Klaus Gottschalk, Potsdam-Bornim, and Chrispus Ndiema, Njoro/Kenia

# Cooling stored potatoes in Kenya

*Computational fluid dynamics and modelling of heat transfer within a potato pile are suitable methods for achieving forecasts of temperature developments in potato stores in developing lands. In cooperation with the Egerton University, Njoro, Kenya a model calculation was created for determining cooling times in potato piles under the climatic and geometric conditions there. These calculations form bases for improving crop storage conditions in Kenyan rural areas.*

Dr.-Ing. Klaus Gottschalk is a member of the scientific staff in the Department of Technology in Preparation, Storage and Conservation at the Institute for Agricultural Technology Bornim e.V. (ATB), Max-Eyth-Allee 100, 14469 Potsdam-Bornim
e-mail: *kgottschalk@atb-potsdam.de*
Prof. Chrispus K.W. Ndiema, PhD, is director of the Dept. of Industrial & Energy Engineering, Egerton University, PO Box 536, Njoro/Kenya

**Keywords**

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The main cause of post-harvest losses in small-scale farm production in developing lands is lack of suitably designed crop storage. In rural areas harvested crops are often temporarily stored in heaps, as piles in grain stores or on building floors.

For perishable products such as potatoes, tomatoes and sometimes onions uncontrolled air moisture and temperature can lead to rapid development of rot. The farmer suffers the losses. He transports the products to the market centres where price is directly dependant on quality. But commercially available engineering equipment can be utilised to create simple and cheap storage which is still effective [4]. The relationship between air movement and temperature distribution within a potato pile in a traditional store as, e.g., in Kenya, is investigated here. While measurement equipment is often not available, or of poor standard, in developing countries, forecasts of temperature development within potato piles and thus the calculation of recommendations for store design were achieved through computational modelling of airflow progression and heat transport.

### Method

Taken as typical store design for piled potatoes was a building (see *fig. 1*) wherein potatoes are stored on the floor. Floor area was 3 m • 4 m, height 2.5 m. The pile had an obelisk form on a floor of wooden slats ~ 0.2 m above the ground. The pile covered a ground area of ~2 m • 3 m with a height of ~ 1.2 to 1.5 m. The store hut sides had openings of ~ 1.6 • 0.8 m opened and closed by hand for air inlet and exhaust. Store ventilation was natural. In a store at Egerton University in Njoro (Rift Valley Province of Kenya) the storage period from May to July was taken with appropriate climate data applied (*table 1*).

Using computational fluid dynamic methods, airflow through the pile cross section was calculated (2-D calculation). The pile cross section had the form of an isosceles triangle or trapezoid. The pile was sheltered by the walls and the roof of the store with inlet and exhaust openings allowing ventilation by air currents coming from outside. To calculate the flow progression within the

*Fig. 1: Example of store in Africa; from [1]*

porous pile, the Navier-Stokes fluid dynamic equation [2] was enlarged by the term for the airflow resistance thus

$dp/dx = a \cdot wb$ and modelled with

$dp/dx$ = pressure gradient in the pile lengthwise flow direction dx; in $Pa \cdot m^{-1}$
w = air velocity through the pile; in $m \cdot s^{-1}$
a,b = computational constants, a = 620, b = 1.64 for average potato diameter = 6 cm

according to experimental results from [3].

After calculations of velocity distributions within the pile cross sections, a validated model of the material and heat transfer through a potato pile – as previously reported [5] was applied.

Involved in the calculations were the variants (a) air inlet lower windward side, (b) air inlet lower windward side with baffle, and (c) air inlet upper windward side. With all variants the air exit was on the lower lee side and the inlet air velocity was 0.5 $m \cdot s^{-1}$.

### Results

With all variants, average airflow velocity through the pile was about the same at 0.018 $m \cdot s^{-1}$. In the pile of porous material the airflow velocity profile developed largely in a similar manner. Only the airflow progression through the pile developed differently in the following ways:

*Table 1: Atmospheric data during harvest period May-July, Rift Valley, Kenya*

| | | |
|---|---|---|
| Temperature nights | 4…11 | C° |
| Temperature days | 15 …22 | C° |
| Air pressure | ~0,96 | bar |
| Relative air moisture | 55 …65 | % |
| Wind speed | ~0,05…1,0 | $m \cdot s^{-1}$ |

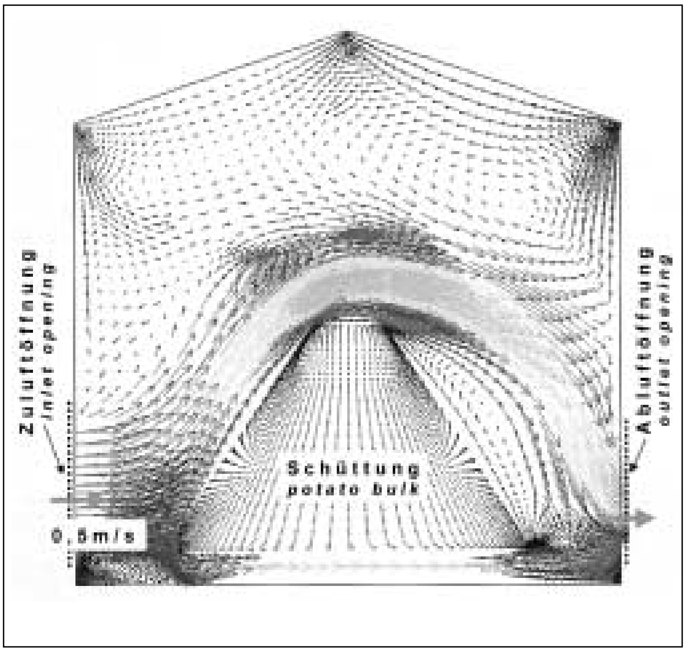


Fig. 2: Air velocity field in store; air inlet and outlet at bottom

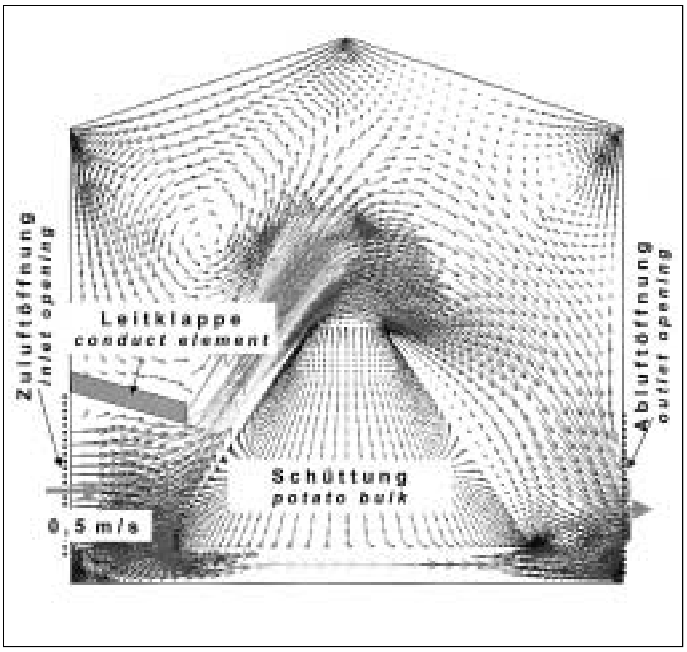


Fig. 3: Air velocity field in store; with air conduct element above air inlet

- (a) in a gradient starting from the lower air inlet side towards the upper air exhaust side, especially in the core area of the pile (*fig. 2*)
- (b) clearly developed and largely even upward airflow in the core area of the pile (*fig. 3*)
- (c) largely evenly distributed horizontal airflow within the entire pile from inlet to exhaust sides.

Here, the pressure differences of the external airflow around the pile closely control the airflows within.

The temperature distributions in the piles for horizontal ventilation of lower and upper layers (1) as well as vertical ventilation in the middle and left/right (2) were calculated (*fig. 4*) in order to be able to determine estimates of the cooling times for the different ventilation variants. Defined as cooling time for the various layers is the point when the target storage temperature is reached.

### Cooling time

In ventilation variant (2) which represents the variant with the baffle fitted over the air inlet (b), the differences in the average cooling speeds for the various layers are less than those of variant (1), according to (c). Additionally, the cooling times with variant (2), according to (b), are shorter. This leads to the conclusion that fitting a baffle unit over the inlet can shorten the cooling time (*tables 2 and 3*).

### Summary

The results apply only for conditions of constant air inflow. In practice, cooler exterior air, mainly in the night, must be used for cooling. While the relative air moisture is fairly high in the early hours of the morning, moisture reduction in potatoes is thus reduced at this time. Timely closing of the openings before noon prevents rewarming and production of condensation moisture. For a consistent throughflow of air, potatoes must be carefully cleaned of stones, soil and plant remainders. Only dry and healthy potatoes may be stored. The ventilation calculations indicate that fitting a baffle unit over the air inlets ensures consistent ventilation upwards through the pile, thus shortening the cooling-down period and avoiding inconsistency of conditions in the different layers. However, this result is achieved only when there's a gap between pile and ground as calculated in the model.

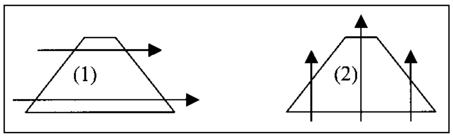


Fig. 4: Calculated variants of ventilated bulks: (1) horizontal, bottom/top; (2) vertical, center/left/right

| Variants | Airway length | Inlet side | Cooling time Centre | Exhaust seite | Average cooling speed (median) |
|---|---|---|---|---|---|
| (1) Below | 2 m | 15 h | 48 h | 95 h | - 0,28 K/h |
| (1) Above | 0,4 m | 13 h | 25 h | 32 h | - 0,82 K/h |
| (2) Middle | 1,2 m | 20 h | 40 h | 68 h | - 0,38 K/h |
| (2) Left/right | 0,6 m | 14 h | 27 h | 40 h | - 0,57 K/h |

Table 2: Cooling time following cooling from 22°C to 11°C

| Variante | Airway length | Inlet side | Cooling time Centre | Exhaust side | Average cooling speed (median) |
|---|---|---|---|---|---|
| (1) Below | 2 m | 10 h | 40 h | 65 h | - 0,16 K/h |
| (1) Above | 0,4 m | 8 h | 15 h | 21 h | - 0,45 K/h |
| (2) Middle | 1,2 m | 10 h | 27 h | 45 h | - 0,22 K/h |
| (2) Left/right | 0,6 m | 9 h | 19 h | 28 h | - 0,32 K/h |

Table 3: Cooling time following cooling from 15°C to 10°C

## Literature

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