Simply COOL !
Energy efficient and gentle storage of fruit and vegetables

Project „Sensor based air management in fruit and vegetables cold stores - COOL"

Funded by: BMWi/AiF - Central innovation program for medium-sized enterprises

Project partners:
- **ATB, Potsdam (Coordination)**
- **KOB - Competence Centre for Fruit Growing – Lake Constance, Ravensburg**
- **IMSAS, University Bremen**
- **CargoPlast GmbH, Salem**
- **EHW Electronic GmbH, Landsberg**
- **Micro-Sensys GmbH, Erfurt**
- **Plattenhardt + Wirth GmbH, Meckenbeuren**
- **Güntner AG & CoKG, Fürstenfeldbruck**

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Before apples, pears or cabbages are available at retail, they have usually been ‚well stored' for a while. Optimized storage with suitable climate control makes seasonal fruit and vegetables available almost all year round. In batches of several hundred tons, the fresh products are stored up to ten months in large cold stores.

Storage consumes energy

The high energy demand of currently 80 kWh per ton product and storage season as well as the quality and weight losses of the stored produce are the main cost factors for fruit and vegetable storage.
Up to 40 % of the electrical energy required to operate these storage rooms is consumed by the fans for air circulation alone.

New: Sensor based ventilation for cold stores

COOL targets a new approach to optimize cold store ventilation. The aim is to ensure an even airflow in the storage room while reducing energy consumption and avoiding product losses. In the future, the application software developed in the project will enable the optimization of fan operation in terms of energy and product quality: newly developed wireless anemometers will monitor the airflow even in inaccessible locations in the store. They will provide the necessary information to control the ventilation as required. In addition, the system will support the designing of new storage rooms with regard to dimensioning, bin design and stacking as well as the planning of appropriate cooling technology.

COOL enables energy savings of more than 20 % and improves maintaining the quality of stored goods.

The study focussed on ways to improve cold room operation in terms of bin design, airflow characteristics of storage bins, built-ins and stacking layout in storage rooms.

Project COOL

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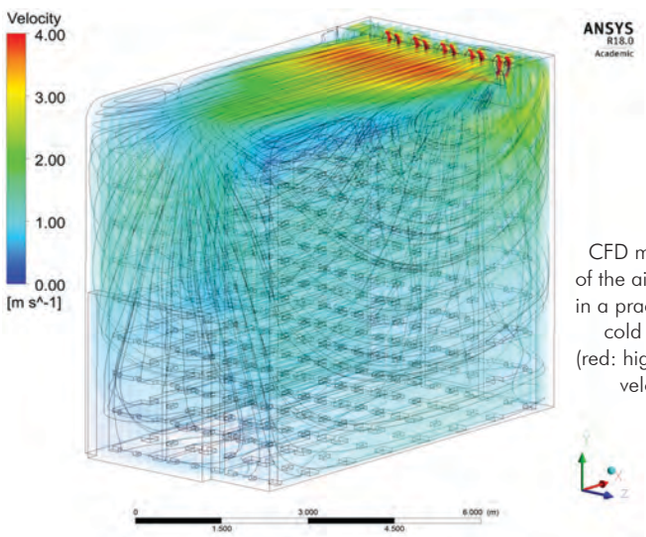
Airflow conditions were simulated using computational fluid dynamics (CFD). Measurements wirth air speed sensors in the wind tunnel, in practice storages and in the experimental cold store in Ravensburg (KOB) served for validation.

Influence of stacking layout

In cold rooms, the storage bins are closely stacked side by side. The air velocity between the bin rows is 0.3 to 2 m/s with an outlet speed at the fans of 3 to 5 m/s. It could be shown that the velocity of the airflow through the bins in the upper stacking area is about 10 times higher compared to boxes near the bottom.

However, varying the distances by 0 to 30 cm between the rows and between bin stacks and wall had only little influence on the air velocity near the product within the bins.



CFD model of the airflow in a practical cold store (red: high air velocity)

Even when reducing the fan power by 75 %, the air roll can be maintained in the storage room, however with significantly reduced airflow through the bins.

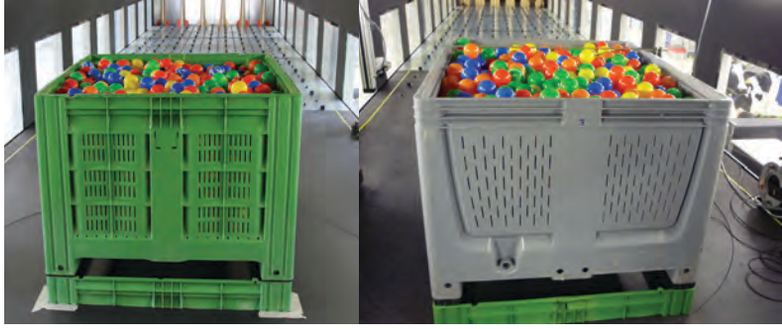
From tree and field to storage:

After the harvest, fruits and vegetables continue to respire: the products absorb oxygen and release carbon dioxide. They produce heat and lose water. Rapid post-harvest cooling and storage is important to minimize metabolic activity and degradation of valuable ingredients. Air movement is required to remove the field heat and the respiration heat of the produces.

Each product has very specific requirements for the storage climate. The storabilitiy of some commodities can be improved by reducing the oxygen concentration and increasing the carbon dioxid concentration in gas-tight rooms (CA-/ULO-storage). This method is used mainly for pome fruit.

For example apples:

For storing, apples are picked before they reach maturity for consumption. Under optimal conditions, apples can be stored in refrigerated CA storage rooms up to ten months at a temperature of 1 to 4 °C, 90 to 95 % humidity, 1- 2 % O_2 and ≤ 4 % CO_2.



Experimental setup for measuring flow patterns of different bin designs in the ATB wind tunnel (Photo: ATB)

Optimizing the bin design

Investigation of the airflow through commonly used large bins for apples in the wind tunnel showed that the air velocity inside the bins between the fruits is considerably reduced to ≤ 0.2 m/s (at an upstream velocity of 2 m/s). The limiting effect is due to the too small openings in the bin walls. In order to improve the flow characteristics of bins, the porosity of the walls (commonly about 7 % opening area) should be adjusted to that of the apple filling in the box (40 %) - by taking into account further required bin properties such as stability and product protection.

Wireless anemometers

New two-dimensional wireless anemometers (IMSAS, Bremen) continuously record the air speed at several points in the cold room for a flow-dependent control of the fan operation.

With a new chip and housing design, the resolution could be increased in the range of less than 0.1 m/s, a uniform sensitivity for different rotation angles could be achieved. The wireless technology allows secure communication from the middle of the cold store i. e. through several meters of fresh produce.

Practice test in a 50 t CA store (KOB):
Reducing the fan speed by 50 % after cooling down resulted in energy savings of 40 % for the fans and of 13 % for the cooling system.
Based on usual energy requirement of 80 kWh per ton product and storage season, this corresponds to a saving of 16 kWh.

Optimization potentials ...

... for an energy-efficient cold storage lie in reducing of the fan speed in the storage phase after cooling down, an airflow-dependent speed control of the fan revolution as well as in modified design and openings of the bins. The application software developed in COOL for the planning and operation of cold stores will enable energy savings of at least 20 % by means of controlled airflow according to the demand.

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