THE AIR-TECHNICAL (CONDITIONING) PROBLEMS OF THE DRY SAUSAGE TREATMENT

By

L. Imre

Department of General Mechanics, Polytechnical University, Budapest

and

Gy. Sédy

Department of Heating and Ventilating, Polytechnical University, Budapest

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Presented by Prof. Dr. A. Macskásy

I. Introduction

In the course of the treatment, i.e. the drying and ripening process of dry sausages (various kinds of salami, sausage of Gyula, etc.) the optimum air-conditioning parameters must be ensured independently of the ambient weather conditions [1, 2, 3].

The methods of ensuring the required air-conditions should be adjusted to the technological requirements, which prescribe the using of fresh ambient air in all periods of the year not only on smoke-curing, but also during the whole drying and ripening process [5, 6].

The treating rooms in spite of their heat-insulation have a certain heat gain or loss — as a function of the meteorological circumstances, and the required internal air-conditions.

The gain or loss of heat has not only energetic consequences, but it can also influence the enthalpy humidity difference ratio of the drying air. The resulting effect is not to be neglected and this problem has also to be considered and solved [4].

To ensure a rational and economical operation the advantageous meteorological circumstances should be utilized in the further stages of technological development, too.

Thus, when designing the equipment for establishing the required air-conditions we must strive to avoid a superfluous energy consumption in case the meteorological conditions give a chance for it.

Although the air-supply to the treating rooms must be accomplished with parameters independent of meteorological circumstances, but on realizing the required air-conditions, the weather conditions must also be taken into consideration and indeed the air-conditioning methods to be adopted may and must be determined on the basis of these circumstances.

2. Chief methods of operation to be adopted for the drying and ripening process

Meteorological circumstances have set up various transitorial states between too extreme — winter and summer — conditions. Although sharp limits cannot be set and the setting of limits is only a convention, nevertheless it is advisable with reference to the frequency, to denominate the chief methods of operation in accordance with them. Both with the "winter" and the "summer" operational conditions, the operational schemes with internal air-circulation and admixing the ambient air must be separately examined.

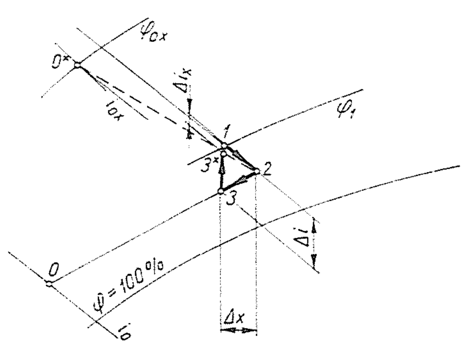

Fig. 1. Operation with controlled admixing of ambient air (winter scheme of running)

For "winter" method of operation there is no need to provide for cooling, that is if the required air-conditions are ensured by admixing an adequately controlled — regulated — quantity of ambient "cool" air. In this case an equal quantity of moisture extracted from the sausages can be let out into the atmosphere, and therefore, it is not necessary to separate the humidity from the air. Thus, it is evident that if the possibility exists to maintain the "winter" method of operation the running with internal air-circulation requires more energy, because the air has to be continuously "dried".

For "summer" method of operation with internal air-circulation, the required air-condition parameters are ensured by cooling, heating and if necessary by humidifying. The same methods may be used if there is need of admixing a certain quantity of ambient air, in which case, however, the energy consumption is proportionately greater. We give the exact interpretation and effectuation of the chief methods in detail in the following.

The precondition of the possibility of maintaining the winter scheme of running is, that the enthalpy of the ambient air (Fig. 1, sign 0) should be less than that of the air to be blown in (sign 1). Assuming — for the sake of simplification — the drying is adiabatic (i_1 = const.) and the water quantity taken up by the air Δx (sign 2), so condition 1 — as it is to be seen from Fig. 1. — can be ensured by mixing in air of condition 0 (sign 3) in a ratio of $\overline{23} : \overline{03}$ and transferring a Δi quantity of heat (afterheating). The situation is the same, if the condition of the ambient air is that of 0^x, but naturally in accordance with our assumption: $i_{0x} < i_1$ — dashed line on the Fig. — only the afterheating is less (point 3^x, $\Delta i^x < \Delta i$).

Of course it must be made possible, for the same quantity of air be let out and in.

It is essential how the term $i_0 < i_1$ can be maintained throughout the year.

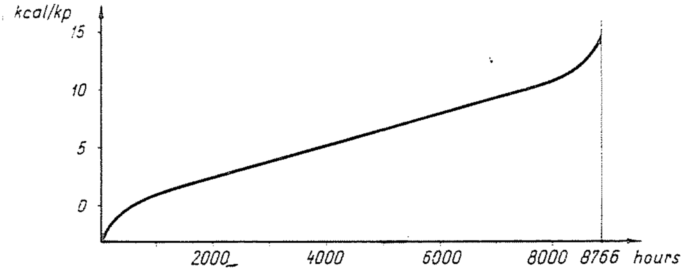

Fig. 2. Enthalpy of ambient air under natural conditions in Budapest, on the basis of statistical data of 35 years

Taking the probable air-condition characteristics of salami-production into consideration — by a moderate evaluation — we may assume the value $i_1 = 7.0$ kcal/kg. The statistical data of Budapest for the last 35 years, show (Fig. 2) that in the course of a year the frequency of a lower enthalpy than this is 60% [9, 10]. But if we take into consideration, that in the greater part of the production process an enthalpy of 8 kcal/kg — or higher — may be adopted, further if we do not take into account the summer repairing period of about one month, we may state, that up to 70% of the annual production period the use of the ambient air is possible, and during this period the abstracted moisture may be let out into the atmosphere and there is no need for cooling-energy. This circumstance — the utilizing of natural air-conditions — makes the procedure very economic and is in full accordance with technological requirements.

On running *the "summer" scheme with internal air-circulation* (Fig. 3) the used air of condition 2 may be brought into the initial condition by cooling it to temperature t_3 (point 3) on the cooling surface with a temperature of t_0 and with additional afterheating Δi. To ensure the obtaining of point 3, only a proportion of the air is to be let onto the cooling surface (by pass). It is also to be seen from Fig. 3 that the temperature of the cooling surface has also energetic consequences. For instance, if the temperature of the cooling surface is $t_{0x} < t_0$, then $\Delta i_x > \Delta i$. (The optimum conditions are to be theoretically gained by a cooling surface temperature corresponding to the tangent point of the tangent drawn from point 2 to the limit curve.)

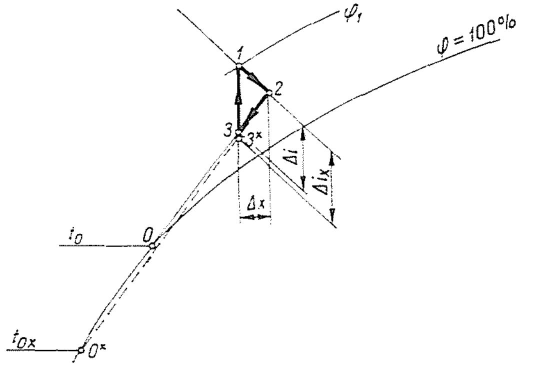

Fig. 3. Scheme of operation with internal air-circulation and cooling

Although the difference is not great, nevertheless, it is advisable — on designing the equipment — to take into consideration the possibility of cooling

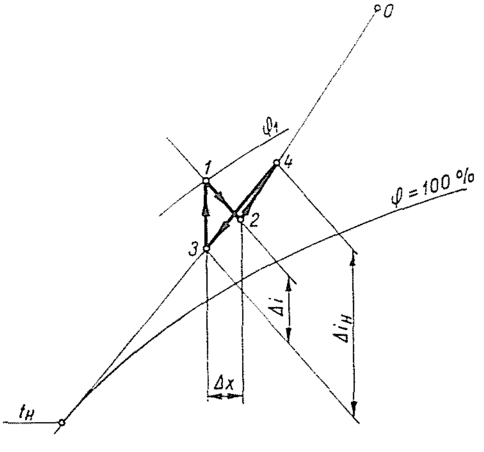

Fig. 4. Scheme of operation by admixing of ambient air to the required ratio during the summer period

surface temperature control, all the more so, as it is also justified by other regulation-technical reasons.

The *"summer" method of operation by admixing of ambient air* may be a technological requirement, and during the period of smoke-curing it is absolutely desirable. Considering, that the blowing in of a high temperature ambient air requires very much energy, special attention must be paid to this procedure. Besides, this circumstance draws the attention to the fact that on examining the power demand of salami preserving (drying and ripening) process it is by far not enough to restrict oneself to the examination of the ripening process only, because with the semi-classic procedures the so-called cooled smoke-curing rooms are likewise operated by letting in ambient air.

It is evident, that on solving the problem of this procedure with the greatest power consumption, the most economic circumstances should be ensured. Fig. 4 shows the air-technical process which is to be carried out.

Air of state 2 is mixed with the ambient air of state 0 in the required ratio (e.g. $\overline{24} : \overline{04}$), then cooled on the cooling surface with t_H temperature to state 3 (Δi_H). The initial state 1 is ensured by afterheating (Δi).

Likewise everything stated about the "summer" method of operation with internal air-circulation can be here accordingly applied.

3. Transient circumstances, special requirements

Due to the changing of meteorological conditions it may be necessary — in the course of the year — to repeatedly switch over from "winter" to "summer" method of operation. Especially in the months preceding or following the summer season such fluctuations are possible in which the enthalpy of the ambient air moves in the region of i_1 and at daytime (or throughout some days) it is higher and at night (or again throughout some days) it is lower than i_1. Such circumstances may be called transitory.

With "winter" method of operation the quantity of the ambient air to be intermixed is determined — according to the above — from the air-technical viewpoints. It is, however, not sure that the ambient air-quantity ensured in this way in every case meets the optimum technological requirements. It may occur, that it differs from them to an inadmissible measure. Naturally, the required quantity of ambient air must also in this case be ensured, and in connection with such problems we speak of s p e c i a l d e m a n d s.

The requirements answering the conditions described may be outlined as follows:

When running the "winter" scheme the ambient air-condition is characterized by $i_0 \geqq i_1$.

When running the "summer" scheme the ambient air-condition is characterized by $i_0 < i_1$.

When running the "summer" scheme the required cooling performance is insignificant (e.g. the heat gain of the treating room is little and there is no drying effect — because, for instance, of storing).

When running the "summer" scheme on intermixing a great quantity of ambient air the total cooling capacity proved to be short (e.g. because of the considerable increase of enthalpy of the ambient air).

When running the "winter" scheme the quantity of supplied ambient air has to be increased.

In the course of any of these methods of operation the relative humidity of air has to be changed from a lower to a higher value and maintained at this level.

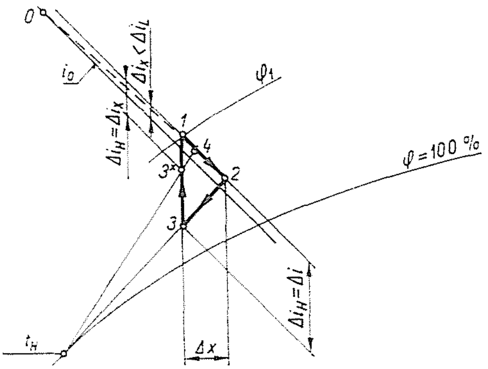

Fig. 5. Limit condition for maintaining the winter method of operation

The air-technical aspects to meet the described requirements are summarized as follows:

The limits of maintaining the "winter" scheme of running is theoretically determined by the condition of $i_0 = i_1$. If $i_0 \to i_1$, then (see Fig. 5) the required afterheating is $\Delta i^x \to 0$.

The output of afterheating may be reduced by very fine degrees through a regulating valve fitted into the calorifer line and using "by-pass". In this case, however, one must take into consideration, that one part of the heat equivalent of fan power (Δi_L) works as afterheating and as soon as $i^x < \Delta i_L$ the temperature of the admixed air becomes greater than t_1 also in that case when the afterheating is switched off. Hence, practically the limit conditions of ambient air-admixing are given by $i_0 = i_1 - \Delta i_L$ and not by $i_0 = i_1$.

Now the essential question is whether in this case it is profitable to change over to the "summer" method of operation with internal circulation.

As can be seen from Fig. 5 in case of changing over, the consumption of $\Delta i_H = \Delta i$ cooling- and afterheating-energy would be required. On the other hand, if we admix a decreased quantity of ambient air putting the cooler into operation (dashed line, point 4) and cool to point 3^x, then the task can be solved with a substantially reduced power consumption this being $\Delta i_H^x = \Delta i^x (\Delta i_H^x < \Delta i,\ \Delta i^x < \Delta i)$. Naturally, quite similar viewpoints are effective in that (rare) case, if $i_0 = i_1$.

If in the course of changing the $i_0 > i_1$ tendency becomes prevalent, it is profitable to continue the admixing of ambient air as long as it is energetically advantageous — not taking at present the technological viewpoints into consideration.

The limit situation is to be seen from Fig. 6. In case of ambient air-condition 0 (i_0) on mixing to point 4 a very substantial cooling energy saving is still to be gained compared to the operation scheme with internal air-circulation ($\Delta i_H^x < \Delta i_H$) and the afterheating demand is essentially less ($\Delta i^x \ll \Delta i$).

If the enthalpy corresponding to the ambient air-condition is already i_{0x} (condition 0^x, dashed line) then admixing at point 4^x the cooling demand

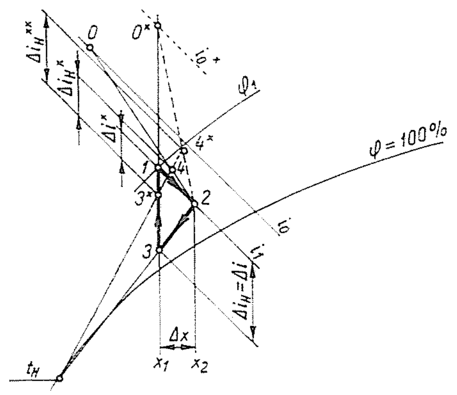

Fig. 6. Admixing of ambient air under transitory conditions

is about the same (Δi_H^{xx}) as in the case of internal air-circulation, however, the afterheating demand is still essentially less.

From all these it can clearly be seen, that the valuation in chapter 2 is correct and may be completed with the assertion, that the operation by admixing of ambient air even under condition as $i_0 > i_1$ may be more economical than the operation with internal air-circulation, partly because some of the abstracted moisture gets into the open air together with the leaving air and so its freezing out can be avoided, partly due to surplus enthalpy the power demand of afterheating is essentially less.

In case of further increasing the enthalpy of the ambient air, the circumstances change in accordance with the assertions described in chapter 2. On basis of the previous considerations the technical and technological management has to decide — taking the technological requirements into consideration — which method of operation would be advantageous and for how long.

Under such external and internal air-conditions on admixing ambient air to a certain ratio (e.g. $\overline{0^x 4^x} : \overline{4^x 2}$, see Fig. 7) it may also occur that at the given cooling surface temperature it is impossible even in principle to achieve state 1 — with the mentioned operational scheme — because the enthalpy of point 3^x is greater than i_1. As it is to be seen from Fig. 7, the circumstances can not be bettered — in the case under discussion — even by increasing the cooling surface temperature to the utmost limits. This phenomenon is indicated by increasing the dry bulb temperature and the decreasing of the relative humidity. In this case there are only two possibilities for ensuring the required air-conditions.

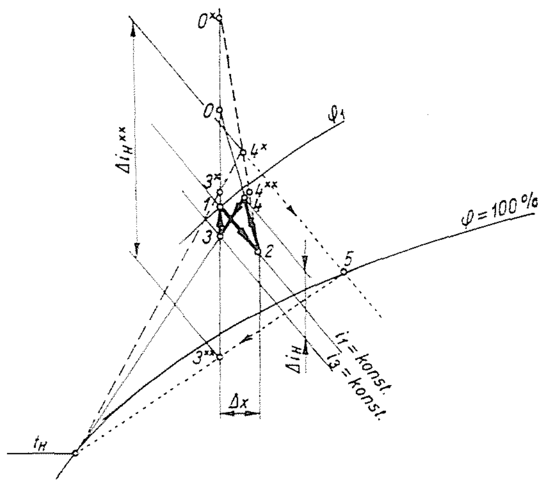

Fig. 7. Conditions of admixing ambient air in case of high enthalpy

If we want to maintain the additional quantity of ambient air, we must also put the humidifying equipment into operation. Adopting the humidifying (point 5, dotted line) we must make sacrifices energetically because $\Delta i_H^{xx} \gg \Delta i_H$. This is justified only by serious technological requirements in certain transitory circumstances. The application of this scheme of operation is limited by the available cooling capacity and the economical characteristics.

If, however, the reducing of the mixing ratio is admissible (e.g. mixing to point 4^{xx}), then the operation may be maintained with a power consumption equal to the initial one.

If the enthalpy of the ambient air — operating on "summer" scheme with internal air-circulation — decreases to the value $i_0 < i_1 - \Delta i_L$, then we must change over to "winter" scheme and the cooling equipment can be shut down.

When operating on "summer" scheme with admixing ambient air the tendency $i_0 < i_1 - \Delta i_L$ becomes more marked, the cooling demand gradually lessens reaching the value of 0. With regard to the fact, that the complete isolation of the cooling surface is not feasible even through by-pass, the decreasing of the wet temperature draws the attention to the necessity of shutting off the cooling equipment and changing over to the "winter" method of operation.

In the course of salami-ripening, one of the most vital stages of the operation is the storing without loss of weight or with only a negligible loss. In this case the drying effect is insignificant or zero and the necessity of cooling arises only because of the heat gain of the treating room. Thus, in case of heat gain the change goes either on the lines characterized by the condition line 12 (see Fig. 8) or takes place by enthalpy increasing by $x_1 =$ const. In both cases it is clearly to be seen, that only by cooling it is impossible to return to the initial state 1, but humidifying is absolutely necessary (2-3-4-1).

Even if the change takes place by a little heat gain (but unvariedly with very little Δx) this being nearly isothermic, the very little cooling and after-

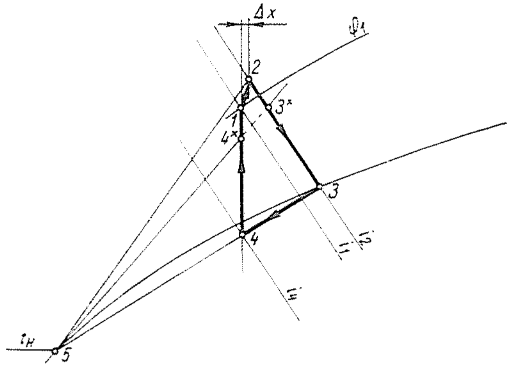

Fig. 8. Operational conditions for storing with negligible weight loss (or without it)

heating demand may cause trouble — because of the imperfectly isolated cooling surface and the afterheating effect of one part of the fan power.

It is clear from Fig. 8, that under these internal conditions even at "winter" method of operation — also with admixing ambient air — we are able to operate only by adopting humidifying, because the mixing point can not even theoretically be brought under point 1.

Naturally, the $\varphi = 100\%$ humidifying is fairly power consuming, although the value of φ_1 is near enough to the saturation curve, and from this viewpoint Fig. 8 is exaggerated — for the sake of better perspicuity.

The process —as was dealt with also in connection with Fig. 7 — however, does not necessitate humidifying to such a degree. For instance, the required conditions might be ensured by humidifying to point 3^x under much better energetical circumstances. This might be achieved by partial humidifying, by shutting off some jet disperser rows or by partially bypassing the humidifyer, and thus, the process is rendered more economic. But apart from this fact the storing without moisture loss, even with greater power consumption, is from an economical viewpoint absolutely advantageous.

In case of a running "summer" scheme — either with internal air-circulation or admixing ambient air, or even by humidifying — it may occur that even when utilizing the whole cooling capacity it is not enough to achieve the required air-conditions.

In case of internal air-circulation and humidifying this can only be the result of insufficient cooling (assuming the correct rating) and may be stopped by improving the cooling performance.

In case of admixing ambient air, however, the exaggerated ratio of mixing — compared with the external circumstances — can also cause this phenomenon. In this case the mixing ratio must be reduced. In any case the equipment must give a signal the moment the cooling capacity is at its maximum to make intervention in time possible.

Technological requirements might necessitate the increasing of the quantity of added external air by the "winter" method of operation.

Assuming (see Fig. 9) that the dry bulb temperature of the ambient air is lower than that of the one to be blown in ($t_{0s} < t_1$, point 0) and we want to

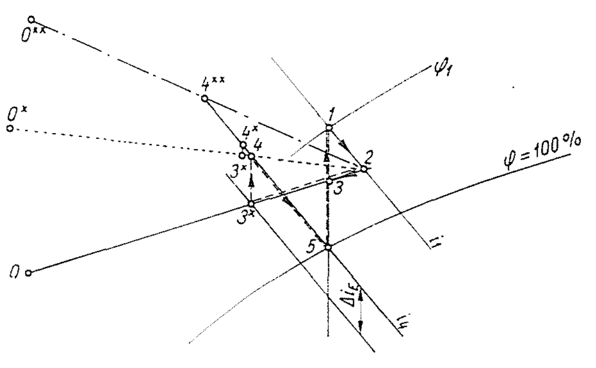

Fig. 9. Increasing of admixed ambient air-quantity using the winter method of operation

increase the $\overline{23 : 03}$ ratio to $\overline{23^x : 03^x}$, then state 1 of the air might be ensured (dashed line) by Δi_E preheating (point 4) and adiabatic humidifying (point 5). As a special requirement more energy is also needed.

Of course in the range $i_0 < i_1$ such a situation might also occur when the external air conditions are more advantageous from our point of view (0^x, $t_{0S}^x \cong t_1$), and enthalpy i_4 might be achieved by less preheating — or perhaps without it — (dotted line, points 3^x, 4^x).

By an automatically controlled operation, after switching in the humidifying and preheating, the mixing point must be achieved by the regulating apparatus. When the external air conditions change, the mixing ratio will naturally — as a function of it — fluctuate to a certain extent. For instance, if the enthalpy — and the dry bulb temperature — of the ambient air increases (point 0**), the mixing ratio increases too (point 4**). The value of the mixing ratio — as is to be seen from Fig. 9 — is also influenced by the degree of humidifying.

The technological programme might in many cases require that the relative humidity φ_1 should be increased in the course of the treatment to a value of φ_1^x, perhaps even at a higher temperature.

The immediate changing over (see Fig. 10) either for a "winter" method of operation (Fig. *a*) or a "summer" one with internal air circulation (Fig. *b*) might be accomplished by preheating (2—3*) and adiabatic humidifying (3*—4*), and further process might be maintained without preheating and humidifying (the normal process will be: 1*-2*-3***-1*).

In practice naturally the changing over will be performed not in a single stage, but depending on the rating of the preliminary heater — by multiple approximation. This, however, does not alter the character of changing, and its period is practically short.

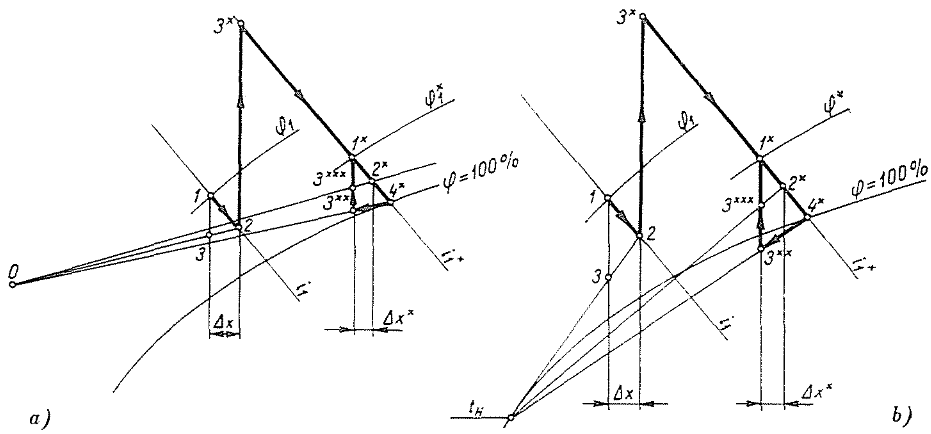

Fig. 10. Change over to operation with air of higher humidity (and temperature)

4. Influence of the enthalpy humidity difference ratio

An adiabatic humidifying of the drying air (adiabatic drying) was generally assumed in connection with our examples. This was done for the sake of simplification, in the practice, however, adiabatic conditions can not be achieved, but only at the most approached.

In the course of salami preserving treatment (drying and ripening) the enthalpy humidity difference ratio $\frac{\Delta i}{\Delta x}$ of the drying air is equally influenced by the heat gain and heat loss of the treating room and by the temperature conditions of salami. In winter and during the heating of salami the tendency of the condition line is lower than the value of the adiabatic one, in summer and on cooling, however, it will be higher.

It can easily be seen, that in the course of the salami drying process it is not indifferent how this tendency indicator changes. Namely, the quantity of moisture to be abstracted with the air quantity standing at our disposal is a function of Δx value achieved in the course of the state changing, because the relative humidity of the air blown in is, for various reasons, a given optimum value.

From this viewpoint a change of state with a higher tendency of condition line than an adiabatic one $\left(\frac{\Delta i}{\Delta x} > 0\right)$, which might be achieved by heat gain of the room or by adequate internal dissipation heat transfer, is more advantageous. Thus, the drying capacity of the air standing at our disposal, and the output of the whole equipment, respectively, might be increased to a certain degree without being compelled to reduce the relative humidity of the air blown in under the optimum value [4].

In certain seasons the enthalpy humidity difference ratio can substantially be reduced — in spite of insulation — by the heat loss of the treating rooms. In order to avoid this an adequate internal dissipation heat transfer must by all means be adopted, and the measure of heat addition to the wet bulb temperature of the leaving medium must be regulated automatically to ensure the required conditions, independent of meteorological circumstances. Our method of controlling the tendency of addition line was successfully applied in practice at the Salami Factory in Budapest with automatic equipment [8].

Summary

In the course of the preserving treatment (drying and ripening) of dry sausages the following viewpoints should be taken into consideration to ensure the necessary air-conditions:

1. The air-conditions should meet the technological requirements.
2. The optimum air-conditions must be ensured independent of meteorological circumstances.
3. In the course of the treatment, for technological and economical reasons, ambient air is needed, and so on achieving the required air-conditions the meteorological circumstances must also be taken into consideration.
4. An up to date and economic solution of the treatment requires full automatization.
5. The influence of the enthalpy humidity difference ratio of the drying air is considerable, and its optimum controlling ensures practical advantages.

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L. IMRE, Budapest V. Szerb utca 23.

GY. SÉDY, Budapest XI. Műegyetem rkp. 3. Hungary.