Atmospheric Freeze Drying – no vacuum required

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Introduction

New Zealand is big in freeze drying. In Cuddon Freeze Dry of Blenheim we have a successful manufacturer (and exporter) of batch freeze drying equipment. In our mussel, kiwifruit, pet food, and dehydrated vegetable industries we have some large scale freeze drying companies. And in our military and tramping rations companies, a range of expert users of freeze drying.

All of this is classic vacuum freeze drying (VFD), an excellent process capable of preserving structure, flavour and bioactivity in many materials. But the equipment is expensive, being based on a large-diameter pressure vessel, vacuum pumps and complex heating manifolds. And it is very hungry on energy. VDF is expensive.

Drying from frozen in a full atmosphere of pressure

Within FIET we have been developing atmospheric freeze drying (AFD) for five years now and it is looking promising. The principle is simple. Put product in a freezer store at (say) -10°C and blow very dry (dew point < -35°C) over it. Water will sublime from the food and diffuse out into the cold dry air. If that air contacts a pile of frozen food at (say) -8 °C, then it will do some drying work and leave at about -10 °C. The job of the equipment is to dry out that air, warm it back up to -8 °C and send it round through the product again.

AFD is not a new concept. A few engineers have seen the promise and have tried heat pump and other solid desiccant approaches. None has quite cracked it yet. What has changed is the ready availability nowadays of very good desiccant wheels with very low thermal mass. We have found that two such wheels, carefully sized and set in cascade, is the secret. One large wheel is placed in an air handler unit beside the freezer tunnel down which the cold dry air is blown. A second wheel makes warm dry air with which to regenerate the large wheel. And the second wheel is itself regenerated using either a small flow of hot air like a normal dryer, or by a heat pump operating over a comfortable temperature range.

Considerations

1. Drying time.

AFD is hideously slow. Water vapour must diffuse out through the food and navigate all the air molecules inhabiting the pores. Where VFD may take two days, AFD may take more than two weeks. That means the drying chamber is 10 times larger. But that chamber is just a light poly-panel tunnel, it is cheap to build. And if the product is sitting waiting in a freezer store anyway, there is no penalty.

2. Not suitable for batch processes

AFD does not suit all situations. It is best operating semi-continuously at large scale, where every day dried product is withdrawn from one end of the tunnel and fresh frozen feed put in the other end. The air flow hits the driest product first, and wettest last. It does not work well under -10 °C because air carries so very little water vapour down there – you have to recirculate air too often to be economic. This restricts AFD to low salt, low sugar foods which don't build too much freezing point depression as they dry.

3. Best for complex shapes requiring a gentle process

AFD suits some products far better than VFD does. Complex shapes and delicate materials such as cut flowers, hop cones, leafy green herbs do not like sitting with one petal or leaf resting on a very hot plate. That one part gets scorched and over-dried while the rest stays moist. AFD provides even heating over the whole surface.

In VFD it is common for the heating plates to get up to high temperatures – 40, 50, even 60 °C. Product can rise to these temperatures late in the drying cycle. But with AFD, not one molecule of product can get above the inlet air temperature (perhaps -8 °C) at any point in the cycle. It is really very gentle.

VFD usually suffers from some point to point variability in a dryer. Vapour paths differ between locations. Building the perfect heating manifold to make each tray identical is very difficult. Here the slowness of AFD becomes a virtue. No part of the product can race away from another. The whole load evens out in moisture content very well.

Trial results

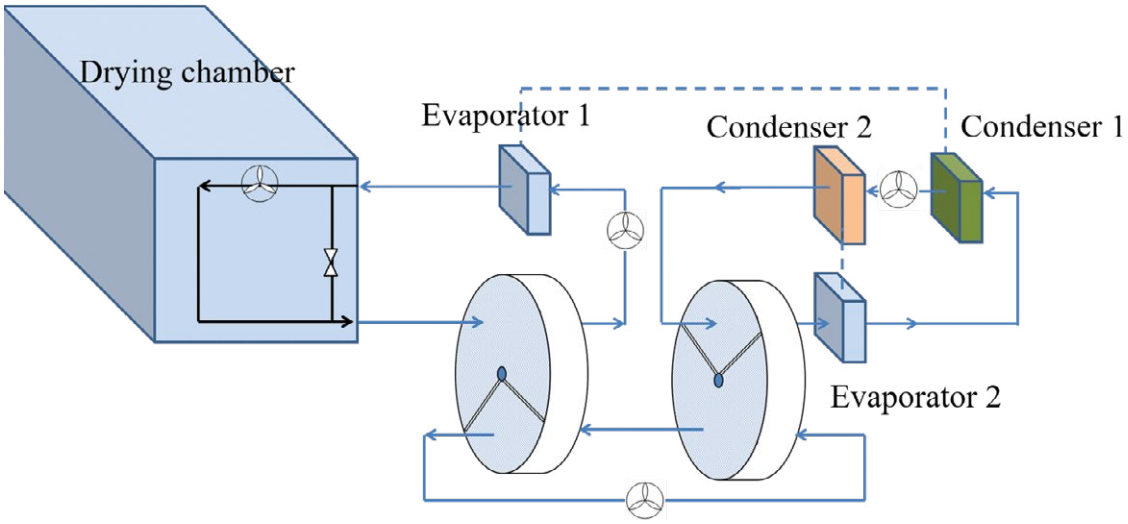
We have performed successful AFD trials on a number of products now, including snap frozen peas, corn kernel, cabbage leaves, frozen smoothie drops, hop cones, mussels, insect larvae and quite a few whose owners would like to stay quiet.

We have built trial devices at three scales:

1. Several airtight mini-scale boxes with a drying capacity of ~1g water/

AFD small scale trial units and examples of dried product

10 kg/day prototype and AFD process diagram



day, which allow us to measure the drying rate of small samples under different relative humidities and temperatures;

2. A bench scale medium-size testing box with a maximum AFD drying rate of 100g water/day for characterising drying behaviour in a semi-continuous process;

3. A proof-of-concept prototype of the desiccant wheel-driven AFD process with a drying capacity of 10kg water/day consisting of an insulated tunnel for semi-continuous drying and an air handling unit holding the cascading desiccant wheel dehumidification system. [The AHU was designed, built and donated by Cooke Industries of Auckland].

Our calculations indicate that, at scales over 2 MT of water removal per day, AFD looks to be about half the capital cost, and half the operating cost of VFD.

Our conclusion

But... the best application looks to be as a finisher to a VFD operation. In vacuum freeze drying, the first 2/3 of the water dries off in well under the first 1/3 of the cycle. If you can keep the product cold and break vacuum after say 30% of the normal cycle time, then transfer the load to an AFD for finishing, you might treble your throughput at the cost of a very simple AFD. Product may need to stay a week or more in the AFD but it will stay very cold and come out very evenly dried. It may not much matter if you leave it over the weekend and pack out on Monday – the final part is the slowest.

FIET
Food Industry Enabling Technologies

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