

XXII. *On Maltose.*

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SOME time ago, Schulze (*Deut. Chem. Ges. Ber.*, vii, 1047) confirmed, without reference to the original paper, that part of my work relating to maltose, described by me in this Journal ([2], x, 581). He added nothing to the evidence given as to the character and constitution of this body; he analysed it in the crystallised state, I dried it in a current of dry air at 100° before burning it; I did so, because I did not consider the crystals sufficiently definite to repay the trouble of a combustion, and without this definiteness, the percentage of carbon, hydrogen, and oxygen would not have settled the matter, for reasons pointed out by me in the work indicated. As M. L. Bondonneau, however, in a note recently presented to the Academy (*Compt. rend.*, lxxxi, pp. 972, 1210) by M. Berthelot, evidently without much knowledge of what has been done on the subject, ignores its existence altogether, I may be permitted to draw attention to a few experiments by which I hope to have settled conclusively its composition and affinities. These experiments were made a few years ago, but I did not then think them of sufficient interest to lay before the Society; the publication of M. Bondonneau's paper simply calls them forth.

All attempts to obtain maltose in anything like well-defined crystals

have hitherto failed, although specimens are easily prepared which show distinct terminal faces under the microscope. The sodic chloride compound, too, cannot easily be obtained in any quantity; that it exists, however, in long, apparently prismatic crystals, there can be no doubt; but I have not yet succeeded in preparing them in a state sufficiently large for measurement, or in sufficient quantity for analysis.

In the absence of the conclusive evidence to be obtained by an analysis of the body if it were to be prepared pure, or in combination, in well-defined crystals, I have, by indirect means, tried to add some facts to those already given, to establish its character and constitution.

In reality, the only point to be settled with regard to the body is that it is not a mixture of a dextrin, of known or unknown properties, and dextrose. Indeed, almost enough has been done in my preparation and analysis of the body to place this point beyond all reasonable doubt, but yet it seemed to me desirable to determine:—

I. If dextrose could be separated from dextrin by the same process by which maltose was eliminated; and

II. If, on submitting to fermentation a solution containing a mixture of dextrose and dextrin in the same proportion as they appear, from the cupric oxide reducing power, to exist in maltose, viz., 65 per cent. dextrose and 35 per cent. dextrin, the same phenomena be observed as with maltose itself.

I. A mixture was made, containing 25 grams of carefully prepared dextrose,* and 75 grams of pure dextrin, prepared by the action of malt-extract on starch-paste, as described by me, and the mixture dissolved in as little water as possible, to obviate the necessity of evaporating. The syrup was then well shaken up with 1000 c.c. of alcohol, sp. gr. .830, and the whole allowed to stand 24 hours. At the end of that time, the alcoholic solution was decanted off. The syrup left on distilling off the alcohol was found to contain only pure dextrose, reducing the same amount of cupric oxide and having the same specific rotatory power as the dextrose employed in making the mixture. The alcoholic solution, as might be expected, was not saturated, nor was the residue insoluble in alcohol nearly free from dextrose; it is enough, however, that the reducing body, dextrose, can be completely freed from the non-reducing one, dextrin, by means of alcohol. This was repeatedly confirmed by treating various mixtures of dextrose and dextrin as described: hence maltose cannot be a mixture, as its action on Fehling's

* The dextrose employed in these experiments was prepared from cane-sugar by the action of sulphuric acid, and purified by crystallisation from alcohol and from water; 1 grm. of this dextrose (dry, $C_6H_{12}O_6$) reduced 2.205 grms. cupric oxide (the cuprous oxide being weighed as cupric oxide). I found the specific rotatory power of this body to be, for the transition tint, + 57.6, a number agreeing closely with that of Béchamp, but differing from that of a few other observers.

solution would seem to indicate any more than lactose is, because, instead of yielding a body capable of reducing cupric oxide as dextrose does on treatment with alcohol, it yields a solution which, on evaporation, leaves a residue having the same optical activity and reducing power as the portion left undissolved. M. Bondonneau says that the portion which does not reduce cupric oxide is γ -dextrin, soluble in alcohol. But as neither of the other dextrins is soluble in this liquid, it is not possible to imagine how this one, if it exists, could not only be soluble, but also have absolutely the same proportionate solubility as the reducing body: for treat maltose in any conceivable way, and it will be found, as shown by me, that the amount of cupric oxide reduced by it, and its optical activity, are always constant. In fact, it is not possible to separate it into two bodies. It can be separated, too, from α - and β -dextrin by dialysis, passing through the parchment-paper with constant reducing power and optical activity, the dextrin remaining on the dialyser. I have found, also, that in separating it from these dextrins by means of alcohol, if the alcohol be so weak as to dissolve the least quantity of either of these bodies, the maltose refuses to crystallise even after months' standing. Or if crystallised maltose be mixed with even 1 per cent. of either of the dextrins, on dissolving the mixture, it cannot again be got to crystallise until the dextrin is separated. Hence, even thus far, M. Bondonneau's γ -dextrin must be abandoned; it is nothing more than the non-reducing part of maltose. The fact that he found it impossible to obtain the so-called γ -dextrin pure should have been almost sufficient to tell him that he was in error.

The second point was settled as follows:—

A solution was made, containing 6.7433 grams dextrose and 3.7767 grams dextrin in every 100 c.c. To 100 c.c. of the solution, 1.5 gram yeast, containing about 0.4 gram solid matter, a quantity capable of decomposing at least 40 grams dextrose, was added, and placed to ferment at 20° in a flask to which two wash-bottles were attached, so that the gas evolved should pass twice through water, a precaution necessary to prevent the loss of alcohol. At the end of about seven days, all action had ceased; the solution was, however, kept at the same temperature (20°) for two days longer, and then poured into a distilling flask, and the washings made with the water in the wash-bottles, using the one nearest the evolution-flask first. On distillation, 100 c.c. dilute spirit were obtained, sp. gr. .99419 at 15.5°; this, according to Drinkwater's tables,* is the sp. gr. of a spirit containing 3.21 per cent. by weight of alcohol: the 100 c.c. therefore contain

* I may remark that I find these tables (*Chem. Soc. Memoirs*, vol. iii, p. 454) of considerable accuracy.

3.191 grams. 1 gram of the yeast employed contained .032 gram of alcohol: hence $3.191 - .048 = 3.143$ grams of alcohol derived from the matter which had fermented. The residue left on distilling off the alcohol was freed from yeast by filtration, and made up to 100 c.c. at 15.5° . This solution had a sp. gr. = 1.01735, an optical activity = $+ 81.8^{\circ}$, and gave a reduction of cupric oxide = 0.3383 gram of dextrose in the 100 c.c. The residue contained, therefore, 4.504 nearly of solid matter; of this, 0.3383 is dextrose; 0.18 is due to the soluble portion of the yeast added; the remainder to dextrin and the non-volatile products of fermentation. The total dextrose employed = 6.7433; of this, 0.3383 gram remained unfermented: hence 6.405 grams dextrose disappeared, to yield 3.143 grams alcohol, or 49.07 per cent.

The optical activity corresponding to 0.3383 dextrose in 100 c.c. solution = $+ 1.93^{\circ}$; the remainder $+ 79.87^{\circ}$ ($81.8 - 1.93$), is due to dextrin, 10 grams of which in a 100 c.c. = $+ 213^{\circ}$: therefore 79.87° corresponds to 3.75 grams in the 100 c.c. against 3.7767 grams employed in the experiment; $3.75 + 0.3383 + 0.18 = 4.1683$ against 4.504 grams, as shown by the specific gravity leaving .3357 gram (a little more than 5 per cent. on the sugar fermented), to represent the non-volatile products of fermentation and the errors of manipulation.

This experiment was repeated several times with results differing but slightly from those given here, and although in the experiment described, a small portion (about 1 per cent.) of the dextrin would seem to have disappeared, yet I am satisfied, from the whole of the experiments, and they have been numerous, that this is to be attributed rather to a slight error of manipulation than to the fermentability of dextrin: hence if a solution of a mixture of dextrose and dextrin be submitted to the action of yeast, only the dextrose (the reducing body) disappears, the dextrin being in all cases unacted upon, within 10 to 12 days at a temperature 20° — 22° . This I know is contrary to the opinions of most chemists; but, nevertheless, the fact is as I state it; dextrin does not ferment when exposed to the action of an excess of yeast, even in presence of a fermentable body at a temperature 20° — 22° , or below. What has led experimenters, from Liebig downwards, to imagine the contrary, will be made plain in the sequel.

A solution of pure maltose was made, containing 10 grams of dry substance ($C_{12}H_{22}O_{11}$) in every 100 c.c.; this gave a reduction of cupric oxide, as if it were composed of 65 per cent. dextrose and 35 per cent. dextrin. 100 c.c. of this solution were taken and submitted to fermentation under the same conditions, and with the same amount of yeast as was employed in the experiments with the mixture of dextrose and dextrin described above. When all action had ceased, the liquid was

submitted to distillation as before, and yielded 100 c.c. dilute alcohol, sp. gr. .9910 = 5.13 per cent. absolute alcohol = 5.124 grams in the 100 c.c. $5.124 - .048$ (from the yeast) = 5.076 grams alcohol: hence the sugar, maltose, yielded 50.76 per cent. alcohol. What remained in the residue consisted of nothing more than the non-volatile products of fermentation and the soluble portion of the yeast. This experiment was also repeated several times with varying quantities of maltose, and the proportion of alcohol was found to vary between 50.4 per cent. and 51.8 per cent. Pasteur gives 51 as the amount per cent. of alcohol derivable from cane-sugar by fermentation, and as dextrose gives only 48—49 per cent. alcohol, according to the same authority and my own observations, maltose must belong to the saccharose, and not to the glucose group. Formerly, chemists who estimated the amount of dextrose in a substance by the quantity of cupric oxide it reduced, were led to the conclusion that dextrin fermented, because if maltose only were present in a solution submitted to fermentation for every 65 per cent. dextrose (the reducing power), 35 per cent. dextrin (the non-reducing power) would seem to have disappeared. Gschwandler (*Bayerischer Bierbrauer*, 1868, 97), agreeing with Reischauer's observations, pointed out that when malt-wort is submitted to fermentation, a quantity of alcohol equal to the amount of sugar contained in the wort (cupric oxide reducing power), plus $\frac{2}{5}$ of that amount, is produced. This is due to maltose, and the $\frac{2}{5}$ instead of $\frac{3}{5}$ to the fact that malt-wort contains other sugars besides maltose.

It is not always possible to ferment maltose completely, any more than it is to ferment cane-sugar; and as a rule I find that, although the yield of alcohol is usually 51 to 52 per cent. of the maltose taken, there mostly remains unfermented in solution with the non-volatile products of fermentation, from 0.5 per cent. to 1 per cent. of the substance employed, unchanged. It may be interesting, also, to know that if a solution containing a mixture of maltose and dextrose be submitted to fermentation, the whole of the dextrose disappears before the maltose is touched. I make this statement on the evidence furnished by numerous observations.

From these experiments it is evident that we shall have to look upon the sugar, maltose, obtained by the action of malt-extract on starch, as a simple body, isomeric with cane-sugar, with a specific rotatory power a little more than twice as great, $+ 150^\circ$ against 147.6° ($73.8^\circ \times 2$), and 100 parts of it capable of reducing only as much cupric oxide as 65 parts of dextrose, and not as a mixture of dextrin with dextrose, as M. Bondonneau regards it.
