TEA FERMENTATION.—Part III.

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HUMIDITY AND ITS IMPORTANCE FOR FERMENTATION.

(a) *What is meant by the humidity of the atmosphere.*—The question of humidity has already been dealt with in *The Tea Quarterly* **1929**, **3**, but I may be excused for recapitulating to a certain extent what will be found more fully dealt with in the former articles. Air at any particular temperature has the property which enables it to take up a definite amount of water in the form of water vapour. If the air contains its full complement of water vapour at any particular temperature it is said to be saturated with water vapour at that temperature, but if it does not contain the maximum amount of water vapour it is capable of taking up, then on exposing any water surface to such an atmosphere some of the water can evaporate into this air at that temperature. The water surface may be a wet fabric or wet leaf, and rolled tea leaf put out to ferment is such a wet surface owing to the water in the expressed sap. Air which is not saturated with moisture can remove water from such bodies and this results in a drying effect. The drying power of the air is determined by the difference between the actual amount of water vapour present and the total amount of water vapour it can hold when saturated at that temperature, as well as upon the rate at which the air moves over the substances to be dried. It is therefore important that we should be able to measure the relative wetness or dryness of the air, *i.e.*, its humidity must be known. When the humidity is high, the air has a low drying power, but when it is low the air acts as a drying agent.

(b) *Measurement of Humidity.*—The humidity of the air is generally determined in practice by observing the difference in the temperatures recorded by wet and dry bulb thermometers lying alongside each other. When the wet and dry bulb thermometers read the same there is no evaporation from the wet bulb, which shows that the air in contact with the thermometer is saturated with moisture. If the temperature recorded by the two thermometers is different, then

moisture is evaporating from the surface of the wet medium on the bulb of the thermometer, which shows that the air is not saturated with regard to water vapour. In other words this air causes a drying effect on the muslin. The greater the difference between the two thermometers, the greater the drying capacity of the air, so that by observing the differences between the readings of a wet and dry bulb thermometer, we can learn how wet bodies exposed to this air will behave, and by referring to hygrometric tables it is possible to determine exactly how much moisture a certain volume of air can take up. For the present it is sufficient to know that when the wet and dry bulb thermometers record the same temperature the atmosphere is saturated with water vapour and has no drying effect. If there is a difference between the dry and wet bulb thermometers, then the air can take up water from the moist surfaces and this results in the drying out of the substances. The greater the difference between the wet and dry bulb the greater is the drying capacity of the air, but it is not possible to gauge what this difference is in any way except by the use of a scientific instrument such as a hygrometer consisting of wet and dry bulb thermometers.

(c) *Effect of the air humidity on fermentation.*—The investigations dealing with the temperature relations during fermentation were discussed in the previous article, but only a passing reference was then made to the effect of humidity on fermentation and the way this air property is bound up with the temperature control of the rolling and fermenting rooms. When the temperature effect on fermentation was being studied, it was found that the humidity of the air played an important part in fermentation. It was pointed out years ago by Bamber, Mann and others that it was necessary to maintain a humid atmosphere in contact with the fermenting leaf. Mann (*Factors which determine the quality of tea*, 1907, 4) states that "the atmosphere should be saturated with moisture, as any drying of the leaf which occurs during fermentation damages the resulting tea, causing oxidation of the tannin, etc., to go too far." Deuss (*Meded. v.h. Proefstation v. Thee*, 1917, 52.) found that a dry atmosphere in the fermenting room resulted in a very uneven fermentation, and the leaf blackened instead of becoming nicely coloured. This blackening effect is due to the drying action of the air in contact with the leaf, and it is particularly noticed if there are any draughts playing on the leaf. Deuss also condemns the practice of countering this drying effect by turning over the leaf mass, because this only results in the formation of a new surface thus facilitating further drying. He also found that it was possible to determine the drying effect quantitatively. When this was done it was found that the drying effect of a dry atmosphere was greater than seemed possible at first sight. A loss of 3 to 4 per cent was quite usual, and this did not seem to matter, but a loss of

10 to 15 per cent was not uncommon. A loss of this nature was decidedly harmful, resulting in an uneven fermentation giving dull infusions and liquors. Deuss advised that the atmosphere surrounding the leaf during fermentation should be saturated or at least be within 95 to 98 per cent of saturation, but in a later publication (*Handleiding v.d. Thee Bereiding*, 1922), he advocates 90-95 per cent saturation at a temperature of 68°-77°F. This demands that the difference between the wet and dry bulb thermometers exposed to this atmosphere should be 1°F. Carpenter and Harrison (*The Manufacture of Tea in North-East India*, 1927.) state that a humid atmosphere helps in the production of reddish substances in the fermenting leaf, but a dry atmosphere results in the production of dark-brown substances. They say it is necessary to prevent the formation of these tannin-brown bodies if good colours are to be obtained in the liquors and in the infused leaf, and according to these authors the most important factor in fermentation is the humidity, which should be as near 95 per cent as possible. Harler (*Quart. Journ. Ind. Tea Assoc.*, 1929, 11.) again stresses the same point, and adds that a high degree of humidity is very necessary for a proper fermentation when the rolling and fermenting room temperatures are high, but on the other hand the humidity must not be so high as to result in any deposition of moisture on the fermenting leaf.

All the investigators of the problems of tea manufacture thus agree as to the necessity of maintaining a humid atmosphere in contact with the fermenting leaf, and this has to a certain extent been recognised to be true by the industry for a long time. However, the methods employed to combat a dry atmosphere during the hot months were only half-hearted until recent years, but where the importance of a high humidity has been realised and advantage taken of modern methods of producing a high humidity, the results obtained have been very gratifying. There are very few factories in Ceylon which do not require some means of producing a humid condition some time or other during the year, but the argument is put forward that the best teas are produced during the dry months when the atmosphere in the rolling and fermenting rooms is very dry indeed. The quality of the tea during these periods, however, depends on the good quality leaf which is coming into the factory for manufacture and ideal conditions for withering, and is not a result of a dry atmosphere for fermentation. The latter condition militates against the possibility of making the most out of a good quality leaf and of thus producing the best tea possible from the material at one's disposal. Even during the wet months of the year there are many days when the humidity is low during certain periods of the day, and although the drying effect produced during this short period may be small, it all tends to make for less uniformity in the tea.

(d) *Maintenance of high humidity.*—The first attempts at maintaining a high humidity were not very satisfactory, estates in general being content with hanging a few wet cloths around the walls of the fermenting room, allowing a gentle flow of water to run down the walls, or covering the fermenting leaf with a wet cloth. These cloths were very difficult to keep clean, especially where the practice of covering the fermenting leaf with wet cloths was adopted. Again the wet cloths hanging along the walls, etc., sometimes hindered the proper aeration of the room, resulting in a close, stagnant atmosphere. This condition was ideal for the development of all kinds of moulds and bacteria, and it is really surprising that there were not more complaints of taints in the tea produced under such conditions. When this fault was recognised, the fermenting room and rolling room walls were pigeon-holed and water was allowed to flow down the walls. Ventilation was improved in this way and the incoming air, passing through the water-stream, evaporated some of the water, became humidified, and cooled the room to a certain extent. These methods were considered satisfactory until actual measurements were taken of the humidity changes produced. When this was done it was found that these methods were very inefficient and could at times be harmful. The wet cloths did not maintain contact between the air and water for a sufficient time to produce the requisite degree of evaporation necessary for anything approaching the proper degree of humidity. If the cloths were duplicated the ventilation suffered and a heavy atmosphere was produced. Pigeon-holed walls with water running down them were also found to be unsatisfactory in increasing the humidity and these had the further disadvantage in that they often caused currents of hot, dry air to play on the fermenting leaf and increased the fault they were designed to eradicate.

The failure of such simple expedients has led to the adoption of certain humidifying plants, some of which have been successfully used in other industries, especially in the cotton factories of Lancashire and India. In Java they advocate the Sulzer Spray apparatus, and a particular installation marketed by the firm Assendelft de Coningh of Soekaboemi, while in North-East India they favour the Vortex system of Mather and Platt, Manchester. Harler (*Quart. Journ. Ind. Tea Assoc.*, 1929, 11.). Several systems are being developed and tried out in Ceylon with apparent success, but it is too early as yet to compare the relative merits of the various plants. Owing to the importance of this question and the possible extension of humidifying installations for warming fermenting rooms, it is proposed to collect as much information as possible of all existing plants and to study their efficiency in actual practice. A certain amount of co-operation on the part of the planting community will be necessary to this end, as it will be impossible to try out every type of installation at the Tea

Research Institute's Factory. Any information given will be gladly received and opportunities to inspect any plant in action will be most welcome.

FERMENTATION IN THE ROLLING ROOM.

It is now generally realised that the process of tea fermentation starts when the leaf is crushed in the rollers, and that some fermentation of the fine leaf occurs during the rolling, while the leaf persisting in the later rolls has almost completed its fermentation during the process. In view of this it is necessary to apply the same precautions to the fermentation in the rollers as in the fermenting room. It may be argued that the leaf cannot dry when it is rolled because it is enclosed in a box, but it must be remembered that the leaf is emptied out of the rollers every half-hour or so, and that this leaf has freshly expressed sap in its surface and is generally considerably warmer than the atmosphere. As soon as the leaf is emptied from the rollers the lumps are broken up and the whole put through the roll-breaker and sifter, which is designed to spread out the leaf in as thin a layer as possible while giving it a gentle upward throw. The fine leaf falls through the sieve and lies exposed to the atmosphere in a very thin layer, thus exposing the greatest surface possible to the air. At the same time if the rolling room windows are open, and this is very often the case, there is a circulation of air in the rolling room. This air movement may at times be quite appreciable, and during the hot, dry weather results in strong draughts of hot and dry air through the rolling room. The air conditions in the room are thus ideal for drying purposes, and, during the roll-breaking, the moist warm leaf is not only exposed to this dry air but everything possible is done to expose as much of the leaf surface as possible to it. It is impossible to avoid surface drying of the leaf under such conditions and damage is done to the leaf, especially to the fine dhools before they are removed to the humid atmosphere of the fermenting room.

It is thus necessary to maintain a high degree of humidity in the rolling room even if the leaf is not completely fermented in this room, but when that is done a high humidity is all the more necessary. Since the rolling room is a large room, efforts to maintain a high humidity by means of wet cloths and flowing water were even less successful than was the case with fermenting rooms so that humidifying plants must be used if a proper degree of humidity is to be maintained.

THE COOLING EFFECT OF HUMIDIFICATION.

When water changes its state from liquid to vapour it takes up heat. As a result of this phenomenon, the water in the muslin of a wet bulb thermometer requires heat when it evaporates in a dry atmosphere to water vapour. The heat necessary for this change is obtained

from the bulb of the thermometer and the air in the immediate vicinity of that bulb. This results in a loss of heat from the wet bulb thermometer and the cooling effect is shown by a drop in the temperature recorded by this thermometer. Evaporation of water into the air therefore requires heat, and when this heat is obtained from the atmosphere it results in a final cooling of the humidified air. Artificial humidification is generally obtained by forcing water under pressure through a narrow orifice in such a way as to obtain a fine spray of water. The water particles in this spray have to be very fine so as to expose as large a surface area as possible to the air if the water is to be vaporised quickly, and in a proper system this spray formation or atomisation is so well arranged that there is no visible mist a few feet from the jet owing to a complete vaporisation of the water. The heat required for the vaporisation of this water is obtained from the surrounding air, so that humidification results in cooling the air at the same time. The greater the amount of water which can be evaporated the greater will be the cooling effect produced, but the limit of cooling is controlled by the temperature of the wet bulb thermometer exposed to the unconditioned air, *i.e.*, the lowest temperature possible with humidification is that of the wet bulb thermometer. Thus, if the outside dry bulb thermometer reads 86°F. and the wet bulb thermometer reads 70°F., the readings inside the rolling and fermenting rooms can be reduced to 71°F. on the dry bulb thermometer, but the wet bulb thermometer should still read 70°F. when the air is completely humidified. This gives an atmosphere 15°F. cooler than would be the case without humidification, which allows the rolling to be carried out under conditions which prevent any unnecessarily high temperatures in the leaf mass during the process, provided all other precautions are taken. At the same time a cooler atmosphere is obtained for fermentation, which is of great benefit in a hot climate. On the other hand, humidification may result in too much cooling for a proper fermentation when fairly low temperatures exist along with comparative low humidities. In such instances the temperatures may be reduced below that necessary for fermentation, but it is advisable to avoid being dogmatic on this point until further investigation has clearly shown what is the proper temperature range for fermentation.

CONTROL OF AIR CIRCULATION.

Humidification is closely bound up with that of air control, and unless the air circulation in a room is under control it is almost impossible to effect successful humidification. It is of no use trying to maintain a high humidity in a room which is open to the outside air, but it is not unusual to see a few humidifying units in an open room. The effort is wasted, since it is just like trying to fill a bucket with a hole in it capable of passing through as much water as is poured into it. One of the benefits of humidification is that of cooling, but this

cannot be successfully obtained if the hot outside air is allowed free entry into the room. There need be no great movement of air outside for this to happen because the cooling effect produced in the locality of the humidifiers will set up air currents in the room, and heat will always travel towards the cooler regions. Very often elaborate precautions are taken to avoid the entry of any hot air from the drying room to the rolling room, although the tendency is for the air to be drawn from the rolling room to the firing room by the fans, while at the same time no attempt is made to keep out the outside hot air. The greatest cooling effect, and thus the most successful humidification, can only be obtained when the room is insulated in such a way as to prevent the entry of any external heat. It is impossible to prevent this altogether as it is absolutely necessary to introduce fresh air into the room, but the water sprayed into the air by the humidifiers must be sufficient to supply the water vapour required by this air so as to increase its humidity to 90 to 95 per cent saturation. Successful humidification can only be carried out therefore in a closed room possessing well-insulated walls and in which the air circulation is under control. The humidifiers themselves generally act as ventilators by drawing in a current of outside air and passing this through the zone of water spray; but if the humidifier is simply a device for producing a spray of water it is necessary to have a separate arrangement for the supply of fresh air and for the exit of the vitiated air. Fermenting tea requires a supply of oxygen and so do the operatives, but the amount of fresh air which must be supplied in order to keep the atmosphere sweet and fresh has never been determined. On the other hand a constant supply of fresh dry air is very essential to derive the benefits of the cooling effect of humidification. If the air circulation is slow it is quickly saturated, and the amount of water vapour which can be evaporated in a given time is also low, *i. e.*, the cooling effect will be little and the leakage of heat into the room will tend to raise the wet bulb temperature in the room. It is therefore necessary to have a good supply of fresh air in order to maintain the proper degree of cooling in the room, and also essential to check the wet bulb temperature in the rolling room against that of the outside wet bulb temperature. If the wet bulb reading inside is greater than that outside, there is stagnation of air in the room and the ventilation needs attention. The humidity and temperature of the rolling and fermenting rooms are thus bound up with ventilation, and it is necessary to control the supply of air as well as the supply of water to the jet of the humidifier. The humidifying installation must be capable of passing enough water in a fine spray in a certain time to supply all the water required for saturation of the volume of dry air admitted in the same period. Too much water must be carefully avoided, otherwise a

deposition will occur on the floor of the room and this is to be deprecated. This should not occur with a properly arranged system working at about 90 per cent saturation. The maintenance of such a high degree of humidity may tend to produce moulds and bacteria in the rooms unless precautions are taken to dry and aerate the room at the end of the day's work. This can be done by opening the windows and ventilators, turning off the water supply, and drawing a strong current of dry air through the room.

To sum up it can be definitely stated that fermentation should be carried out in a very humid atmosphere and that the benefits of humidification are:—

(a) It prevents surface blackening or drying of the fermenting leaf and thus gives a more even fermentation, resulting in more uniform infusions and brighter liquors.

(b) It produces cool conditions for fermentation and rolling, especially for rolling.

THE INFLUENCE OF ROLLING IN FERMENTATION.

There is no doubt that the manner of rolling is also of great importance in fermentation, but very little investigation appears to have been carried out in this direction. The method employed in applying pressure, the time taken for rolling and the speed at which the rollers rotate vary considerably among the various tea-producing countries.

Carpenter and Harrison (*Manufacture of Tea in North-East India*, 1927.) state that the speed of rolling has little or no effect on the tea produced, provided that the number of revolutions is the same in each case. This means that slower rolling involves a longer rolling period and therefore more rollers per factory. In one experiment, one roller revolved at 58, while the other revolved at 78 per minute for the same period. The fast roll gave 20% B.O.P. and 10% O.P., whereas the slower rolling gave 10% B.O.P. and 20% O.P. with very much more tip than the fast rolling. On the other hand the liquors from the fast rolled tea were better than the others. Their experiments have shown that hard rolling gives stronger teas but more stalk than light rolling. Finally, they recommend a roll of 55 r.p.m., carried on as long as possible with hard pressure, but draw attention to the importance of the humidity and temperature of the rolling when this is done.

Deuss (*Handleiding v.d. Thee Bereiding*, 1922.) draws attention to the need of great care in filling the rollers and warns his readers against filling the first roller too quickly, otherwise the leaf balls too much and flat leaf results. He recommends a slow, continuous supply of withered leaf into the rotating roller, and that the roller should thus be gradually filled.

The period advised in the case of the first roll is 15 minutes, as he claims that this will give very well twisted leaf. According to Deuss the first roll should not be faster than 50 r.p.m., and 45 r.p.m would be preferable; 50-55 r.p.m. for the second; and 55-60 r.p.m. for the third. Higher speeds than this are detrimental. He points out that the time for applying pressure depends on the time the leaf takes to acquire a twist, so that if pressure is applied before this has occurred too much broken leaf will be obtained and the tea will contain too many flaky particles. There is no doubt that all these questions are important in relation to the shearing effect of the rolling on the leaf and the way in which the various parts of the leaf are separated for fermentation, but the manner in which they affect the fermentation is not dealt with. The pressure applied affects the temperature of the leaf in the rollers, and with heavy pressure this temperature tends to run high so that it is necessary to lift the cover occasionally during the rolling to allow this heat to escape, while sifting should be very carefully carried out. Very little appears to be definitely known about the rolling process, so that it is very necessary to determine how various degrees of withering and different kinds of leaf affect the simple breaking up of the pluck in the rollers, and how these varying factors as well as the pressure applied and the speed of rolling affect the temperature of the leaf and therefore its fermentation.

(*To be continued.*)