Lab 6: Water Activity, Dehydration and Psychrometrics

Group 7
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Abstract: Water Activity and sorption properties are some of the most important physical properties of biological materials. Many microbial and biochemical reactions depend on water, and from this water activity one can predict the shelf life and stability of the material. When discussing food packaging the rate of moisture transfer in the drying process and through the packaging can be estimated through water activity and sorption properties.

Discussed and calculated are many different ways of measuring these properties with the samples of coffee creamer and paper towels. From these measurements many predictions can be made about specific biological materials. Moisture sorption isotherm describes the relationship between water activity and the equilibrium moisture content of a food product at a constant temperature.
I. Moisture Analysis and Water Activity

1. Oven Drying –
   a. **Introduction:** Oven drying is essentially applying low heat over a long period of time to biological materials. This technique is used for a variety of purposes. It is a technique used for dehydration in food to extend shelf life. Other uses include sterilization and drying for laboratory equipment. Also, drying ovens with ceramics not only are used for pottery but needed for the manufacture of many commercial products. Shown below is the calculated weight of paper towels and a coffee creamer before and after oven drying. The wet and dry basis moisture content is then calculated from these weights.
   b. **Procedure:**
      i. Take 2 tin pans, label each pan with sample material (paper/coffee creamer). Zero the pan on scale for each sample.
      ii. Weigh 2-4 grams of paper towel. Weigh 1-2 grams of coffee creamer. Record the initial "wet" weights.
      iii. Place samples into over in the Processing Lab. Note the temperature of the oven.
      iv. After 2 hours, reweigh the samples. Record this as the dry weight.
   c. **Data:**
      | Sample      | Wet Weight (g) | Dry Weight (g) | Wet Basis Moisture Content (%) | Dry Basis Moisture Content |
      |------------|----------------|----------------|------------------------------|---------------------------|
      | Coffee Creamer | 2.48           | 2.2812         | 8.02                         | 0.0871                    |
      | Paper Towels  | 2.31           | 2.1511         | 6.88                         | 0.0734                    |
   d. **Calculations:**
      i. **Wet Basis MC**
         \[
         M_{wb} = \frac{m_{H_2O}}{m_{H_2O} + m_{dm}} \\
         m_{H_2O} = \text{Wet Weight} - \text{Dry Weight} \\
         m_{H_2O} = 2.48 - 2.2812 = 0.1988
         \]
         \[
         M_{wb} = \frac{0.1988}{0.1988 + 2.2812} = 0.0802
         \]
      ii. **Dry Basis MC**
         \[
         M_{db} = \frac{m_{H_2O}}{m_{dm}} \\
         M_{db} = \frac{0.1988}{2.2812} = 0.0871
         \]
e. **Discussion:** – Based on data, coffee creamer and paper towels have a moisture content that is relatively similar to each other but this data shows coffee creamer has a higher moisture content. From drying in the oven, coffee creamer had a mass moisture of 0.1982 g, whereas paper towels only decreased by a mass moisture of 0.1589 g. The dry basis moisture content of coffee creamer is 8.71%, which is slightly higher than paper towels, having a dry basis moisture content of 7.34%. According to data, we are able to see that coffee creamer holds more moisture than paper towels do in over drying, due to the dry basis moisture content.

2. **Moisture Analysis**

a. **Introduction:** Moisture analysis is a measurement of moisture content in a material. Moisture content can be determined two separate ways, wet and dry basis. Wet-basis expresses the ratio of moisture mass to the total mass of the substance, including the moisture, whereas dry-basis expresses the ratio of the moisture mass present to the mass of the dry matter. The LJ16 Infrared Dryer determines the moisture content of the sample by a gravimetric method. It gives an output of %moisture, %solids, or weight, depending on settings. From there, the instrument can be used to determine wet or dry basis moisture content.

b. **Procedure:**

   i. Zero the weight of an aluminum pan on the Mettler Toledo LJ 16 Infrared Dryer.
   ii. Weigh out 2-4 grams of paper towel. Distribute evenly over the entire pan. Record the initial weight.
   iii. Set Temperature to 105°C, and the drying time to 10 minute.
   iv. Select %100...0. Press Start. When the lamp stops blinking the drying operation is complete.
   v. Use the switch key to switch between weight and percentage on the display.
   vi. After drying is complete, note the final weight and the final percentage (wet basis moisture content).
   vii. Use these values to convert the wet basis moisture content to dry basis moisture content and to find the final dry weight.
   viii. Repeat this procedure with 1-2 grams of coffee creamer, temperature at 130°C, and drying time as 6-8 minutes.

c. **Data**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Wet Weight (g)</th>
<th>Dry Weight (g)</th>
<th>Change in Weight (g)</th>
<th>Wet Basis Moisture Content (%)</th>
<th>Dry Basis Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee creamer a.</td>
<td>1.5</td>
<td>1.46</td>
<td>-0.04</td>
<td>2.67%</td>
<td>2.74%</td>
</tr>
<tr>
<td>Paper Towels b.</td>
<td>2.23</td>
<td>2.049</td>
<td>-0.181</td>
<td>8.11%</td>
<td>8.83%</td>
</tr>
<tr>
<td>c.</td>
<td>2.306</td>
<td>2.039</td>
<td>-0.267</td>
<td>11.6%</td>
<td>13.1%</td>
</tr>
</tbody>
</table>
d. **Calculations:**

**Wet Basis MC:**

\[
\text{M}_{wb} = \frac{m_{H_2O}}{m_{H_2O} + m_{dm}}
\]

Coffee Creamer:

\[
\text{M}_{wb} = \frac{.04}{.04 + 1.46} = 0.0266 = 2.67\%
\]

Paper Towels:

\[
\text{M}_{wb} = \frac{.181}{.181 + 2.049} = .08116 = 8.11\%
\]

\[
\text{M}_{wb} = \frac{.267}{.267 + 2.039} = .11578 = 11.6\%
\]

**Dry Basis MC:**

\[
\text{M}_{db} = \frac{m_{H_2O}}{m_{dm}}
\]

Coffee Creamer:

\[
\text{M}_{db} = \frac{.04}{1.46} = .02739 = 2.74\%
\]

Paper Towels:

\[
\text{M}_{db} = \frac{.181}{2.049} = .0883 = 8.83\%
\]

\[
\text{M}_{db} = \frac{.267}{2.039} = .1309 = 13.1\%
\]

e. **Discussion:**

Each group had either the coffee creamer or the paper towels. The three sets of data is from three of the groups. For paper towels, both group’s values are very similar, showing the instrument accuracy. The wet weight represents the initial weight of the paper towels, and the dry weight represents the final weight of the paper towels after they have dried for ten minutes. The change in weight is the amount of water lost, or mass of H\textsubscript{2}O. The wet basis moisture content is the percentage loss of moisture before dried, while the dry basis moisture content is the loss after the paper towels have been dried. Data shows paper towels have a higher moisture content than coffee creamer and therefore lose more mass in drying.

We encountered some instrumentation problems while performing the moisture analysis experiment with the infrared dryer. We were not familiar with the buttons, and had trouble setting the temperature. With some help, we realized that we had to turn the orange button on the back of the machine in order to set the temperature.

3. **Water Activity**

a. **Introduction:** Water Activity refers to the ratio comparing vapor pressure of a food and the vapor pressure of distilled water at the same conditions. Because organisms such as bacteria and mold grow at higher levels of water
activity, it is important to reduce the ratio in order to impede their growth. The shelf-life of a food is inversely proportional with its water activity. In this lab, the Aqua lab water activity meter is used to measure the water activity of paper towels and coffee creamer.

**b. Procedure:**

i. Place a small piece of paper towel into a disposable sample cup.

ii. Turn the sample drawer knob to OPEN/LOAD position on the Aqua lab water activity meter and pull the drawer open.

iii. Place your prepared sample in the drawer. Check the top lip of the cup to make sure it is free from sample residue (an over-filled sample cup may contaminate the chamber's sensors).

iv. Slide the drawer closed.

v. Turn the sample knob drawer to the READ position to seal the sample cup with the chamber. This will start the read cycle. The first $a_w$ measurement will be displayed on the LCD after about 3 minutes.

vi. Repeat for the creamer.

**c. Data:**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Water Activity ($a_w$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee Creamer</td>
<td>0.562</td>
</tr>
<tr>
<td>Paper Towels</td>
<td>0.514</td>
</tr>
</tbody>
</table>

**d. Discussion:** Water activity describes the availability of free water content within a substance that is readily accessible for utility. Though the human body is made up of approximately 70% water it does not hold that the entire 70% is free water. The 70% describes the human body's moisture content, which is much different from the body's water activity. The term “free water” describes the disposition of the water. Water that is bound within the structure of some molecule or encapsulated within an organism is not free water. This water is not available for metabolic/enzymatic activity. Water activity is useful to measure because the products water activity is correlated with its rate of degradation. This information is useful to estimate a product's shelf life which determines how much effort has to going to the storage of this product.

The food industry utilizes water activity properties to ensure quality products for their consumers. The biggest concern for the food industry is microbial growth. The majority of microbes grow in warm, moist places. Microbes are unwanted as they present a threat to ones wellbeing. Foods that will be consumed within a short period of time are afforded cost for refrigeration. Refrigeration is expensive and is used only in required cases like dairy, produce, and meats. For products that need be stored for extended periods of time freezing and drying methods are used to do ways with most, but not all free water.

Dried fruit has an $a_w$ of .60 which is very similar to the coffee creamer. At this $a_w$ dried fruit is susceptible the osmophilic yeast. Seeing that the coffee creamer's free water is less than the flour, the coffee creamer would
be, at minimum, less susceptible to this mold. There products also have additives that help ward off bacterial growth and the containers they are packaged in ensure in moisture seepage. The water activity of the paper towel is even less than the coffee creamer which means that it is even less susceptible to microbial growth. The data that we recorded may have been higher in some degree due to the materials pulling moisture from the air. As tested in other parts of the lab, the relative humidity in the lab was dramatically higher compared to what it was outside. Improperly loading the material onto the sampling disk could also skew our data.

II. Psychro-Dyne
   a. **Introduction:** The Psychro-Dyne is a very simple and accurate instrument used to get measurements of wet and dry bulb relative humidity and dew point temperature. One thermometer has a wet cloth over the bulb, and a motorized fan provides constant air motion over both thermometers. When the temperature stop decreasing, the wet and dry bulb temperatures can be recorded. The hygrometer is another user-friendly instrument that gives digital readings of the relative humidity and ambient temperature. The relative humidity can also be determined manually by using the Psychrometric chart.
   b. **Procedure:**
      a. Take the wick and saturate with distilled water. Open cover of Psychro-Dyne and place wick onto the left thermometer (re-wet as needed). Close cover.
      b. Turn the knob clockwise to turn on the fan.
      c. Hold or set the instrument in a horizontal plane with the thermometers facing the operator.
      d. After the fan is on, the wet bulb temperature (the temperature with the wick) will start to decrease.
      e. Readings should be taken when the wet bulb temperature stops decreasing. This will take 2-3 minutes.
      f. Use the Digital Humidity/Psychrometer to measure the relative humidity and temperature reading at each location. Use the MODE button to measure $T_a=$Ambient Temperature, $T_d=$Dew Point Temperature, $T_w=$Wet Bulb Temperature.
         i. Lab
         ii. Metal Shop
         iii. Outside in the breeze-way
   c. **Data:**

<table>
<thead>
<tr>
<th>Location</th>
<th>Wet Bulb Temp (C)</th>
<th>Dry Bulb Temp (C)</th>
<th>Relative Humidity (%RH)</th>
<th>Ambient Temperature (C)</th>
<th>Dew Point Temperature (C)</th>
<th>Wet Bulb Temperature (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>60</td>
<td>71</td>
<td>47.9</td>
<td>73.4</td>
<td>54.8</td>
<td>57</td>
</tr>
<tr>
<td>Metal</td>
<td>57</td>
<td>73</td>
<td>39.5</td>
<td>71.6</td>
<td>49.2</td>
<td>51.3</td>
</tr>
</tbody>
</table>
d. Calculations:

Graph 1. The above graph compares the different measurements at each location.

The following calculated values of Relative Humidity were attained using the Psychrometric chart.

- Lab: 59.3°C
- Metal Shop: 46.2°C
- Breezeway: 50.33°C

e. Discussion: From the following data, the ambient temperature was warmest inside the lab, and coolest outside in the breeze-way. The Digital Dew Point Temperature followed the same trend, decreasing as we went from a closed indoor room into the open air. The relative humidity as measured on the hygrometer showed that the lab was the most humid, the metal shop was the least humid, and the breeze-way was in between. The calculated values of relative humidity from Psychrometric chart, however, were slightly higher values than that which was read from the psychro-dyne instrument. This could be due to instrumental error or error in calculations of using the Psychrometric chart.
Conclusion:

Water activity is the ratio of the vapor pressure of water in a system to the vapor pressure of pure water at the same temperature. It is directly related to relative humidity of the air surrounding a sample, at the same temperature. Water activity is a very important factor in the food industry. The majority of chemical reactions and microbiological activity are dependent on water activity.

We performed several experiments that related to water activity. In experiment one, we were able to determine the moisture content of two samples that underwent oven drying. We saw that the wet moisture content and dry basis moisture content of both coffee creamer and paper towels did not differentiate much. In the second experiment we used two more of the same samples from experiment one. The samples underwent drying using an infrared dryer. The infrared dryer was more efficient and allowed the samples to dry faster than the oven dryer. The wet basis moisture content and dry basis moisture content was significantly lower using the infrared dryer. In the third experiment, we were able to calculate the water activity using the Aqua Lab Water Activity Meter for each sample. By knowing the water activity of the samples, we were able to determine other properties of the samples. For the last experiment, we used a Psychrometer to measure the ambient temperature, dew point temperature and wet bulb temperature at different locations. The ambient temperature and the dew point temperature proved to be higher the more closed in an environment. All experiments posed some sort of error, either from instrumentation error or miscalculations, but with more experimentation these errors can be reduced.