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Infrared-Thermography for Climate Control in Big Box Potato Store

Maintaining an uniform climate in a big box potato store places high requirements on climate controls currently available. Thermography helps to optimise climate control by extensively measuring the temperature distribution. Small changes in temperature are discernable, making air jet effects visible. Tests were made in a free convective ventilated store (FCV) to determine to what extent temperature data ascertained thermographically online can serve as an actuating variable for climate control.

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Keywords

Potato store, climate control, thermography

Literature

Literature references can be called up under LT 04207 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Maintenance of an adequate climate in a big box potato store is not easy to achieve. Climate control of stores, especially in free convective ventilated stores (FCV), with floor areas up to 5000 m^2 and box stack levels up to 8.5 m cause the big challenge for maintaining and keeping the optimal temperature of 5 °C all over the store. Especially in FCV-stores it is found that potato temperatures at a level of 1 metre and a level of 8.5 m are diverging continuously apart above the normally existing temperature difference of approximately 1.5 K. This happens during a prolonged storage period even though of an achieved and retained potato temperature of average 5 °C. Therefore it may happen at the end of the storage period in April that potatoes are stored slightly too cool in the lowest stacks and slightly too warm in the top most stacks. Above all anticipated sprouting and additional tuber shrinkage due to transpiration emerge in the upper levels. Shrinkage of up to 2.4 % will be expected because of such ventilation faults [1].

Up to the present conventional climate controllers are not able to control temperatures to such an extent that an adequate temperature distribution can be achieved in the store, provided that no mechanical ventilation blowers are temporarily activated to equalise the store air. In the majority of cases the climate control in FCV-stores only respects the average temperature of a low number of sensors distributed in the potato boxes.

Basis for optimising climate control, especially in FCV big box stores is therefore the development of a 3 dimensional working control algorithm. For such a way, more temperature data are available for controlling, and additionally, it is possible to respect temperature changes on the surface of the boxes caused by air movement. The chance to record these temperature changes on the surfaces, the application of thermography is obvious.

Within the framework of a BMBF promoted research project, the Institute of Agricultural Engineering Bornim (ATB) had to solve the problem to which extent online temperature data, thermographically measured with infrared-thermography, can be used for temperature control in a free convective ventilated store.

Table 1: Emission degrees of different materials

Material	Emissivity e
Potatoes	0,85 - 0,92 [3,4,5,6]
Wood	0,87 - 0,91[3,4,5,6,11]
White writing paper (paper marker)	0,95 [10]
Polyamide resin film	0,94
Blackened reference sheet	0,92 [10]
Copper, polished	0,04 [11]

The experiments were done in the institute and in the potato big box store of the co-operative of FRIWEIKA [2] in Weidensdorf/Saxony, Germany. Conventional Pt100- thermal resistive sensors were applied for the analysis. The infrared camera ThermaCam SC 500 (FLIR Systems GmbH) was used as thermographical measuring system.

Analysis of the infrared data

For a better comparison of the thermal imaging measuring system and the conventional measuring method, it has to epitomise the bases of thermography. At the thermographical measuring procedure, the thermal radiation of a body/field is recorded in an infrared wavelength range of 8.5 up to 13 µm. The radiant flux Φ depends according to Stefan-Boltzmann's law on the temperature T as well as on the emissivity ε (emission degree) of the surface area A:

$$\Phi = \sigma \varepsilon T^4 A$$

The proportionality constant σ is called Stefan-Boltzmann's constant.

The emissivity as the material parameter expresses the relation between the specific radiation of a black body ($\varepsilon = 1$) and the radiation of a real body at the same temperature ($\varepsilon < 1$). It is dependant on the wavelength λ, the temperature T, the material (e.g. potato, wood, steel), the surface properties and the radiation angle of the examined object. To every part of interest of the recorded infrared image (*Fig. 1*), a corresponding area has to be assigned with a defined emissivity

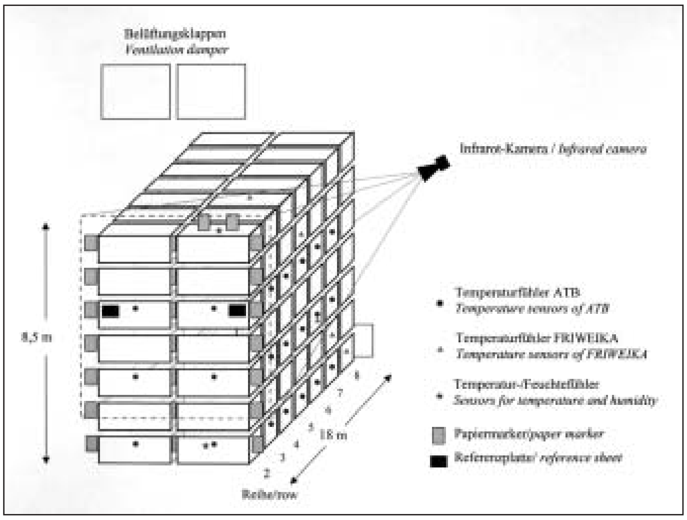

Fig. 2: Stationary installed measuring station with conventional and thermal imaging measuring technique

taken from literature [3, 4, 5, 6] or by means of own examinations [7, 8, 9] (*table 1*).

Additionally, the used analysis software ThermaCam® needs exact information about the surrounding conditions of the infrared camera (temperature, air humidity) as well as the camera distance to the measuring point of every selected measuring area. For direct comparison of thermal images and conventionally measured temperatures, a blackened metal sheet is used as a reference sheet, prepared with matte lacquer to get a defined emissivity, which is fixed on the potato boxes. Also, by this sheet temperature changes can be recorded conventionally using a contact thermometer.

Respecting correction factors, all analysis results confirm that temperature values determined by thermography and conventional temperature measurements correlate very excellently, if the conventionally measured temperature is gained from the identical surface.

Logging of temperature data

Software for long distance data transfer was developed for saving the conventional and infrared-recorded data from a stationary installed measuring system in the big 15-kiloton box potato storehouse in Weidensdorf (*Fig. 2*) and transmitting these data online to the institute.

Additionally, this software permits to gain an insight into the company-owned climate data computer system (weather values, store temperatures, and damper opening times) and to download relevant data for analysis.

Climate data of the storage periods 2002/2003 and 2003/2004 are collected and evaluated to incorporate them into a calculation model allowing the prediction of temperature distribution inside the boxes and in these areas, which are not "visible" for the IR camera. The spatial model respects temperature changes and ventilation effects, respectively, being discernible fast on paper markers and on the stock surface resp. the box surfaces in delayed time, too. At the moment, real measuring values are recorded with a number of conventional sensors and compared with data gained from a ventilation model calculation and passed account into an optimised climate control.

First results of the investigation show that different ventilation scenarios like warming up, cooling and airflow development in the store can distinctly be visualised as film sequences.

Paper markers are reacting very fast on temperature changes that arise when airflow is changing or when fresh air is passing through the ventilation dampers, for instance. Because of the small heat capacity of paper ensigns quick temperature changes and ventilation processes can be visualised. Therefore, "paper markers" are fixed beside the boxes for capturing fast temperature changes by the IR-camera. Front sides of the wooden boxes and the reference sheets react faster on temperature changes than potato surfaces. Temperature changes in the store caused by ventilation processes were verified inside the stock after adequately longer time periods.

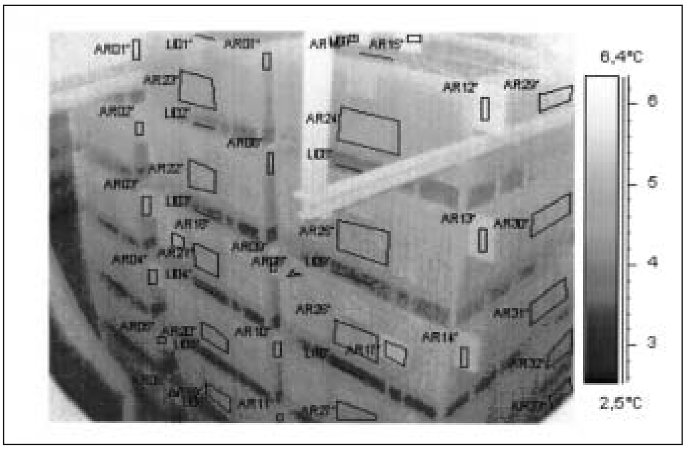

Fig. 1: Infrared image of a big box store house in selected fields, respecting e. g. different material characteristics (emission degrees) and the camera distance for exact rectification are taken into consideration, to achieve a correct quantitative temperature recording

Conclusions and outlook

Thermography opens new possibilities to visualise and evaluate climate control processes [12]. Application of thermography allows verifying model calculations more exactly. However, it is only one of several analytic methods. Additionally, the interpretation of infrared images requires special experiences. A verification of the temperature values, measured by thermal imaging, is essential for a correct quantitative temperature recording.

Economical prospects of success for using the thermal imaging measuring system as temperature controller depend to a large extent on the relative exquisiteness of the procedure, compared with competing conventional processes. Because of the relatively high investment costs for the infrared camera, additionally required equipment, and staff requirement, this procedure is only of interest for big stores under current conditions. But in these cases, storehouses with optimised climate control can rack up the camera costs when shrinkage of the potato tubers is reduced by 1,2 % within 7 years [13].