical relation between the amount of impurities present, and the amount of lime most proper to effect their separation; because the agency of lime is indirect, not direct,—because it does not effect any separation by *combination*, but by *determination*. To place this matter in the strongest point of view, the following case may be cited.

If sixty-three parts by weight, exactly—of ordinary crystallized oxalic acid* were to be dissolved in water, and if it were required only to separate the oxalic acid absolutely by means of lime, without employing more than the amount required of the latter agent, the problem would be solved with the greatest ease. Every tyro in chemistry knows that for effecting this separation—twenty-eight parts by weight, *exactly*, of lime would be the proper quan-

* It is necessary to be precise in this expression. There are two substances known as crystallized oxalic acid, both of which are really combinations of oxalic acid with water. The ordinary crystallized oxalic acid is composed of one equivalent of real or dry oxalic acid, and three of water; and the other of one equivalent of real or dry acid, and one of water. Dry oxalic acid has never been obtained, although it may be caused to unite with certain bases, and thus be demonstrated to exist. In the experiment above cited, it exchanges its water for lime, with which it unites. The expression, dry crystallized oxalic acid, is absurd.

tity; which being added, a solid, and insoluble, combination of the lime and the oxalic acid would result—would deposit; and the remaining liquid would be water absolutely pure.

If the impurities which contaminate cane juice, and other natural sugar-containing juices, assumed the tendency of forming a direct, invariable, and determinate, power of combination with lime, an exact theoretical relation between the relative quantities of the two, necessary for effecting combination and separation, would exist; but as such theoretical relation is totally opposed to the actual conditions,—the arguments founded upon the contrary assumption fall to the ground.

If we cursorily pass in review the experiments detailed in this chapter, with the object of eliciting from them their legitimate deduction, we shall be led to the following important facts:—

That impure, or crude, sugar-containing juices refuse to crystallize, until a large portion of their accompanying impurities has been removed:—That, moreover, such juices are very prone to undergo fermentation; hence the removal of such impurities is of the first importance:—That lime will effect the removal of such an amount of the impurities as will admit of subsequent crystallization:—That it is impossible to add lime in such a manner that some of this agent shall not remain. Hence, that even under the most favourable supposition; namely, that the use of lime has removed all impurities (which is not the case); still, the resulting liquor will not be sugar and water, but a mixture of sugar, water, and lime.

But, it has been demonstrated, that if a solution of sugar, water, and lime, be boiled together, the sugar is rapidly destroyed. Hence it follows—that lime, when used as a purifying or defecating agent for crude sugar-containing juices, is, under any circumstances, a most destructive agent, and that some better agent is a desideratum.

It will have been clearly indicated, moreover, that any rational attempt to limit the injurious agency of lime, will be in the direction,—not of primarily apportioning the amount of lime to be used, but of separating, by some agent not injurious to sugar, all excess of the agent which may remain in the cleared or defecated liquor. This, so far as I am aware, is an impossibility*. Moreover, if there be question of separating any excess of defecating agent, the practical chemist will turn his attention to an agent of far greater efficacy, as a defecator, than lime—an agent which long since would have been employed in the sugar manufacture, if any means for separating it had been known.

In detailing the prominent effect of the agency of lime, on sugar solutions, both pure and mixed,—I have purposely avoided all chemical remarks as to the rationale of this agency; from the conviction—

* That is to say, in practice—on the small scale, and by the exercise of great care, lime may be separated with such exactitude even by oxalic acid, that the sugar shall not be perceptibly injured. But a still better plan consists in the use of sulphurous acid, under circumstances which, having noticed in May 1848, I caused to be printed in the summer of that year, and have subsequently taught in the laboratory.

that they would little avail the practical sugar producer. In point of fact, the agencies thus brought into play are so multifarious, so complex, or so ill understood, that even a full recapitulation of all that is known on the subject, would be of but little use.

The general rationale of the agency of lime on pure solutions of sugar and water may be grasped, by remembering:—That sugar is a body of acid reaction:—Hence, that it readily combines with bases:—That under the agency of lime and heat it readily yields glucose, which substance is also possessed of an acid quality. Finally, that glucose, under the prolonged action of lime and heat, rapidly changes into glucic, melasinic, sacchulmic, and sacchumic acids, besides many other imperfectly known bodies.

The action of lime and heat, on the impurities existing in sugar-containing juices, is referable to the property which albumen and several other organic bodies assume, of becoming to some degree insoluble, when they are exposed to incipient destruction.

Thus, all that can be stated on this point amounts to the simple expression of the fact—that lime determines the separation of a certain amount of the impurities existing in crude sugar solutions.

One important remark, however, relating to the use of lime as a defecatory agent, cannot be too strongly impressed upon the sugar grower. It is this: that whatever the rationale of the employment of lime, in the sugar-boiling operation on raw juices, may be—it is certainly not that, as is frequently stated, of neutralizing acidity. The term acidity is here to be understood in a general sense as relating to such acids as the acetic and lactic. In strict chemical language the term acid is extended even to sugar itself.—(See Def. Acid, p. 17.) Were there no greater necessity for using lime than this, it is clear that chalk would be a most efficient substitute; for whilst it would be equally potent with lime in neutralizing acidity, it could be employed in any quantity without fear of injury. The agency of lime on solutions of Muscovado, or other impure sugar and water, has purposely been omitted here, inasmuch as it will be discussed with the greatest propriety under the head of refining. It is well to remark, however, that there is no similarity between the kind of impurities existing in raw juices, and those in coloured sugars. The former chiefly consist of albuminous bodies natural to the juices; the latter of glucose, glucic, melasinic, sacchulmic and sacchumic acids, generated by the action of heat and lime on sugar.

CHAPTER VI.

THEORETIC INDICATIONS TO BE FOLLOWED OUT IN THE EXTRACTION OF SUGAR FROM RAW SUGAR—CONTAINING JUICES; AND VIOLATION OF THESE INDICATIONS, IN THE PRESENT PROCESS OF SUGAR MANUFACTURE.

A CONSIDERATION of the deductions arrived at in the previous chapters, leaves no doubt existing as to the proper indications to be followed out, in the extraction of sugar from raw sugar-containing juices. I might have said, indication,—for every subsidiary matter tends to the one great end, of reducing the complex saccharine juice, with all possible haste, to the condition of a solution of sugar in water.

Although, in practice, the sugar producer will never attain this theoretical summit of perfection, yet he should always regard the various stages of his manufacture from that assumed point of view:—which, if never permitted to be varied,—never allowed to be overcast with vague doubts,—each succeeding well-directed experimental effort will assuredly lead nearer, and nearer, to the truth. If once departed from, however—if once the sugar-extracting operation be viewed from other directions, though apparently nearer to the mark,—then the whole perspective of the theory is gone;—confusion takes the place of order, doubt of precision, fallacy of facts;

—the reasoning process breaks down, and all attempts to emerge from the mental chaos are in vain.

The great aim to be kept in view during the process of sugar extraction, being the removal with all due haste of every thing except sugar and water, the subsidiary indications are, to evaporate the latter at the lowest temperature, consistent with practical necessities,—and to effect crystallization in accordance with the rules laid down in Chapter II.

In carrying out the first or grand indication, it is evident that we should seek for some defecating or purifying agent which is either capable of being totally removed from the sugar solution,—or which, if allowed to remain, should be productive of no injurious tendency.

The latter alternative, however, would be a mere compromise; as by admitting it we immediately violate, to some extent, the grand condition of procuring an unmixed solution of sugar and water.

Having thus sketched the theoretical indications which science proclaims as necessary to be carried out, in the manufacture of sugar from raw juices, I will now offer such a general summary of the method followed in the sugar-producing colonies, as shall enable the reader to appreciate the extent to which the above theoretical conditions are violated.

It must here be premised, that, although the plan of colonial sugar manufacture for all countries is essentially, up to a certain stage, identical, yet, when various colonies are compared as to the respective process of sugar extraction followed by each,—a casual observer might imagine the existence of distinctions as essential, which in reality are merely collateral; and which involve no difference of principle whatever. As it would be exceedingly inimical to exposition of principles, to break in upon the current of observation, for the purpose of announcing mere collateral discrepancies between the machinery, or the processes, of different colonies—I will here observe that, in describing the general operation of colonial sugar manufacture, in reference to the fulfilment or the violation of theoretic indications, I shall select, as typical of colonial operations in general, the process now usually followed in the West Indian islands.

Much has been written, and with great justice, on the very imperfect expression of juice from the canes by the process of mill crushing. Although experiments have demonstrated the sugar-cane to be made up of 90 per cent. on an average of juice, and 10 per cent. of woody fibre, it appears that the average amount of juice expressed by the mill is not more than 50 per cent.

The proper method of obviating this great loss of raw material is altogether a matter for the consideration of the engineer, and does not come within the sphere of chemical comment.

The juice as it comes from the mill is with as little delay as possible treated with lime, as follows, in order to effect a partial purification:—

The overseer* commences his operations by putting

* "The man at the clarifier first raises by heat the cane juice to a temperature of about 180°, at which time a dark scum forms at the top; he then throws into the heated juice a small portion

into a series of wine glasses some of the juice to be defecated.—He then adds to each in succession a portion of lime,—either previously mixed up with water, or with syrup, to the consistence of gruel or thin pap. Immediately the contact is effected between the lime and the cane juice, a discolouration of the latter ensues; the amount of discolouration varying (*cœteris paribus*)—in direct proportion to the quantity of lime employed. Having added a different quantity of lime agent to each of the glasses, the operator judges by the resulting tint, which result is the best, and he is guided accordingly by this evidence, as to the quantity of lime he shall add to the general stock of juice to be defecated.

The amount of lime being determined, it is added to the juice in a copper, or an iron vessel, hung over a fire. Sometimes this vessel is the last of a range hung over one long flue; sometimes, on the contrary, it is heated by a separate fire. In either case its contents are heated to about the temperature of 180° Fahr., when a thick crust of impurities forms upon the surface of the liquid and begins to crack. The fire is now damped, and the crust removed by skimming; occasionally*, however, the clear liquid is drawn off by a racking-cock from underneath.

of cream, or milk of lime. After waiting two or three minutes, until the scum again forms over the surface, he dips out a wine-glassfull, and if he sees the mucilage form in well-defined flakes and rise to the top, leaving a clear liquor of a pale amber, or Madeira wine colour, he is satisfied; if not, he adds more lime; but if he finds that the mucilage will not coagulate thoroughly without such an amount of lime as would deepen the colour naturally, he stops, and trusts to the skimming."—*Moody*.

* "Almost always—I never saw the other done except with

In order that the full defecating agency of lime shall be exerted, it is necessary to apply a greater heat than 180° Fahr.; the liquid, in fact, should be brought to the boiling point. Here, however, there is a difficulty:—immediately on the commencement of ebullition, the supernatant crust becomes broken into fragments, and mechanically incorporated with the fluid so intimately, that it can no longer be removed by skimming, but requires a filtration process to be had recourse to.

The process of clearing or defecation having been effected, and the crust separated by skimming, racking, or filtration, the process of boiling is commenced. A series of copper or iron pans, diminishing in size as they approach the fire grate, and usually four or five in number, are hung over one common flue, or rather fire-place, in which the canes, after their juice has been expressed, are burnt as fuel. This fuel generates a very powerful blast of flame, which not only plays under each of the series of pans, but may be even seen to escape from the chimney.

This plan of hanging many consecutive boiling pans over one common flue is in itself most improper. It was first introduced with special reference to the peculiar kind, and the limited amount of fuel at the operator's service, and would appear to be persisted in chiefly in deference to old opinions and customs.

*The pans, too, are usually so deep, that great vio-

steam clarifiers in St. Croix, where they first take off the crust, then add lime afterwards, boil and skim in the clarifier."—*Moody.*

* "The arrangement of the fire and the size of the pans depend on the principle that the juice must *simmer* to allow of

lence is done to the rule, that the amount of evaporation, other things being equal, is in proportion to the extent of surface of the liquid to be evaporated.

The cane juice having entered the first of these evaporating pans, the process of evaporation begins. At this stage, the juice is merely brought to a slight simmer, the heat applied being usually insufficient to cause it to boil rapidly. On the surface of this and every other pan in the series, a scum arises, which from time to time is removed by the process of skimming, and put aside for the purpose of yielding rum hereafter.

After the evaporation in the first pan of the series has proceeded to the desired extent, an attendant ladles its contents into the next—in which, and in every subsequent one, until the last two, the process of skimming is repeated*. Eventually the juice (now a syrup) is ladled into the teache, or last boiling pan, wherein it is at length brought to that degree of concentration judged most proper to admit of subsequent crystallization.

It would be impossible by mere description to convey an idea of the manifestations of the proper degree of boiling having been achieved. The peculiar sound which the syrup emits when dropped from the ladle into the general contents;—the resistance it offers on being stirred;—the peculiar appearance of its bubbles;—all afford good indications

efficient skimming. If it *boils*, the skimmer cannot *catch* the *scum*."—*Moody*.

* "In the last two teaches the scum is brushed back into the preceding one, the liquor being too sweet to lose."—*Moody*.

to the practised boiler: but the evidence most generally followed is that which also the refiner avails himself of at home, namely, the proof of touch. A drop of the syrup being placed between the thumb and forefinger, and the two separated, a thread of syrup is formed, of varying length, and varying tenacity, according as the syrup has been more or less boiled. In this thread, also, crystals are occasionally seen, the presence of which affords valuable evidence. In the process of vacuum-pan boiling, these crystals are the operator's surest guide.

From the last, in the series of evaporating pans, the *teache*, or *tayche*, as it is called, the inspissated juice is ladled into shallow wooden vessels termed coolers; seldom more than eighteen inches deep; where it is allowed to accrete into a semi-crystalline mass.

These shallow coolers have been loudly and justly reprehended, as most inimical to the formation of crystalline sugar; and certain it is, that a chemist, if made to draw an inference from their appearance and necessary effect, without any collateral guide,—would be constrained to infer, that in the West Indian sugar-manufacturing operation—*perfect crystallization was a result to be avoided!*

In these shallow coolers the accreted mass is allowed to remain, until it has acquired sufficient consistency to admit of its being dug out, and carried away, in buckets, to the curing-house, without leaking entirely away. In this curing-house it is put into casks, with perforated bottoms, each hole being loosely stopped by the stem of a plantain leaf;

and through which the uncrystallized portions of the mass, at least in part, leak into the molasses tank.

This is the ordinary plan followed; but it is subjected to many modifications, in different places.

As might have been inferred from a consideration of the plan of curing the sugar just described, the badly crystallized mass yields up its non-crystallized portion with great difficulty. The process of curing or drainage occupies, in general, many weeks; and, even at the expiration of that long time, is so incomplete, that it is not unusual for some 20 per cent. of the weight of a hogshead of sugar to leak into the hold of the ship on its way to Europe, and to be pumped into the sea. In a recent case which came under my notice, 25 per cent. had thus been lost, and the master of a trading vessel* informed Dr. Evans, as I am told by this gentleman, that his ship was often one and a half foot deeper in the water off Barbadoes than when arrived in the British Channel.

In order to expedite this process of curing, recourse is had on some estates to the expensive contrivance termed a pneumatic chest. This instrument consists of a chest of iron, or copper, supplied with a false bottom, either of finely-perforated plate or cane-wicker work;—on which the sugar to be acted upon, for the purpose of drawing off its molasses, is put. Under this false bottom is a space which communicates with a powerful air-pump;—by the action of which, a partial vacuum can be pro-

* Captain Fowlis—who estimated the loss from this cause at from 3*s.* 6*d.* to 4*s.* the cwt., or 3*l.* 6*s.* to 4*l.* the ton.

duced, the tendency of which is to draw the more liquid portions of the mass through the falso bottom.

The effect of such a contrivance as this, when made to act upon a badly crystallized sugar, need not be indicated. Not only are the uncrystallized portions drawn into the reservoir, but also a large amount of the small ill-developed crystals.

A pneumatic chest, to be really useful, should be employed upon a well-crystallized sugar—a material which, as a general rule, drains perfectly well of itself, without any mechanical aid whatever.

The process of sugar manufacture here described is, as was previously remarked, the typical one of the West Indies; it has, however, been modified in various ways. Thus, as regards the boiling range, instead of pouring the juice from one pan to the next in order, by the process of dipping, the pans in some ranges have been furnished with valves, to admit of the passage of the fluid towards the teache. Ranges of this kind have been frequently heated by steam.

Several modifications (some, unquestionably, improvements) have been made on the teache, chiefly with the view of reducing the period during which the concentrated syrup is allowed to remain exposed to the agency of the fire. One of these modifications consists in an addition to the teache, of an internal hollow core exactly fitting it, and supplied at its under part with a valve, opening inwards. This core, technically called a "skipper," being dropped from a crane into the teache, the contents of the latter open the valve, and rushing at one gush into the core, may be removed bodily, by raising the core through the medium of the crane.

Another good modification of the teache has been introduced by the French into some of their colonies. It consists in altering the form of the teache into the shape of a coal-scuttle, the lip of which rests in such a manner on a pivot, that, at the proper time, the whole teache may be raised by leverage, and its contents poured out. This kind of teache is called a *bascule*.

Amongst the essential modifications which have been attempted from time to time on the colonial manufacture of sugar, with variable amounts of success, may be enumerated the following:—

1. Filtration of the raw juice.
2. Filtration of the defecated juice.
   a. Mechanical.
   b. Chemical (through animal charcoal).
3. Improved methods of defecation.
4. The use of the vacuum pan*.

If the impurities which are so inimical to the crystallization of sugar out of the crude juice, were merely of a mechanical nature, a process of mechanical filtration would be reasonable enough; but if those impurities be really of a chemical nature, then such mechanical filtration is entirely out of

* The processes of claying and liquoring, under whatever modification, are here purposely omitted, as not being improvements of the sugar manufacture—but merely an extension of that manufacture beyond the usual colonial limits, into the art of the refiner.

place. Accordingly, the process of preliminary filtration is spoken of with universal discontent by all who have tried it. Not only is it totally inefficacious in effecting the end desired, but it is productive of much positive harm. It has already been remarked, that raw vegetable sugar-containing juices are most susceptible of fermentation; hence the operation of filtration, even if productive of benefit in this stage, should, to be useful, be most rapidly conducted. Now this is impossible,—for chemists very well know that raw vegetable juices in general, even although thin and limpid to the view, pass through filtering tissues most tardily. Add to this the amount of porous surface, moistened with fermentable liquid, exposed during the operation to atmospheric influences; and it will be readily understood that preliminary filtration is most fatal to the interest of the colonial sugar-maker. I would, by no means, extend this remark to a rough process of straining, at this stage, for the purpose of removing broken pieces of cane, fragments of leaves, and other mechanical impurities, which might somewhat inconvenience future operations. Such an operation, however, is not one of filtration, but of straining.

Should the process of mechanical filtration be executed after defecation? As a general rule, doubtless this question should be answered affirmatively, as being a step in the right direction; but so long as lime is used as a defecator, the process of filtration will be deprived of half its value. Not only is the flocculent scum developed by lime most unfavourable to the process of rapid filtration, but the advantage gained is more specious than real, inasmuch as so many impurities still remain in juices defecated by lime, that, although the act of filtration may have yielded a liquor of great brightness, it becomes turbid, and throws up more scum on the further application of heat*.

With regard to filtration through animal charcoal, it can never be profitably applied to the treatment of raw juices, or those as have merely been exposed to the process of defecation, without subsequent concentration. It has been demonstrated, that this agent produces its maximum effect on sugar solutions of about the density of 28° Beaumé; hence, if employed at all, it should be at the interval between the last boiling-pan and the teache. Numerous experiments, however, have convinced me that animal charcoal should never be employed in the colonies for the purpose of making any but absolutely white sugar. The beautiful straw-coloured tinge, so admired by grocers, and which all sugars by a proper system of defecation can be made to assume, animal charcoal has a tendency to destroy—imparting a disagreeable neutral tint in its place.

The expense of using animal charcoal, too, in the West Indies being somewhat about £2 per ton of

* "The sliminess which affects the bag filters is a great disadvantage to charcoal filters. I have known the charcoal frequently clogged; and, when washed with care and placed in open casks for collection for re-burning, ferment to such a degree as to char the casks, and reduce the value of the charcoal by a considerable production of white ash."—*Moody*.

sugar, is in itself a most serious obstacle to its general adoption.

The last essential improvement introduced into the colonial sugar-manufacture is that of the vacuum pan, an instrument which merits so full a description, that this shall form the subject of a separate chapter.

CHAPTER VII.

THE VACUUM PAN.

At the ordinary level of the sea the atmosphere exerts a pressure of 15 lbs. on every square inch; and, whilst exposed to this pressure, water boils at a temperature of 212° Fahr.*

If, however, by means of the air-pump or otherwise, a portion of the atmospheric pressure be removed from the water's surface, then the degree of heat necessary to effect ebullition is reduced—reduced, too, in a known and definite ratio, so that for every pound of atmospheric pressure taken off, a proportionate diminution of the boiling temperature is accomplished.

Not the most perfect vacuum which we are capable of forming, is sufficient to cause water to boil at ordinary atmospheric temperatures without the application of any extraneous heat—simply because water is not a fluid of sufficient volatility. If ether, however, which is a far more volatile liquid, be exposed to the same treatment, it boils with violence: water under similar circumstances would merely be rapidly given off in the form of vapour.

* In a metallic vessel. Gay-Lussac has proved that water boils at 214° in one of glass; owing, apparently, to its adhering to glass more powerfully than to a metal.

The rationale, and also the laboratory practice of increased evaporation under diminished pressure, has already been explained*. It now remains to be stated, that the vacuum pan is merely an instrument which unites to the principle of evaporating under diminished pressure, the application of a certain, but comparatively small,—amount of artificial heat.

To the Honourable Mr. Howard we are indebted for the invention of this most useful instrument †, which has already effected such improvements in the home refinery process, and which is destined before long to extend its ameliorating influence to the colonies abroad.

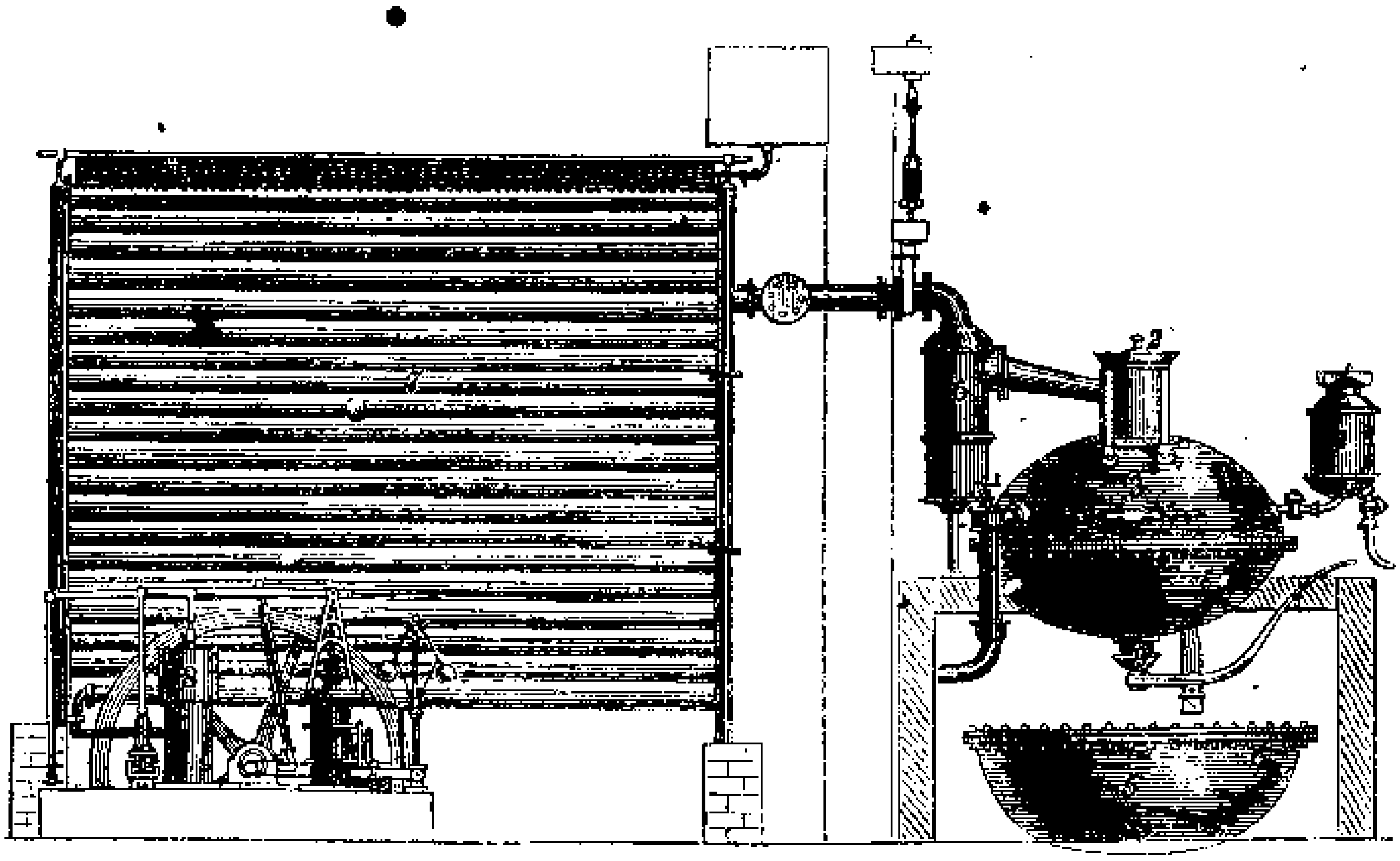
The vacuum pan may be described as composed of two copper segments of spheres joined together at the edges. The lower hemisphere is imbedded into a steam jacket or space, into which steam, of a varying pressure up to 3 lbs. to the inch, can be forced; and in order to increase the area of heating steam surface beyond the amount furnished by the lower segment of the pan, there passes internally a coil of copper pipe, through which a current of steam may be made to rush. It is obvious that any liquid put into a vessel of this kind, will be exposed to so large an amount of heating surface that it must soon arrive at its boiling point; but the vacuum producing part of the apparatus has yet to be described. Attached to the pan at its upper part is a pipe of communication, with a cylindrical vessel called a

* See note, p. 58.

† His patent was taken out in 1819.

condenser *, and which is exactly similar to the condensing apparatus in a low-pressure steam engine; consisting either of a means of injecting a gush of cold water through a series of minute holes, which plan is called that of direct condensation, or else of a series of small tubes exposed to the external agency of water—a plan denominated that of indirect or tubular condensation. Beyond this condenser, and communicating with it, is a powerful air-pump.

The accompanying woodcut, however, represents a condenser (7) of a different and more effective kind. It is the external condensing system of Messrs. Pontifex.



* Between the vacuum pan and condenser is a vessel destined to contain any solution which may boil over. This vessel, however, theoretically—may be considered as a mere expansion of the vacuum pan. This is indicated in the diagram by the figure 6. The other portions of the apparatus are as follow: (1) the measure, (2) the man-hole, with ground cover, (3) vacuum pan, (4) proof stick, (5) heater, (7) condenser, (8) steam-engine and air-pump, (9) escape valve of the vacuum pan, through which its contents pass into the heater.

The action of this apparatus in the aggregate will be as follows:—The pan being filled to the desired extent with sugar solution to be evaporated, steam being let on to the jacket and into the coil, the temperature of the liquid continues to rise. Meantime the air-pump being set to work, a partial vacuum is produced, and the atmospheric pressure exerted upon the syrup in the pan is gradually lowered to such an extent, that the liquid begins to boil.

The vapour resulting from this ebullition passing into the condenser, is exposed to the agency of cold water, and immediately assumes the liquid state; finally, this condensed water is drawn off by the *air* pump, as it is called, although the instrument performs the mixed function of pumping both air and water.

Such are the essential portions of the vacuum pan, but certain accessory parts are yet to be described. The most important of these is the appendage called the proof stick, a contrivance by means of which the operator can from time to time remove and examine a portion of the evaporating syrup, without the least destruction of the partial vacuum. Attached to the copper segment of the pan is a thermometer, for the purpose of indicating the temperature of the syrup, and also a vacuum gauge, as it is technically called, an instrument on the barometric principle, by referring to which the amount of atmospheric pressure exercised at any period on the evaporating liquid can be at once read off. On the summit of the upper segment of the pan is a man-hole*, supplied

* The aperture through which a man enters the vacuum pan for the purpose of cleaning it.

with an accurately ground cover, and by the side of it an entrance for each successive charge of liquor, which passes from an adjoining vessel of determinate capacity called the *measure*.

At the lowest part of the under hemisphere is situated a valve, through which the sugar solution, when sufficiently boiled, is allowed to escape into another vessel called the heater, or occasionally the cooler*.

This heater may be compared to the lower segment of a vacuum pan, minus its coil, being a copper pan imbedded in a steam jacket, by the agency of which a graduated heat may be applied.

The use of this instrument is to allow the conditions of time and prolonged fluidity for the more perfect development of those crystals, the formation of which had been already commenced during the operation of vacuum boiling.

Fuller details of the employment of the vacuum pan and its accessory, the heater, will be given under the head of "refinery operations,"—such a general account of these instruments merely being here given,

* The indifferent application of the term heater and cooler, the one for the other, is curious, although easy to be explained. So long as sugar solutions were boiled in open pans under the ordinary atmospheric pressure, and at a temperature of 220° and upwards, the vessel in which the boiled liquor was allowed to assume a temperature of 176° might appropriately enough be denominated a cooler. But under the process of vacuum-pan boiling, at a temperature of about 140°, this vessel, in which the latter degree of temperature becomes changed to 176°, as before, is to all intents a heater; still the old name is in many refineries maintained.

as might suffice for the purpose of investigating the advantages, and disadvantages, of the colonial operation of vacuum boiling.

It is a subject of much surprise to many persons who have witnessed the results of vacuum-pan boiling at home in refineries, that when used in the colonies it has been productive of such ambiguous results. This surprise will vanish when we consider the conditions under which a vacuum pan can be profitably worked, and how difficult of attainment these conditions have hitherto been in the colonies. However objectionable in most points of view the ordinary colonial evaporating process may be, it, nevertheless, is well adapted to the end of removal of impurities by surface skimming—an operation which is totally impracticable when the vacuum pan is employed. Hence, although this valuable instrument exercises the full amount of its well known and legitimate influence—although it may effect evaporation at the practical minimum—although an experienced boiler may be present to *strike* or let off its contents at the proper time; still, the result of boiling an impure juice in vacuo will in all cases be—an impure sugar.

This fact is at length becoming so well recognised, that a gentleman of much practical experience, as an engineer in the West Indian colonies, informs me of a resolve he had made, never again to set up a vacuum pan on any West Indian property, (save a few exceptional estates on which the juice was remarkably pure,) except under a guarantee that the juice should have been submitted to charcoal filtration—this being the only means, at that period known to him, as capable of effecting the necessary amount of defecation.

It may very safely be asserted that the great utility of the vacuum pan has yet to be demonstrated to colonial sugar growers. Hitherto, even on estates where it has given a qualified satisfaction, the true genius of the instrument has been altogether misunderstood. Instead of aiming at the production of a well crystallized result, mixed with a thin syrup of drainage, or molasses, admitting of easy removal, and then leaving the sugar almost dry, the general aim of the colonial sugar-maker has been to produce, by high or stiff boiling, the maximum amount of semi-crystalline produce. If this kind of material were a marketable commodity in its present state, the endeavour of aiming at its maximum produce would be intelligible; but as it requires the expensive process of liquoring (Def. p. 19) to render it fit for the market, the process of stiff boiling is in contravention of all proprieties*.

The method in which the process of liquoring is commonly practised in the West Indies is fearfully wasteful, and in other respects open to the greatest censure.

Under the definition of liquoring, p. 19, the principle of that operation has been explained. I will now

* Dr. Evans informs me that in the island of Java there are used vacuum pans having an escape aperture in the side, through which the solid concrete is shovelled by a man sent into the pan for that purpose after each boiling operation. A patentee, moreover, actually proposes to grind this kind of concrete into grains by a mill!

offer, in anticipation of another part of this treatise, a concise explanation of the mode of conducting it in refineries, in order to demonstrate most powerfully the destructive mode followed in the colonies.

Under the proper conditions of temperature, hereafter to be mentioned, the refiner puts his boiled and crystalline syrup into moulds, supported on their apices, and the hole of each apex stopped with a pledget of brown paper. Here the mass is allowed to cool; and, when cold, the plug in the apex being withdrawn, each mould is supported on a corresponding earthen pot. A portion of syrup, technically known as green syrup, more or less coloured, now drains away, and the cone of sugar is left comparatively dry. The sugar forming the base or face of each cone being now removed by a revolving cutter, termed the *facing machine*, the sugar so removed is mixed with water to the consistence of a thin magma (technically named clay), and reimposed on the base of the cone. This is the operation termed in refineries claying, (Def. Claying, p. 18). After some hours the operation of liquoring commences by pouring on the smooth surface, or face left by the subsidence of the clay, a concentrated aqueous solution of sugar. The result of this operation is, that the colouring matters of the sugar are totally washed into the pot below, and a loaf of white sugar is formed.

As conducted in refineries, the operation of liquoring is most philosophical, and most efficient—an operation without which, or the equivalent one of prolonged claying, a thoroughly white sugar cannot be made. Its success depends so entirely on the purity and saturation of the *magma liquor*, or aqueous solution of sugar, that the preparation of the latter is a matter to the intelligent refiner of greatest solicitude. If the magma liquor be *coloured*, it is evident the sugar which it is employed to wash cannot be *colourless*. If the magma liquor, also, be not fully saturated, it will become so during percolation, at the expense of the sugar which it is intended to cleanse,—and the loaves will be partially dissolved. This is too evident for further comment. What, then, would be thought of the refiner, who, in violation of the obvious principles just laid down, should attempt to liquor by means of water? And yet this is the kind of liquoring very frequently performed in some of the West Indian islands where vacuum pans are used. The concentration having been carried on, as I have already remarked, to a higher extent than propriety warrants, the mass is cooled, thrown into a pneumatic chest, and affused with water by means of a garden pot! The air-pump is now put vigorously to work; a partial vacuum is produced underneath, and the water of affusion, carrying with it many impurities, and much sugar also, is drawn into the cistern below. It is a fortunate circumstance that the crystals or grains of vacuum boiling are usually large, and, therefore, less easily soluble than they would be if they presented greater surface to the agency of the solvent—otherwise the loss attendant on this most improper operation would be greatly augmented. The final result of this rude process of liquoring is, a large-grained dusky yellow sugar, now generally used for the purpose of sweetening coffee. Considered in the abstract, without reference to the steps by which it was obtained, this sugar might be taken as a proof of the benefits of colonial vacuum-pan boiling; and hence, from want of a fuller acquaintance with the subject, the most erroneous notions have been disseminated.

The rude process of liquoring by water, already described, is not invariably followed, it is true, in the colonies; sometimes a portion of juice, defecated and evaporated, to a certain extent, is substituted. Occasionally, too, the refinery process of making pure magma liquor has been adopted, but still under circumstances involving the greatest improprieties.

The propriety or impropriety of the claying and liquoring operations, in the colonies, can only be correctly judged of by reference to the precise end desired to be achieved. Thus it is possible to conceive a manufacture injured, even to ruin, by instituting false comparisons between it and another, and by the introduction of appliances, admirably adapted to the former case, but adverse to the latter. The colonial application of the process of liquoring, even when well managed, is emphatically open to the remarks just made. The refiner's object is to procure a white sugar, and the process of liquoring is absolutely necessary to give him this; therefore, cost what it may, the operation must be followed. The object of the colonial sugar-maker, however, is, and has been, to obtain a *yellow* coloured sugar;—a staple which may be made in the greatest perfection of tint without the employment of any claying, or liquoring process whatever; without charcoal, alumina, or lime; as will be hereafter demonstrated. True it is, that if the cane juice be boiled too high, especially if in contact with lime, and other impurities, (see Acid, Glucic and Melasinic, Def. p. 17,) the process of liquoring will be required to remove such a portion of them, that the resulting sugar shall have a marketable colour. But the contemplation of this fact brings us back again to the conclusion already arrived at:—That no secondary appliances—not even the vacuum pan—can accomplish any great amelioration of the sugar produce, whilst made to operate upon an impure juice.

CHAPTER VIII.

THE COLONIAL PROCESS OF CLAYING.

UNDER the definition *Claying* (page 18, Def.) has been given a condensed account of this operation. It is necessary now to contemplate it a little more narrowly in detail. The operation is more particularly followed by the Spanish and Portuguese colonies; and in a modified form also by the natives of Hindostan.

The general manner of conducting the operation is as follows:—Instead of putting the sugar to be drained into casks, it is placed in large earthenware or iron cones, after the method of refineries, and the green syrup is allowed to percolate away.

At this period, a magma or pap of white clay and water is superimposed; the agency of which is, manifestly—to wash away a portion of the chemical colouring impurities existent in the yellow sugar. The operation of claying is repeated twice or thrice, each coat of clay as it dries being removed, and another substituted in its place.

This claying operation is a most extravagant one; involving the loss of a third part of the original contents of the cone; and producing, after all, a sugar which, even at the base of the cones, or nearest to the clay, is far from white.

It has already been remarked, that in India a modified process of claying is pursued. An equivalent process would be a more correct expression; but not to discuss one principle under many heads, the term claying may be retained to express the Indian operation.

Instead of using clay, or a magma of sugar and water termed clay by the English refiners, the Hindoos generally attain the end of washing their raw sugar partially white, by superimposing on the base of the conical contents masses of hygrometric weeds or damp cloths; the effect of either being—the gradual liberation of water, and, consequently, the partial removal of chemical colouring impurities.

By following the processes of claying or liquoring, under almost any of their modifications, the darkest sugars may be made comparatively light coloured; and thus may be made to yield a product capable of misleading the unwary.

Thus it often happens that samples of light coloured sugars are displayed, and appealed to, as triumphs of some new method of sugar manufacture,—the only beauty of such sugars being such as is derived from the claying or liquoring processes; and which sugars, before the application of these processes, might have been almost black. This mode of displaying sugars is a piece of charlatanry which cannot be too severely reprobated. There is another scarcely more defensible, namely,—the display of large crystals or grains, which every chemist knows any sample of cane sugar can be made to assume, by mere devices of evaporation and cooling. (See page 28.)

It cannot, however, be a matter of wonder that the latter deceit should be largely practised, when it is considered that the sugar community has elevated the question of grain into a most unsafe position; and has made it a false criterion of qualities with which it has no connexion whatever.

The sugar broker, or refiner, attaches great importance to the touch which certain sugars impart when pressed, or rubbed between the finger and thumb; and accordingly as it feels soft or hard, it is pronounced weak or strong:—this criterion, like many others which have been misapplied, is, within proper limits, safe and good;—without those limits, productive of serious errors.

The first body into which sugar becomes changed, in the downward series of destructive metamorphoses, is glucose or grape sugar; which, if present in any considerable quantity, is most inimical to the formation of large crystals; it moreover imparts to the mass a condition of clammy pastiness. Under these circumstances, the sense of touch would be a very safe guide to the purchaser of raw sugar; who would be acting consistently in repudiating all sugars, possessing small grain, *from this cause.* But the rule may be extended to the furthest limits of falsehood; even to the absurdity of pronouncing refined sugar in powder—*weak*, but the same sugar in the lump—*strong*.

Having discussed the fallacy of being guided implicitly by the sense of touch, it remains to show the fallacies attendant on the sense of taste.

Nothing is more common than the affirmation, that one certain sugar has more sweetness than another, or that it possesses more saccharine matter; and, to place the affirmation in its most absurd light, the amount of sweetness or saccharine matter is made to decrease in proportion to the purity of the sugar. Thus, it is a very common affirmation, that white sugar does not sweeten so well as yellow sugar; in other words, that pure sugar does not sweeten so well as that which is impure:—*because the former has less saccharine matter than the latter!* Such is the common assertion:—one that may be heard very widely disseminated indeed — from the cook in our own kitchens, to the brokers in Mincing Lane; and, strange to say, in refineries too. Once admit the assertion to be valid, and to what a chaos of absurdity are we led. The whole system of sugar refining, with all its costliness, all its complexity, all its experience, is prosecuted—for what? To render sugar less saccharine,—to effect a destruction! Such is the necessary conclusion.

To explain these discrepancies between language and facts, is not so difficult as it may at first seem,—they originate in the use of lax expressions, based upon the evidence of the most fallacious of all our senses—the sense of taste.

It is a fact very well known to physiologists, that when certain tastes of different kinds and of different amounts of intensity are combined, so that they affect the gustatory organs at once,—the judgment, although unable to discriminate between them, and forming a conception alone of that taste which is most familiar, or most predominant *as to kind;* nevertheless as to the qualities of strength or pungency,—the judgment conveys a mixed idea of both. Or when two bodies are mixed,—one alone of which has a taste,—(practically or absolutely) the effect of the tasteless body is often confounded with the effect of the other.

The above is not a mere fine-wrought philosophical deduction; but one which has been applied to practice, and its truth demonstrated in many ways. Thus the dishonest tavern keeper adulterates his spirit, particularly gin, with tincture of capsicum, and his beer with cocculus indicus:—in either case to impart a fictitious alcoholic strength. The most untutored palate would distinguish between the taste of gin, and of cayenne pepper, alone; but, when mixed in certain proportions, the pungency imparted by the latter to the gustatory organs is recognised, but not discriminated—both together conveying the vague idea of strength.

As to cocculus indicus, it is devoid of pungency, but is a narcotic; nevertheless the judgment is equally deceived as in the former case.

Again, to take another instance, there are few snuff-takers with nasal organs so obtuse, as to be incapable of distinguishing lime, powdered glass, extract of logwood, sand, sal-ammoniac, or smelling salts, from the powder of tobacco. Yet in the form of snuff the nose is continually deceived. All these foreign bodies may be and frequently are mixed with snuff to give it a pungency: each agent conveys an impression, but loses its individuality—the idea of tobacco preponderates over all the rest.

Thus is it with impure or coloured sugars, which consist of sugar, plus many foreign bodies, each possessing its own abstract individual taste;—conveying when alone a notion both of kind and degree;—but when in conjunction—only the latter: which goes to augment the predominant idea of sweetness, conveyed by the most familiar, most prevailing substance of the mixture—sugar.

Here is a fruitful source of the fallacy adverted to; but there is another. The idea of sweetness, as conveyed by sugars equally pure, varies in direct ratio to the amount of comminution:—Hence large-grained sugars seem to be less sweet than those the grains of which are small. The reason of this will be evident, when it it is considered that all substances which are insoluble in the saliva are totally devoid of taste,—and that the taste of all other substances is in direct ratio to the rapidity with which they are dissolved in the mouth.

It is very evident, then, that the sense of taste is far too fallacious in its nature, and tends to inferences far too vague, for the decision of such an important matter as the amount of actual sugar in any saccharine mixture; such as raw sugar, under any of its conventional denominations, must be regarded. (Pages 2 and 22, def. *Muscovado*). Neither is the test of specific gravity at all more decisive; for, in the most impure of raw sugars, the total amount of impurities bears but a very trifling ratio to the mass;—and, moreover, possesses a specific gravity so little different from that of sugar, that for all practical purposes it may safely be asserted, that all samples of raw sugar, of equal dryness, form, with equal amounts of water of equal temperatures, solutions, the specific gravities of which are also equal. Hence the hydrostatic or saccharometer test cannot, any more than other plans of taking specific gravities, convey the least idea of the purity or impurity,—the goodness or badness, of raw sugars.

CHAPTER IX.

ON THE NATURE OF MOLASSES, AND THE PROPER METHOD OF TREATING IT, WITH REFERENCE TO THE PRODUCTION OF SUGAR.

Having successively considered the chief methods pursued to effect drainage of the non-crystallized, from the crystallized portion of concentrated saccharine juices, and in what respects they are adequate or inadequate to the end desired, it now remains for me to devote some attention to the product of such drainage; which product is denominated by the vague term "molasses."

It may be inferred from the remark at p. 60, that the investigation of the nature and properties of molasses will best be prosecuted by starting from the assumption that sugar may be concentrated by evaporation, without any destruction whatever; in which case the molasses, or liquor of drainage, would be the precise analogue of that resulting from crystallized saltpetre;—would consist of nothing but a solution of sugar in water*. I have already remarked that this condition it is impossible absolutely to achieve; but by removing from the solu-

* See pp. 57, 58.

tion to be evaporated all destructive agents, and by properly regulating the application of heat, the amount of destruction may be reduced to such a minimum,—that the molasses, or syrup of drainage, shall virtually, though not actually, be an aqueous solution of pure sugar.

Descending from this extreme summit of excellence to the other extreme of the scale, we at length arrive at the results of Soubeiran's experiment, p. 36, wherein every particle of sugar was destroyed.

Within the limits bounded by these two extremes, the ratio between the amount of sugar destroyed, and the amount crystallized, may vary indefinitely; each product yielding a liquor, or syrup of drainage, to which the general term molasses will be applied; although such liquor of drainage may be anything from an aqueous solution of sugar, accompanied by some mere traces of foreign bodies,—up to a compound of little else than glucose, mixed with its black acid derivatives.

It is evident, therefore,—that the term molasses is a most indefinite one, and should never be used in argument unless its meaning have been specially limited to the conditions of the instance under discussion. It appears, then, that liquor of drainage, or syrup (molasses), there ever must be, as the result of the crystallization of sugar,—even under the most favourable circumstances; and the question of the best mode of treating it, for the purpose of obtaining its sugar, must be determined by reference to its richness in that substance.

And here the sugar producer is met, on the very threshold of his subject, by the necessity of accommodating his operation to an ill-defined popular taste. Were it a question with the colonial sugar producer of selling the pure material—*sugar*, his course might indeed be very difficult,—but it would at least be well defined. At any price,—cost what it might,—he would be driven to cleanse all his raw crystallized material from every particle of colouring, or other non-crystallized substances; in other words, from every particle of its *molasses*. Such, however, is not the desideratum which the sugar producer has in view; the public expects him to produce a coloured sugar; that is, a white sugar, each crystal of which is coated with a certain amount of molasses; to which latter the qualities of moistness and colour are due. Now the question of how much molasses shall be thus allowed to remain, as a coating, involves the consideration of such indeterminate matters as—variety of popular tastes; of manufacturing expenses;—the comparative value of sugar and rum, &c. As a general rule, however, the West India sugar producers, (those of Jamaica excepted, who obtain a high price for their rum,) consider it profitable to boil the juice very stiff, and export the muscovado sugar in a very undrained state. The glaring impropriety of this procedure has already been pointed out, p. 90; therefore I need not advert to it again. It is desirable, however, to find adequate causes for a practice which appears so repugnant to all common intelligence.

The causes are chiefly as follow:—1. The desire of the overseer to make a display of the quantity of sugar shipped. 2. The low market price of molasses by itself, compared with the market price of molasses as forming a part of muscovado sugar. It is painful to have to record the fact, that the real owners of a great number of West India estates are not the ostensible ones, but merchants or brokers at home; who, by way of mortgage, have a direct lien on the property; and, indirectly, have the privilege of exclusive management, with all the commercial advantages thereby accruing. Under these circumstances it is too frequently an object with the resident agent to make a display of a large amount of sugar produced on his estate, whereas the amount is merely one of sugar, plus the molasses absorbed. The material being thus placed on shipboard moist and undrained, may, under the circumstances of a fair wind, and easy passage, arrive here without great loss. If it do so arrive, its sale may be accomplished. The English grocer, by dint of mixing it with dry refinery pieces, and a certain portion of dry East India or Mauritius sugar, at length forms a compound of remunerative selling price, and all parties are satisfied. If, however, the passage should be rough,—causing much agitation to the cargo, if the temperature should be unusually high, or the hogsheads unusually leaky, then a large portion of the molasses percolates into the hold, and is pumped overboard.

Thus the present West Indian sugar manufacture is made to assume an appearance of risk and uncertainty which, so far from necessarily belonging to it, —at least in the way indicated—may, by a system of improved treatment, be prevented altogether.

It is a question very commonly put by the colonial sugar producer,—whether a specimen of sugar resulting from a certain process will stand the voyage?

To such a question there is one general answer. Any sugar will stand the voyage provided it be well drained, and that it be freed from all impurities which are of a deliquescent nature. Sugar itself is unalterable, in an atmosphere of very considerable dampness; and the mere adherent brown, or yellow, coat of molasses, which imparts the peculiar colour and sensation of moisture, without clamminess, to good muscovado sugar,—is not sufficient in itself to cause any loss by drainage.

As regards the second reason which influences the West India sugar producers in allowing their staple to be largely admixed with molasses, viz.—the low value of molasses by itself as compared with that of molasses when it forms part of muscovado sugar,—it will be evident, on reflection, that the amount of sugar contained in bad molasses may be so small,—so much admixed with impurities, that it either may not pay for re-evaporation, or that it must be evaporated alone. To evaporate it in the teache, mingled with fresh or uncrystallized syrup, would be impracticable, on account of the mass of impurities which would be thus imparted. It will be, moreover, evident that, beyond a certain point of richness in sugar, and general purity, molasses may thus be treated with propriety. Hence we are brought again to contemplate the first grand source of all improvements in the colonial sugar produce,—the perfect defecation or purification of the juice. Until some process conducive to this end be generally followed by our colonists,—until some means be devised of rendering the molasses or syrup of drainage so pure, that it may be returned without prejudice to the teache, and boiled with the concentrating juice,—the chemist will expatiate in vain on the theoretical indications of low boiling and perfect drainage, as necessary to the production of a well crystallized sugar. So long as the general run of molasses is of its present average impurity, so long will it be impossible to be boiled except alone—a process involving the use of more fuel than the West Indian colonist can command: indeed, if he could, the result would be scarcely marketable; and so long will the weight of semi-solid saccharine produce (sugar is a wrong term) obtained—be the result of the first, and only boil. If, however, the sugar producer could be made to follow some plan of defecating his juice, that would insure a molasses so pure,—that it might be returned to the teache, and the process repeated through several operations,—he would then have no plea for the continuance of his present ill-judged plan; which may be, without impropriety, designated an operation of smuggling,—devised for the purpose of selling molasses under the name of sugar.

If the West Indian sugar growers were to be furnished at once with a never-failing means of producing a large grained, and therefore an easily cured, sugar, to the exclusion of all other sorts,—their produce would have to encounter a difficulty which the consumer would scarcely have imagined. Such large grained sugars are very unfavourable to the perpetration of certain mysterious operations of legerdemain*, which grocers understand too well. They will not mix. A small grained sugar may

* Termed by grocers "*handling.*"

readily be incorporated with glucose, with pieces, or bastards, and other less innocent bodies,—without such incorporation being discoverable to the eye. A large grained sugar, on the other hand, is a most refractory material for these little manipulations; its crystals,—no matter how mingled with contaminating agents,—never ceasing to manifest their native brilliancy, and thus proclaiming the fraud. It is most easy, then, to understand why the grocer, as a rule, does not encourage these large grained sugars. He cannot "*handle*" them,—and therefore brands them with a fault. He says they are deficient in saccharine matter,—that they will not sweeten. True it is that comparatively small portions of these large grained sugars are sold,—and sold at high prices; but merely as fancy articles, on the proceeds of which the grocer nets too little, to make their sale an object of primary solicitude.

Such is the source of one prejudice against dry and large grained sugars—a prejudice originating amongst the grocers. There is also another, which originates amongst refiners;—who are adverse to the general consumption of these beautiful colonial sugars, for the very obvious reason—that the consumption of their own staple is thereby lessened. The refiner's expressed objection is remarkable, as embodying a philosophic idea not at all known to chemists, and, in fact, adverse to all chemical analogy. He is in the habit of saying that such large grained sugars produced in the colonies contain a great amount of water, and that hence they are, what he terms—weak. Now, for the sake of argument, we will assume this to be the fact, and will see how it bears upon the refiner himself. If the vacuum pan accomplishes the incorporation of water with sugar in the colonies, of course a similar effect results at home *in refineries*. Hence the refinery operation, thus proved to consist in effecting the crystalline incorporation of water with sugar, must be profitable beyond any limits which the public, and the Chancellor of the Exchequer, have hitherto assumed: and this enormous profit should be at once adequately taxed! To such absurdities are we led, by arguing from loosely-expressed current data*.

* Lest it be thought I unjustly impugn the science of practical men well conversant with sugars, I will here mention two circumstances; one for the truth of which I vouch, the other communicated to me by one of our largest metropolitan copper manufacturers. Towards the end of the summer of 1848, I showed to a London broker a very fine sample of well crystallized colonial sugar. His comment was most peculiar. He told me that—" now-a-days popular taste required the grain of sugar to be of a different shape to mine; people now liked grains with *rounded angles!*" The copper worker's anecdote is as follows:—" I was once sent for in a great hurry," he very naïvely told me, " to a refinery where a vacuum pan of mine had been some time in work. I lost no time in hastening there, for the message was urgent. 'I want you to get a hole bored in the dome of that pan,'—was the sage request of the refiner, on my arrival. 'A hole in what?' said I. 'In the dome of that pan;' answered the refiner. 'But for what?' 'Because it is too tight—there is too much vacuum —in short the pan won't do.' In vain I remonstrated, in vain I pointed out the absurdity. The refiner had only one answer,— 'His boiler said the pan was too tight,—and bored a hole must be forthwith.' It was accordingly done." In fairness to the refiner it should be remarked that his vacuum pan had formerly a leak in it; which leak having been stopped, the boiler *fancied* that the pan worked less satisfactorily than before. From these premises a very absurd conclusion was arrived at, as we have seen.

CHAPTER X.

IMPROVED METHODS OF DEFECATING OR PURIFYING SUGAR-CONTAINING JUICES.

HAVING pointed out the injurious agency of lime as a defecating agent, I will now pass in review the chief methods which have been had recourse to from time to time for accomplishing the important end of defecation, without the employment of that destructive,—although not very efficient,—alkaline earth.

And here I will remark, that there scarcely exists a mineral salt, of whatever kind,—that does not, when a solution of it is added to sugar-containing juices, at the proper temperature—usually about 180°,—cause the precipitation of bulky, flocculent masses; being combinations of the impurities existing in the juice, with the mineral base of the salt. By witnessing effects of this kind, persons unacquainted with chemistry have been led to the most unsafe conclusions, and numerous are the pseudo discoveries thus palmed upon the world.

To defecate merely, or effect the separation of impurities from sugar-containing juices,—is but one portion of the problem to be solved. The defecating process must be effected without destruction to the sugar; and by an agent that is so perfectly under control, that any excess of it, above the quantity necessary to effect defecation, shall be easily removable. For practical purposes, another and a most important condition, must be achieved:—the whole must be effected within the limits of a remunerative cost.

It is painful to con over the numerous projects,—specious enough at a first glance, but in violation of the rules of guidance, or indications laid down, —which have been thrust upon the sugar producer, and the refiner, so often, and with such unvarying failure,—that all new plans, however intrinsically good, are regarded always with suspicion and doubt, —often with neglect or contempt.

Thus, in a patent specification lately published, sugar solutions in the colonies, and in refineries, are proposed to be defecated by operations that would effect the liberation in the sugar of—nitric, sulphuric, prussic, and oxalic acids;—without any provision for removing either of these deadly substances! Fortunately there is a chemical safeguard here. The presence of a minute trace of oxalic acid prevents the crystallization of sugar,—and the same remark applies, though less forcibly, to the presence of nitric and sulphuric acids. The author of this patent being totally ignorant of chemistry, was misled by the fallacious appearance of a mere separation of coagula.

Foremost amongst the materials which have been employed at various times, both in the colonies and for refinery use, is the earth, alumina, in some of the various states which it may be made to assume. The idea of employing alumina seems to be derived from a somewhat analogous application of this substance, for the making of vegetable colouring matters, termed lakes. Thus, if a decoction of logwood be mixed with a solution of the salt alum,—which is a compound of sulphuric acid, potash, and alumina,—and a solution of potash added, the earth, alumina, is set free; and immediately combining with the colouring matter of the logwood, both fall in union, and constitute a precipitate which, when dried and powdered, is called a lake. Instead of logwood, various other vegetable, and some animal, colouring bodies, may be substituted; and with a similar result.

Following out this idea, alumina has been employed with the view of separating the colouring matters out of solutions of muscovado sugar, and the general vegetable impurities out of cane juice.

On cane-juice I have never had an opportunity of trying it; but on solutions of muscovado sugar I have frequently tested the powers of alumina, without, in any case, being much struck with its utility. A certain defecating effect it unquestionably produces; but by no means to the extent that would induce one to anticipate any vital or radical improvement in the sugar manufacture,—home or colonial,—by generally adopting it. Not long since I was called upon to witness the effect produced by a mixture of alumina, sulphate of lime, and bone black, on a solution of Khaur sugar *. The experiment was shown me as a triumph, but I was at a loss to conceive how the result could have been worse.

* A most impure result of the native sugar manufacture in Hindostan.

Alumina, as prepared in its purity by chemists, would be inapplicable to the purpose indicated, no matter how successful in its results,—merely from considerations of expense:—many cheap modifications of the material have, therefore, been from time to time devised. One of the most general of these was discovered by the Honourable Mr. Howard (the inventor of the vacuum pan), in 1812; and consists of a mixture of sulphate of lime, free lime, and alumina. This mixture, commonly known as *Howard's Finings*, is prepared by adding to a solution of alum in water, a portion of cream of lime, sufficient to combine with all the sulphuric acid of the alumina, to throw down the alumina, and to leave an excess of lime. The supernatant liquor of this operation, consisting of sulphate of potash, must be absolutely washed away; or it will impart an injurious quality of deliquescence to such sugar as may be prepared with the finings. In a patent of some years' standing, chalk instead of lime is used to decompose the alum; with what advantage, however, is not so obvious.

In France and other countries where sugar is largely manufactured from beet-root juice, the *sulphate of alumina*—(not alum, which is the potash sulphate of that base)—is largely employed as a defecating agent. On solutions of muscovado sugar I can affirm from experience, that its defecating properties by no means come up to the expectations I had been induced to form.

Very far superior to all other agents as precipitants for the vegetable impurities of natural sugar-containing juices,—as also for the impurities existing in muscovado sugar,—are the acetates, particularly the basic, or sub-acetates of lead.

So wide is the sphere of operation which these bodies possess, as precipitants of the albuminous and coloured matter of vegetable juices, that even the juice of beet-root, which after being allowed to remain in contact with the air for about half an hour becomes black,—is instantly purified to such an extent that, when filtered, it resembles water. Not only do these salts of lead precipitate the general impurities from raw vegetable juices,—but even a number of dark-coloured decoctions are rendered, by treatment with it, comparatively colourless in a few instants. Chemists have long been aware of this property—have long used the acetates of lead as precipitating agents for certain albuminous and coloured matters, in the laboratory, with the most perfect success; every attempt, however, to employ these agents satisfactorily, even on the small scale, for the purpose of throwing down the impurities from muscovado sugar in solution, or from cane-juice, was unsatisfactory; whilst on the large scale the attempt, when tried, failed altogether.

The reasons of this failure, in the employment of lead salts, for the purpose indicated, are various; as will presently be recognised.

The first problems to be solved are these: either to use the lead salt in such exact proportion to the amount of impurity with which it is intended to combine, that both shall fall down in combination, and be capable of removal; or to add a known excess of lead salt to the sugar solution,—to separate the precipate caused by filtration,—then to throw down from the filtered liquor all the remaining lead by means of some precipitating agent not productive of injury to sugar: and, as a subsidiary problem,—to remove the acetic acid liberated from the lead, either as an insoluble compound, or to combine it with some body that shall neither be injurious to sugar, nor to health,—and separable, if possible, by the process of drainage.

Such are the necessities of the case,—even in the laboratory, on a small scale. Let us examine how they can be met.

The first problem does not admit of solution;—it involves an impossibility: inasmuch as, however small, above a certain microscopic limit, the quantity of lead salt added,—the filtered solution will still contain lead: although a fresh addition of more lead salt to the filtrate will not fail to produce a new precipitate. This circumstance can be accounted for, by assuming the concurrent formation of two or more compounds of lead and vegetable matters; one compound being soluble, and the other not*.

In operating on sugar thus,—we are reduced to the necessity of disregarding, as a means of safety, all apportionment whatever:—the only way left open to us is, to precipitate the excess of lead.

Simple as this may appear as a laboratory operation, it cannot be accomplished by the ordinary laboratory means. The usual agent employed by chemists to separate lead out of solutions is hydrosulphuric acid gas;—a body which throws it down effectually from sugar solutions, it is true, but spoils

* For a parallel case, see pp. 66, 67.

the sugar:—in consequence of the facility with which, by trifling circumstances, it is decomposed, with the liberation of sulphur. Hence,—so frequently had the experiment been tried, and with such uniformly bad success, that not only was the idea of employing these agents in combination relinquished, but the ruin of the sugar was attributed not to the proper cause—viz: the effect of hydrosulphuric acid employed to separate the lead:—but to the lead itself.

The employment of hydrosulphuric acid thus being out of the question, we have next to examine the other means commonly employed in the laboratory for accomplishing that end. Occasionally sulphuric* acid is used to separate lead out of solutions; which end it accomplishes perfectly, even out of those of sugar; but if sulphuric acid be employed, it is incumbent on the operator to add one exact quantity—no more—no less: if too much, the free or uncombined overplus of acid, by acting on the sugar, would speedily convert it—first, into glucose, and thence downward in the scale of destruction into glucic, melasinic, sacchulmic, sacchumic acids, &c.: if too little, there would remain an excess of lead; which not only is injurious to health, but, also, if boiled with sugar, a very destructive agent.

The question of lead, then, as a defecator for sugar, seemed hopeless. Its remarkable action was witnessed, admired, and abandoned;—until in the year 1839, Messrs. Gwynne and Young took out a patent

* Sulphuric acid has lately been tried by a gentleman in India, who utterly failed, however, in achieving the object proposed.

for the separation of the excess of lead by means of the diphosphate of lime;—an agent which, in the laboratory, can be made to succeed perfectly: but which I believe to be, both on the score of expense and uncertainty, totally inapplicable on the large scale.

These gentlemen, however, deserve great praise for their investigations; which are, chemically considered, of a masterly kind. Although the operation necessarily failed in practice, for reasons which I have indicated, its perfect success in laboratory quantities demonstrated the most important fact,—*that the acetates of lead*, per se, *were not injurious to the constitution of sugar*.

This demonstration having been accomplished, the chemist was warranted in resuming the task of finding out some precipitating body that should not only act in the laboratory under chemical superintendence; but one that should act anywhere, and in any quantity.

Such an agent I was fortunate enough to discover in July, 1847. This precipitant is sulphurous acid gas: the methods of employing which I have recorded in another publication, and therefore need not repeat here; seeing that my present object is simply to record a chemical fact.

Since the period of July, 1847, the efficacy of this gas has been tried on the large scale in a refinery, and also on cane juice; in both cases with the most perfect success.

CHAPTER XI.

THE OPERATION OF REFINING.

The term, sugar refining, is applied, as is well known, to the operation, or series of operations, by means of which the dark impurities are extracted or separated from white sugar, and the latter is isolated.

Hence the terms, white sugar and refined sugar, have grown to be synonymous; and the idea has been created that white sugar must necessarily be the product of a second operation. This notion is most fallacious; and not more fallacious than injurious: by causing the impression, that no such body as white sugar could be primarily extracted from the cane juice, or other sugar-containing juices.

Very frequently do we hear the colonial sugar-growers subjected to many, and adverse, remarks, because they have not, as it has been asserted, developed their art, with the rapidity that modern scientific aids would have enabled them to do.

Much of this animadversion is unjust; for not only until the passing of Sir Robert Peel's Sugar Bill, in 1843, was the colonial sugar producer not encouraged to make a product beyond a certain limit of goodness, but he was not permitted to do so; every step he took in this direction being checked by a high protective duty, with the object of favouring the home refineries.

Immediately the sugar duties were readjusted, the intelligent colonial sugar growers availed themselves of the opportunity to improve their staple; but, unfortunately, they began with machinery instead of chemistry. They relied on improved means of boiling; not having yet procured the proper liquid to be boiled. Whilst their new experiments were being prosecuted,—whilst they were bearing most stoically their present losses, and looking forward to a brighter future, England became deluged with finer sugars of Cuba and Brazil, made by the claying operation. The West India sugar grower was undersold, and too frequently ruined. Often do we hear the question put—wherefore the West India sugar grower does not practise the claying process? The question manifests little acquaintance with the subject at issue. The process of claying, be it remembered, is not indicative of an improved sugar manufacture, as is commonly supposed; but merely indicative of the fact that, at the expense of time, of labour, and a third of the material operated on,—it has been deemed expedient to accomplish the washing out a certain amount of impurities from muscovado sugar. These facts being well considered as premises, the conclusion may very safely be arrived at—that the claying operation can only be remuneratively practised under one of the following conditions:—either in communities where slavery prevails, or where the price of labour (as in India) falls below the usual average*.

But to return to the subject of sugar refining.

In commencing the study of this manufacturing

* This remark only refers to the actual use of clay, not to the operation termed claying in refineries.

operation, it will be useful to consider the theoretical indications to be followed out.

The substance to be operated upon is raw sugar; and the object to be kept in view is—to extract the maximum of impurities, with the minimum of expense, and of loss.

It has been already remarked (p. 20, def. *liquoring*), that if muscovado, or yellow sugar, were contaminated by chemical or soluble impurities only, the processes of claying and liquoring would effectually remove them. This, however, is far from being the case. If a portion of the purest colonial sugar (made without animal charcoal), be dissolved in water, the presence of mechanical or floating impurities will be very manifest. Such impurities must be got rid of at any cost, before the sugar can be refined. The most obvious way of accomplishing this removal, would seem to consist in mechanical filtration through fibrous textures, followed by evaporation; and this succeeded by the processes of claying and liquoring.

It happens, however, that, even were this process the most desirable, as well as the most obvious, yet the filtration of such sugar in thick solution is no very easy matter,—on account of the glutinous nature of the chemical coloured impurities; as the experimenter may prove by means of a filter of paper: however, by allowing sufficient time,—the thing, as an experiment, may be done; and I will suppose it done, for the sake of the next demonstration.

The liquor, when so filtered, if placed between the eye and a ray of light, will be found to be entirely free from the mechanical impurities formerly visible;

but it will be as dark from the presence of chemical impurities as before filtration. The indication, therefore, is obviously, to reduce those chemical impurities, by means of some combination, to a mechanical, or filtrable condition. The usual agent employed for this purpose in refineries, is an aqueous solution of lime; that is to say—lime-water.

If a portion of the dark filtered solution be mixed with a portion of lime-water, in a test tube, and heated by a spirit lamp flame, a manifest change will be observed. A portion of the soluble impurities will be found to become insoluble, assuming the condition of brownish flakes, and rendering the solution turbid.

The liquor now will be found to pass much more readily through a paper filter than before; and, moreover, it will have been considerably lightened as to colour.

If the filtration process be conducted with less care, the liquor, as it passes through, will be contaminated with a portion of the separated impurities; which, in point of fact, are so delicate in their physical nature that the slightest force breaks them up and partially redissolves them:—a circumstance which, as may be imagined, would materially impede the filtering operation, on a large scale. However, for the purpose of demonstration, it can be, and sometimes is, accomplished.

If a little white of egg and lime-water be mixed with a portion of the solution, while cold, and the mixture be then heated in another test tube, the same kind of result will be accomplished as in the last experiment, but with this addition:—the albumen of the white of egg, or the blood during coagulation, will envelope each floating particle of the mechanical impurity developed by the agency of lime, and bring it to the surface of the liquor in the form of scum; leaving the subnatant fluid clear and bright.

If the result of the last experiment be filtered, a fluid will come through,—red, if blood has been employed, yellowish or amber, if the white of egg. Either of these solutions, on being evaporated, evolves an animal smell, and eventually yields crystals, from which the non-crystalline portion may be drained, and the crystals rendered white, by the process of claying (real or virtual), either alone, or succeeded by the process of liquoring.

If, instead of evaporating the liquid immediately after passing through the filter, it is made to percolate through granular bone black, the result is marvellously improved. Every trace of colour is dissipated, and the liquor feels less glutinous to the touch: it has acquired also (owing to the removal of impurities) an increased facility of crystallization. The smell of the animal matter, however, generally remains.

Having gone through these preliminaries, we are now in a position to contemplate the process of refining, as now prosecuted.

A good refinery should consist of not less than four floors;—if more, all the better. Its walls should be strong, its planks well seasoned, and close; and steam pipes should be laid on throughout, so that a temperature of 80° can be easily commanded every-where, except on the ground floor, or fill house, the bastard curing room, and the stove; the former of which will require a temperature of 120°, and the latter of 112° to 115° Fahr.

Through the middle of each floor is a large square hole, capable of being shut by means of a trap door; and through which the sugar is pulled from the lowest floor to the highest, by means of a gin or small crane.

This is the best arrangement for a refinery; although the details of arrangement may vary considerably. The conditions which I have laid down, are adapted to the supposition that the sugar is dissolved on the highest floor, and that it is subsequently worked down to the lowest; where, having been boiled, it is filled into moulds. These conditions are the most natural, and the most rational; but they are sometimes violated; the sugar being dissolved on one of the lower floors, and, subsequently, lifted again. By this latter method of procedure the height of a floor or story can be saved; but the operation of pumping is usually involved,—an operation which is never to be recommended*.

Another floor or story in refineries is frequently saved by a less objectionable plan,—the liquor prepared for boiling being discharged on the ground floor, and sucked up into the vacuum pan on the second.

Wherever in a refinery the process be commenced, the first operation consists in effecting the solution of sugar, in such a mixture of water, lime-water, and

* Liquor can be raised by the pressure of steam much better than by the more common operation of pumping.

blood,—technically called spice,—that the resulting liquor at the temperature of 212° Fahr. shall have a specific gravity by preference of about 1·241— equivalent to 28 degrees of Beaumé's saccharometer. This operation, which is called *blowing up*,—is thus performed.

The blow-up pan is a square or rectangular painted iron, or, much better, plain copper, tank—supplied with a perforated false bottom, under which is laid horizontally a three-armed tubular perforated pipe of copper, in connexion with a steam main. The use of this arrangement will be presently obvious. The sugar being put into the pan along with the predetermined quantity of blood, lime-water, and water —the quantities of each being adjusted by no fixed rule,—the blow-up man lets on his current of steam, which, penetrating into the arms of the trifid horizontal pipe, emerges in sharp jets through the small apertures of the latter, and heats the contents of the blow-up pan with great rapidity to the boiling temperature. For this blow-up operation, some houses use high pressure steam, some low pressure. There is now a prevailing opinion in favour of the latter, in consequence of a belief that high pressure steam is destructive of sugar. Mr. Pontifex* now prepares a solution pan, similar in construction to the heater:—i. e. the necessary heat is imparted by means of a steam jacket, thus avoiding the escape of any steam into the solution. This gentleman informs me that the advantages attendant upon the

* The Messrs. Shears, of Bankside, have since borne testimony to the same effect.

use of this form of pan are very great; a perceptibly larger amount of product, and of better quality, being the result. That the injection of high-pressure steam into sugar solutions is destructive, is rendered highly probable by the investigations of M. Violette, who has proved that wood may be carbonized by means of steam of only 6 lb. pressure to the inch. (See *Journ. de Chim. et de Physique*, 1848.)

The result of boiling the contents of the blow-up pan will have been anticipated from a consideration of the experiment I have supposed to have been performed in a test tube; a thick, bulky, offensive scum arises to the surface of the liquid, which might be skimmed off with tolerable facility, and the subnatant liquor left in a state approaching to mechanical purity. This skimming, however, is never practised in the present day, filtration being had recourse to, as a much more efficacious plan.

The process of filtration now universally adopted, is the bag filtration system, as it is called; and which offers the advantage of a very large surface, comprehended within a very small space.

The bag filter consists of a sack about 5½ feet long, made of twilled cotton, prepared for this specific use. When to be employed it is used as follows:—The bag itself, which is about two feet broad, is squeezed loosely into a smaller bag (open at the bottom), made of very coarse material, and technically known as the sheath. By this arrangement the whole filtering area of the bag is effective, although it is made to occupy very small dimensions. Each bag, with its accompanying sheath, is tied by the following device to a brass nozzle, slightly expanding at one end, to which the bag is affixed, and having a screw turned at the other end. The mouth of the bag, along with its sheath, having been brought well over the bell of the brass nozzle, is tied, sheath and all, moderately tight by means of strong cord. As it would be next to impossible, however, to whip the cord sufficiently tight to prevent the bag slipping off, on a weight of sugar being poured into it, the following plan of tightening it is had recourse to. A small copper bar of about four inches in length, being pushed under the cord, is twisted round until the necessary degree of tightness has been effected. The bar is now kept in position, and the twist prevented from returning by means of a second turn, of cord. Many of these bags, usually about thirty-six, are hung in one series, as will be presently described; of which series there must be two.

A cast-iron tray, perforated with the requisite number of screw-holes to correspond with the number of bell-nozzles, is made to form the upper part or roof of a wrought-iron chest, supplied with doors removable at pleasure, and rendered air-tight in their frames, during filtration, by means of tow and red lead made into a pad (which engineers call *a gaskin.*)

At the inferior part of this chest are two exit cocks; one supplied with a pipe that conducts the filtered fluid away, and the other, technically called the foul-liquor cock, through which a portion of the filtered liquor may be examined from time to time.

One other orifice has to be mentioned;—it is for the purpose of admitting steam: in an atmosphere of which the filter bags are caused to remain, during the whole period that filtration goes on. This is for the purpose of enabling the liquor to maintain its temperature—therefore to remain liquid; and hence, to pass through readily.

The filter chest and its accessories having been thus described, the operation of bag filtration will be readily understood. The let-off cock at the blow-up pan being turned, the blow-up liquor necessarily runs into the trays forming the roof of the filter chest; thence into the bag filters, and from them into the lower part of the chest. The first few buckets full of liquor which pass are always turbid. The liquor is, therefore, allowed to flow away through the foul-liquor cock, until a portion, being examined in a wine glass or phial by the transmitted light of a candle or lamp, appears quite bright.

This period having arrived, the whole mass of liquor is allowed to run on to the charcoal filter, or cistern, as it is more generally called. These charcoal filters, or cisterns, are of various shapes, and made of various materials. The usual material is iron, and the usual shape that of a cylinder of about sixteen feet high, or more,—by eight feet in diameter. Interiorly, the cylinder is supplied with a false and perforated bottom, on which is laid a piece of woollen. If made of iron, the cylinder should be internally well painted with two coats of white lead on one of red. Copper is the preferable metal, but few refiners will encounter the expense of using it for charcoal cisterns.

Instead of the deep charcoal cistern just described, some manufacturers employ shallow tanks of iron or lead. The only advantage which these shallow tanks present over deep cisterns is,—that they are better adapted to low buildings, and do not involve any perforation of the floors. Unquestionably the decolourizing effect of charcoal is best exercised by the use of deep cisterns.

Whatever the form of the charcoal cisterns, they should never be made of, or lined with, lead, inasmuch as a crust of carbonate of the metal becomes formed, and no sooner formed than dissolved in the sugar solution; where it may be generally found, if sought for. In this way I discovered, in the first day's liquor of one of the largest London refineries, a considerable amount of lead.

I do not advert to this subject with the object of proving that the amount of lead present in the solution would have exercised any perceptibly noxious effect on the health,—or any perceptible destructive agency on the sugar,—but to record the fact of its presence, and thus to guard future experimenters from referring the origin of such lead to any specific process of refining, in which the acetates of lead have been employed, and from which they have been totally separated.

The process of conducting filtrations through bone black, although remarkably simple in theory, yet requires some amount of practice to insure the maximum of success. The principal results to be aimed at are—to accomplish the maximum rapidity of percolation, with the minimum of colouring matter left in the filtered liquor.

This due rapidity of percolation is sometimes regulated by the exit cock, under the false bottom of the charcoal cistern—in which case the upper part of the cistern, above the margin of the charcoal, serves the purpose of a tank of reception for the whole bulk of the liquor which has come away from the bag filters. In other establishments, the charcoal cistern is supplied with a cover perforated with two holes—through one of which the liquor is allowed to enter—through the other, a jet of steam; which latter is said to prevent fermentation, and to impart to the charcoal that amount of temperature most conducive to the desired decolourizing effect. In any case the outside of the cistern should be protected against cooling influences, by a coating of felt, and a casing of wood.

In allowing the liquor, as it comes from the bag filter, to run on to the charcoal, care should always be taken to prevent the surface of the charcoal from being much disturbed. This object is usually attained by allowing the stream to impinge on some hard body laid upon the charcoal;—a piece of broken pot, or a brick tile, is commonly used.

Whether the liquor be allowed to run on to the charcoal gradually, or whether it be poured on at once, the surface of the charcoal should never be suffered to become dry. This neglect would infallibly cause the resulting filtrate—or filtrated liquor—to be turbid, or, as the refiners say, *milky*.

If deep cisterns be used, the liquor need not be caused to linger in the charcoal, by turning off the exit cock, or otherwise—the first produce of filtration being usually perfectly decolourized and bright. Wherever shallow tanks are employed, however, the charcoal must be allowed to soak or digest with the liquid for a considerable time, before the latter is fit to draw off.

It is said, in general terms, that one ton of bone black, well burned, is capable of perfectly decolourizing three of sugar. But this remark must necessarily be vague, and open to modifications, due to the influence of many collateral circumstances; as the reader will easily recognise. It must not be imagined, however, that the refiner unpacks his charcoal so soon as it ceases to effect the perfect deprivation of all colour. He allows it, in point of fact, to remain until the last portions of filtered liquor, instead of being colourless, are considerably darker than dark sherry.

The refiner, however, manages in this way. He commences his refine* by using newly-burned charcoal and good sugars; he then goes on using sugars more and more impure, until the end of the third or fourth day, distinguishing his liquor as first day's, second day's, and third day's liquor, &c.; from each of which, respectively, are prepared sugars of corresponding quality.

In order to judge of the mechanical purity of liquor from the charcoal cisterns, it is submitted to a very rigorous optical test: a wine glass or small phial full being collected, is held between the flame of a candle and the eye, when the slightest speck of mechanical impurity is perceptible, and is considered improper. If these mechanical impurities exist

* A refine is the series of consecutive solutions, or *blows-up*, upon which one charcoal filter system is made to act.

beyond a certain amount, the result is a cloudiness or opalescence; and the sugar produced from such liquors will be generally of a grayish cast. As regards chemical impurities, they are very seldom sought after by refiners, who entertain the most fallacious notion,—that bone-black filtration is competent to remove all bodies, of whatever kind, except sugar and water. The opinion is in nothing more unfounded than in respect to lime—a body which refiners imagine to be most especially removed by the charcoal filtering operation. The fact, however, is, that lime, both combined and in the caustic form, may be generally, if not invariably, detected, by means of the appropriate tests; and, if the blow-up pan be of iron, or if the painted internal coating of the iron charcoal cistern be abraded, distinct traces of this metal will also be discoverable. Indeed, refiners often suffer from the existence of iron oxide in their sugars—to which red streaks or spots are thus imparted*.

I will now assume a sufficient quantity of liquor to have come away from the charcoal, to admit of the operations of vacuum boiling. The let-off cock

* More than one patent has been taken out for the use of iron-salts as agents to defecate or purify sugars; and iron preparations have been lately tried in the house of Messrs. Fairrie—but with invariable want of success. Terry's patent, involving the use of prussiate of potash and sulphuric acid, and thus liberating a cyanogen salt of potassium and iron (the bi-ferro-cyanide of potassium), was tried in the house of Messrs. M'Fie of Liverpool; and, I am assured by one of the firm, with the result of colouring the goods—in this case *blue*—owing to the reaction of the undecomposed prussiate on a portion of liberated iron oxide.

of the charcoal cistern I will assume to communicate with a tank placed above the level of the vacuum pan—so that the liquor contained in the tank shall fall into the measure, and thence into the vacuum pan, by the force of gravity.

The operation of vacuum boiling.—When treating of the subject of colonial sugar manufacture, in Chapter VII.,—so full a description of the vacuum pan, and of the general process of vacuum boiling, has been given, that it only remains here to be remarked that, whether in the colonies, or in refineries, the operation and the end to be achieved by it are the same.

The reader will therefore assume that the liquor, having come from the charcoal tanks, has been subjected to the process of boiling, and has subsequently been allowed to remain in the heater for the necessary period (say half an hour for good solutions) to admit of the grain becoming sufficiently developed,—the operation of filling the moulds or cones begins.

These moulds for loaves or crushed lump, and occasionally pieces, are either made of sheet iron, painted white internally—or of copper. The larger moulds, however, employed for accomplishing the drainage of bastards (see Bastards, Def. p. 18,) are generally made of rough clay ware.

For every kind of mould, copper is the best material; but the great expense of using it is a drawback to its general use, to such an extent, that very few of the more wealthy sugar refiners employ this metal, for any mould above the size necessary to contain a fourteen pound loaf.

Previous to the commencement of the filling operation, the moulds standing in triple or quadruple row, the hole in the apex of each accurately plugged with a pledget of brown paper, technically called "*a stop*," are placed base upwards around the fill-house in such a manner that the rearmost row is supported by the wall, and each successive row by the one behind. Thus arranged, the greatest portion of the area of the fill-house is clear, enabling the operator or operators to fill any mould at pleasure.

The art of filling is very simple; one man dips, by means of a copper ladle, a portion of the crystallized mass, which he pours into the fill basin, an instrument something like a copper coal-scuttle, with

two small handles. This fill basin, when charged with its contents, is carried underhanded, and somewhat between the legs of the fill-house man, to its destination,—*i. e.*, the moulds, which are then filled to the brim.

If the moulds were now left merely filled, their contents would aggregate irregularly, and a good loaf would not result. Some little time after the operation of filling, therefore, the process of hauling, as it is technically called, is had recourse to. It consists in agitating or incorporating, by means of a wooden spatula, some two or three inches in depth of the filled mass. Care, however, is taken not to push the hauling spatula too deep into the contents.

The process of hauling having been gone through, the cones are allowed to remain in the fill-house for a period varying with the size of the loaves—and hence of the mass to be cooled. Supposing 14 lbs. loaves to be the size, a period of twelve hours is amply sufficient.

The filled moulds are now put into a basket, let down through the *pull-up hole*, and elevated to the second floor*, called the liquor loft, where the important operations, first, of natural drainage, then drainage effected by claying and liquoring, are conducted. Formerly, as I have remarked under the Def. Claying, real clay was employed, but now a mixture (not solution) of sugar and water,—to which the term clay is applied,—has taken its place.

As soon as the filled moulds arrive in the liquor loft, each is placed over a glazed earthen pot, the

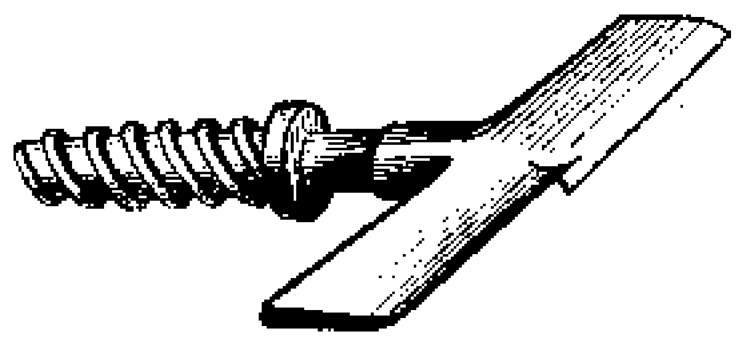
* The ground floor being considered the first.

paper stops having been previously removed; and a bradawl is pushed up into the mass to the extent of two or three inches. Drainage now proceeds with an amount of rapidity dependent on the amount of concentration to which the mass had been brought by evaporation, and on the absence of glucose and other impurities. If the evaporative concentration have not been carried very far, the result is said to be low —or free-boiled;—if the contrary,—the designation high—or stiff-boiled is applied.

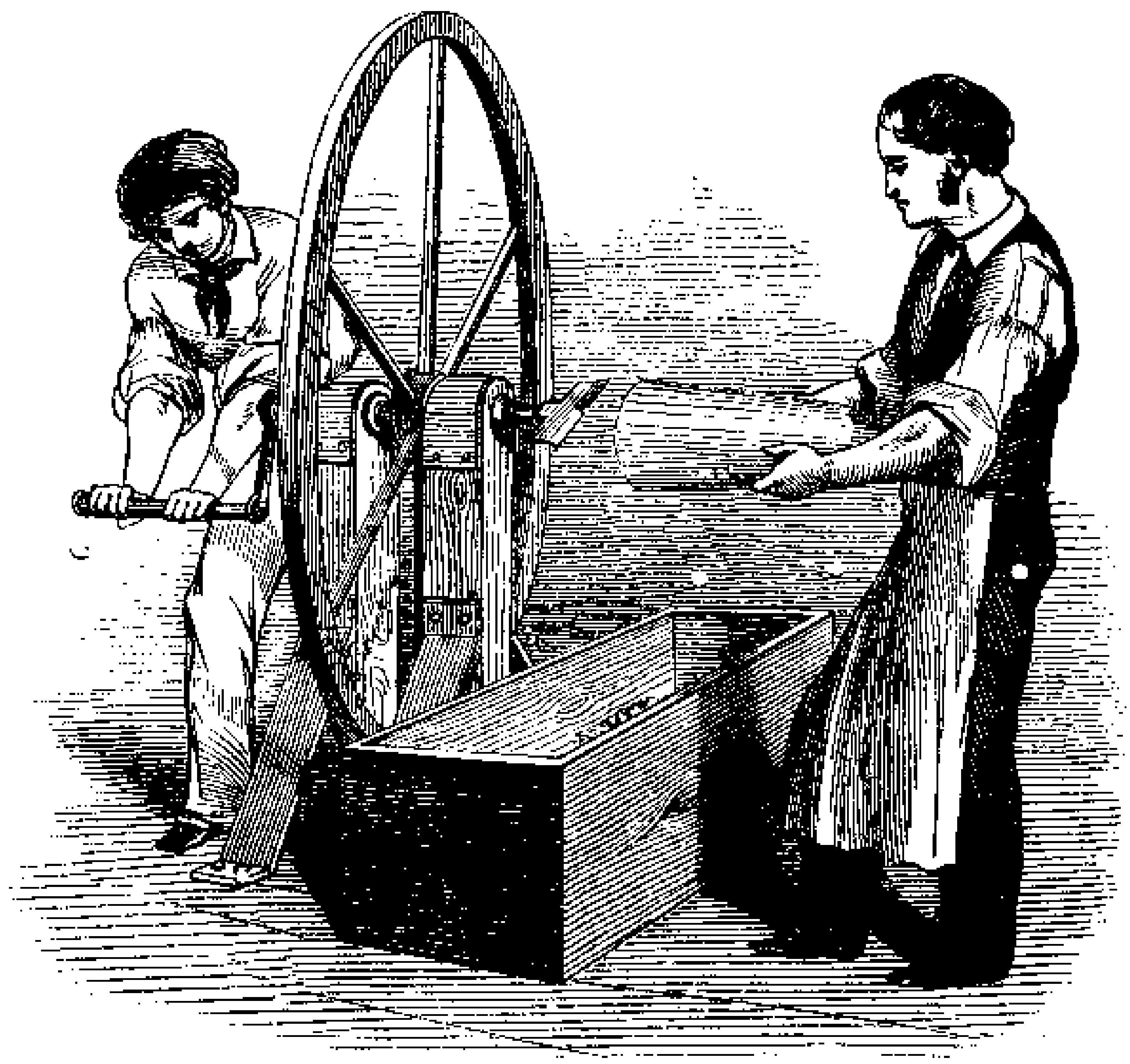
As heavy compact loaves are a great desideratum to refiners—owing to the great cohesion of such loaves enabling them to withstand, without much injury, the agencies of damp air, and the various mechanical shocks to which they will hereafter be exposed,—it is a main object in the refinery operation to carry the evaporative agency to the maximum extent, consistent with free subsequent drainage. If carried beyond certain limits, however, the loaves either will not drain at all, or their syrup runs away with such difficulty that a great monetary loss is incurred. In refineries the object of boiling *stiff* is intelligible enough, and founded on a scientific principle. In the colonies the object, although intelligible*, is most fallacious, and in direct contravention to all scientific indications. The colonial sugar grower, who argues the existence of a refinery precedent for stiff boiling, forgets this most important difference, that, whilst the refiner boils as stiff as is consistent with free drainage,—he, the colonist, boils stiff, whether he can drain or no.

* See pp. 106, 107

When the first or natural syrup of drainage has ceased to flow, each mould is removed, and a few inches (equal to the depth disturbed by the operation of hauling) of the mass removed by a revolving blade, with a central axis connected to a flywheel,



and worked by a grindstone handle. This instrument is termed the *facing* machine, and the chilled and badly-crystallized sugar thus removed falls into a box.



The contents of the moulds after natural drainage are said to be *in the green,* and the portions removed are termed *green cuttings.*

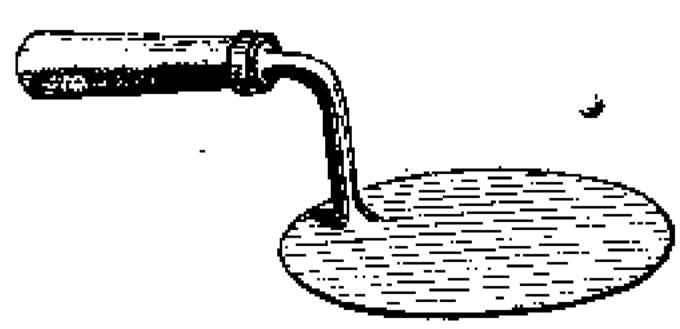
The moulds with their contents are now set again upon pots (the same or others, at the operator's pleasure), and preparations for the claying operation are made. The green cuttings being put into a pan are kneaded with water at first into a doughy consistence; and, finally, more water is added, until the whole is reduced to the condition of a thinnish magma, termed *clay*.

Upon the base of each cone, again placed on the syrup pots, is now poured so much of this clay as is sufficient to about half replace the amount of material cut away by the operation of facing.

In order to understand the precise rationale of the process of claying, it is necessary to remember that the claying agent is a saturated solution of sugar almost pure in water, mixed with a larger portion of sugar, suspended but not dissolved. No sooner does the clay agent touch the surface of sugar in the mould, than a downward current of sugar solution is established; carrying before it a portion of coloured syrup, and causing the base of the sugar cone, to the extent of some inches, to assume a white appearance.

One operation of claying, however, is insufficient to effect a perfect whiteness throughout the loaf, and a repetition of the operation is not so effective as the process of *liquoring* (see Liquoring, Def. p. 19), which is now in refineries universally followed. The liquor used for this operation is, as I have already remarked (Def. Liquoring), a saturated solution of pure sugar and water. It is prepared by dissolving in pure water—*i. e.*, not containing lime or spice—a porous kind of lump sugar—such as results from the latter working of the refine, on the fourth day—in a blow-up pan, used exclusively for this purpose; and filtering the solution through a charcoal cistern in the ordinary way, but with much care. When filtered, it should be colourless, and should possess a density at least of 32° Beau., at a temperature of 70° Fahr. Owing to its possessing this high density, magma liquor is not prone to ferment; it may, therefore, be kept in tanks for a considerable time without danger. These liquor tanks, however, should be situated in a cool part of the building,—their usual position being under the roof in a loft, to which the external air has free access.

The operation of liquoring is commonly performed by means of a garden water-pot, without the rose,—and simply consists in pouring upon the base of each conical lump of sugar, yet in the mould, as much as the mould will contain, an even surface having been previously made by an instrument termed the *bottoming trowel.*



The operation of this liquoring is precisely like that of claying, which has been described in detail; and it effects the total separation by drainage of all chemical colouring matter. Fourteen pound loaves, if made of well-purified sugar, should be rendered neat or white by two successive liquorings. The coloured engraving at the end of the volume represents the appearances which cones of sugar present in glass cones during the successive processes of claying and liquoring*.

It is almost too obvious a matter for comment, or indication, that the last syrups of drainage, technically called *drips*, resulting from the operation of liquoring, are much purer—or, in other words, contain much more sugar—than the natural syrup of drainage, and that resulting from the operation of claying. Accordingly the drips are collected, and put into a tank alone, to be hereafter boiled up with a fresh working of sugar.

It will easily be observed, whether a loaf requires more liquoring or not, by lifting it from the pot, and noticing the colour of the syrup which leaks away. This observation, it is scarcely necessary to remark, should be made when the drainage has almost ceased. If the drops are limpid, the operation has been complete, and the loaves are said to be *neat*;—if they are coloured, another liquoring is indicated.

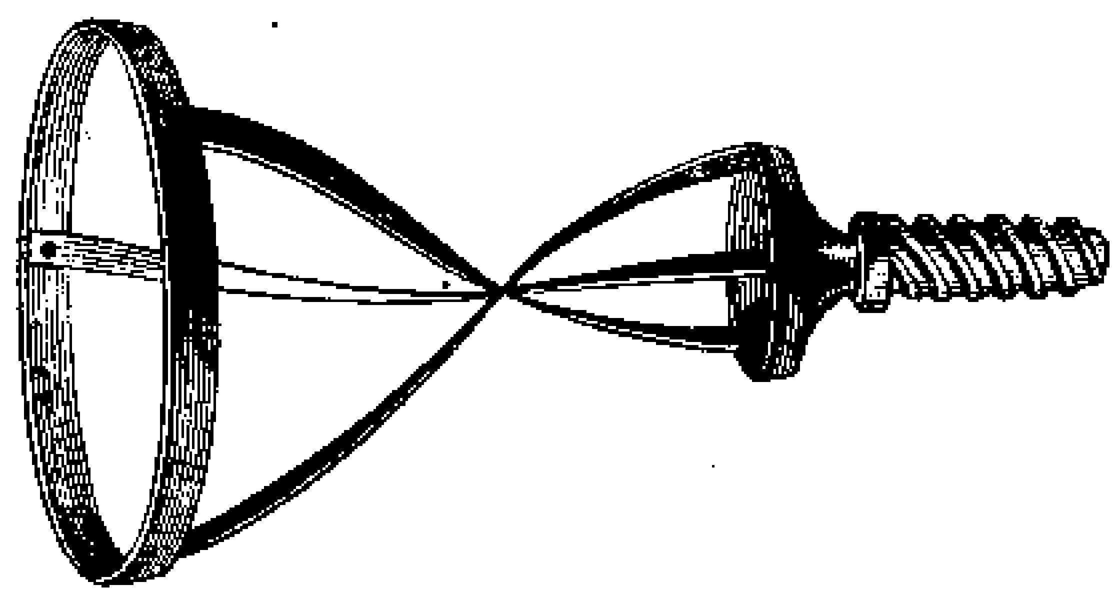
The loaves are now allowed to remain for two or three days, when the clay is cut or scraped away from their surface by a kind of triangular blade.

This operation is called brushing off. The loaves are slightly loosened in their moulds by striking the edges of the latter smartly against the upper end

* Nos. 5 and 6 in this plate represent the appearance which a loaf assumes when the process of liquoring proceeds unsatisfactorily, owing to the presence of an inordinate amount of glutinous (in a mechanical sense) impurities.

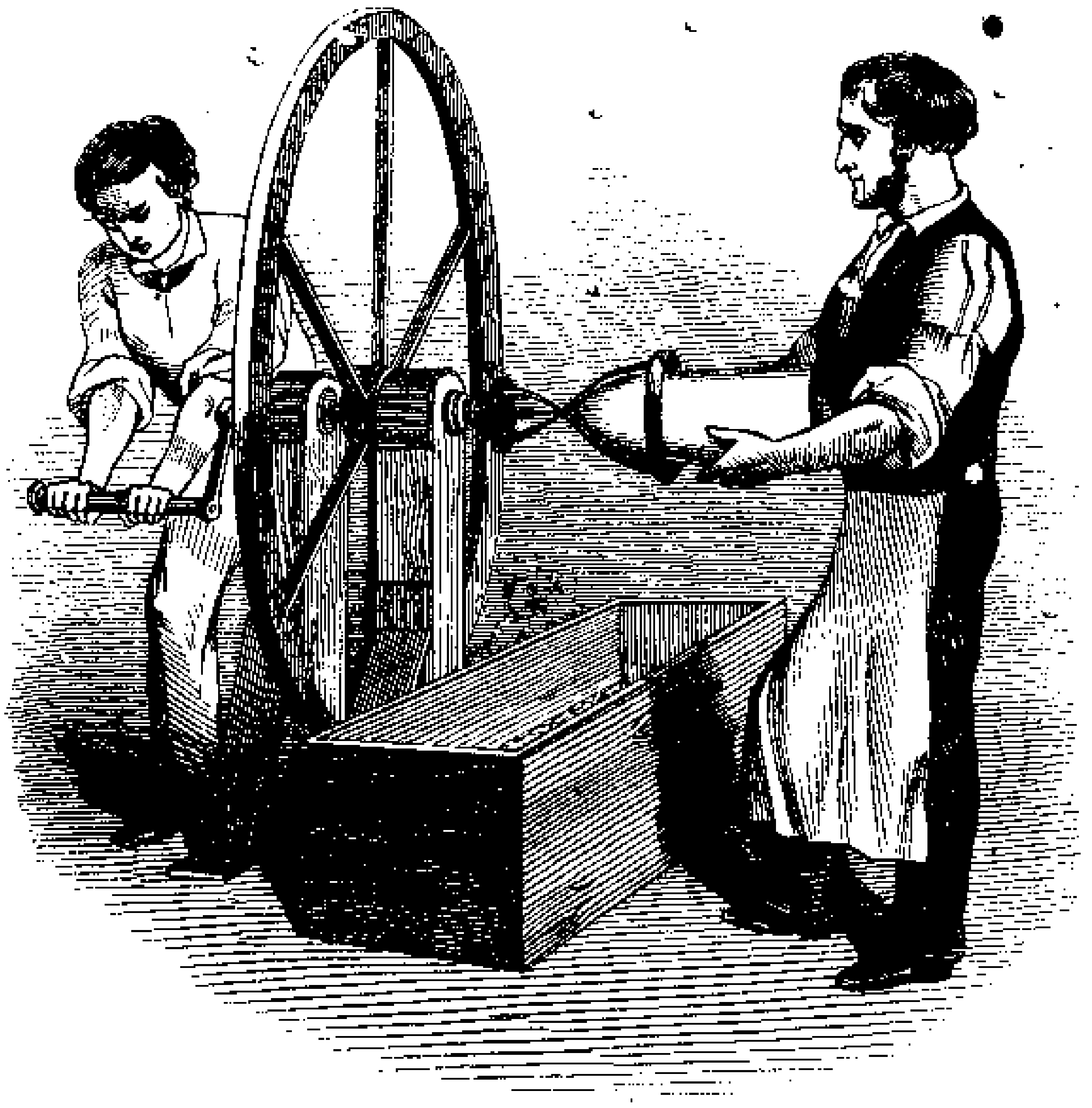
of a vertical post. This loosening contributes to perfect the drainage.

At the stage of loosening, a loaf may be completely removed from its mould, for the purpose of effecting an examination; which examination, in point of fact, is frequently made. When the loaves have become sufficiently dry to permit of being handled, they are taken out of the moulds, and their apices or noses are trimmed into regular form by means of the *nosing* machine, an instrument consisting of three cutting blades, so arranged on a rotatory shaft that the desired angle for the apices shall result.



Not only is this operation of nosing desirable, for the purpose of imparting a sharp well-defined apex to the loaf, but also for removing a small amount of dark-coloured sugar, of which the apex is, under the most favourable circumstances, composed. The efficacy of the claying and liquoring operations depends on the preponderance of gravity over capillary attraction. Hence there may be conceived a theoretical limit at which the two forces are balanced: practically this point of equalization between the two forces is at a few inches above the apex of the cone; and corresponds with the limit of impure sugar.

Occasionally, when liquors have been overboiled,



or when the material operated upon has been impure sugar, the point of equalization between the two forces is many inches above the normal line. To expedite the drainage of such cones they are stuck into a kind of funnel, the neck of which joins a suction pipe in communication with the air-pump of the vacuum pan. The result of this treatment is too obvious for comment.

The operation of *nosing* is never performed on the larger kind of loaves, which are known in commerce under the denomination of lumps; but the coloured portion of the apex is simply cut off by means of a knife struck by a mallet.

The loaves now, if sufficiently dry, are wrapped in paper, and the last traces of moisture driven off by the operation of stoving. The stove is a chamber, or rather a hollow tower, provided with many rows of trellis work, and heated by steam pipes to a temperature not above 115° Fahr. If higher, the sugar is discoloured. The operation of stoving lasts about three days, when the loaves being taken out are ready for sale.

If, instead of loaves, the manufacturer desired to obtain the material known as crushed lump, the contents of the moulds would never be stoved at all; but when sufficiently dry, they would be taken out, and struck with a mallet, until reduced to a mass of disaggregated crystals. At least this is the plan followed in making the better kind of crushed lump. In Scotland, however, where crushed lump is employed more largely than in England, and where the maximum of whiteness is no object, the processes of claying and liquoring are omitted, the natural drainage of the sugar being sufficient to effect the desired result. I am informed, however, by a Scotch refiner, that for this operation the very best sugar must be used, and that it must be boiled very low or free.

Much of the economy of refining depends on the proper employment of the syrups of drainage, and on this point the following axiom should never be lost sight of—*That every syrup of drainage is more impure for equal specific gravities of aqueous solution, than the sugar from which it has drained.*

This axiom will indicate the following rule to be adopted in the treatment of syrups:—namely, to add the purest syrup to the purest sugar, and *vice versâ*.

In proportion as sugar solutions are more frequently reboiled, so do their impurities continue to increase (pp. 36, 57, and seq.), until at length the impurities, when washed out, leave the crystals of sugar so far asunder that the mass, instead of being hard and compact, is so porous that pressure with the end of a stick leaves an indentation: such masses could not be stoved for loaves, neither could they be profitably broken down for crushed lump, inasmuch as the crystals are small and ill-developed, in consequence of being admixed with so many impurities that the operation of crystallization has been impeded.

Chemically speaking, however, they consist, or by adequate liquoring can be made to consist, of sugar as pure as the hardest loaves; they therefore serve for making the magma liquor as already described.

When the impurities have so accumulated in syrups, that it is no longer profitable to obtain the white sugar out of them by the process of claying and liquoring, a compromise is effected of the following kind. They are no longer liquored with magma liquor, which would not be remunerative, but with syrup; and the result is called pieces. This is the real Jamaica sugar of many grocers.

When the material to be boiled is not sufficiently good to yield a light yellow product, dark clammy semi-crystallized masses are obtained, technically known as bastards. (See Bastards.) It cannot be too emphatically expressed, however, that the terms, pieces and bastards, are purely conventional;—that no intrinsic or essential difference whatever exists between them;—that both are admixtures of sugar with impurities;—and that such impurities *may* be separated—although it be not remunerative to do so.

Indeed the demonstration of this may be easily effected, by rubbing the pieces, or bastards, with alcohol, and filtering through paper. Cold alcohol does not dissolve sugar, but it readily dissolves the glucose and dark acids with which the latter is associated, and leaves the sugar nearly pure. The latter, if dissolved in water, and carefully evaporated, leaves a result not distinguishable from that arising from any other pure sugar solution.

Bastards being the most impure kind of refinery crystallized produce, the reader will have anticipated the remark, that the syrup of drainage from bastards is treacle. (See Treacle, Definitions.)

The direct refinery operation being now gone through, it remains for me to describe the collateral processes of the scum, and charcoal departments. The reader will therefore revert to the filter bags,—which necessarily contain all the mechanical impurities, or scum, as it is called, developed by the operation of boiling the mixture of raw sugar, water, lime-water, and blood.

This scum, being somewhat bulky, must necessarily contain a large amount of sugar, to lose which would be totally irreconcileable with the close economy of civilized manufacture. The simplest plan in theory, to obtain such sugar,—would seem to be the common laboratory process of washing. So glutinous, however, is the impurity, and so bulky, that hot water will not pass through with the necessary rapidity: hence other means of extracting the contained sugar must be adopted. These means are as follows:—The bags being turned inside out, the contained scum is transferred to larger bags (scum bags), and exposed first to a pressure effected by the imposition of weights; afterwards, it is boiled with lime water;—and finally exposed to the pressure of a screw, or of hydrostatic power; by which means the greater portion of the sugar is removed.

When removed, the liquor—scum liquor, as it is called—is one of the most impure, offensive liquids that can well be conceived. Its colour resembles porter;—its smell that of putrid blood;—its taste, according to such evidence as I can collect, is somewhat sweet. On this latter point I am free to own that I can bear no direct testimony.

If there be any truth in the chemical deduction previously arrived at—viz: that the rapidity of decomposition for sugar solutions, *cæteris paribus*, is in direct ratio to the amount of impurities contained—this scum liquor must be a focus of so much mischief that it should never, under any pretext, be incorporated with the raw sugar of a refine. But now the practical question arises:—what is to be done with it? To evaporate so weak a solution of sugar and water—even devoid of impurities—would be practically impossible—seeing that the process of evaporation must be prolonged to the extent of destroying the chief part of the sugar. (See pp. 36, 57, and seq.) Then how much are the difficulties of the position increased by the presence of animal matters and lime! In fact, scum liquor is surrounded by most unyielding conditions; not only must it be added to the next *blow-up*, but added *at* *once*, or else fermentation sets in, and it is decomposed.

It is evident, then, that the present operation of sugar refining is one of gradually increasing deterioration. On account of the necessity the refiner is under of adding impure saccharine solutions to such as are comparatively pure, he pursues a system of working in and in, most destructive to the staple of his operations; and were it not that treacle is a general receptacle for impurities, refineries would run themselves out, or be brought to a close.

This system of in-and-in work is one cause which prevents a refiner from knowing the exact per centage amount of produce yielded by any given sugar; but there is another, namely, that involved by the use of magma liquor, which necessarily confuses the weighed results.

Refiners have been thought extremely tenacious in guarding against the disclosure of the per centage amount of sugar obtained, and doubtless that tendency exists; but, in strict truth, they cannot tell, so much is one operation involved in those which precede and follow.

It is not here asserted that a refiner cannot, by taking the average of a considerable period, obtain a general result of his produce; but to ascertain the amount of pure sugar obtained from any given sample, is, by the present refinery operation, impossible.

To illustrate the unsatisfactory looseness of the deductions which are sometimes made from inadequate data furnished by the refining operation, the following narrative will suffice. I was shown a kind of laboratory-book belonging to a London refiner, and in which the assertion was made, that about 82 pounds of white sugar out of the 112 of raw material were obtained in his establishment: no experiments were mentioned, but merely the dictum laid down. I subsequently examined the boiler as to the means by which the deduction was arrived at; when it appeared that the deduction was not proved, but merely assumed, as being in accordance with certain experiments made,—not in the refinery, but in the laboratory. The process of liquoring was not adopted in these experiments, but the sugar in the green state was assumed to have a certain per centage of colouring matter. "After all," remarked the boiler very candidly, "I never could see how this result of 82 pounds was ever arrived at; and I consider the result of our best working to be more like 75 or 76."

There is a considerable affectation prevalent among refiners, of considering their manufacture absolutely perfect. A very large London refiner would lead the world to believe that he does not produce in his refinery any bastards. He does not *sell* any, it is true, considering it more profitable to purify this product to the extent of enabling it to be converted into pieces. This same refiner also entertains the notion, that he absolutely extracts *all* the sugar out of his scum; whereas I know, on authority that is unquestionable, that he sells the scum of one of his refineries alone for 5*l.* per week to a party who converts it into bastards and treacle.

Most refiners have an instinctive horror of owning to the employment of blood. I once was taken to a London sugar house, which has the credit of being considerably in advance of others in the general economy of the whole operation. Amongst other matters, I was informed that no blood was used. A personal examination of the blow-up pan, however, during an operation, corrected the error fully to the satisfaction of myself and friends. Having viewed attentively every part of this refinery, I found that the only difference between it and many others which I had seen consisted in the remarkable cleanliness of the floors.

The Treatment of Charcoal.—In London many refiners do not reburn their own bone black; indeed some refiners possess none of their own, but rent the material at a stated price. Others, however, burn their charcoal, even in London: in the provinces the plan is universal.

Although various processes have been tried for effecting the purification of animal charcoal without the aid of heat, they have all been discontinued; and the process of dry distillation is universally had recourse to. This process is now, I believe, universally conducted in cast-iron retorts,—either exposed to the direct action of the fire, or set in a kind of oven, according to the most approved plan followed by manufacturers of coal gas. Not only do retorts, when exposed to the direct agency of fire, become speedily destroyed by oxidation, but occasionally the bone black is apt to be over-burned, whereas in the dome-set retorts this result cannot occur.

That over-burning of bone black is injurious, has been recognised by many persons, but I am not aware that the reason of the injury has been explained. Indeed, to recognise the full amount of that injury, for the sake of making an extreme case, a special experiment is required; inasmuch as it is scarcely possible to apply the necessary amount of heat to a large retort, even when acted upon by the open fire. The first evidence of incipient over-burning of the bone black is a peculiar glazed appearance which the grains possess, and which is probably a mere physical effect, and dependent on an increased density of mass, from the close approximation of particles. If the heat be pushed still further, the agency of the charcoal in the bone black on the accompanying phosphates, liberates such an amount of phosphorus, that any sugar solution passed through such charcoal is completely spoiled. In the dome-set retorts, not even the first ill effect can well occur. The decolourizing effect of bone black is much impaired, if it be not washed free from sugar before burning: such is the fact, but the rationale is not understood.

During the process of burning, the bone black gives off a great quantity of gaseous and condensable empyreumatic products, amongst which ammonia, and Dippel's animal oil, predominate; thus proving, if any evidence were wanted, how far the legitimate influence of the bone black, as a mere decolourizing agent on sugar, has been interfered with by the presence of the animalized matters derived from blood. As soon as the evolution of volatile matter has ceased, the charcoal is raked out with all due rapidity into iron chests, and at once covered over, so that all ingress of air may be prevented; otherwise a large portion of the charcoal would be consumed.

As regards the theory of the action of bone black, I confess myself entirely ignorant. Although cognizant of the various theories which have been mooted from time to time to explain this agency, I have met with no explanation yet that seems at all satisfactory; and want of time has prevented me from devoting any great attention to the matter.

I am far from convinced that the decolourizing agency is due to the charcoal of the bone black in the least degree; and, so far as I have seen, the opinions of Messrs. Gwynne and Young, recorded in the Annals of Medicine for June 1837, would appear to be correct:—namely, that the agency is due to the 90 per cent. of phosphates of lime and ferruginous compounds, with which the 10 per cent. of charcoal in bone black are associated. I may mention, also, that this opinion is advocated by Mr. Fairrie, the refiner, of London, Liverpool, and Glasgow.

CHAPTER XII.

ON THE DEFECTS OF THE PRESENT REFINERY OPERATION:—GENERAL SUMMARY—CONCLUSION.

THE chief defects of the present refinery operation are as follows:—

1. The necessity of employing lime water and blood.

2. The great accumulation of sweet waters arising from the washing of the charcoal.

3. The process of in-and-in workings.

4. The deteriorating influence of scum liquor on solutions of sugar.

After the exposition which has already been given, (at p. 62,) of the injurious agency of lime on sugar, little remains to be stated on that point here. Indeed, the amount of lime as used in refineries is but small; the earth never being employed in substance, but always as lime-water; hence the injurious agency of this alkaline earth is in a manner reduced to its practical minimum. Still, even under these circumstances, its ultimate destructive agency must be great, when it is considered that each successive syrup contains the lime, not only of its own operation, but of many preceding operations—modified only by the amount of lime removed (if any) by the bone-black filtration process.

The employment of blood, although effecting a considerable mechanical separation of one set of impurities, and thus enabling the liquor to pass rapidly through the filter bags,—nevertheless imparts not only red colouring matter, but also the peculiar odorous compound of the blood. The colouring matter, it is true, can be removed by animal charcoal,—but only, as must be evident, by diverting a certain amount of the efficacy of that substance from its more legitimate agency of removing the vegetable colouring matter of impure sugars. As to the odorous matter, it is never separated from the liquors to be evaporated, however bright they may be to the eye; and is only removed from the crystallized sugar by the processes of claying and liquoring,—which force it into the syrup,—and, lastly, into the treacle. Hence it is that the coloured refinery products—pieces and bastards—although somewhat like Muscovado sugar in appearance, possess a most offensive smell. The coloured sugars resulting from a refinery process, where no blood is used, cannot be distinguished from real Muscovado sugars—the best proof of the assertion that the peculiar smell of the two former is due to the odorous matter of blood. Another very strong proof of the presence of this odorous matter consists in the fact, that the condensed vacuum-pan steam evolves a peculiarly nauseous smell of perspiration. The perspiratory fluid of animals is well known to be elaborated from their blood; and, taking advantage of this fact, a celebrated writer on forensic medicine*

* Barruel.

has proposed to distinguish medico-legally between the blood of brutes and the blood of man by treating the suspected blood with sulphuric acid, when the peculiar perspiratory smell of the animal will be evolved.

The accumulation of sweet waters arising from the various washings to which the charcoal must be subjected is a very serious inconvenience, which is much felt now that the effective bulk of bone black has been so greatly increased beyond the *few inches* mentioned by Derosne, the patentee.

If these washings accumulate faster than the necessities for water in the future operations of blowing-up,—the inconvenience—not to say positive loss—to the sugar refiner will be great indeed.

The effect of in-and-in working, as producing a cumulative amount of destruction, has already (page 147) been so fully enlarged upon, that it need not be further adverted to—and a similar remark applies to the injurious agency of scum liquor.

It now merely remains for me to add, that the process of employing sulphurous acid as a precipitant for lead—used as a defecator—is equally good for refinery, as for colonial, operations; as I have proved most rigorously, both on the small scale and the large.

In conclusion, I beg here to thank the various gentlemen, far too numerous to mention, who have aided me in my investigations on sugars for the last eighteen months.

To Messrs. Evans, Thwaites, and Co., refiners, of Cork, my acknowledgments are particularly due for

the very prompt and liberal manner in which they responded to my application for leave to try the efficacy of my process in their house. The various experiments conducted on the small scale in a laboratory, built by them for the occasion, having led to a successful trial on the large scale with most satisfactory results,—their house has now been specially altered for the purpose of adapting it to the genius of the new process*.

* Since the period when the above was printed, my coadjutors have become far too numerous for special acknowledgment. I must not, however, omit the name of Messrs. Shears, of Bankside, who have fitted up a model house on their premises for demonstrating the new operation, and to whom I am indebted for many valuable suggestions as regards the mechanism of my process.

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