
CLIN. CHEM. 36/3, 544-546 (1990)

Sample Evaporation and Its Impact on the Operating Performance of an Automated Selective-Access Analytical System

Carl A. Burtis

In a series of gravimetric and analytical experiments I measured how much analytical error is ascribable to sample evaporation during routine operation of the Dimension™ analytical system. This error, a time-dependent function, is related to the volume of liquid placed in either a 0.5- or 2.0-ml cup and whether the cup is capped. For the 0.5-ml cups, analytical error at a 4-h residence time ranged from 12% to 16% (uncovered) to 8% to 13% (covered), whereas errors for the 2.0-ml cup ranged from 6% to 10% (uncovered) to 2% to 5% (covered). To minimize evaporative loss, I recommend (a) protecting the surface areas of the samples, (b) using larger samples, and (c) minimizing the time that a sample is in its cup before and during analysis.

Additional Keyphrase: analytical error

Evaporative losses from a sample cup can be a significant source of analytical error in the clinical laboratory, causing errors reportedly ranging from 1% to 10% per hour (1-5). Techniques used to minimize this type of error include layering the sample surface with silicone oil (6, 7) or protecting the surface of the sample with either a cover over all (1-3) or capping the individual sample cups (1, 8).

The "Dimension 380" (Du Pont, Wilmington, DE 19803) is a selective-access analytical system in which individual covers are used to retard loss of volatile analytes or liquids from the sample cups. During routine operation of the Dimension system, samples are poured into either 0.5- or 2.0-ml sample cups, and a disposable, snap-on cap is placed over the top of each one. The cap has a centrally placed 3-mm aperture through which a sample probe is inserted and withdrawn. The capped cups are then placed into their assigned positions in a 60-compartment sample wheel. The Dimension is then programmed to organize and schedule its workload automatically and systematically to obtain as many aliquots of each sample as needed for the test(s) ordered. Depending on the number of samples in a given analytical run and the number of tests ordered, the time that a sample remains in its cup in the system (the "residence time") can range from a few minutes to a few hours.

During routine operation of the Dimension, my coworkers observed that results of repeat analyses were generally higher than initial results. Closer inspection showed that this was ascribable to sample evaporation. Consequently, a study was conducted in which the efficiency of the sample container cap for retarding evaporation was determined as a function of time and sample volume. Here I (a) present the experimental results of this study, (b) discuss the factors that influence the magnitude of the evaporative losses that we encountered in the routine operation of the Dimension, and (c) describe techniques that can generally be taken to minimize evaporative losses from sample cups.

Materials and Methods

To demonstrate that sample evaporation was occurring from the 0.5- and 2.0-ml sample cups used in the Dimension, we dispensed specific volumes of water into capped and uncapped sample cups. The weight loss of each was determined as a function of time by weighing the cups and their contents at 1-h intervals for as long as 8h. The analytical balance used (Model AE1163; Mettler Instrument Corp., Hightstown, NJ 08520) had a repeatability of ±0.01 mg and had been calibrated against weights certified by the National Institute of Standards and Technology, Gaithersburg, MD. Upon completion of this gravimetric study, the results from each 9-h experiment were statistically processed, and the rate of evaporative loss was determined, both quantitatively and relatively.

To quantify the effect that sample evaporation would have on the analytical results produced in routine operation of the Dimension, we used it to analyze aliquots of a pooled specimen of serum for glucose. Here, the increase in

544 CLINICAL CHEMISTRY, Vol. 36, No. 3, 1990
glucose concentration resulting from evaporation was measured as a function of time and the volume of sample, and was measured in both the 0.5- and 2.0-mL cups, capped and uncapped. As a control, a fresh aliquot of the pooled serum was poured into a sample cup and immediately analyzed at each measurement interval. Glucose was chosen as the test analyte, because the method is precise (i.e., within-day imprecision is less than ±1%) and the required sample volume is only 3 μL.

Results

Results obtained from the gravimetric measurements demonstrated evaporative losses from both the 0.5- and 2.0-mL sample cups, because the net weight of the aliquots of water placed in them decreased linearly with time during the experiment. As summarized in Table 1, the magnitudes of the rates of the evaporative losses were a function of the volumes placed in the cups and whether or not they were capped. In general, the rates of the quantitative evaporative losses were larger for the 2.0-mL cups (7 to 41 μL/h) than for the 0.5-mL size (3.1 to 15 μL/h). However, when these quantitative losses are converted to relative losses, the largest losses were observed for the 0.5-mL cups (1.5% to 3.2% per hour) when compared with the 2.0-mL cups (0.7% to 2.9% per hour). Protecting the sample surfaces by capping the cups decreased evaporative losses from both cups—about four times more effectively with the 2.0-mL cups than with the 0.5-mL size.

In the analytical experiment, the glucose concentration of the aliquots of the pooled sera placed in the cups increased as a function of time (Figure 1) and paralleled the rates of evaporative losses that we observed in the gravimetric experiment. As a control, a fresh aliquot of the pooled serum was measured at each 2-h interval, and its concentration was found to be constant during the 8-h experiment [mean = 1.036 ± 0.98 (0.9%) mg/mL]. As observed with the gravimetric data, the magnitudes of the increases in glucose concentration—and, hence, the analytical error—were a function of the volume of the sample and of capping or not capping the individual cups. For example, when the glucose concentrations of the individual aliquots were plotted after a 4-h residence time as a function of sample volume, the increases in glucose concentration were greatest for the volumes placed in the 0.5-mL cups (Figure 2) as compared with the 2.0-mL cups (Figure 3). As indicated, capping effectively decreased the analytical error due to evaporation, especially in the case of the 2.0-mL sample cups.

Discussion

Minimizing sample surface. Once an aliquot of a sample

\[ \text{Evaporative loss} = \frac{\text{mass loss}}{\text{sample volume}} \times \text{time} \]

Table 1. Gravimetry of the Evaporative Loss from Water Samples as a Function of Time, Sample Volume, and Protection of the Sample Surfaces

<table>
<thead>
<tr>
<th>Sample vol, mL</th>
<th>Sample surface</th>
<th>Rate of evaporative loss (^a)</th>
<th>Ratio (U/C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cup volume 0.5 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.125</td>
<td>U</td>
<td>4.0</td>
<td>3.2</td>
</tr>
<tr>
<td>0.250</td>
<td>U</td>
<td>5.9</td>
<td>2.4</td>
</tr>
<tr>
<td>0.375</td>
<td>U</td>
<td>7.8</td>
<td>2.4</td>
</tr>
<tr>
<td>0.500</td>
<td>U</td>
<td>14.5</td>
<td>2.9</td>
</tr>
<tr>
<td>Total cup volume 2.0 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.500</td>
<td>U</td>
<td>14.5</td>
<td>2.9</td>
</tr>
<tr>
<td>1.000</td>
<td>U</td>
<td>23.8</td>
<td>2.4</td>
</tr>
<tr>
<td>1.500</td>
<td>U</td>
<td>32.2</td>
<td>2.1</td>
</tr>
<tr>
<td>2.000</td>
<td>U</td>
<td>41.2</td>
<td>2.1</td>
</tr>
</tbody>
</table>

\(^a\) U = uncapped; C = capped. \(^b\) Ambient temperature = 24.1 °C.
is transferred into its sample cup, evaporation will begin and can result in an analytical error as large as 16% during a 4-h interval. Evaporation occurs at the liquid/air interface, so the magnitude of evaporative loss is proportional to the exposed surface area of a sample (5) and ambient air flow. Thus, the analytical error resulting from evaporation can be decreased by covering the surface of the sample to minimize the exposed surface area and protect it from ambient air currents.

The caps that are provided with the 0.5- and 2.0-mL sample cups used in the Dimension both protect the surface and minimize the effective sample surface and are effective in reducing evaporative losses and the analytical error resulting from it. However, their effectiveness is proportional to the size of the cup and the volume of sample placed in it, being much more effective with the larger cups.

Sample volume and cup size. Our results indicate that evaporative error can be minimized by using larger (here, 2.0-mL) cups. For example, the 4-h analytical error for the 0.5-mL cup ranged from 12% to 16% (uncovered) to 8% to 13% (covered), whereas errors for the 2.0-mL cup ranged from 6% to 10% (uncovered) and from 2% to 5% (covered). In addition, the data shown in Figures 2 and 3 reconfirm an earlier observation (6) that, for a given sample cup, the evaporation loss is least when a cup is 25% to 75% full. Thus, for the 0.5-mL cup the sample volumes should be 0.2 to 0.4 mL and for the 2.0-mL cup, 0.6 to 1.5 mL.

Sample resident time. Once an aliquot of a sample is placed in its cup, evaporative loss is directly proportional to resident time. With systems such as the Dimension, the resident time for any given sample depends on the number of samples included in a batch, the number of tests ordered for each sample, and the processing rate of the system. The data given in Figures 2 and 3 can be used to predict, for example, the effect that a 5-h resident time would have on the evaporative error for a given sample volume. For example, if a 125-μL sample were in an uncapped 0.5-mL cup for 5 h, the error solely ascribable to evaporation would be about 20%. Errors of this magnitude are clearly unacceptable, but they can be minimized by processing runs of fewer samples and transferring samples into their cups just before a run is started. For example, four runs of 15 samples each would dictate that the longest resident time per sample would only be 1.25 h, yielding an expected analytical error of about 5.0% for a 125-μL sample in an uncapped cup.

Evaporative errors are often difficult to detect with modern quality-control procedures. It is now recommended, and is becoming common practice, to run quality-control samples only once a day or at the beginning of each work shift. In this situation, the resident time of the quality-control samples would be relatively short and, consequently, evaporative errors minimal. If a quality-control sample is to be used to detect evaporative errors, it should be placed in an analytical sequence such that its resident time would approach that of the longest resident time one would expect a test sample to encounter in the routine operation of a given analytical system.

I acknowledge the assistance of Sandy Bradshaw, Peggy Hall, Evelyn Ealy, Cathy McDowell, Judy Morton, and Vivian Smith for their astute observation that substantial evaporative errors were occurring in the routine operation of the Dimension, and for their persistence in convincing me of them.

References