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MEETING HELD AT THE MIDLAND HOTEL, BIRMINGHAM,  
ON THURSDAY, DECEMBER 9TH, 1909.

Mr. W. H. EVANS in the Chair.

The following paper was read and discussed :—

### *The Uses of Sulphur in the Cultivation and Curing of Hops.*

By ARTHUR AMOS, B.A.

THE reasons for the selection of the above title to my paper are two. Firstly, because, in occasional conversations with brewers, I have found that there exists a certain amount of confusion in their minds as to the exact purposes for which sulphur is used by hop growers. And, secondly, because I am anxious to find out whether, in the opinion of brewers generally, sulphur in the hops is at any time detrimental to the beer brewed ; and, if so, what is the limit beyond which it begins to be detrimental ? in other words, how much sulphur can the hops contain without damaging the beer ?

Sulphur is used by hop growers for two entirely distinct purposes. Firstly, it is used in the form of "Flowers of Sulphur," as a preventive of hop mould or mildew. Secondly, it is used in the form of "Roll Brimstone," which is burnt during the drying of the ripe hop cones.

I. *Flowers of Sulphur for Mould*.—Hop mould or hop mildew is very similar to other common mildews, such as those which grow upon the Rose or the Oak. It is a fungus disease which grows upon the upper and lower surfaces of the hop leaves, and lives parasitically upon them. During its life it exhibits three distinct stages or forms upon the hop plant.

The first stage consists of white powdery spots upon both upper and lower sides of the leaves, and later this form also appears on the "burr" or buds of the hop cones. In the latter case it prevents the "burr" from developing into hop, forming instead hard white knobs. Later still, these hard white knobs turn black owing to the formation of tiny black mould fruits upon the knobs. These black fruits are the second form of the mould and contain the mould spores which lie dormant during the winter, and give rise again to the white form the following spring. This stage is not formed until the hops get ripe. No doubt the appearance of these deformed, hard, black, mouldy hops is well known to brewers in mouldy hop samples. I have with me a sample of mouldy hops which will show the black mould fruits that I have described.

The third stage is called by growers "Red Mould"; it is really a continuation of the White Mould. It is produced when the mould begins to grow upon fully formed hops, and it has the effect of changing the colour of the hops from green to the so-called red colour. This change, when once it has started, takes place very rapidly, and sometimes an apparently healthy garden turns "red" in a very few days.

A considerable amount of the bad colour of the 1908 crop was due to this red mould.

The best preventive (and in the case of hop mould prevention is far better than cure) of all the stages of the hop mould is sulphur. In the form of a very fine powder, called Flowers of Sulphur, it is largely used by growers. There are two means by which it may be distributed:—

(1) By a knapsack sulphurator.

This consists of a tin containing sulphur with a bellows attached. The knapsack is carried by a man on his shoulders, who works the

bellows with one hand and with the other directs the sulphur, which comes out through a tube upon the lowest hop leaves. This apparatus is used from the time when the hops have just started to grow until they are about half way up the strings. This early sulphuring does much to check the mould starting, and, as the cost is trifling, is very economical.

(2) By means of a horse-drawn sulphurator.

This consists of a machine on wheels, which carries a supply of sulphur; the sulphur is blown into the air by a fan, which is driven by being geared with the wheels of the machine. As this machine is drawn through the garden a cloud of sulphur is driven into the air, and this cloud slowly settles upon the leaves. This sulphurator is not generally used until the hops have reached the top wire, since, otherwise, too much of the sulphur settles on the ground and is wasted. This method of sulphuring may (if the attack of mould be very serious) be continued at intervals to within a few days of picking. If the hops are formed, some of the sulphur will lodge in them, and be retained during the picking and drying, and so contaminate the sample. The sulphur in this case remains in the hops in the form of free sulphur.

II. *Burnt Sulphur for Curing Hops.*—When hops are being dried on the kilns, a quantity of sulphur (in the form of roll Brimstone) is invariably burnt beneath them during the first two or three hours of the drying. The fumes of burnt sulphur (sulphur dioxide) pass through the hops, and by their passage bleach the hops, and are in part retained by the hops.

The amount of sulphur used is usually about  $\frac{1}{2}$  lb. of sulphur to 10 bushels of green hops, or, approximately, 5 lb. of sulphur to 1 pocket of hops. If the hops are very green, when picked, as much as double this quantity may be used.

Now one often hears of brewers advising growers to dry their hops without burning sulphur, and of the brewers being surprised that this advice is not carried into effect. Let us examine what really is the use of burning this sulphur, because, obviously, if it merely serves to change the colour of the hops and does nothing else, it is *economically of no value*.

Sulphur acts upon the hops in three distinct ways: firstly, as I have said, the colour is changed. If hops are dried without the use of sulphur the dried hops have a dull dirty-green appearance. The

effect of the sulphur is to make the hops appear bright and yellow, and much more attractive to the eye. I do not think a buyer could ever pass by a bright sulphured hop and give preference to a dull unsulphured one, even if he knew that the latter was unsulphured. I well remember seeing unsulphured hops on an oast floor for the first time. It transpired that the dryer had put the sulphur in the kiln as usual and had lighted it, but that the sulphur had for some reason gone out soon after being lighted.

Secondly, the odour is changed. Hops dried without sulphur have a very peculiar odour. I can best describe it by saying that it resembles that of withered foliage. How is this brought about? If green hops be left in bags in the sun, some kind of fermentation is set up and the hops heat in the bags and become discoloured; so, too, on the kiln, it is probable that in the absence of burnt sulphur some fermentation takes place, which results in this peculiar smell. The effect of the burnt sulphur is to prevent this fermentation.

Thirdly, it hastens the drying process. When ripe hops are picked the bracts or petals composing each hop are all tightly shut up; now when sulphur is burnt with hops it has the effect of causing the bracts or petals to open out so that the hot air can more readily get to the green sappy strigs of the hops and dry them, and in consequence of this opening of the petals a better draught through the hops is obtained. When hops are dried without sulphur, this opening of the hops, or "feathering" as it is called, does not take place, or takes place to a less extent, consequently the cores or strigs of the hops are more difficult to dry and the hops take from one to two hours longer in drying. This shortening of the length of time of drying is alone sufficient to make the use of sulphur economical.

The sulphuring of hops on the kiln is again a source of sulphur contamination; in this case the sulphur is present not in the free state but in the combined form of sulphur dioxide.

Thus we see sulphur may exist in dried hops, either as free sulphur or as sulphur dioxide.

During this season I have carried out two series of experiments to show, in the first place, how soon in the formation of the hop cones flowers of sulphur can be retained in the dried hops, and to what extent it is retained, and in the second place what proportion of the sulphur dioxide burnt during drying is retained by the hops.

*Experiment I.*

In this experiment single alleys were used as plots and were labelled. These alleys were separated from each other by four intervening alleys. The plots were sulphured at different dates corresponding with different stages in the development of the hops. In each case the plots were sulphured at the rate of  $\frac{1}{2}$  cwt. per acre. The plots were all picked on September 22nd and samples were taken from each plot direct from the pickers' baskets. These samples were dried in the air and put away for analysis.

The actual crop grown was 10 cwt. per acre.

*Method of Analysis.*—So far as I could learn there was no method in general use for estimating the free sulphur (as distinct from the burnt sulphur) in general use. I was fortunate, however, with the assistance of Mr. A. D. Hall and Dr. Russell of the Rothamsted Research Laboratory, in being able to work out a method. In a preliminary experiment about 0.2 gram of sulphur was put into each of three test tubes. One test tube was filled with chloroform, another with toluene, and the third with benzene. The test tubes were tightly corked and put into a steam oven. After 24 hours they were examined, and it was found that the toluene had completely dissolved the sulphur, whilst the chloroform and benzene test tubes still contained traces of sulphur.

The object of heating the sulphur in the steam oven is to convert the insoluble part of the sulphur into soluble sulphur (a reaction which takes place slowly at 100° C.).

In the actual experiment 20 grams of dry hops were weighed out and put into a soda water bottle. The bottle was nearly filled with toluene, securely corked and put in the steam oven for 12 hours.

The toluene extract was then run off and filtered, and fresh toluene was added to the hops. The hops were extracted another 12 hours in the fresh toluene.

The second extract was run off, filtered and added to the first extract, and finally the hops in the bottle were washed with a little more toluene and the washings added to the extracts.

The toluene extract was then distilled. The residue containing the hop resins as well as the sulphur was transferred to a porcelain crucible and ignited with caustic soda and sodium nitrate. By this means the sulphur was converted to sodium sulphate. This was dissolved in

dilute hydrochloric acid and finally precipitated as barium sulphate and weighed as such.

TABLE I.—*Free Sulphur contained in Dry Hops.*

Plot.	Date of sulphuring.	Date of picking.	Size of hops when picked.	Percentage of sulphur contained.
A	August 9th	September 22nd	In full "burr"	0
B	" 16th	" "	Half-grown	0·016
C	" 23rd	" "	Almost full grown	0·057
D	September 21st	" "	Ripe	0·145*

\* In this analysis the ignition of the sulphur was too vigorous, and a little of the material was lost.

The table shows that the hops in Plot A, which was sulphured whilst the hops were in full "burr," contain no free sulphur.

The hops in Plot B, which was sulphured a week later than Plot A, contain a very small quantity (0·016 per cent.) of free sulphur.

The hops in Plots C and D, sulphured still later, contain increasing quantities of sulphur.

The conclusion, therefore, is that hops sulphured in "burr," or at any previous time, contain no free sulphur in the dried sample. Further, if hops are sulphured after the "burr" has begun to develop into "hop," some of the sulphur will be retained in the dry hops, the amount depending upon the interval of time between the acts of sulphuring and picking.

#### *Experiment II.*

The second experiment was carried out to ascertain what portion of the sulphur burnt during drying is retained by the hops. The method of determining the burnt sulphur (sulphur dioxide) retained consisted in distilling the dried hops with hydrochloric acid, collecting the distillate in bromine and estimating as barium sulphate.

The first part of the experiment shows that the amount of burnt sulphur retained by the hops is in some measure proportional to the amount of sulphur burnt. The hops dried with 15 lb. of sulphur contain 0·21 per cent., and those with 25 lb. contain 0·31 per cent.

TABLE II.—*Burnt Sulphur in Hops.*

Sample.	Weight of sulphur burnt.	Load of hops.	Sulphur dioxide (SO <sub>2</sub> ).	Size of oast.
I	lb. 15	bushels. 250	per cent. 0·21	sq. ft. 400
II	25	250	0·31	400
III	Sulphur went out after lighting	250	0·02	324
IV	16	250	0·24	324

The second part of the experiment consists of an analysis of those hops (which I have described earlier in the paper) in which the sulphur went out accidentally very soon after it was lighted. It shows that these hops contained practically no burnt sulphur (0·02 per cent.). For the sake of comparison I have analysed hops from the next kiln, in which the sulphur did not go out, and these contain 0·24 per cent.

In conclusion, I may tell you that I am anxious to obtain the opinions of brewers upon this question of sulphur contamination of hops. Does sulphur present in these comparatively small quantities—

0·3 per cent. of SO<sub>2</sub>, burnt sulphur,

0·2 per cent. of free sulphur,

really do any harm; and, if so, what is the harm that it causes?

Firstly, as regards the burnt sulphur; this is very volatile, and I think it is generally agreed by brewers that this passes off during the boiling of the wort, and is therefore of no importance. Moreover, I understand that a certain amount of sulphites are commonly employed for preserving the beer, so that even if this burnt sulphur were retained in the beer, it would only be of importance as increasing the sulphites present.

Secondly, as regards the free sulphur, used to combat the attacks of mould. The case of this is not by any means so clear. The possibility of this sulphur being deleterious in hops was first brought to my notice in 1908, when, admittedly, large quantities of sulphur were used by growers to check the very serious attacks of mould in that year.

Mr. Gretton, in his evidence to the Royal Commission appointed to enquire into the condition of the hop industry, stated, "We have had

to reject two-thirds of the fine samples of English (1908) hops offered to us," for this reason, that they contained too much sulphur.

It has been suggested that the sulphur is converted to sulphuretted hydrogen in the brewing process, and this produces an unpleasant smell and taste in the beer, especially if the beer is destined to be kept a long time.

I do not know how far this suggestion is founded upon experiment, or what proofs or indications there are in support of it; but there is a certain amount of chemical improbability; sulphur is chemically somewhat inactive and is not readily converted to sulphuretted hydrogen; on the other hand, it is well known that the Burton waters do contain large amounts of sulphates, and chemically these are much more readily converted into this noxious substance.

I am hoping that in the ensuing discussion this point may be criticised and explained; as well as any other possible advantages and disadvantages of the presence of sulphur in dry hops.

#### DISCUSSION.

Professor A. J. BROWN said that the subject was apt to carry with it a good deal of misconception, owing to the manner in which the different methods of employing sulphur in connection with hops were so often confused. Mr. Amos had made it quite clear that there were two sorts of so-called "sulphur" associated with hops: one true sulphur, or brimstone, which accumulated in the hops while they are growing on the poles, and the other a gas sulphur dioxide, resulting from the burning of sulphur on the kiln. With regard to the presence of true sulphur, or brimstone, in hops, the extent to which it might be deleterious had always been a debated point in his own mind. They were well aware that a large firm referred to by Mr. Amos very strongly objected to the presence of free sulphur in hops. He was under the impression, however, that the objection referred especially not to hops which were used in the copper, but to those used in cask for what was usually termed "dry hopping." To the presence of free sulphur in these hops, he believed, was attributed a form of stench occasionally noticed in beer. Some years ago he made a few experiments in regard to this question. In the first instance he added some free sulphur to a cask of beer, and found that subsequently the beer developed a smell resembling the ordinary

stench of beer. He also experimented with various samples of hops known to contain sulphur. He did not obtain similar results, but the number of his experiments was small, and he did not think it wise to draw definite conclusions from them. He was inclined to think that the firm referred to by Mr. Amos was somewhat exceptional with regard to the strong objection taken to the presence of small amounts of sulphur in hops. He should like to hear an expression from the different brewers present as to what they thought of the effects of free sulphur in hops. There were very few English hops which did not contain more or less sulphur, for sulphuring on the poles was an almost invariable practice in this country, but there was no doubt that in some cases a much larger quantity was present than seemed either necessary or desirable. Hitherto, he had not been able to obtain any thoroughly reliable quantitative method of determination of the amount of sulphur in hops, and the method suggested by Mr. Amos seemed a very desirable one to try. He hoped shortly to make some experiments with it. Another aspect of the use of sulphur in connection with hops related to the sulphur dioxide derived from sulphur burnt on the kiln during curing. The amount of this harmless antiseptic introduced into beer by hops used for dry hopping was very small indeed, and probably the amount present in copper hops would be entirely or almost entirely expelled during boiling in the copper, so there appeared to be but little likelihood of this form of "sulphur" directly influencing the brewer, but indirectly it might exert some influence. Mr. Amos had pointed out three effects of sulphuring on the kiln. One was that the sulphur dioxide produced improved the colour of the hops. This might make the brewer give more for the hops, but that seemed to favour the grower rather than the brewer. The second point related to the manner in which it appeared to control a natural fermentation of the hop and assisted in the preservation of its aroma. This was a very important question, and it suggested that the use of sulphur on the kiln from this point of view deserved very careful attention. The third very interesting point was that the use of sulphur on the kiln hastened the drying process through the action of the sulphur dioxide tending, as suspected by the author, to expand the bracts of the hops. When one watched the drying process on the kiln, one was struck by the way in which the bracts of the hops opened out, and if that was due to the

influence of sulphur dioxide he could easily understand that its influence might be very useful. A question occurred to him, which related to the determinations of sulphur dioxide given by Mr. Amos. He would like to know what length of time elapsed from the time the hops experimented with were cured until the time when the determinations were made. It seemed probable, as sulphur dioxide was a very volatile gas, that the amount present when hops were fresh off the kiln might diminish rapidly on storing. He should also like to ask Mr. Amos what was the most recent view with regard to the manner in which free sulphur exercised its well-known power of destroying parasitic plant moulds such as the hop mould. He knew that various suggestions had been made from time to time to account for the action of free sulphur, but so far he believed none of them had been satisfactory.

Mr. J. M. LONES said that whilst, no doubt, there existed among brewers a diversity of opinion as to whether a moderate quantity of free sulphur in hops exercised any harmful effect on the flavour of the beer, there was a decided opinion against the use of mouldy and diseased hops, and he took it, from what Mr. Amos had said, that in this country sulphuring was a necessary part of hop cultivation—in the gardens to arrest disease and on the kilns to assist in the preservation of the hops. But the question was often forced upon them whether sulphuring was not frequently overdone, particularly during the drying. Brewers who passed a numerous quantity of samples through their hands must have noticed that a proportion of the samples bore evidence of an excessive use of sulphur during the drying, which, in their opinion, depreciated the value of the hops. In the interests of the growers themselves that appeared to be a matter for their careful investigation. Mr. Amos had stated that from 5 to 10 lb. of sulphur per pocket dried was burnt in some oast houses, and the grower had, no doubt, practical reasons for using such quantities, but to the layman they appeared to be in excess of what was required for preservative purposes, and the question arose as to whether the amount could not in many cases be reduced—even in very bad seasons—with an all-round advantage, as it could be reasonably assumed that the amount of sulphurous acid absorbed by the hops was in proportion to the quantity of sulphur employed. It was a difficult matter to point from experience to any particular case

where the flavour of beer had been damaged by the use of hops carrying free sulphur, to any extent, for while at times certain fermentations were found to give off a distinctly sulphurous odour which was generally attributed to the presence of sulphur in the hops used, whether that was the actual cause it was not easy to say, as the odour noticed might be due to other well-known causes. Mr. Amos had referred to the Continental method of first sun-drying the hops, and then finishing them off on the kiln with the use of sulphur, and had pointed out that when the  $\text{SO}_2$  was applied to partially dried hops, the amount absorbed was much less than if the sulphur was employed as in the English method. Before cold storage was adopted a view used to be held that the Continental method of drying was responsible for the Continental hops not making such good yearlings as English hops when stored at ordinary warehouse temperatures. That seemed to support the view that the use of sulphur on the kiln was beneficial as a preservative to the hop itself. He would certainly like, however, to have the opinion of Mr. Amos as to whether the amount employed could not be reduced in many cases to a point where the advantages to be claimed for its use could still be retained, while the objections against its use would be considerably modified.

Mr. W. R. WILSON said that Mr. Amos had referred to mildewed hops, but he did not understand him to say definitely whether the mould on hop plants was always of one species only.

Mr. AMOS replied that it was.

Mr. WILSON, continuing, said that he had never been able to understand the attitude of the hop-grower in regard to the question of sulphur, because they used sulphur in the form of sulphurous acid, in the drying of hops, and at the same time objected strongly to brewers using sulphur in beer in the form of bi-sulphite preservative. The two things seemed to himself very much on all fours. It was demanded that they should not use it in beer, and he had very considerable sympathy with that. If it was undesirable in beer it was equally undesirable in hops. He thought the objection to sulphur was largely a sentimental one. He had never seen any great objection to sulphur with regard to the flavour of beer. But the public generally would not care for the idea that they were drinking some form of sulphur in their beer. If they wanted sulphur they might go to Harrogate and get it. Personally, he did not like the idea of having

sulphur in his beer, and he did not think the public did either. If they could do without bi-sulphites in beer, and he thought they could, it would be very much better for the general standing of beer with the public that they should not be used. But if the hop-growers were going to make use of sulphur on the kiln, he did not see that the brewers would gain much by giving up the use of it in beer. If the growers said they were better without it in the beer, he agreed with them and thought that the hops also would be better without it. With regard to the use of sulphur on the hop-poles, there was no doubt they could not at present do without it. They had attacks of mould, and it was not practicable to preserve the hops without using sulphur on the poles. But he could not help thinking that the hop-growers were resorting to sulphur too much. Surely, it must be possible to produce new forms of hops which would not require so large an amount of sulphur. Hop-growers might bear that in mind to a greater extent. It seemed to be thought that there was no hope of preserving hops in any other way. With regard to the use of sulphur on the kiln, in the form of sulphurous acid, he had never yet been able to see the benefit of it to the brewer. He quite followed where the hop-grower came in, because if the grower were to put unsulphured hops on the Boro' he could not sell them. He rather gathered that Mr. Amos thought that the sulphur on the kiln was no advantage from the point of view of the brewer, and that it did not matter much. Personally, he disagreed with that. He thought it was a disadvantage because it prevented the brewer from judging them properly and impartially. They very well knew that with regard to isinglass, if they had a suspicion that a sample of isinglass had been bleached, they would not look at it, and the same seemed to him to apply to hops. Mr. Amos had suggested that one reason for using sulphur was to improve the appearance, and another was on account of the smell. The difference in smell was certainly very remarkable as between sulphured and unsulphured hops. It was quite true that a brewer would not use an unsulphured hop unless he knew what the peculiar smell and appearance was due to, as it was totally different to what he was used to. But all the same it seemed to him more than probable that the smell of the unsulphured hop was the true smell and the smell to be desired. He understood that this difference in smell was produced by fermentation, but he did not understand whether the use of sulphur in drying

absolutely stopped the fermentation, and whether if sulphur was not used in the drying process, the fermentation continued in the pocket.

Mr. AMOS said that the fermentation took place before the drying process had proceeded very far. If sulphur were used, fermentation did not take place.

Mr. WILSON, continuing, said that he had not quite followed that. But it was very interesting, and especially what was said about the opening of the hops being due to sulphur. He did not know whether any explanation could be given of that, but it seemed very curious that the sulphur should open them in that way, and he quite saw the value of sulphur in the drying process from that point of view. He believed Mr. Amos had not referred to the keeping qualities of hops, dried with and without sulphur. It was usually said that hops would not keep if they were not dried with sulphur. But he had seen and used a certain growth year after year, which was dried without sulphur, and he inclined to think that these unsulphured hops kept better than the sulphured ones. He did not fancy that even in mouldy years the sulphur had any keeping qualities, or had more than a very slight effect upon them. If the hops were slightly mildewed, there might be a slight effect, but ordinary slightly mildewed hops were quite capable of keeping themselves without sulphur. Mr. Lones had mentioned that foreign hops did not keep as well as English hops, but he could not say that he (Mr. Wilson) had noticed that himself, so long as the hops were cold-stored. With regard to the sulphur in the beer, he very much doubted whether it made much difference. They generally got sufficient sulphates in the water in one form or another, and if they were going to get a stench there was probably enough sulphur in that form to give it, but he thought it depended much more on the yeast than on the sulphur. He himself had seen in the laboratory the same wort pitched with pure cultures of different yeasts, and several gave a perfectly normal smell, and one gave a pronounced stench. They would get a stench if they had the right yeast to produce it without sulphur in the hops. But, although they had got sulphur in their worts already, he did not care about additional sulphur being added unless there was some very good reason for it. Sulphur on the poles he considered was at present unavoidable, but he hoped that the hop-growers would do their best to do without it in other forms.

Mr. F. H. AULTON said he was under the impression that in some of

the hop-growing districts it was customary to sow the sulphur on the ground; he would like to know if that was so. He would also like to know whether Mr. Amos thought there was any likelihood of the mould coming in the shoddy or other kinds of manures used; if so, would it not be possible to dress the manure with lime or some other anti-mould mixture previous to putting it on the ground? Mr. Amos spoke of the sulphur being burnt on the fires: was it actually burnt on the fires or in pans in the well of the kiln? if the former, would it not cause arsenic trouble? With regard to the sulphur making the cones open out, he noticed, when he had been on the kilns, that generally the sulphur fumes had passed away before the hops reached what he believed was called the "pen-featless" stage. Regarding the use of sulphur on the poles, was it not natural that the grower should risk using a little sulphur rather than have the whole of his growth spoiled by the mould? also, he thought that, in a bad season like the last, with the present high prices and low stocks, even the most particular brewers would prefer hops plus a little sulphur to no hops at all. He did not think it had ever been really proved that the sulphur stench one sometimes came across came from the hops; if not, was it true that the small amount of sulphur introduced by the hops was absolutely detrimental to the beer? he had no doubt many of the members present could remember the quantity of brimstone and treacle they consumed (under protest) when they were young, and it appeared to have suited some of them.

Mr. F. L. TALBOT thought papers such as that which brought hop and barley growers into closer touch with the operative brewer must have a good effect. The Midland brewers welcomed such papers very heartily. He was very much inclined to disagree with Mr. Wilson on certain points. They knew that a great many air-dried hops had been brought into the market lately, and one firm had declared that all their hops were air-dried. When he saw those hops he came to them absolutely with a prejudice in favour of them, but having seen a good deal of them his prejudice had gone absolutely in the other direction. He agreed with Mr. Amos that air-dried hops did not keep as well, nor turn out as well as hops dried with an ordinary fire kiln. In carrying back his enquiry as to why certain hops were not so satisfactory as others, the only difference he could find was that one was dried without sulphur and the other was dried with. It had been a growing

belief in his own mind and one that he had taken up with due caution, but he should like to be corrected if he were wrong, that it was possible that the difference might be due to the absence of sulphur in drying. His view was rather confirmed by Mr. Amos, and he assumed that in air-dried hops there could be no sulphur.

Mr. AMOS said that he thought they burned as much sulphur as with other hops. Those he had seen were air-dried with sulphur.

Mr. TALBOT said that he was unaware of that, and he would like to know whether Mr. Amos considered air-dried hops were as satisfactory in respect of yearlings as ordinary kiln-dried hops. He was very glad to be corrected. Another question related to flowers of sulphur, and their use to the growing plant. Had that anything to do with the introduction of arsenic into the hops ?

Mr. AMOS said that sulphur could be bought guaranteed free from arsenic.

Mr. TALBOT, in conclusion, said that absolutely air-dried hops did not make as good yearlings as fire-dried hops.

Mr. B. G. C. WETHERALL enquired whether the experiments, of which the results were exhibited, related to hops which were air-dried or those dried by the ordinary action of the fire ?

Mr. AMOS said that they were air-dried, quite out of contact with any burnt sulphur, so as to keep other sulphur out of the question altogether.

Mr. WETHERALL, continuing, said that he was rather interested to know whether the samples which the lecturer had experimented with were air-dried, because it was just possible that the hops dried by direct action of fire would take up a certain amount of sulphur from the effects of the fuel used on the kiln. Another question relating to the presence of sulphur in hops. Was it not possible that as pressure-coppers were brought into more general use, they would have to face a rather serious problem as regards the presence of sulphur ? because beers brewed under pressure did not evaporate like those in an open copper, with the result that the free emission of volatile sulphur was curtailed, which, in consequence, would be more liable to be absorbed by the wort during the boiling period, since it could not escape so readily as in an open copper. Brewers, therefore, who used pressure-coppers would be very careful in their selection of hops, especially if they had any suspicion of sulphur, because it seemed that any sulphur in the copper would be more liable

to be carried over to the beer. If pressure-coppers were taken up more than at present, growers would be face to face with a problem they had never yet had to consider. Mr. Wilson had referred to the disuse of bleached isinglass, suggesting that it was not appreciated by brewers. He was talking to an isinglass merchant the previous week and he was sorry to find that bleached isinglass was still favoured by brewers. The merchant told him that some of the brewers refused to have anything but bleached isinglass, and they were very pleased to pay him a little more to have it bleached. Of course, the merchant did not mind, because it meant extra profit. He did not think the brewers would be pleased to buy hops on the same principle. Personally, he thought he would sooner buy a dull sample which was free from any sulphur, as he thought the presence of sulphur in hops, especially in the case of a very delicate East Kent hop, was apt to impart a false flavour.

Mr. W. SCOTT remarked that the stench which was sometimes noticeable during fermentation had been attributed by Mr. Wilson to the yeast alone. No doubt sulphuretted hydrogen would be produced by the fermentative action of yeast in a medium containing sulphur, and he had observed that in the more heavily hopped beers the smell was more pungent than in those hopped to a lighter degree; and this, in his mind, proved that the yeast, of itself, could not produce the undesirable smell unless sufficient sulphur were present, otherwise the less heavily hopped beers pitched at a similar time with the same strain of yeast would give rise to a proportionate supply of sulphuretted hydrogen. Reference had been made to pressure-coppers, but his experience was that the pressure attained during the boiling process had no appreciable influence on the amount of sulphur retained, assuming that the degree of smell produced during the subsequent fermentation was taken as an indication of the amount of sulphur present. They could quite understand that the hop-grower was desirous of improving the eye appearance of his hops as well as having some deeper and possibly more important motive. In the kilning process he could readily imagine that the limited heat would not be sufficient by itself to kill all the mould or other germs that the hops contained, but possibly the sulphur dioxide fumes might be effective in so doing.

Mr. AMOS said that it was not a question of killing the mould on the kiln; it was a question of stopping the fermentation.

Mr. SCOTT asked whether that fermentation was not due to some organism.

Mr. AMOS said it might be in some cases.

Mr. SCOTT, continuing, said he understood the fermentation was due to the life of an organised ferment, and, though pleading ignorance of practical hop growing, threw out the suggestion that the final destruction of mould or other germs was, at any rate, partially secured by the influence of sulphur fumes. With regard to German hops, no doubt the characteristic "feel" and colour of these hops were due to the different kiln treatment which had been described by the lecturer. Many brewers made a point of using these hops as yearlings, because of their rather too pronounced flavour if used earlier; this pointed to their keeping qualities being satisfactory. The difference in the English system seemed to be in applying the sulphur early on in the kilning process, and, as explained by Mr. Amos, the hops being in a wet state would retain more sulphur than the German hops that had been subjected to an air-drying treatment before the sulphur was applied.

Mr. F. M. MAYNARD considered the paper was a very practical one, dealing with a subject all wanted discussed. In the matter of "stench" due to sulphur, he was strongly of the opinion that it was the flowers of sulphur used on the poles at the later stages of the growth which produced this, yet with the rock sulphur used on the kilns was it not possible that, although burnt with a view of producing only  $\text{SO}_2$  as a bleaching and preservative agent, a portion of it might be sublimed and mingle with the hops in the form of flowers of sulphur, and in that way also be carried forward to the coppers and fermenting vessels? In his mind this was the only form in which sulphur ever gave rise to stench, and this only resulted when it was reduced by a certain function of the yeast cell whereby it yielded a compound, throwing off the characteristic smell of sulphuretted hydrogen. This would appear to be confirmed by the fact that, in its normal state, flowers of sulphur were practically inert, yet when coming in contact with hop mould it destroyed it, this being evidently due to a chemical action taking place between the mould and the sulphur, forming a toxic compound. He did not think that the yeast alone, or in conjunction with the sulphates in the water or sulphite preservatives, was ever responsible for the production of "stench," nor did he see how, in any case,  $\text{SO}_2$  used in the mash could be, after passing through the copper and hop-

back, since the heat would, in either case, be more than sufficient to drive off the gas. How pressure-coppers could influence the retention of  $\text{SO}_2$  in the wort was difficult to comprehend. He agreed with Mr. Scott that there should be no more objection, on the score of health, to the infinitesimal quantity of sulphur absorbed in beer than to the large amount taken in the form of brimstone and treacle, the physiological effect being the same.

Mr. T. H. POPE said that the method employed by the author did not estimate the whole of sulphur dioxide which came in contact with the hops on the kiln, since if it produced alterations in colour and flavour it must itself undergo change. With regard to the use of sulphur on the poles, he would like to know whether, in the history of hop growing, there was any mention of any other substance being employed for that purpose. They knew that such moulds affected other things besides hops, and in such cases sulphur was not used. With regard to the wine industry, the vines were subject to the attack of moulds somewhat similar to those affecting hops, and in that case the growers had succeeded, to some extent, in replacing their old stocks by resistant stocks not liable to disease. If that were done in the case of hops, the use of sulphur, which did appear to be objectionable to some extent, could be done away with. He hoped Mr. Amos would continue his experiments, and give them the benefit of his results at a later date.

The CHAIRMAN said that with regard to the question of sulphured hops, if the brewers required an unsophisticated material doubtless the grower would supply it, but from his experience of the working of the Foods and Drugs Act on a county authority he was satisfied that the public often gave preference to a sophisticated material, and so long as there was a demand so long would there be a supply; perhaps the brewers gave a like preference. He had been struck by the statement regarding the different coloured moulds, and would like to know whether they were really the same. He had experience of different coloured moulds in malting, namely, the blue mould (*Penicillium glaucum*) and the red mould (*Fusarium hordei*), the former attacking the living corns and the latter the dead ones. Was there any analogy between these and the white and red moulds appearing on the growing hops? He had looked up the question of the solubility of sulphur in wort and apprehended little danger on that score, seeing that according

to a Continental authority the amount of sulphur dioxide which found its way into the wort from the highly sulphured hops was 33 to 36 parts per 10,000, rising to 46 to 55 parts per 10,000 from more highly sulphured ones. He had seen it stated that the sulphur dioxide in wort diminished when left in a closed vessel for a week, and this led him to raise the point whether pressure boiling of wort would tend to increase or diminish the amount of sulphur dioxide passing into solution. He understood that the sulphuring of hops had a beneficial effect in preserving the resins and oils, and that the sulphurous acid absorbed by hops varied in proportion to the degree of sulphuring. Only a portion of the absorbed gases remained unaltered, while another portion was oxidised to sulphuric acid, and the third entered into combination with the organic constituents of the hops. The question was whether that portion which entered into combination caused the stench to which reference had been made. Another beneficial effect of sulphuring, he understood, was the destruction of colouring matters, the elimination of which was necessary for the production of pale ales. Referring to the question of air-drying of hops, he was of opinion that direct fire heat was superior to radiant heat, judging from his experience in air-drying in malt. It was impossible to get the same palate in malt from radiant heat as from direct fire heat; might it not be the same in hop drying, that the direct fire heat improved the aroma and keeping properties of the hops.

Mr. AMOS replied. He said the discussion had been of immense interest and value in explaining the way in which the brewers of the neighbourhood regarded the presence of sulphur in hops. Proceeding to reply in order to the various questions, Mr. Amos said that with regard to the manner in which sulphur destroyed mould, various theories had been suggested from time to time. One was that it oxidised to sulphur dioxide, and so destroyed the mould. He did not think anything was actually known on that point. Some of the members had suggested that sulphur should be replaced by some other antiseptic for preventing moulds, and in particular it was said that Bordeaux mixture should be used instead. But Bordeaux mixture contained copper, and copper was a real poison, while they were not aware that sulphur was a poison. The grain of wheat was dressed before it was sown, and the mixture was never sprayed on the wheat. In relation to other kinds of mould, sulphur was always used in the

case of moulds, as distinct from other fungous diseases. White powdery mildews were always dealt with by the use of sulphur in some form; it was also used in the form of liver of sulphur, in which case the liver of sulphur was dissolved in water, and sprayed. In his paper he had stated, in enumerating the advantages of using sulphur in the drying of hops, that sulphur accelerated the rate at which hops could be dried. It had occurred to him since that he had rather overstated the matter, and while it was true that sulphur on the kiln did accelerate the rate of drying, his evidence was not so full as to substantiate altogether what he had said, and he would like to withdraw that observation with regard to the feathering of hops: that was rather a suggestion on his part than the statement of an actual fact. It had been found that they could be dried more quickly by one or two hours if sulphur was burnt underneath them. With regard to the time at which the samples were analysed, whether immediately after drying or whether at a later period, the actual figures were from samples picked and dried this year; the samples were taken from pockets and kept about six weeks before analysis. He had no figures to show whether the sulphur dioxide passed off after a time, and whether any was lost from the hops in the pocket. That was very possible, and it would be interesting to carry the experiments further. Another thing of considerable interest was the view held by some present, with regard to the action of sulphur dioxide in helping the hops to keep afterwards, and also as to whether the sulphur dioxide helped in the preservation of the resins. It was very satisfactory from his own point of view to find that the majority considered that sulphur in some way did help to maintain the properties of the hops. In regard to air-dried hops, sulphur was burnt as in the ordinary open-fire system; but, in the case of hops dried with hot air, the draught was produced by the action of fans driven by engines, and therefore the sulphur passed through the hops at a very much quicker rate. In the ordinary open-fire method of drying, the draught during the first part of the drying while the sulphur was burning was very slow indeed. It was one of the chief difficulties to be overcome, to get the draught to start to go through the hops; whereas, with a fan, the draught would go through very quickly and the sulphur, therefore, passed away very quickly. Therefore, it was quite conceivable that air-dried hops would contain much less sulphur dioxide than open-fire dried hops, and that might

possibly account for the fact, mentioned by Mr. Talbot, that a lot of the air-dried hops did not keep so well. That was a very possible explanation. With regard to an observation by Mr. Wilson, he might add that experiments were being carried out at Wye College with the special object of growing hops that should be resistant to mould. Parents were being sought all over the country with the view of finding varieties more or less resistant to mould, and which should be employed as parents for producing new varieties not subject to moulds; but time was required, and they had only been commenced a very few years and had not yet advanced very far. They hoped that in the course of years they would get varieties fairly resistant to moulds, and they would be able to use less sulphur. Another remark by Mr. Wilson was to the effect that possibly the yeast might be responsible for producing stench in those cases where the same wort appeared either with or without stench. It was clear there must be two factors to produce stench, namely, the factor of sulphur, and, secondly, a specially impure yeast, and the stench was the result of the two factors combined. Another question raised related to the sowing of the sulphur upon the ground. As a matter of fact, that practice was followed by some growers. But it could do no possible good, because there was no mould to kill, and they could not kill mould until it had got upon the leaves. It was when the hop leaves began to be formed that the mould appeared. Reference had been made also to the possibility of mould being introduced in manures. This was not possible; manures and shoddy might contain various moulds, but these moulds were not capable of growing upon hop leaves. It was like expecting a monkey to breed a man. There was no fear of mould being introduced into the garden by shoddy. The life-history of the hop mould was absolutely definite. The mould was produced by mouldy hops which dropped into the ground. In the spring, when the weather became warm, the little mouldy fruits absorbed the water. Then they suddenly burst, and the seeds of the mouldy fruits were thrown into the air, and in that way were carried to the lowest of the hop leaves, and produced the white spots. There was no chance of the mould being introduced into the hop gardens by shoddy or by manures. With regard to the pressure-coppers, he knew nothing about them, and was unable to say anything on the question. Nor was he able to say anything with regard to the causes of the stench, which were outside

his province, or as to the effect of the sulphur upon resins. The Chairman had suggested that the red mould and the white mould might be two distinct sorts. As a matter of fact, the white mould on the hop, the black mould and the red mould were one and the same. The white mould on the leaves was perfectly obvious. With regard to the change from white mould into red: if a hop covered with white mould was tied to a green well-developed hop, whilst still attached to the plant (as he had often done himself), they would notice that in a few days the sound green hop would begin to take on a pink tinge where it touched the mouldy hop, and in the course of time a perfectly sound hop would gradually turn red, proving that one form was simply a continuation of the other. In conclusion, he wished to thank the Meeting for the way they had received his paper.

The CHAIRMAN briefly moved a hearty vote of thanks to Mr. Amos for his kindness in coming to Birmingham and reading his interesting paper.

This was seconded by Professor BROWN, who said he had particularly appreciated the answers to some of the questions. There was still one more he would like to ask relating to the red mould. He would like to know whether that redness was due to actual mould spreading over every part of the hop, or was it due to something made by the mould, some enzyme cause?

Mr. AMOS replied that he did not know. It was not the colour of the mould that produces the redness, it was some change in the texture of the hops that produced the colour. He did not know whether the mould actually introduced into the leaf produced the change or not.

Mr. AMOS briefly thanked the Meeting for the resolution of thanks, and invited the Members to inspect a variety of samples of hops on exhibition, an invitation which was accepted.