PLS100BL : Lab 8
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Ideal Post Harvest Conditions for Preserving Seed and Grain

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Introduction and Background

Biologically active seeds and grain produce a circumstance in which fungal contamination and insect pests can successfully deteriorate product quality. In addition to lowering the market value of crops, these biotic factors could even produce harmful mycotoxins like aflatoxin and fumonisin. Therefore, for the human race, it was a transformative discovery that removing enough moisture from the post-harvest product using the sun's energy or salt or a combination of both makes conditions too dry for most fungus and insects to survive or feed. This principle was deployed in the storage and distribution of food as it came to be known as "dry chain" as opposed to "cold chain," the use of refrigeration. Since the advent of this process, the sale of safe, consistent, and top quality product has driven the agricultural economy. Any units that become affected by ecological factors and pests contribute towards post harvest loss and must be discarded. From its inception, the timeless method of initial drying upon harvest has proven to be the primary choice in mitigating this damage in seeds and grain. As stated, low levels of moisture appear to successfully establish conditions that are unfavorable for pest survival. Luckily, in the case where seed viability is unimportant, dry harvest products (seeds, grains, and legumes) can tolerate very low levels of humidity without damage, making these products food staples and essential to food security. Maintaining low levels of moisture during storage, transport, and stocking is key for preventing infections. Since there is a constant exchange of water molecules based on the relative humidity of the air and the internal moisture content of the seeds, this experiment seeks to understand this relationship in more detail and as it varies between subjects of different material composition.

Methods

Barley, representing starchy grain, and lettuce seeds, representing oily seeds, were subjected to a range of relative humidity temperatures for two weeks. They were sealed in glass chambers with saturated salts. Saturated salt solutions, often used to calibrate hygrometers, maintain their concentration regardless of temperature by securing water molecules in the solution and facilitating the return of water vapor molecules from the air above the surface of the solution. When this situation reaches equilibrium, the relative humidity in the air settles at a constant that

is dependent on the molecular characteristics of the salt (mainly solubility). With this, we can establish a range of RH in this experiment at values 0, 8 , 32, 52, 67, and 75. After two weeks, we should expect the moisture content in the seeds to reflect these values. Due to possible issues with this calibration, the relative humidity values were verified by Humidicator strips inside the chambers and the subjects were assessed for their relative humidity using the AquaLab Water Activity Meter. On March 7th, both commodities were taken out of their two week incubation and, for each RH treatment, three replicants of groups of 25 seeds and three replicants of groups of 25 grains were weighed. The results were recorded as fresh weights and returned to their controlled RH containers until drying. On the 14th, they were retrieved from drying conditions and weighed again. The results were recorded as dry weights. These fresh and dry weight measurements will be used to calculate water content on fresh weight basis and dry weight basis. In turn, these values will serve as the moisture content while we construct isotherms for each species across the range of empirical relative humidity values.

Results

Barley Grain and Lettuce Seed Graphical Data

Amid a few errors in data collection, the viable results from the experiment are represented graphically in the section below, including a theoretical benchmark for comparison. The fresh and dry weights of the test commodities were compiled and reported into a table. The resulting difference value (for weight of water lost in drying) informed our calculations for moisture content on a fresh and dry weight basis from the respective formulas:

Fresh weight basis (%) = (weight of water lost / initial total weight) x 100
Dry weight basis (%) = (weight of water lost / final dry weight) x 100

Isotherms were then created from these results to allow for conversion between MC and eRH in each species. The accuracy of these graphs were finally evaluated against the theoretical

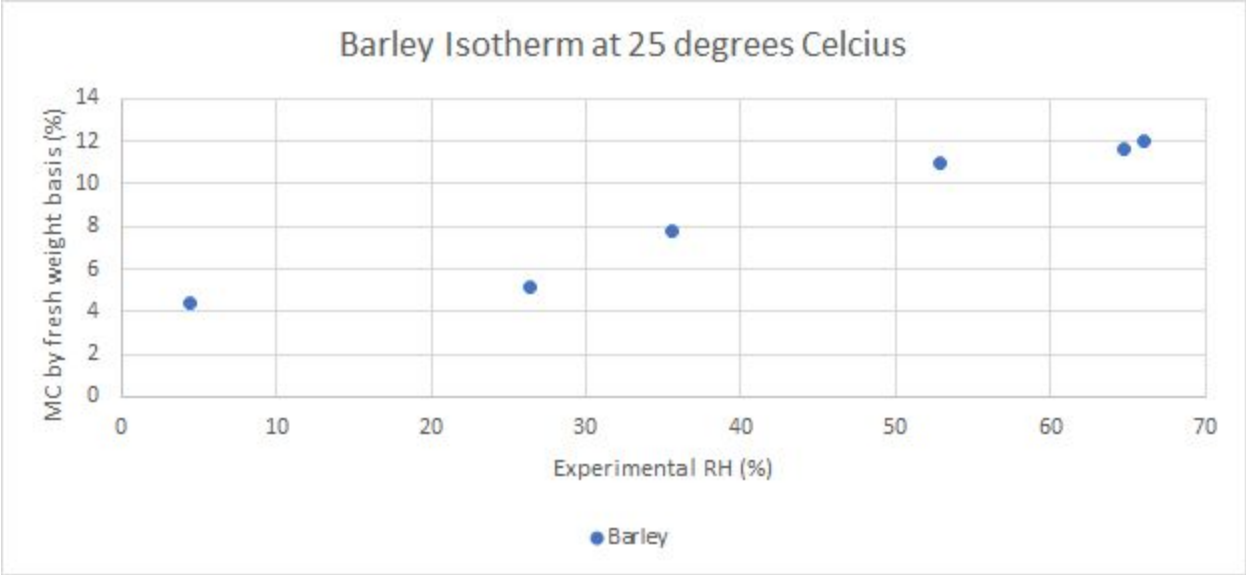
isotherm from the Cromarty equation.

	Barley			Lettuce		
RH Anticipated	RH Measured Barley	Fresh	Dry (avg)	RH Measured (Lettuce)	Fresh	Dry (avg)
0	4.4	41.81	38.904	8.7	1.014	0.784
		37.28			0.0937	
		43.01			0.0829	
8	26.4	44.5	43.168	25.1	0.5	0.475
		46			0.5	
		46			0.5	
32	35.6	46.389	37.76	40.2	0.536	0.562
		31.803			0.838	
		44.602			0.456	
52	52.9	40.16	36.98	53	0.299	0.641
		45.07			0.808	
		39.38			1.036	
67	66	46	41.368	64.2	1.027	0.8
		43.5			1.126	
		51.5			0.53	
75	64.8	56.2	41.801	73.1	0.944	0.711
		38.6			0.843	
		47.1			0.689	

Figure 1. The AquaLab RH readings, fresh weights, dry weight averages for each RH treatment are tabulated above. The fresh weights were recorded for each replicant here but the values were averaged for each treatment in the following table, just as they were for dry weights initially. The fresh weights for lettuce at RH=0% were not properly recorded so the data points for that treatment were excluded from the final analysis.

Barley				Lettuce			
Fresh Avg	Water weight	Fresh weight basis	Dryweight basis	Fresh Avg	Water weight	Fresh weight basis	Dryweight basis
40.7	1.796	4.412776413	4.616491877				
45.5	2.332	5.125274725	5.402149741	0.5	0.025	5	5.263157895
40.9313333	3.171333333	7.747935567	8.398658192	0.61	0.048	7.868852459	8.540925267
41.5366667	4.556666667	10.97022711	12.32197584	0.71433333	0.073333333	10.26598227	11.44045762
47	5.632	11.98297872	13.61438793	0.89433333	0.094333333	10.54789415	11.79166667
47.3	5.499	11.62579281	13.15518767	0.82533333	0.114333333	13.85298869	16.0806376

Figure 2. The loss of water weight during the drying process is calculated as the difference between the fresh weight average and the dry weight average. This value is used to derive MC on a fresh weight basis and dry weight basis from the formulas provided.



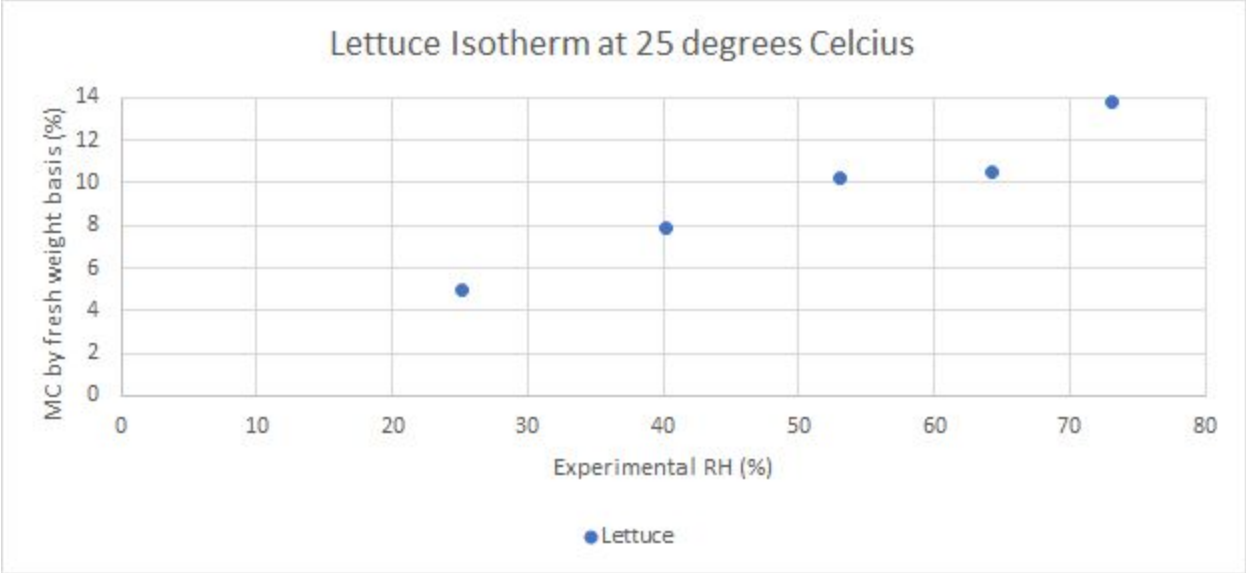
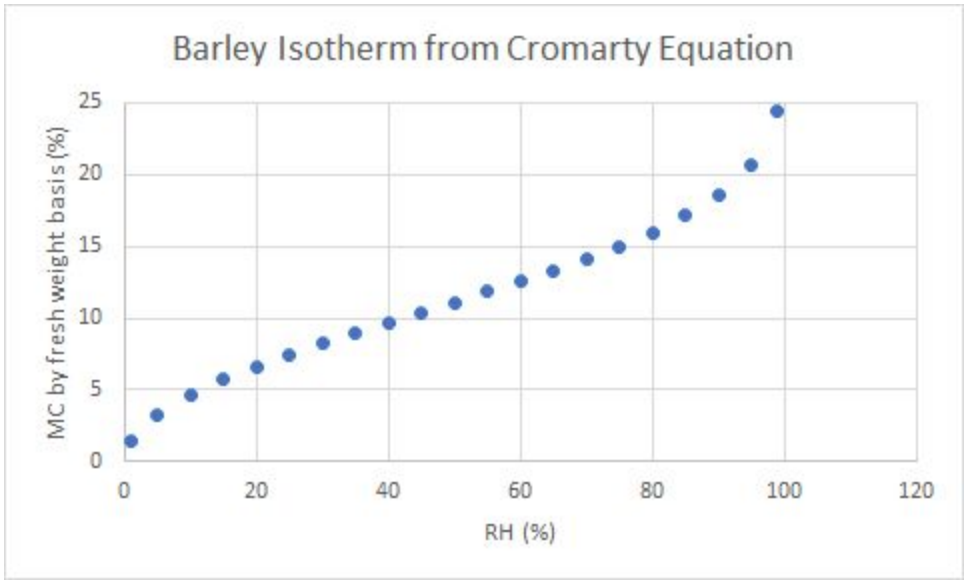


Figure 3. The graphs above relate MC by fresh weight basis to the RH readings from the Aqualab for each treatment in barley (top) and lettuce seeds (bottom).



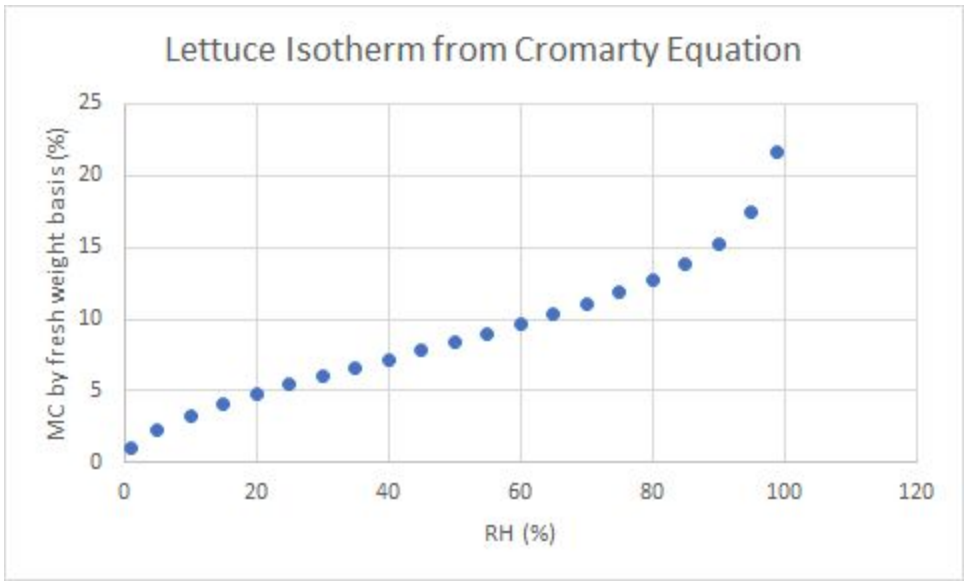
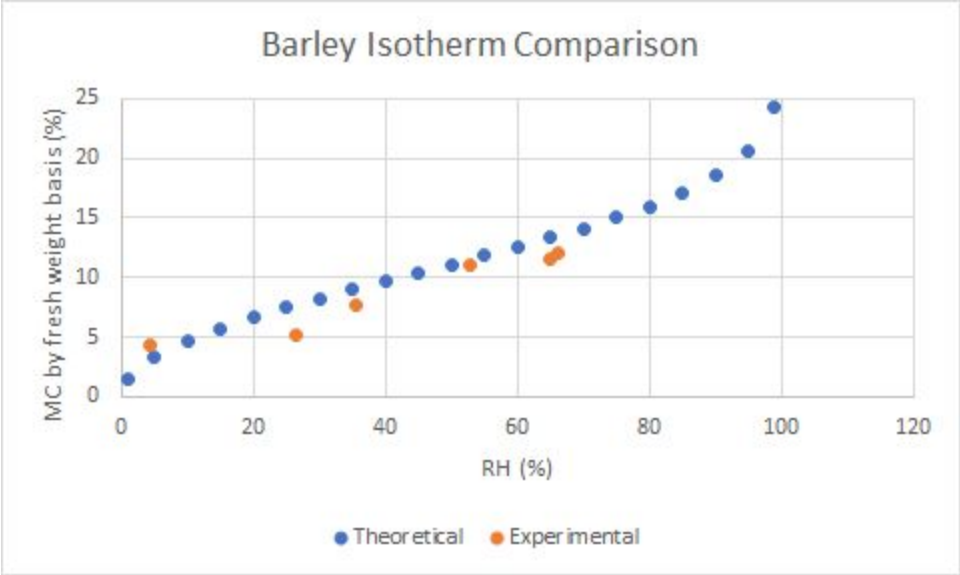


Figure 4. The scatter plots above are representations of the Cromarty equation developed to predict the relationship between water activity (RH/100) and seed MC given temperature and oil content. The barley curve is leveled at 1.4% oil content and the lettuce curve at 33.8% oil content. Both isotherms are set with the given temperature of 25 degrees Celsius.



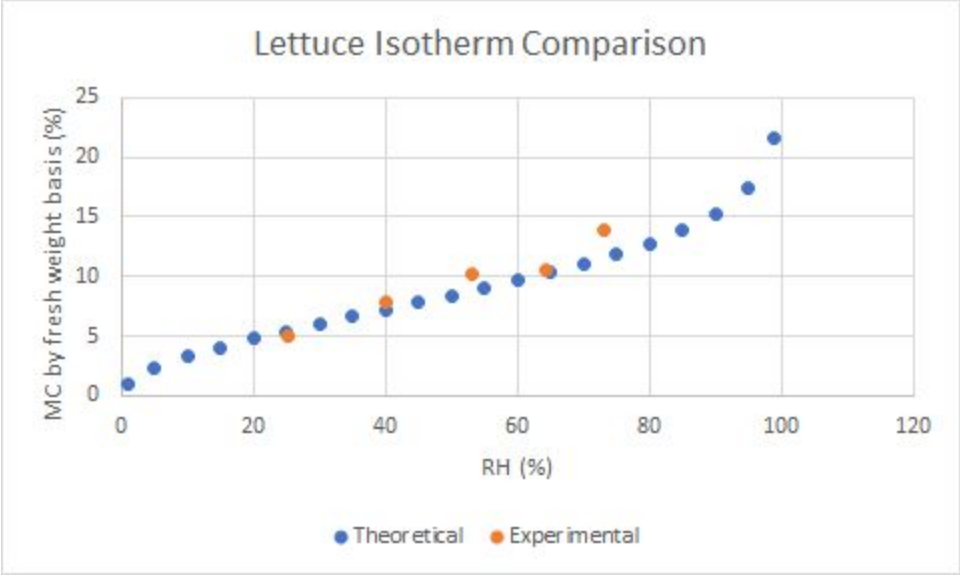


Figure 5. The previous four graphs, which includes the Cromarty and experimentally derived isotherms for barley and lettuce each, are overlaid in the graphs above for more obvious visual comparison.

Discussion

Being hygroscopic products, the barley and the lettuce seeds will experience change in moisture content that is in accordance with change in the equilibrium relative humidity of the surrounding air in storage. This relation is primarily influenced by temperature and oil content in the seed. Based on the dynamics of the MC/eRH relationship, it would follow that, at higher temperatures, the grain and seeds would absorb more moisture at given RH conditions. For this experiment we are assuming that temperature was controlled and remained constant during all

exposure to the RH treatments. After the drying and during the second weight measurement, the test subjects were considerably warmer to the touch. However, since the seeds were not returned to their RH treatments after drying and, instead directly measured, the influence of the RH in the laboratory during the weighing can be ignored and any error in the dry weights is most likely inconsequential.

With temperature controlled and eRH used as an independent variable, the experiment establishes that the relation between the MC and eRH can be called an isotherm, a steady temperature state. In this case, the construction of an isotherm for each species of test subject should yield graphical data that highlights the effect of oil concentration on MC.

The data ultimately presented a weak picture of the relationships we sought to demonstrate. Given missing data points, high variability, and off-target treatments, the final results' similarity to our theoretical standard of comparison was determined not conclusive and we were subsequently unable to make a clear argument for the prevalence of the effect of oil content in the variability of our calculated subject moisture content against incremental relative humidity treatments.

The Cromarty equation was developed in the pursuit of preserving seed in effective designs for gene banks. It predicts the equilibrium relative humidity for seed moisture content (and visa-versa) at a given temperature based on the composition of the seed, the primary factor being oil content. Graphically, this makes the Cromarty equation (featured below) an isotherm.

$$M_e = \{(1 - D_0) \times \text{sqrt}\,[-440 \times \ln(1 - a_w)]\}/[1.1 + (T/90)]$$

The differences in the isotherms at 1.4% and 33.8% were subtle but seemed to indicate that an increase in oil content results in vertical compression of our MC/eRH curve. This implies that a high oil content product resists taking on a high internal moisture content at a given eRH compared to a product with low oil content that would take on more internal moisture at the same eRH. This makes sense in light of the properties of oil. As nonpolar components take up more space per seed, a polar substance (in our case water) would not be able to integrate itself within the seed due to insolubility. The lettuce seed was the example for this phenomenon in this lab. The barley is comprised mainly of starch, a polysaccharide, that is soluble in water. We would expect its MC/eRH curve to be vertical stretched since it has less physical barriers to moisture internalization. The results of the experiment showed this stretching to be very minute and, even visually, is unlikely to be considered significant. We determined that this is most likely due to the experimental errors that plagued our data collection.

Initial examinations of the data revealed that some RH readings from the AquaLab diverged greatly from the intended levels inside the containers. This was true in the case of 0% and 8% containers for both the barley and the lettuce. Of these, readings that were otherwise in order were still usefully included in the graphs as evidence demonstrating the MC/eRH relationship as it pertained to oil content. The dry weight measurements for lettuce seeds in 0% RH were subject to some unspecified human error and excluded from the analysis, reducing the accuracy of the lettuce isotherm by some small amount in comparison to the barley results. The barley RH readings themselves were far from perfect however. The highest RH level was intended to be 75% but the AquaLab reading provided a reading of 64% as the internal RH for the grain. A

reason for the discrepancy in our relative humidity treatments could have been the process of saturated salt solution forming a top layer in the container which would have left unexposed and unsaturated salt. Since the amount of each salt is vitally important for saturation and, in turn, the equilibrium relative humidity, this situation could have accounted for these errors. The humidicator strips, while they might be reliable in other contexts, were not sensitive enough to initially alert us to the inaccurate eRH levels.

References

Bradford, K. J., P. Dahal, and P. Bello. 2016. Using Relative Humidity Indicator Paper to Measure Seed and Commodity Moisture Contents. Agric. Environ. Lett. 1:160018. doi:10.2134/ael2016.04.0018