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Ventilation of potato storage piles

The main target in long-term storage of potatoes is to reduce losses and safeguard the quality of the tubers. The reduction in mass has a special importance in storage. This mass loss can be calculated through a model of the mass and heat exchange processes between the potato pile and through-flowing air. In this way the associations between different air conditions during ventilation (temperature, humidity and air exchange rate) on the temperature development and the mass loss in the potato pile can be investigated. The target is predetermination of ventilation conditions for minimizing of mass/ weight losses in storage.

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In order to calculate the air temperature, the potato temperature, the humidity of the air and the water content of the potatoes, a thermodynamic model of the mass and heat exchange procedures between the potato layers and the through-flowing air was developed [3,4]. According to a layer model (*fig. 1*) the potato pile was viewed as a homogeneous heap consisting of layers, each layer of the thickness of the typical diameter of a potato, for instance, 60 mm. The thermodynamic condition of the air and every layer of potatoes was altered under the influence of mass and heat exchange procedures between every layer and the through-flowing air. In this case, the air flowed consistently through the pile, for instance from bottom to top. Alterations in the ventilation (before the first layer) in association with time can be taken account of in the calculation.

The mass and heat exchange between air and every layer is recorded through a system of equations for the mass or heat transition, and from balance equations for the retention of heat and mass [2]. The equations serve the description of heat retention, mass retention, heat transport and mass transport. Of importance for the agreeing of the models are the equations for heat transition:

$[j_Q]_{Oberfläche} = \alpha\ (T_K - T_L)$

and mass transition:

$[j_m]_{Oberfläche} = k\ (x_k - x)$

with: T_k potato temperature, T_L air temperature, x air humidity, x_K air humidity with potato temperature and j_q or j_m material flow density for heat and mass transport through the potato surface.

In the verification of the model, there had to be identified the mass transition coefficients k and the heat transition coefficients α_0 over the Reynolds number

$Re = w \cdot d_K/\nu$

and the Nussel number concerning the through-flow of porous material in piles (from [1])

$Nu = \alpha \cdot s / \lambda$

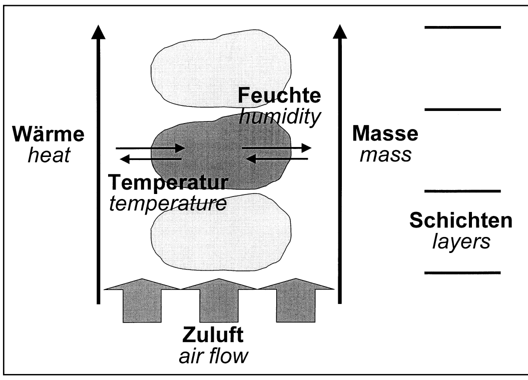

Fig. 1:Layer model of potato pile for identifying mass and heat transfer

would be modelled on the influence of airflow rate and air speed on the heat transition:

((Formel einsetzen))

(heat transition coefficient)

with

((Formel einsetzen))

(Air speed)

In this way is $s = d_K \cdot \pi/2$ the path of the air stream over half of the potato surface m_L, mass stream of the air (according to the air volume rate, ρ_L mass density of the air and A_L cross sectional area of the silo.

To this is added equations for consideration of evaporation or condensation developments and for calculation of air humidity.

The model enabled transient calculation of temperatures and humidity over a freely-chosen length of ventilation period in association with the (possibly transient) condition and volume exchange rate of air. The air intake condition (temperature and moisture content) can be presented as a constant, or as actual weather data.

Ventilation trials

For verification of the model a grain drying trial station at the institute was used for the ventilation of a sample of potatoes under defined conditions. The silo of the trial station

Table 1: Mass loss after ventilation period: comparing experiment with simulation

Mass loss in %		First layer	Last layer	Middle layer	Middle value	Min.	Max.
Cooling	Measuring	0,25	0,43	0,41	0,36	0,16	0,70
	simulation	0,38	0,22	0,30	0,30	0,22	0,38
Warming	Measuring	2,40	2,60	2,45	2,49	2,16	2,80
	simulation	1,13	1,09	1,10	1,10	1,09	1,13

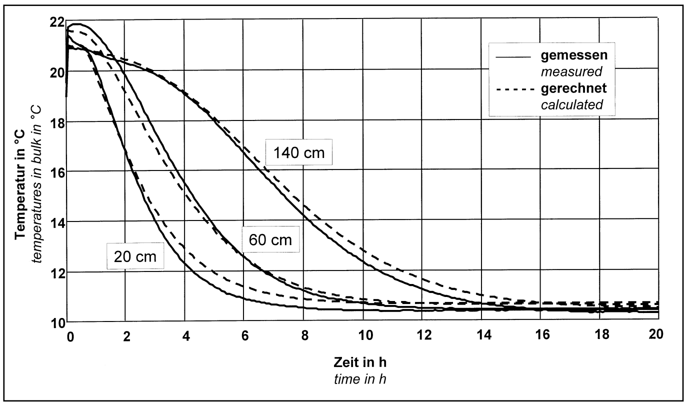

Fig. 2: Development of temperature in the potato pile during cooling

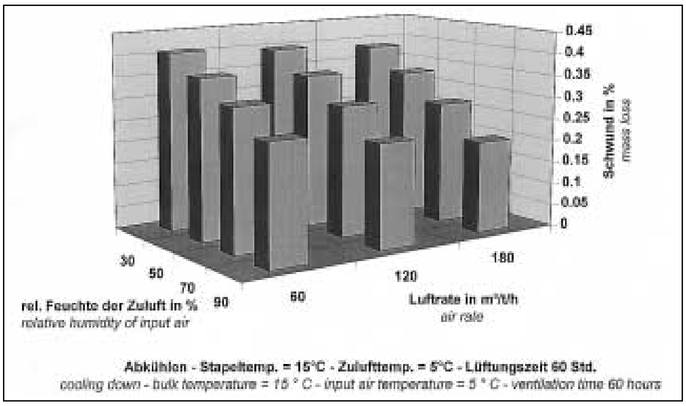

Fig. 4: Mass loss in association with airflow rate and relative humidity of inlet air during warming

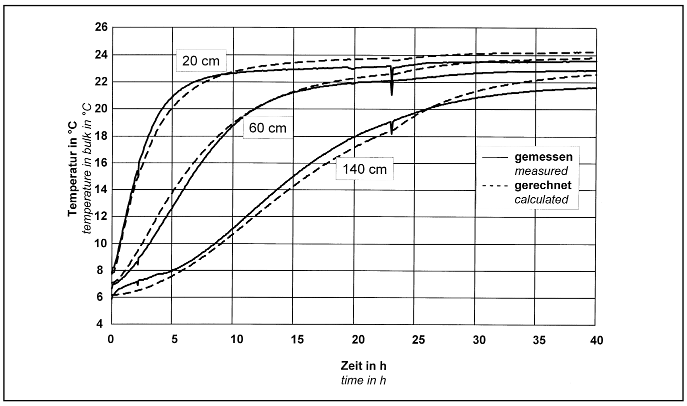

Fig. 3: Development of temperature in the potato pile during warming

was accordingly filled to a height of around 130 cm with 65 bags of potatoes each of around 5 kg weight (see fig. 2, S. 325). The bags were individually weighed before and after each trial in order to assess weight loss. A number of temperature sensors fitted at different heights permitted the recording of temperatures within the potato heap at different heights. Throughout the trial the humidity and temperature of the air intake and outflow as well as the air speed in the intake pipe were additionally recorded at fixed intervals. Two trials were carried out: firstly covering the warming of the potatoes and secondly covering their cooling-down. Both trials were carried out under pre-set and consistent air intake conditions, thus:

by warming:

Temperature of air intake: 24.5¯C, constant

Humidity of air intake: 21%, constant

Pile height: 1.3 m

by cooling:

Temperature of air intake: 10.5¯C, constant

Humidity of air intake: 50%, constant

Pile height: 1.2 m

Potato variety:

Adretta, dry matter content: 18.2 to 24.2%

Total weight before trial at warming:

325 kg

Total weight before trial at cooling:

317 kg

Air speed through the pile:

w = 0.05 m/s, constant for both trials

After identification of the coefficients regarding mass and heat transition k or a, a good agreement between the model calculation and the trial was achieved in respect of the temperature development in the pile (*fig. 2,3*). At the same time the coefficient of the mass transition k to k = 0.00144 $kg \cdot s^{-1} \cdot m^{-2}$ was identified. The heat transition coefficient α had to be corrected by the factor $\alpha_0 = 1.9$.

Results

In the warming trial, notable deviations in the mass loss between trial and simulation were noted whereas good agreement was realised in the cooling trial (table 1). The higher transpiration through increased biological activity with the warm potatoes is not yet sufficiently modelled. However, in the simulation too, it can be recognised that in the course of warming there's a far higher mass loss compared with in the cooling phase. In the topmost layer, mass loss was greater than in all the proceeding layers in both trials. This could be traced back to the contact between the open air and the surface of the pile.

Based on the agreements with this model, calculations are possible for the forecasting of mass loss under different air inlet conditions. At the same time, the question is posed as to what extent the variation of the air volume rate, and the variation of the relative inlet air humidity, influence the mass loss. After the warming session, the weight loss was substantially more than that after the cooling trial. This effect can be traced back to the higher water vapour absorbency capacity of warmer air.

Ventilation of in-store potatoes

Through use of inlet air of higher humidity, mass losses can be greatly reduced (*fig. 4,5*). The mass loss is higher during the warming compared with during the cooling phase, and increased strongly in-line with the airflow rate (fig. 5). Additionally, through warming with too-high temperature differences between warm inlet air and cold potatoes, the tendency for condensation where the inlet air has a higher relative humidity – particularly in the lower potato layers – cannot be avoided (the condensation effect is demonstrated in fig. 5). In the cooling process, on the other hand, the effect – which is also well known to farmers – of higher volume rates of air is a reduction in mass loss (fig. 4) .

Literatur

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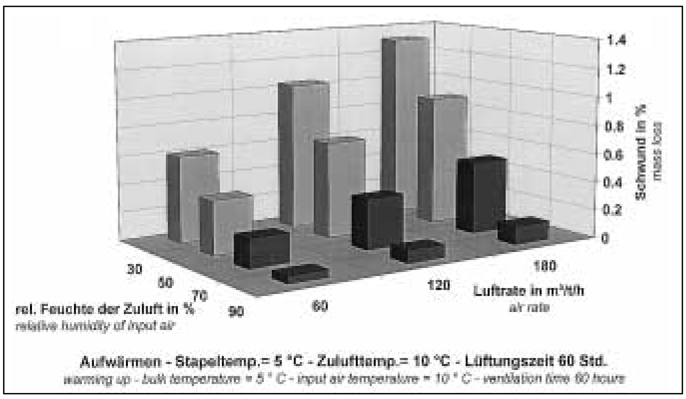

Fig. 5: Mass losss in association with airflow rate and relative humidity of inlet air during cooling