

## THE STATEMENT OF ANALYTICAL RESULTS.

BY J. F. LIVERSEEGE, F.I.C.

*(Read at the Meeting, December 2, 1896.)*

THE question I wish to discuss is, not how far should analytical results be given in reports, but to ask what are the principles by which the number of significant figures given in a result should be decided.

The following analytical results have been reported in recent prosecutions under the Sale of Food and Drugs Act :—

- I. A whisky was  $34\cdot71^{\circ}$  under proof.
- II. Alcohol, 78·03 per cent in spirit of nitrous ether.

III. Peas containing 3.11 grains of sulphate of copper per pound.

IV. Butter with 19.88 per cent of water present.

V. Milk adulterated with 11.77 per cent. of added water.

VI. Coffee adulterated with 68 per cent. of chicory.

The first four are statements of fact, the others are expressions of opinion. If two distillations of alcohol often differ by 0.2 per cent., what is the use of giving a second decimal place? Is there any probability that the analysts of III. and IV. would again obtain 3.11 grains or 19.88 per cent. as the result of other analyses? Ought a milk standard to be used to calculate the added water to 1 per 10,000? If these second decimal places have no meaning, is it wise to appear to claim such a high degree of accuracy? It seems to me to be reasonable to expect that a *second* decimal place should not appear on a certificate, unless it is probable that the *first* could be again obtained in another analysis, and that, unless the unit is certain, adulteration should only be certified to 5 or 10 per cent.: in VI., for instance, report 65 or 70 per cent. of chicory to be present. Suppose that in I. another analyst found 34.91° under proof, some magistrates would consider this a much more serious difference than if one analyst certified 34.7° and another 34.9° under proof. I also think that in V. the analyst would have felt rather foolish if, in answer to questions, he had admitted that there might be 15 or 20 per cent. of water added, instead of the 11.77 per cent. certified to be present.

In water analysis decimals appear very largely; the following are single analyses (not averages) taken from standard works. Total solid matter, 108.88, 220.92, 320.72; nitrogen as nitrates, 6.499, 14.717, 19.858; ammonia, 1.366; organic nitrogen, .141, .298, .531; organic carbon, .142, 1.792, 2.662; total hardness, 116.9, 140.8.

It appears to me that in each case the last figure of the result is superfluous and should be omitted, the previous figure being increased by one if the last figure is 5 or more. If 250 c.c. of water were taken for the total solid matter recorded as 220.92, the residue would weigh 0.5523 gramme, and each milligramme error would affect the result by 0.4; one decimal place is therefore as much as should be put in any ordinary analysis. In the determination of ammonia, an error of 0.5 in 5 c.c. of ammonium chloride solution is possible, or 10 per cent. I would suggest that to proceed by units from 1 to 25, and then by 5 up to 100, irrespectively of the decimal place, would be better than putting meaningless figures; 1.366 would then become 1.4. When the amount of hardness present exceeds 50, the unit figure becomes very uncertain, and 116.9 may for practical purposes be written 117 or 120. Similarly, nitrogen as nitrates, "6.499," should be written 6.5; and my experience of organic carbon and nitrogen makes me think that the third decimal place cannot be depended on. It is no doubt advisable to record the exact figures found in the laboratory notes, but in reports and printed matter these extra figures appear to me to be unadvisable and misleading.

These superfluous decimals also appear in other chemical work. A recent paper on lemon-juice stated that one fluid ounce contained 34.089 grains of citric acid; the milk analyses giving such specific gravities as "1.03148" are well known, and the following quotations cannot easily be surpassed. "Use a 0.0845691 per cent. solution of K<sub>4</sub>FeCy<sub>6</sub>, 3Aq." "The factors for a volumetric solution of iodine are:—Salicylic acid, 0.18132606; thymol, 0.2956772; and  $\beta$ -naphthol, 0.37843106."

In text-books, the meaning of "per cent." is sometimes doubtful; it may be by weight, or by volume, or grammes per 100 c.c. In my own notes, I have for some years been in the habit of using "%" in cases where there can be no ambiguity of adulteration "%," for instance, and for per cent. *by weight*. Per cent. *by volume* has been expressed by the sign "v/v" (*i.e.*, volume on volume), and grammes per 100 c.c. by "w/v" (*i.e.*, weight on volume). These signs show readily exactly what is meant. Alcohol S.G. 0.838, for instance,  $84\% = 88.7 \text{ v/v} = 70.4 \text{ w/v}$ .

## DISCUSSION.

The PRESIDENT (Dr. Stevenson) said he thought that, as a rule, insignificant decimal places were better dispensed with, but in some cases it was perhaps a matter of convenience to insert them. For instance, in water analyses, where some of the factors really required the use of three decimal places for their proper expression, it was more convenient to state the results all through to three decimal places than to jump about from two to three. In cases where the third place had no real significance it might be filled by a cipher for the sake of symmetry.

Mr. ALLEN said that he was in the unusual position of disagreeing with the President, for he thought that, if a fraction were cut short by omitting the concluding figure, the place of this figure ought not to be filled by a cipher, inasmuch as a definite value was thereby assigned to it which was not intended. If the figure was assumed to have no significance whatever, the place ought to be left blank.

There was only one excuse for the use of these long decimals, and that was that the chemist gave the results he got. He put them forward, not as the strictly correct results, but as the actual results of his work, and if these results required a decimal fraction to express them, they should be stated accordingly. That was the only excuse, except in the case of gold and steel analyses. The third decimal place in a steel analysis had a distinct significance in the case of phosphorus and sulphur, and affected the second place, where any variation became of consequence. He was afraid the public sometimes looked upon analysts as quacks, more or less, because they reported to two or three places of decimals in cases in which it was exceedingly doubtful if they would get on repetition a result agreeing even to the first place of decimals. The Society itself occasionally offended in this respect, for, in the circulars recently issued to members respecting the form of milk certificates, and which was made necessary by the decision in the case of *Fortune v. Hanson*, the sum of the results of a milk analysis was directed to be stated to two decimal places! He (Mr. Allen) felt very strongly that it was a mistake to pretend to express results with extreme accuracy unless such accuracy could be approached reasonably closely; and he thought that, except in special cases like those he had mentioned, the sooner the practice was discarded the better.

Mr. CASSAL thought there was a great deal to be said on both sides of the question. He agreed with a good deal of what Mr. Allen had said, and to a certain extent with the author of the paper, but it had to be remembered that public analysts were not their own masters in all matters of this sort. Mr. Allen had alluded to milk, and had caused some laughter by mentioning the fact that the statement of results to the second decimal place had been suggested in the Society's circular; but what was one

of the effects of the case of *Fortune v. Hanson*? It was this: If public analysts wished to avoid being put to serious inconvenience, and wished to avoid following the practice which in his student days was known as "cooking," the percentage of added water would have to be stated to a decimal place in most cases. If the percentage of added water was stated to the nearest whole number, as used to be done, it would be necessary to alter the percentage of non-fatty solids, which had now to be given on the certificate, for it necessarily happened that in most cases the percentage of added water calculated from the non-fatty solids ran into a decimal. It was not necessary, of course, to go to the second place of decimals.

With regard to water analyses, he thought that absolutely unnecessary figures ought not to be stated at all, though in one place he had been for a long time practically compelled, through no fault of his own, to state the result of certain water analyses in parts per 100 million (laughter). It was done originally, he believed, because it was thought that those who had to consider the figures understood whole numbers, but did not quite appreciate decimals, and the result was that they were provided with "parts per 100 million" because they had then got something to catch hold of (laughter).

The real way out of the difficulty was to apply common sense to the matter. It was one which required to be dealt with according to the individual merits of every case in which it arose.

Mr. BEVAN said that the case of *Fortune v. Hanson* had been to a large extent set aside by the decision in the case of *Bridge v. Howard*. In that decision it was clearly shown—at least the judge allowed it to be understood—to be quite unnecessary to state the quantity of added water to a decimal fraction. The percentage of solids-not-fat in the case of *Bridge v. Howard* was 7.95, and the added water, calculated to one decimal place, was 6.5. He (Mr. Bevan) had called it 6 per cent., and the judge, having made the calculation for himself, said that as a matter of fact the percentage of added water had been under-stated, but took no exception to this.

Mr. CASSAL said that his experience was that the accuracy of an analysis would be doubted by non-experts if, when the figures were asked for, the actual figures, including the decimals, were not given. He might say that on one occasion a magistrate wanted him to leave out the decimal figures in the non-fatty solids reported in his certificate in order that the method of calculating the amount of added water might be made "more clear."

The PRESIDENT said that Mr. Cassal's experience appeared to be exceptional. He himself had been in the habit for twenty-five years of stating whole numbers only, without fractions, in the case of milk. In regard to certain other things, such as coffee, he had taken still greater latitude, as he would not venture to distinguish between, say, 55 and 60 per cent. in the case of coffee adulterated with chicory, and he had found magistrates sufficiently reasonable to see the force of this.

He was glad to think that the difference of opinion between Mr. Allen and himself was, after all, but a small one.

---