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Freeze Drying at Atmospheric Pressure
- New Product possibilities

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INTRODUCTION
In the production of artificially dried ingredients in different dishes, soups and cereals we find today two dominating technologies, direct heated driers operated at 60°C to 90°C and vacuum freeze drying operated below -30°C. Direct heated dryers have a lower production costs than vacuum freeze dryers but with a much lower quality of the dried product. Vacuum freeze dryer, on the other side, is so expensive that its use is limited.

The new technology developed is based on heat pumps in combinations with dryers. It gives considerably lower production costs than vacuum freeze-drying but with similar qualities of the dried product. The focus have been on the design, dimensioning and operation of such heat pump dryers using a combined mode with drying temperatures below and above the product freezing point as shown in Figure 1. By using heat pumps in drying of heat sensitive materials drying temperature and relative humidity can be controlled. The technology saves energy and is more environmentally friend than direct heated dryers. Several materials have been dried in test plants, like fish products, fruits, vegetables and dairy products. These products quality and properties can be controlled as for example color, taste, bulk density and rehydration. By changing the operation mode and time period with atmospheric freeze-drying quality parameters will be influenced. Generally, the longer this time period is, the lower the product shrinkage and the higher the rehydration index.

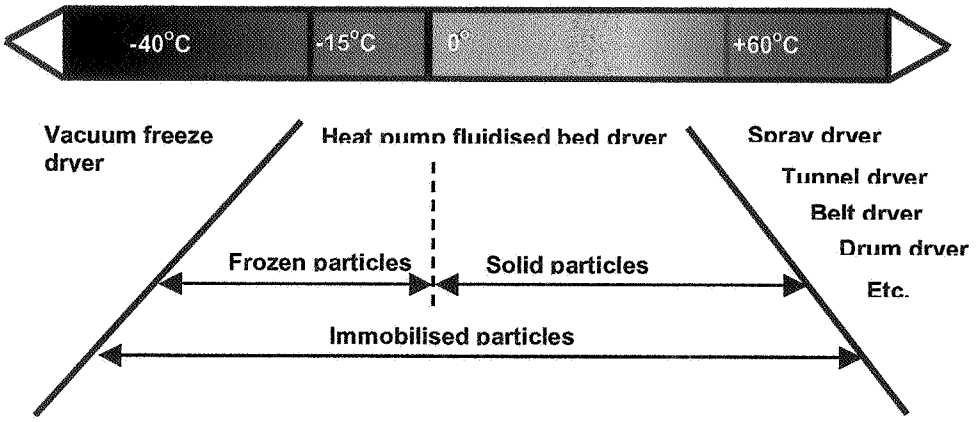

Figure 1. Temperature regime for heat pump dryers

PRINCIPLE
Heat pump dryers are attractive for the processing of heat sensitive materials since the drying conditions are easily controlled. Aside from being able to save energy this dryer design is based on an environmentally friendly technology. In Norway it has been applied industrially for the drying of fish and apples. The additional successfully dried products are fish, fish residues, fruits, vegetables, dairy products, biological and other active or heat sensitive materials. The drying modes allow controlling implying a high final product quality, which is indicated by hardness, porosity, density, rehydration, colour, aroma and other properties.

A schematic layout of a continuous industrial heat pump dryer is shown in Figure 2. The drying circuit is closed and the air is dehumidified in the air cooler. The energy removed (condensation of air moisture) from the air in the air cooler is used to heat the air in the air heater. Energy used for the compressor and fan is rejected in the external condenser. This system gives a controlled air quality at the inlet of the drying chamber. The dryer is

operating after the adiabatic drying principle. It is also possible to make non-adiabatic dryers with heat added to the product in the drying chamber. Depending of the product to dry this will increase the capacity of the dryer 250 to 400%.

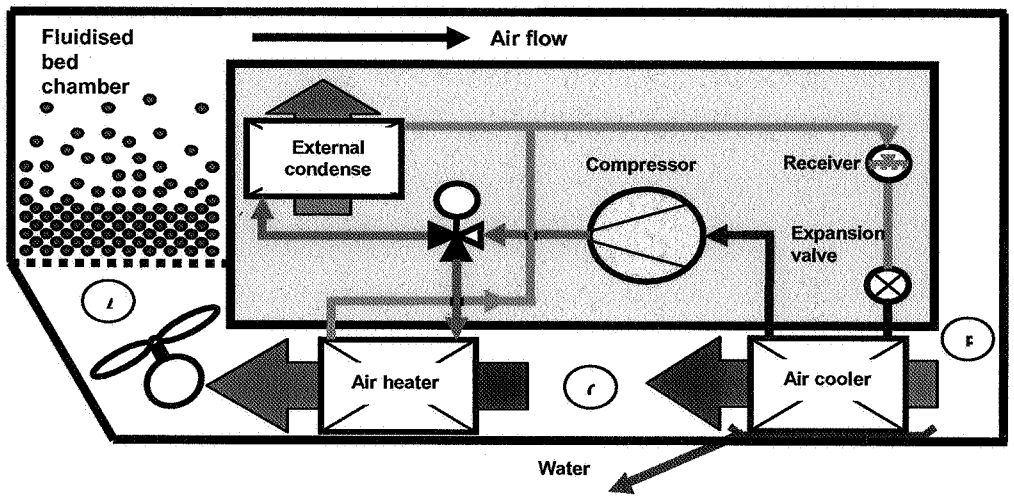

Figure 2. Schematic layout of a heat pump fluidised bed dryer

The advantages of the heat pump dryers are:

- Low energy consumption due to a high SMER that is expressed by:

$$SMER = COP/(dh/dx) \quad [kg\ water/kWh] \quad (1)$$

$$COP = Q_o / W \quad [-] \quad (2)$$

Typical SMER are in the order of 2 to 5 depending on the drying temperature.

- Drying conditions can be regulated with drying temperatures from –20°C to 110°C. Quality parameters of the product can be controlled due to the low temperatures and the possibility for partly freeze drying.
- The technology is environmentally friendly due to the recirculation of the drying air and the high thermal efficiency of the dryer.

To achieve as high SMER as possible, industrial fluidised bed heat pump dryers should be designed according to the following "design rules":

- Drying operation with optimum bed height to attain a higher relative humidity at the dryer outlet
- Stable fluidisation due to the sorption characteristics of the material being dried
- Continuous, not batch operation, due to the lowering of capacity and efficiency during a batch process
- As high inlet temperature in the dryer as possible, due to improved thermal efficiency and capacity
- As low refrigeration capacity as possible, as long as the desired production is achieved (over-sizing will increase dh/dx and reduce SMER)
- The choice of evaporating and condensing temperature of the heat pump should be the combination giving the best combination of COP and dh/dx (an optimum might exist).

RESULTS

Quality of the dried products is influenced to a large extent by the drying temperature. As an example the Figure 3 shows the influence on bulk density for 5 mm cubes of codfish dried at different temperature from –10 to +30°C. The final water content was in all cases below 10% and initial water content about 80% on wet basis. In some of the drying tests a temperature program was used with varying time period at drying temperatures below the freezing point of the product. As can be seen from Figure 4, the lower the drying temperature and the longer time period with freeze drying temperatures the lower the bulk density of the cod pieces. This again will influence the rehydration ability of the product. In Figure 5 we can see that the longer time period at freeze drying conditions and the lower the drying temperature the higher the rehydration ability (Strømmen 1994). Quality parameters such as taste, texture and colour are influenced by the drying temperature program. The temperature program could be a step up or a step down process.

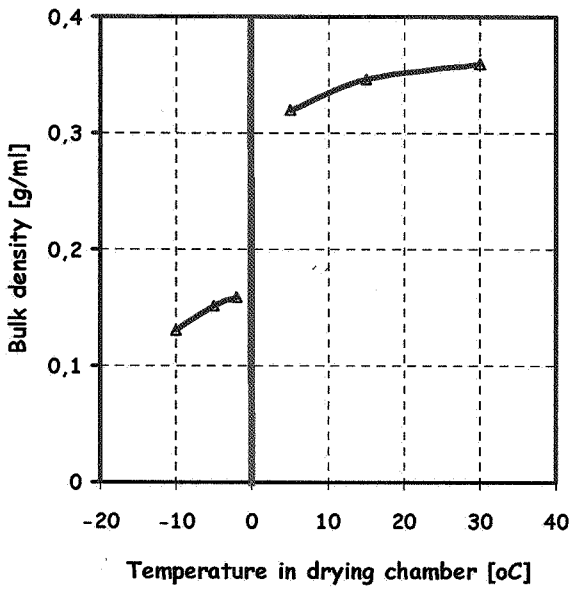

Figure 3. Bulk density of cod pieces dried at temperatures from –10°C to 30°C

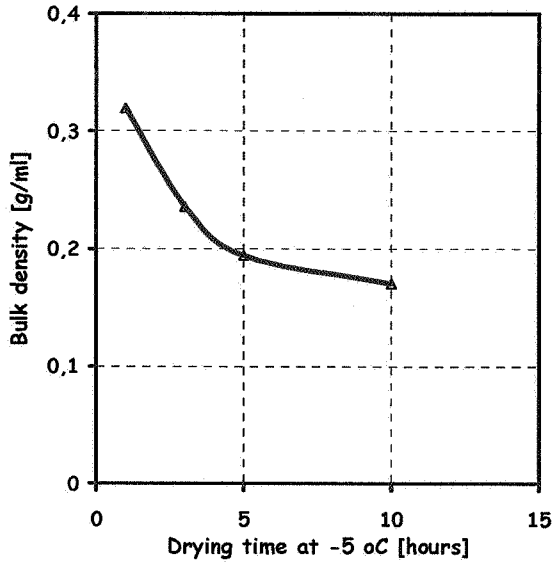

Figure 4. Bulk density of cod pieces dried at different drying time with initial temperature of –5°C and final drying at +30°C

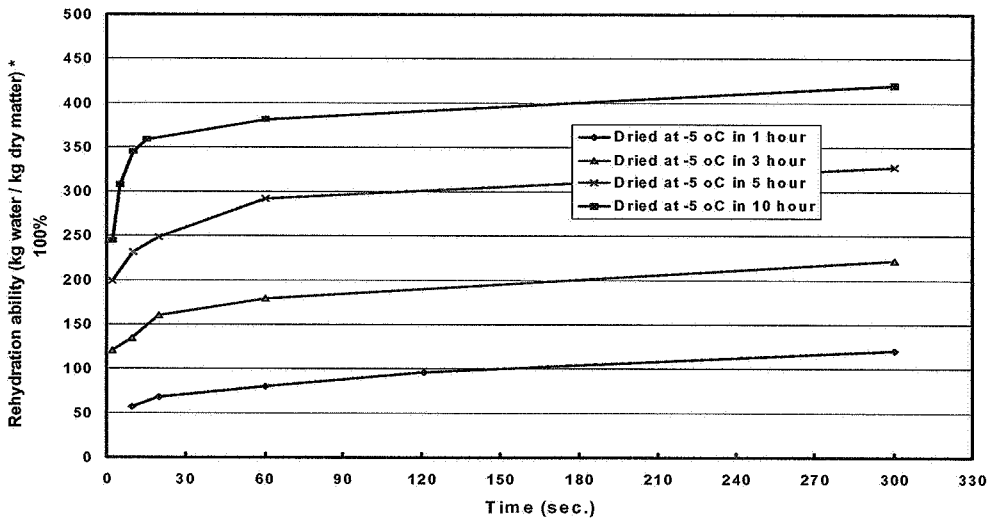

Figure 5. Rehydration ability of cod pieces dried with different time periods at freeze drying conditions

SUMMARY

Heat pump dryers make it possible to dry with temperatures below and above the freezing point of the product. This combines the best advantages from the vacuum freeze dryers and the warm air dryers and gives a high influence on quality parameters such as: taste, colours, texture, bulk density and flavours. The energy used in heat pump dryers is only 20-30% of a traditional dryer, and have SMER of 2 to 5. Combinations of step up or step down programs of temperatures gives possibilities of new improved products on the market. Tests of fish products, fish residues, pat foods, fruits, vegetables, dairy products, biological and other active or heat sensitive materials have shown improved quality aspects.

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