



Moisture Sorption on Tobacco of Various Origins

Philip T. Attwool, Daryl Williams, Surface Measurement Systems Ltd.

This paper demonstrates the application of DVS Advantage-2 for large tobacco sample size using relative humidity steps and cycling methods.

Introduction

The moisture sorption properties of tobacco are critical for the characterisation of their drying and shelf life stability. Tobacco is vulnerable to both temperature and humidity shocks which can occur during transport. Once tobacco becomes wet, it can lose taste, any added flavour or even its combustibility. Problems can also occur with very dry tobacco, which can become too fragile to be used in manufacture.

Method

Moisture uptake kinetics for tobacco were studied using a DVS Advantage-2 vapor sorption instrument. This instrument is especially designed for real world samples up to 5 cm in diameter and 4 g in weight. Tobacco from two light brands of cigarettes, designated as A and B, were purchased from a grocery store in London. These cigarettes were chosen from different manufacturers in order to follow possible differences in their matrix and preparation. In addition, some of their ashes were also studied in the DVS once the cigarettes had been smoked.

Results

Figure 1 shows gravimetric data for a 0.257g tobacco sample from light cigarette A at 25°C. The powder was equilibrated at 0% RH for five minutes before the experiment was started. A desorption step at 0% RH was performed followed by a sorption study at different relative humidity steps up to 90% RH. Finally desorption was performed step-by-step down to 0% RH. The relative humidity cycle is shown in blue in Figure 1 while the percentage change in mass is in red.

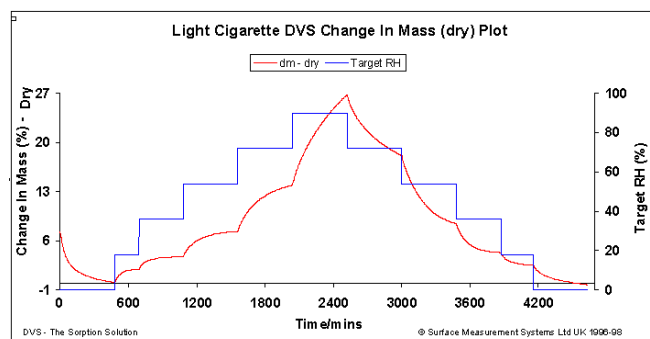


Figure 1. Effect of relative humidity on light cigarette tobacco A.

The isotherm derived from Figure 1 is shown below in Figure 2.

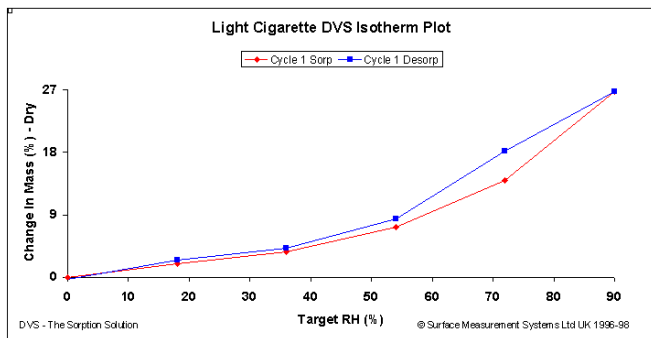


Figure 2. Water sorption/desorption isotherm for light cigarette tobacco A.

The data in Figure 1 shows a 7% mass decrease during the first 0% RH step. Then, up to 50% RH, the sample follows simple adsorption kinetics with each step tending towards equilibrium sorption. For higher relative humidity adsorption steps, no equilibrium is reached. The cumulative sorption at the end of the 90% RH step is 26.7% moisture content. During the desorption steps a decrease in mass is observed which never reaches equilibrium. The isotherm plot (Figure 2) shows a very low hysteresis up to 50% RH. Hysteresis is defined as the difference between the sorption and desorption curves. A higher hysteresis is observed in the range of 50 to 85% RH, which is due to water penetrating deeper into the tobacco sample. Finally, it is interesting to observe that after the last desorption step, the tobacco has dried by 0.30% more than during the first 0% RH step. This probably represents the thorough drying occurring in the DVS although an alternative explanation could be the loss of any volatile flavours.

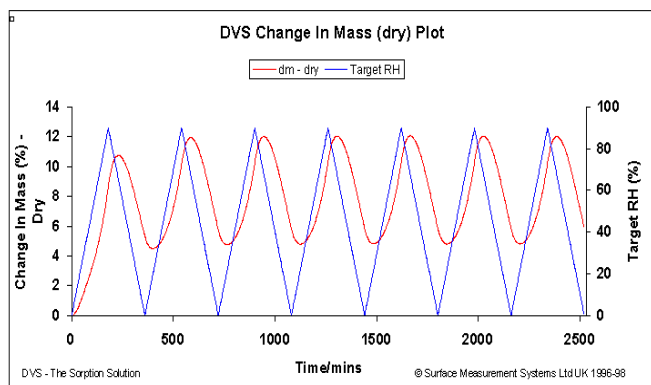


Figure 3. Water pickup during relative humidity cycling for light cigarette tobacco A.

An interesting alternative way to study water sorption by tobacco is to examine its stability to repeated relative humidity cycles. This interesting feature of DVS performance is useful for illustrating the effects of cumulative damage due to relative humidity cycling. It is a way to simulate the daily fluctuations in ambient relative humidities in some countries or the repeated movement of stock into and out of a warehouse environment. Humidities were chosen that would span a sufficient range to severely challenge the sample. As shown in Figure 3, the humidity extremes selected were 0% and 90% RH and the ramp rate was 30% RH per hour. Seven cycles were completed (shown in blue) and the response of the sample is shown in red. It is clear that dried tobacco gains more moisture after the first cycle. As a result of each relative humidity cycle, the tobacco is gaining a little more moisture.

This information is replotted in Figure 4 where the hysteresis between sorption and desorption is a way to visualise the product stability, especially since the data from Figure 3 can be converted to a series of hysteresis loops. Repeated cycling shows that tobacco is reaching a sorption or desorption equilibrium very quickly for brand A of the light cigarettes.

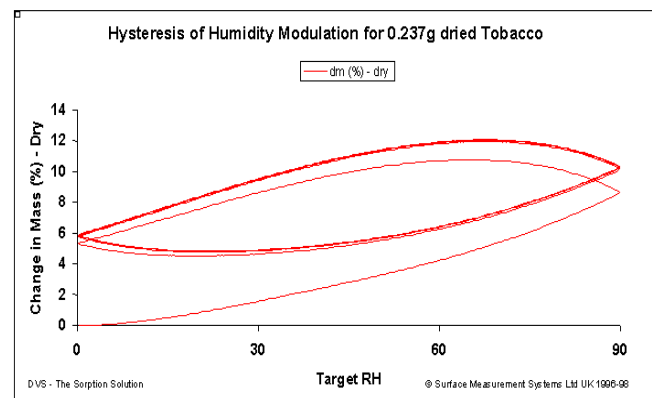


Figure 4. Multiple hysteresis phenomenon for light cigarette tobacco A.

For the sake of comparison, Figure 5 shows gravimetric data for a 0.327g tobacco sample from brand B of light cigarettes at 25°C. The powder was equilibrated at 0% RH for five minutes before the experiment was started. Then

a drying step at 0% RH was undertaken followed by a sorption study at different relative humidity steps up to 90% RH. Finally desorption was performed step by step down to 0% RH. The resultant isotherm is shown below in Figure 6. Two full sorption and desorption cycles were completed.

The data in Figure 5 shows a 5.6% mass decrease during the first 0% RH step. Then the sample does not follow simple adsorption kinetics and no steps tend towards equilibrium sorption. The cumulative water pickup at the end of the 90% RH step is 27% moisture content. During the desorption steps a decrease in mass is observed which never reaches equilibrium. The isotherm plot (Figure 6) shows a very low hysteresis up to 50% RH.

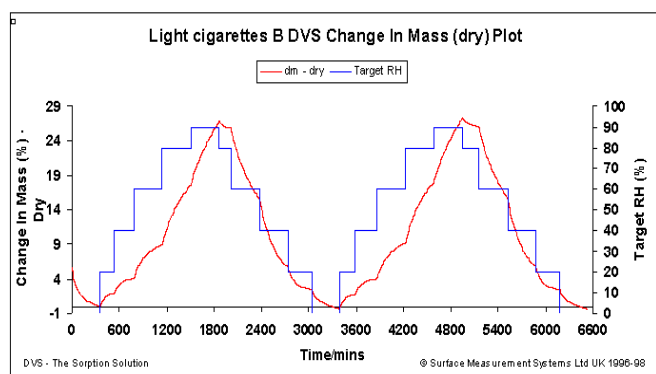


Figure 5. Effect of relative humidity on light cigarette tobacco B.

Fast kinetics with a low amount of water uptake and low hysteresis are a characteristic of surface water adsorption. This type of behaviour is shown in Figure 6 at low relative humidities. However, a higher hysteresis is observed in the range of 50 to 85% RH, which is due to water penetrating deeper into the tobacco sample. The two cycles shown in Figure 6 are very similar. Finally, it is interesting to observe that after the last desorption step, the tobacco is drier by 0.20% moisture content than after the first 0% RH step.

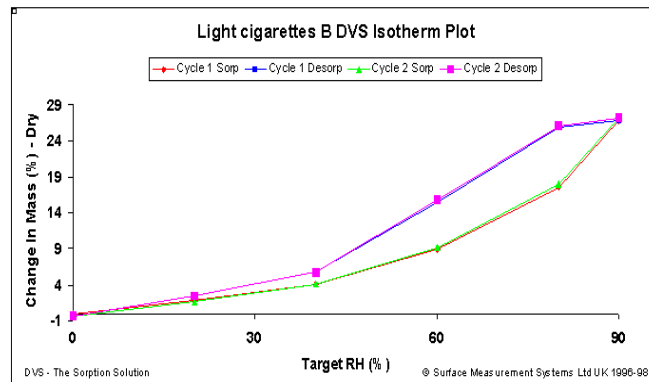


Figure 6. Water sorption/desorption isotherm for light cigarette tobacco B.

Finally, Figure 7 show gravimetric data for a 14.67mg ash sample from smoked light cigarette brand B at 25°C. The powder was equilibrated at 0% RH for five minutes before the experiment was started. Then a desorption step at 0% RH was performed followed by a sorption study at different relative humidity steps up to 90% RH. Finally desorption was performed step by step down to 0% RH. In Figure 7, a 0.2% mass decrease is observed due to drying during the first 0% RH step. Then up to the 60% RH stage, the sample follows simple adsorption kinetics with each step tending towards equilibrium sorption. At higher relative humidities, no equilibrium is reached. The cumulative sorption at the end of the 90% RH step of the first cycle is 84.4% moisture content. During the desorption steps, a decrease is observed which always reaches equilibrium. Before the second cycle, 6.4% moisture content remained in the sample. At the end of the 90%RH step of cycle 2, the cumulative sorption is 80.2% moisture content. Before the third cycle, 8.1% moisture content remained in the sample. At the end of the 90% RH step of cycle 3, the cumulative sorption is 77.0% moisture content. It is interesting to observe that for cycle 3 the 80% RH desorption step is not reaching equilibrium.

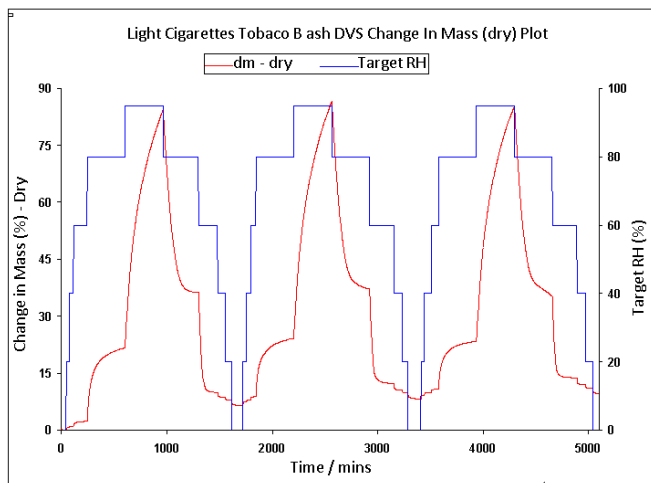


Figure 7. Three consecutive measurements on 14.67mg light cigarette tobacco B ash.

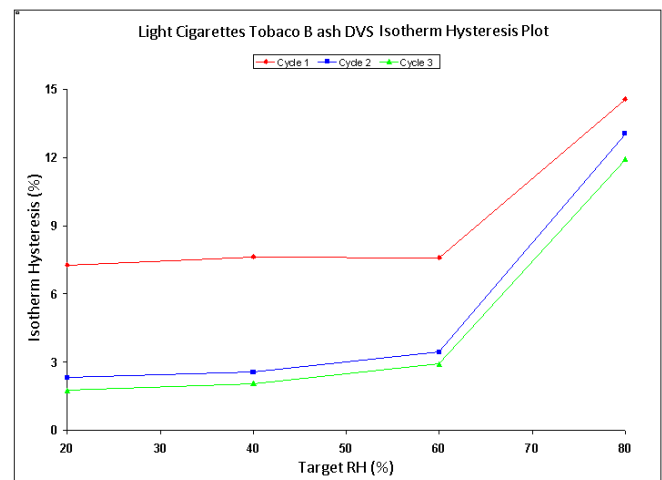


Figure 8. Multiple Isotherm hysteresis phenomenon for light cigarettes tobacco B ash.

The isotherm hysteresis plot (Figure 8) shows such behaviour better. These interesting features of DVS performance are also useful for illustrating the effects of multiple cycles of water sorption or desorption on materials. It is a way to estimate the remaining moisture in daily fluctuations of ambient relative humidities. Figure 8 shows that repeated variations of relative humidity leads to an increase in the residual moisture content of the sample. Furthermore, from Figure 8 it is obvious that cycles 2 and 3 are very similar. It means that the remaining moisture inside the sample tends to stabilise. For brand B light cigarette ash, it can be estimated that after three to four more sorption/desorption cycles, the remaining moisture inside the sample will reach a maximum value of 10% of the mass change.

Conclusion

The flexibility of the DVS software enables tobacco water uptake measurements to be undertaken easily and quickly. Tobacco shows a generally fast equilibration but with variable hysteresis. The tobacco can be humidity cycled in a number of ways in order to follow the stability to relative humidity shocks. This is a very important test for shelf life testing. The DVS offers the ability to be very creative with relative humidity cycling in order to fully characterise the water sorption properties of tobacco or ash.

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Head Office:
Surface Measurement Systems, Ltd
5 Wharfside, Rosemont Road
London HA0 4PE, UK
Tel: +44 (0)20 8795 9400
Fax: +44 (0)20 8795 9401
Email: science@surfacemeasurementsystems.com

United States Office:
Surface Measurement Systems, Ltd, NA
2125 28th Street SW, Suite I
Allentown PA, 18103, USA
Tel: +1 610 798 8299
Fax: +1 610 798 0334

