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Application possibilities and limits for thermography

Examining Horticultural Products

After harvest, as a result of complicated heat and material exchange procedures between the products and their surroundings, temperatures occurring on the surfaces of fruit and vegetable are mostly lower than the air temperature. The distribution of these surface temperatures can be measured with infrared thermography systems. Variations in temperature are visible in the form of colour differences which are evaluated per computer image analysis. Possibilities and limits of thermographic systems in investigation of quality alterations are demonstrated in the following report.

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Certain properties of harvested fruit and vegetables such as moisture condition, product content levels and maturity stage at harvest have great influence on post-harvest quality changes. Normally, quality losses begin immediately after harvest, caused by depletion of reserves (breathing) and through transpiration-caused moisture losses.

Through choice of harvesting time and the resulting post-harvest conditions (storage, transport, marketing) such losses can be successfully combated.

Both breathing and transpiration also influence the thermal condition of the product. Moisture losses are the result of complicated heat and material transport procedures between product and surroundings.

The intensity of transpiration thus depends upon certain product properties (size, form, structure and permeability of surface), on condition of the surrounding air and surfaces round about, and on air flow conditions in the vicinity of the product.

Normal interior air conditions lead to a temperature on the product surfaces which is dominated by the proportion of evaporation cooling through transpiration. Even products with substantial natural protection against transpiration (apples) indicate temperature differences of more than 1 K between surfaces and surroundings with free convention on the individual products. With very sensitive products (radish roots), the differences are up to 6 K.

First uses of thermography for plant investigations lie more than 40 years in the past [1, 2]. Because of price drops and improvements in the user-friendliness thermography has developed into an important engineering science tool, especially within the last ten years.

The basic aim of this work is the investigation of possible thermography uses in non-destructive determination of product properties and associated procedures for quality retention and the determination of application limits in this context.

Fig. 1: Thermo vision camera system

Materials and methods

Experimental investigations were carried out on a variety of horticultural products under laboratory conditions with an infrared thermography system (Varioscan 2011, Jenoptik) (*fig. 1*). The existing heat image system consisted of a nitrogen-cooled camera head coupled to a computer with the required control software and also a commercial evaluation software for the image analysis.

The infrared detector (type MCT) worked in a wavelength range between 8 and 12 µm. Temperature development was <0.1K. Minimum image succession time 0.8 s. The system is applicable in the temperature measuring range between – 30 °C and + 1200 °C and a lens distance from 0.25 cm.

The image analysing software enables the determination of temperature from individual points as well as the average temperature from lines or available areas (*fig. 2*).

For estimating the exterior freshness of the products, two transpiration resistances characterising the condition of the products and that of the immediate area (outer layer) were applied. Through an ATB-developed procedure, these were determined via heat and material balances in association with the product surface temperatures [3].

Various questions were investigated with regard to thermography measurements in association with quality protection measures:

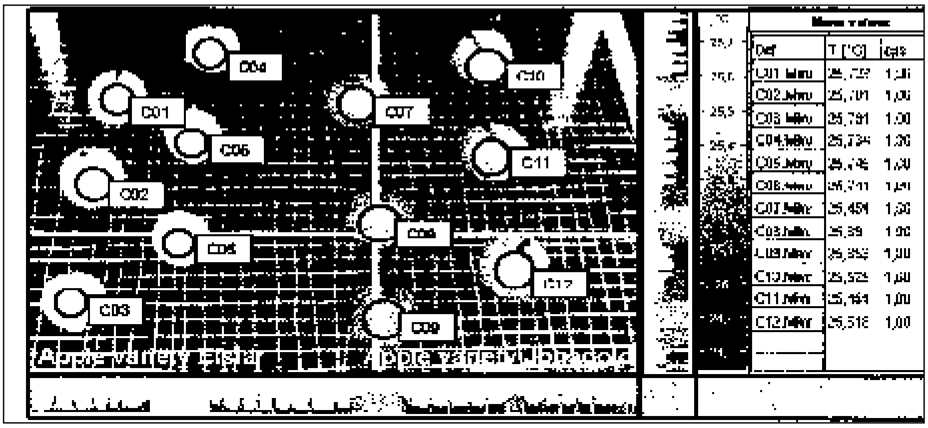

Fig. 2: Software of image analysis - mean surface temperatures of two apple varieties at natural convection

- the intensity of product transpiration at harvest for analysis of ante-harvesting conditions
- the intensity of product transpiration for evaluation of post-harvest climate-caused stresses
- local transpiration differences between parts of plants for evaluation of freshness
- the intensity of product transpiration for determination of development stage (ripeness of apples, flouriness, varietal differences)
- local differences in transpiration between plant parts for evaluation of mechanical stresses and microbial attack.

Results and discussion

The temperature differences which are able to be evaluated by the heat image system are, in controlled flow conditions (e.g. free convention), dependent on the product moisture status and the water vapour partial pressure difference between product surface and surrounding air. These values are larger in direct ratio to the freshness of the product and the decreasing moisture content of the surrounding air.

The transpiration resistance of horticultural products stretches over a very wide range. Whereas values of 0.25 s/cm are measured with young radish roots, these lie at over 500 s/cm with stored apples. Under comparable ambient conditions with free convection, individual products show temperature differences between 6 degrees and less than a tenth of a degree.

Analysis of ante-harvest conditions

Many products allow a large enough difference in temperatures for the evaluation of ante-harvest conditions. The tissue resistance of carrots at harvest, e.g., with free convection per individual product lie in the range between 1 and 6 s/cm. With normal area climate conditions (20 °C, 50% rel. m.) average temperatures between the product surfaces and surroundings of from 1.5 to 5.0 K.

Evaluation of post-harvest climate

The evaluation of post-harvest climate forces were possible for all product types investigated up until now (from radish roots to apples). In the range of product types with higher transpiration resistances, measurable effects are only apparent after a few hours.

Freshness as measured by local transpiration differences between parts of plants

With a variety of product types there are sufficiently large temperature differences between different plant parts (fruit and stem in the case of apples) present, and which present clearly measurable changes during the post-harvest period. These differences can be applied in direct relationship to the freshness of the product.

The differentiation of post-harvest product condition

The transpiration behaviour of many products alters with the natural development of the product.

In association with ASTEQ work supported by the EU, two types of apple (each represented with three different stages of maturity) were investigated by heat image analysis after appropriate periods of storage. In *figure 3* the surface temperatures of the six variants are shown. With comparable area climate conditions, significant differences in the surface temperatures of both types (Cox and Jonagold), which were in a variety of maturity stages after storage, were measured.

Evaluation of mechanical damage and microbial attack

With the above-mentioned investigated apple varieties defined mechanical damage causing no destruction of outer tissue layers was not evident.

Contrary to this, mechanical damage with carrots could be classified clearly through the different transpiration behaviour.

Using peaches as an example it could be shown that damages of surface tissues as a result of microbial activity lead to locally different transpiration intensities.

Summary

In principal, thermographical systems are suitable for the investigation of horticultural products in the post-harvest period. They can lead to new discoveries as far as quality is concerned and, through this, play a role in quality protection.

The direct use of heat imaging systems under practical conditions in the post-harvest period reaches its limits very quickly on a number of grounds. On the one hand, costs for such a system still remain comparatively high. On the other, application possibilities are limited through varying temperature conditions.

Literature

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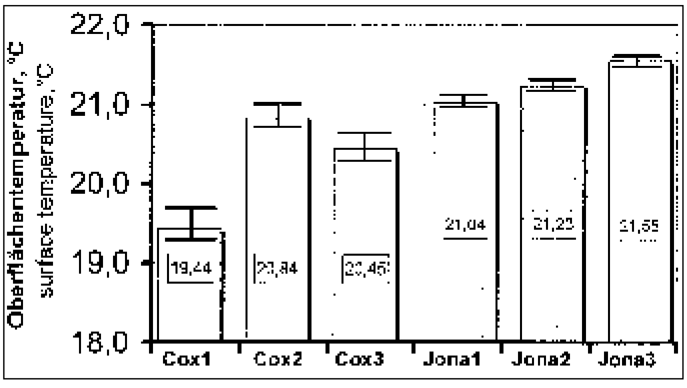

Fig. 3: Surface temperatures of two apple varieties of different developmental states at natural convection