Field testing of an innovative solar powered milk cooling solution for the higher efficiency of the dairy subsector in Tunisia

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Institute of Agriculture Engineering, Tropical and Subtropical Group
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Note: *This document aims to serve as internal documentation for all project partners. It shows the progress and decisions taken at the University of Hohenheim related to technical issues of the solar milk cooling system and its common implementation in Sidi Bouzid. For any suggestion or question, please don´t hesitate to contact us.*

1. Inception Workshop in Tunisia 7th-10th September 2015

Group picture in front of a visited milk collecting center

First of all, we would like to thank the INRAT and ICARDA for the organization of the inception workshop which was a great opportunity to get to know all project partners, exchange information and plan activities. Likewise we appreciate the efforts of all partners of Sidi-Bouzid for their suggestions and organization of the visits to farms and milk collecting centers.

Milk collecting center and milk transport vehicle

Tanks for milk storage at 4°C

Farms of the region

Commonly used aluminum milk cans (40 Liters)

Milking pumps found in all visited farms

Transport vehicle

After having presented the initial system, visited the site an heard the suggestions of Tunisian experts, it was concluded that the on-farm milk cooling system should cover following aspects:

a) The size of the used milk cans should be as big as possible and similar to the commonly used 40L cans.
b) It is important to cover (be able to cool down) the whole amount of daily milk production of the selected farms.
c) The system should focus on cooling milk before/during transport to the milk collecting centers (max. 3h after milking), while the storage of milk over night is a secondary goal.

<u>It was determined to use the same type of milk cooling system for all farms (in single, double or triple capacity for on-farm mobile milk cooling of 60, 120 or 180 Liter per day)</u>

2. New design for the isolated milk cans (two per System)

The final version of the isolated milk-can is able to cool down and storage 30 Liter milk by using 6 Kg ice.

Prototype of the final version of the isolated milk can

The milk-can is made of stainless steel (Material number 1.4301 / AISI-304 / V2A), isolated with rubber and covered with aluminum sheets. The adapter for ice, closes tightly the milk can with help of a sealing ring and clamping ring. The milk-can is able to cool down 30 Liter milk from 35°C to 15°C in around 90 minutes with 3 ice-blocks(tins) of 2kg weight each. This, can take place during the transport in a vehicle. Even at 40°C ambient temperature, the milk inside increases its temperature less than 0.5°C per hour. The isolated milk-can can be

also used to store milk during the whole night by adding additional 4kg ice (Please see milk quality assessments below for more information)

The weight of the isolated milk-can is around 11 Kg without adapter and ice. With 30 Liter milk and 6 Kg ice, the weight remains under 51 Kg (full weight of a conventional 40L Aluminum milk-can: 46Kg). The new isolated milk-can is designed to be carried by two persons with help of its comfortable handles.

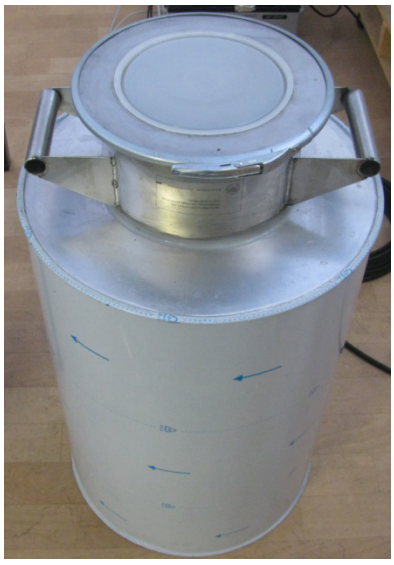
Dimensions: Ø430mm, 700mm height (conventional 40L milk-can: Ø340mm, 600mm height)

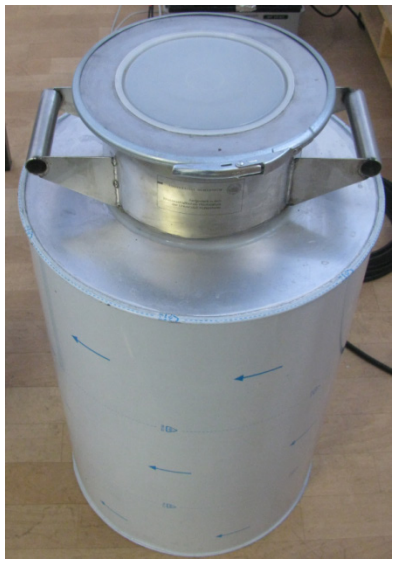
3. System configuration:

Consists of PV Modules, Batteries and control unit, to provide solar electricity to the ice-maker(DC-Freezer). The ice produced in 2kg Ice-tins is used for milk cooling in 2 isolated milk cans (Morning milk and evening milk). Every milk-can has an adapter to place a maximum of 6 kg Ice (3 tins). Inside the Ice-maker, 25 Ice-tins can be stored for an autonomy of 4 days during rainy weather.

Ice-maker with batterie, control unit(Socobox) and data logging

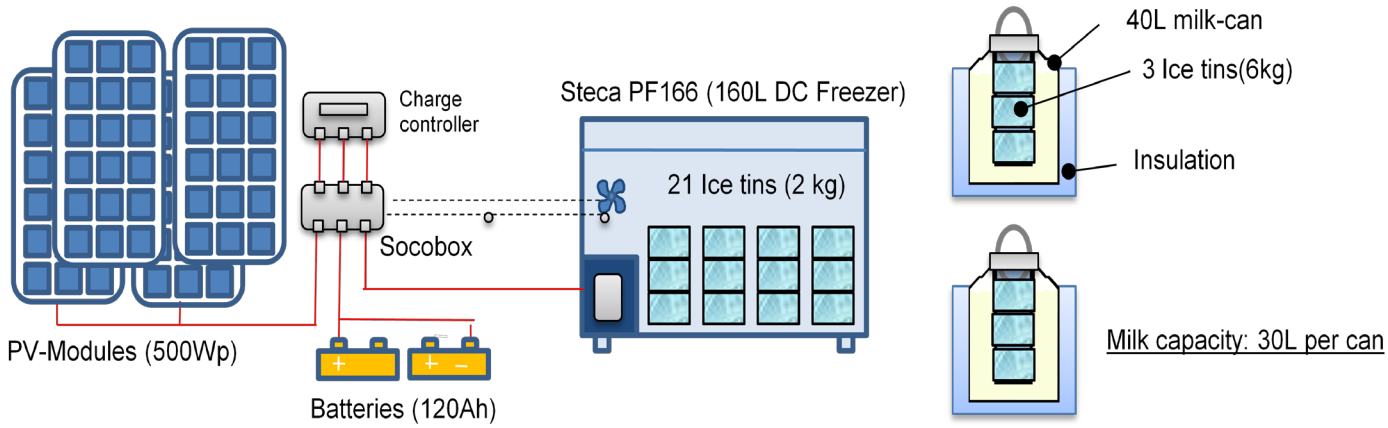
25 Ice-tins inside the ice-maker





Two milk cans per system for milk cooling of a total of 60 L/day

PV Panels for 3 systems (1 system needs only one structure)



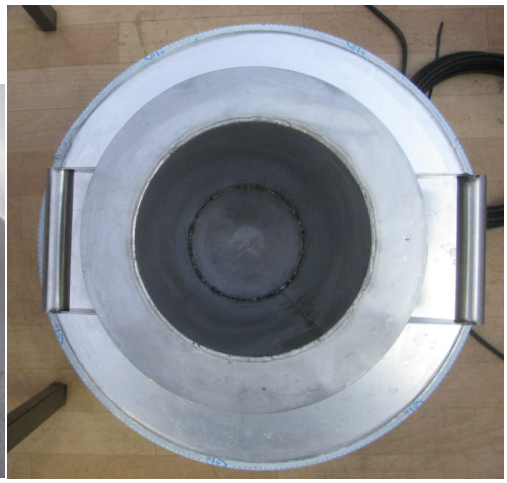
System configuration of one single system (PV modules with structure, charge controller, socobox, DC-Freezer and 2 Isolated milk cans)

The control unit socobox (designed at the University of Hohenheim), adapts the freezing power to the actual solar radiation and manages the remaining energy with a "power saving mode" during rainy days. The batteries storage solar energy excess to be used at night to produce more ice, increasing overall daily ice production.

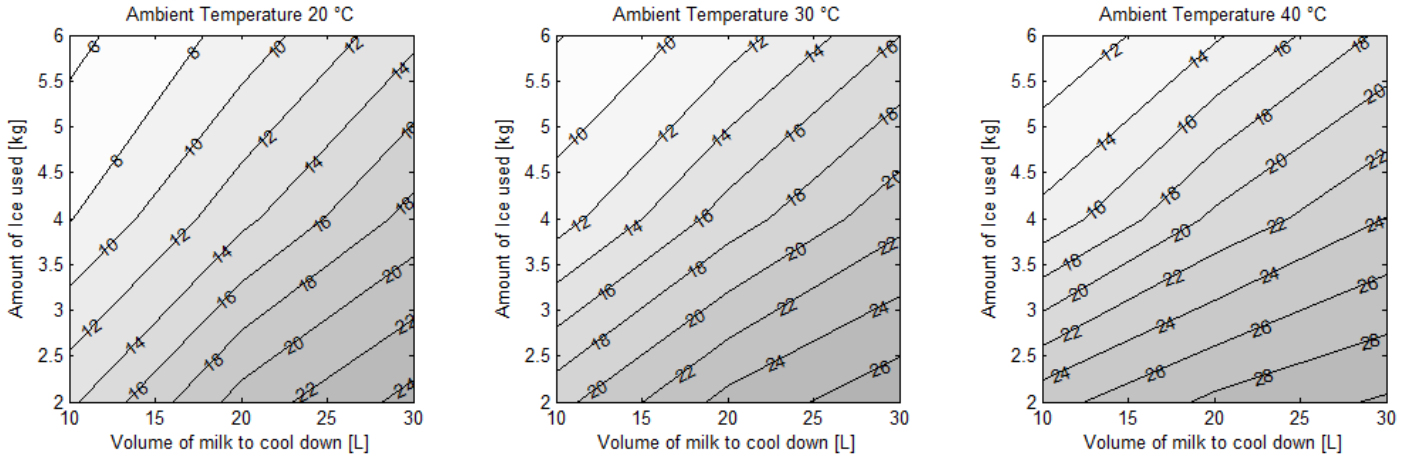
The maximum capacity of the system is 30+30 liter per Day. The temperature of the milk at the time of delivery in the milk collecting center (around 3h after milking) will depend on the relationship between amount of milk and ice introduced in the milk-can.

Ice-tins

Tag for 30 Liter inside the milk-can



place for 3 ice-tins (total of 6kg ice)

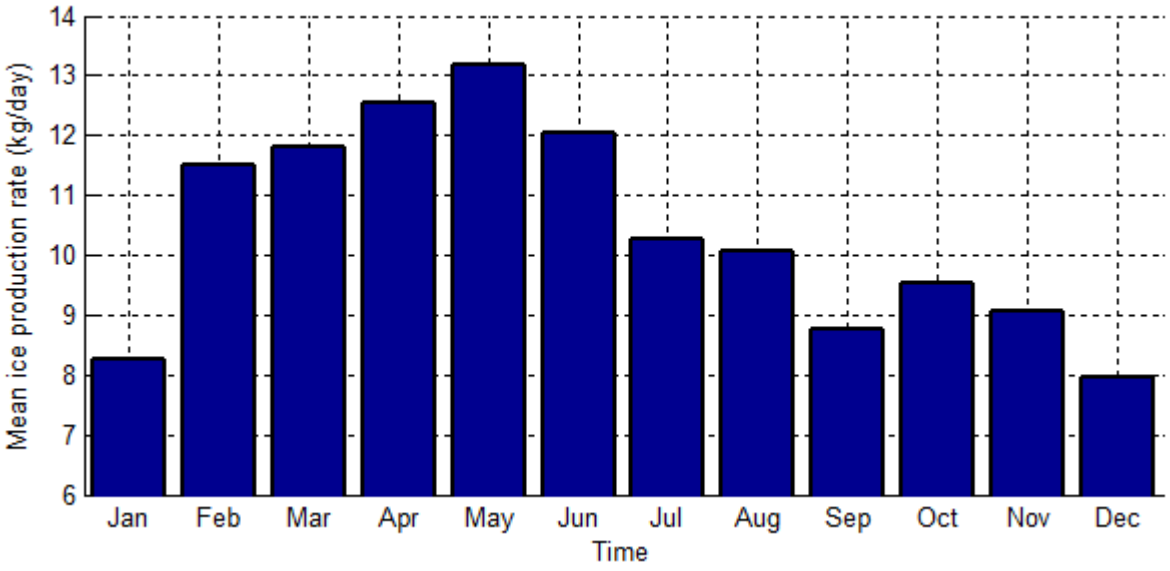


Expected milk temperature 3 hours after milking(36°C). Dependence on milk/ice ratio and ambient temperature.

4. Solar Performance:

The ice production rate depends on weather conditions. Since the refrigerator is able to store 50 Kg ice, even during rainy days, there will be fresh ice available to be used for milk cooling. Nevertheless, the ice production will vary during the year as shown in next figure. This means that, in the period between March and June, 12 Kg ice per day (mean value) can be extracted from the refrigerator while from September to February, only 8 kg/day (mean value) can be used. The amount of ice used for milk cooling will be selected by the end-user according to the amount of milk that has been milked and the number of frozen tins available in the refrigerator.

<u>The ice-tins that were not used one day, can be used the day after in order to match farmer needs.</u>



Simulated ice production rate for Sidi-Bouzi (mean values over the whole month)

5. Field testing:

10 Systems for on-farm cooling of 30+30 Liter milk per day will be delivered and installed in 6 farms in the region of Sidi Bozid. Following configurations are possible:

- 4 Farms with 2 Systems (120 L/day) + 2 Farms with 1 System (60L/day)
- 1 Farm with 3 Systems (180 L/day) + 2 Farms with 2 Systems(120L/day) + 3 Farms with 1 System(60L/day)

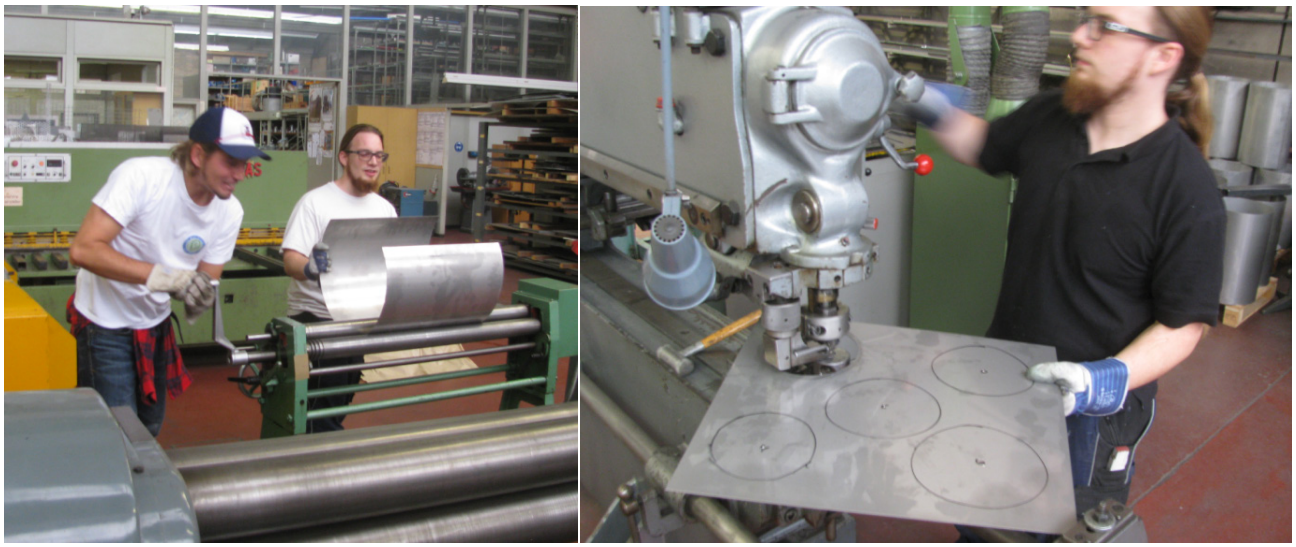
Every system requires:

a) A dry and non heated space protected from rain and sun for the installation of the freezer.
b) A solar surface for the installation of the solar panels.
c) Distance between Solar panels and freezer lower than 10m.

For more information and the preparation of the farms, a document in french with title " Les conditions préalables à l'installation" is kindly available.

6. Preparation of the materials at the University of Hohenheim:

The 20 isolated milk-cans needed for our common project, are produced per hand at the workshop facilities of the Institute of Agriculture Engineering under the supervision of technical staff members of the dairy plant of the University of Hohenheim. Previous to the transport to Sidi Bouzid, all cans will be cleaned under standard procedures and approved from the dairy plant for it use in the dairy industry.



Production of milk can casing and covers

Electrical welding with shielding gas inside the milk-can

Electro-chemical cleaning of welding lines

Mechanical polish

Welding lines are cleaned with commonly used methods for milk tanks: Electro-chemical cleaning and polish (mechanically and with final abrasive blasting with glass beads)

The 25mm isolation is made from water resistance rubber glued to the milk-can walls. The aluminum sheets protect the isolation and are watertight. The bottom of the milk-can is isolated with hard foam in order to support the total weight and make the can stable for its daily use.

Rubber isolation

aluminum casing

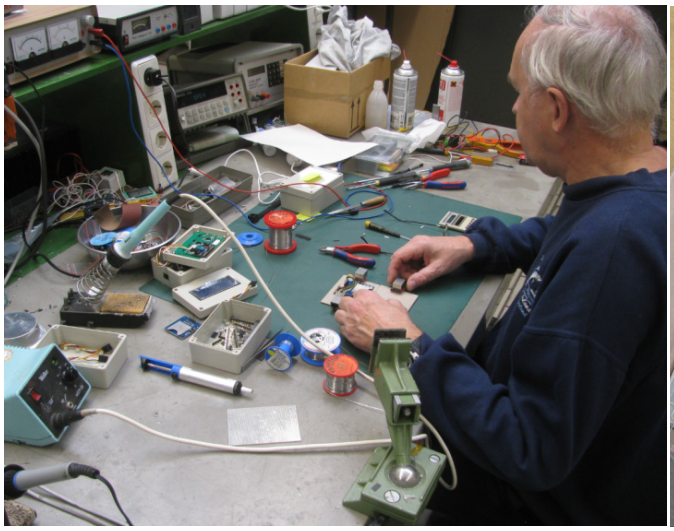
hard foam for the can bottom

before placing the casing

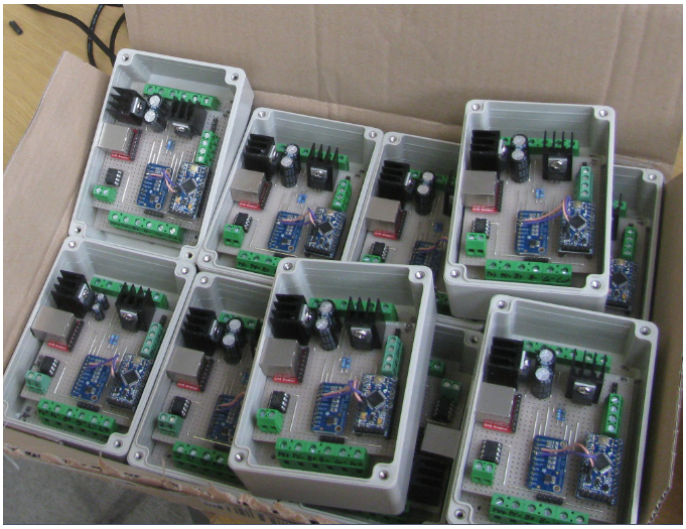
The material cost of a single isolated milk-can is around 160€. (The final cost of a conventional steel less 40L milk-can in Europe is around 220€)

The hand-made production of all milk-cans could be theatrically finished by 25th of December. One prototype is available so that it would be possible to contact milk-cans-producers (In Tunisia or Europe) for a future commercialization of the isolated milk-cans.

Besides the production of the milk-cans, all control units (Socobox) has been assembled and need now to be cabled and tested under real conditions before it pre-installation at the company Phaesun.



hand production of the socobox and data logging units



final socobox units for controlling the DC-Freezer

The socobox unit can be in future produced by an specialized company with a expected cost below 50€.

7. Performance testing of the whole system under real conditions:

From November 2nd, one system in its final configuration has being tested under typical summer conditions in Sidi-Bouzid. The climate chamber is able to emulate the course of a day (based on typical weather data and solar simulations) controlling photovoltaic power and ambient temperature simultaneously.

Final system configuration inclusive all components

Climate chamber for testing under real conditions

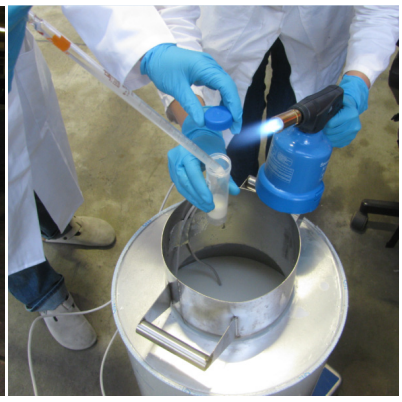
In the next weeks, all control units (socobox) will be tested under real conditions to avoid failures on the field.

The facilities and climate chamber of Hohenheim are kindly available for all cooperation partners of the project to carry out training, assessments with students or just as "show-room" of the final system.

8. Performance testing of the whole system under real conditions:

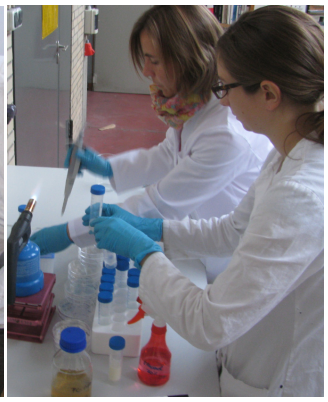
In order to have a first evaluation of the new isolated milk-can, a quality assessment (bacteria counting plates) has been carried out with real milk under temperatures of a typical summer in Tunisia. A standard method with ager plates was used for bacteria counting of samples without cooling, cooling in the isolated milk-can, and instant cooling for a best-case comparison.

Picking up milk at the university farm



extracting milk samples

melted ice after 3h



sample dissolutions

The experiments were started one hour after milking (this fact need to be avoid for future measurements) for three different scenarios:

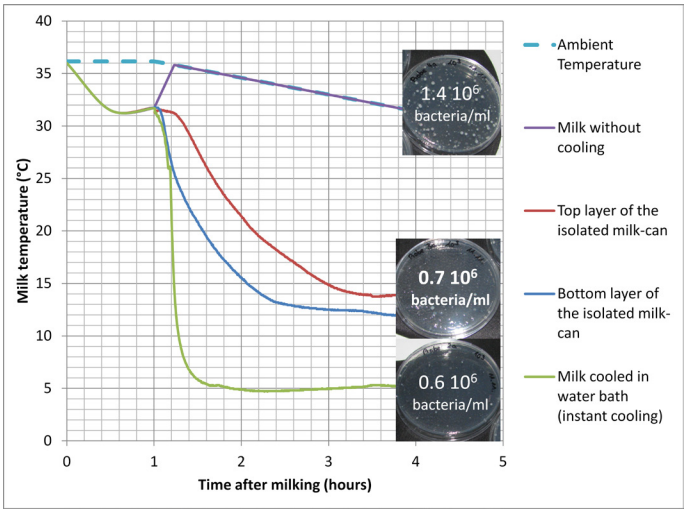
a) No cooling (milk remains at ambient temperature)

b) Cooling in the isolated milk-can (Temperature sensors on top and bottom of the can, both placed touching the interior wall)

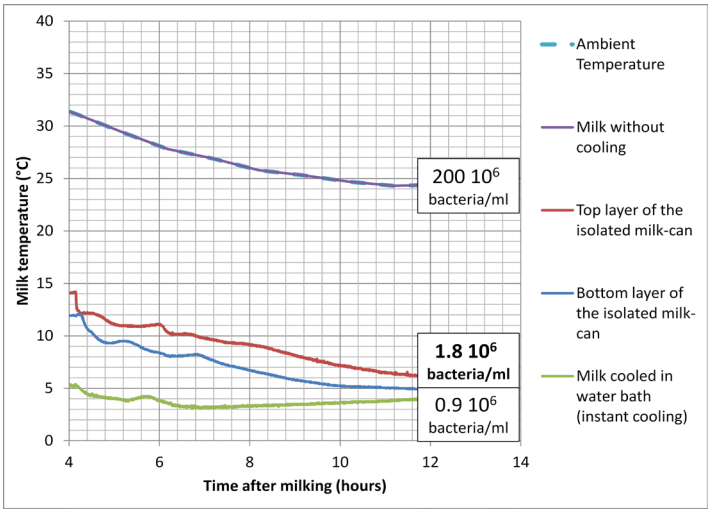
c) Instant cooling at 4°C as best-case scenario.

The preliminary results confirmed a good performance of the isolated milk-can for cooling during the first 3-4 hours after milking. A temperature difference of max. 5°C can be observed between top and bottom while the milk quality was similar to the one that had been cooled rapidly to 4°C.

The isolated milk-can can be used for storage for further 12 hours by adding additional ice. The results showed that this fact can avoid the spoilage of the evening milk. This might be useful for days without transport availability for the evening milk.



Milk cooling in the first 3-4 hours after milking



Adding additional ice for storage over 12 hours

Note: *These results are preliminary reference values to be confirmed in further assessments in Sidi Bouzid and Hohenheim.*

9. Further steps:

	December 15	January 16	February 16	March 16	June-July 16
Preparation of needed materials					
Pre-instalation at Phaesun					
Training of Tunisian system expert					
Transport to Sidi Bouzid					
Installation					
Start of on-field testing					
Technical Workshop at Hohenheim					

10. Contact persons at the Institute of Agriculture Engineering:

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