

Feasibility of Carbon Capture from Plants

Plants are very effective in capturing carbon from the atmosphere. The question to ask is how feasible is it to use plants for carbon capture?



Florida backyard, note biodiversity versus standardized mediocrity in the landscape

Feasibility of Carbon Capture from Plants

- Good afternoon, I have had a career in chemistry, chemical engineering and statistics, My BS degree was in chemistry and then went on to get a MS in statistics and a MS in chemical engineering. My forte especially in later years was problem solving.
- The key to problem solving is to ask the correct questions.
- When we moved to Florida, every January I would plan our trips for the year to visit our grandchildren around the country and sometimes around the world. My wife would ask can we afford all these trips? The correct question to ask is can we afford not to?
- We worry about the rain forest, look for exotic methods to remove CO₂ from the atmosphere but what about our own backyard?

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- A question to ask is do we pursue a “plant” farm like the wind farms and harvest plants specifically to capture carbon from the atmosphere or do we change our home landscape to maximize plant diversity and change how we maintain our yards?
- We currently pay \$50/ton for yard waste disposal. If it were possible to remove half the leaf water in the field, twice the amount of yard waste could be removed for the same price. Could some type of device be added to landscape trucks to remove water in the field (spray dryer, rotary dryer, etc)?
- There is also cost savings in more business trimming plants rather than trips to the landfill. What would be the true economic impact?
- Would low moisture contribute to a more “compostable” or “usable” waste?
- Also, relatively low temperature can be effective in removing pathogens.

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- The first step is to determine how much carbon plants absorb from the atmosphere. Cellulose ($C_6H_{10}O_5$) is over 40% carbon while celery is 90% water. The expectation is that plant leaves will have somewhere between these two levels of carbon. (Should mention the celery water is a measurement of the stalk, no idea what the level would be in the leaves)
- Also important is how the water is attached – physically or chemically bonded and exactly how it is bonded. Sucrose ($C_{12}H_{22}O_{11}$), which we get from sugar cane by a separation process, can be dehydrated with sulfuric acid to yield carbon. Can the chemistry be studied separate from the separation process?
- Folks here from the north experience 4 seasons – plants leaf out in spring and lose their leaves in the fall but this presentation looked at tropical and subtropical plants. They can hold their leaves for years rather than months making harvesting of the leaves independent of season. The leaves also don't change color as much. Most tropical and subtropical plants don't like the cold.

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- To determine what plants are most suitable to carbon capture, I selected three species to examine. They were dehydrated at 190°F and the resulting material weight after 2 hours varied from 20 to 40% of the starting leaf weight. It is assumed that most of the volatile loss is water and a large amount of the remaining material is carbon. Palm leaves retain 40% of their starting weight even after 4 hours at 190°F. (There are over 2500 species of palms in the world.)
- From left to right Schefflera(SC), Awabuki Viburnum(AV), Zamia Furfuracetria(CB)



**Cardboard plant
can be spray
painted for
Halloween, July 4**

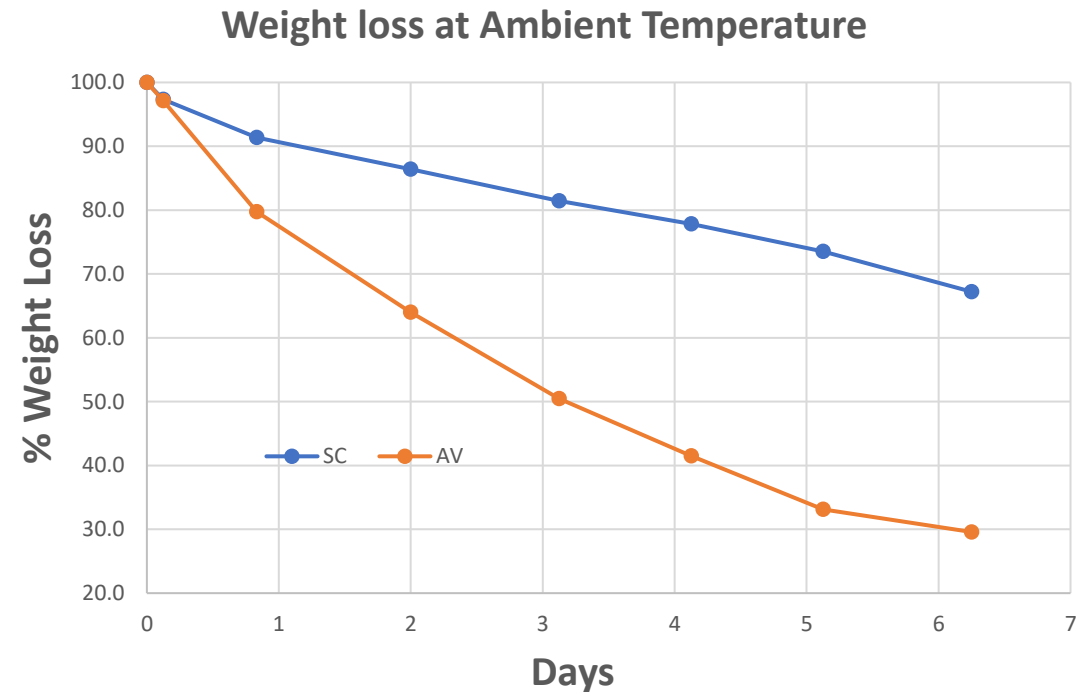


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- The next question to ask is why heat the leaves, why not just let them dry out in the yard? The answer is that could take days or even never happen. We do have air plants that grow without soil and we have leaves that root themselves if they drop to the ground (Jade plant).



Cymbidium Orchid - air plant, does not require watering or nutrients (40lbs before hurricane Ian)



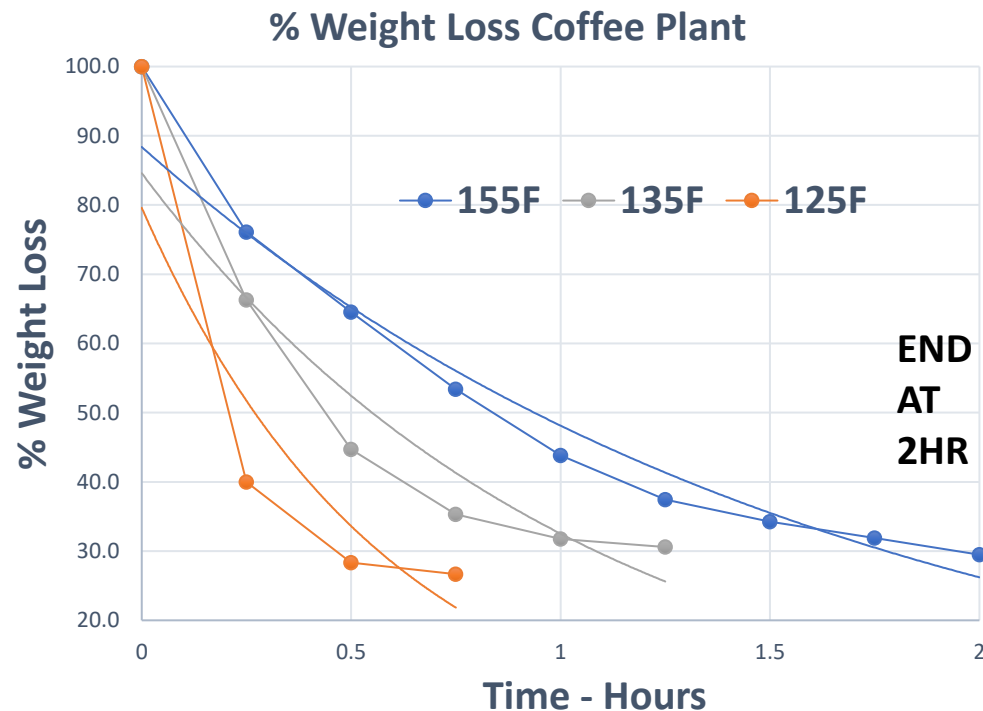
Days are needed to dry plants at ambient temperature

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- My expectation was that when heated the leaves would lose weight exponentially – simple first order decay rate.
- This leads to two parameters, when do the leaves lose half their weight and when do the leaves lose half of their potential water loss. A palm that can lose 60% of its weight at 190°F will have half its potential water removed at 30% weight loss.
- The third step was to determine when in the dehydration process the leaves stop active exchange with the atmosphere. This last step was done by determining at what point carbon dioxide stops being generated by the leaves. Fresh cut leaves can generate 150 ppm carbon dioxide per gram per hour. This ability to produce carbon dioxide can be reduced or eliminated by dehydration.
- **What was not done was to measure the volatiles that are generated even at low temperature from the leaves. This would be an interesting study in itself.**

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- Before discussing the 3 target plants I should note some early work on the Florida coffee plant (*Psychotria nervosa*). Statistical results are for a first order decay fit of $\ln W = \ln W_0 - kT$. Can generate a 3D plot of weight loss vs time and temperature



Statistical results

	Wt % 125F	
Intercept	4.481693 R Square	0.962946
X Variable 1	-0.60782 Adjusted R Square	0.957653
	Wt % 135F	
Intercept	4.508974 R Square	0.951096
X Variable 1	-1.16949 Adjusted R Square	0.934794
	Wt % 155F	
Intercept	4.509928 R Square	0.935943
X Variable 1	-2.52226 Adjusted R Square	0.871887

What do the leaves look like when dried



SC precond at end point



SC no precond at end point

Final dried plants
can change shape
depending on
temperature



Dried crushed SC, "clean material"

$CuSO_4 \cdot 5H_2O$ vs anhydrous
 $CuSO_4$ Loss of hydrated water?

What do the leaves look like when dried

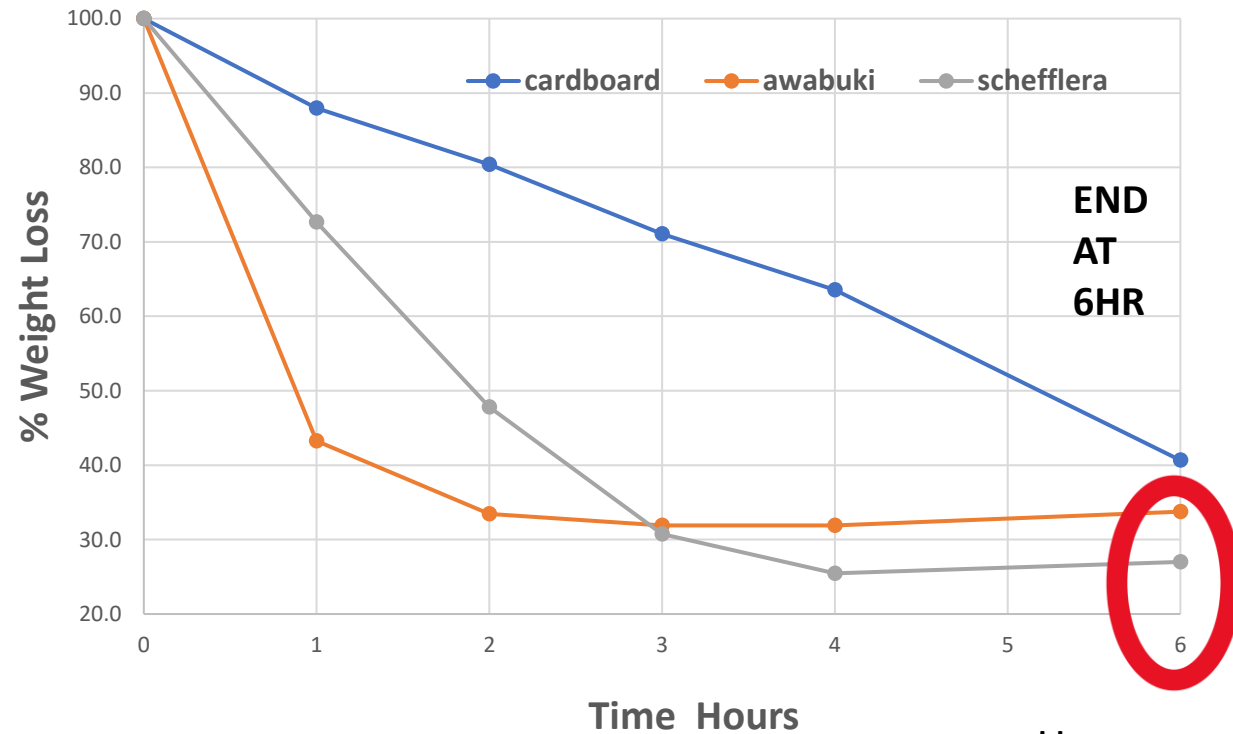


AV quick to change color at 125F
Leaf doesn't wilt but loses water and chemistry changes – no chlorophyll?
Change in turgor? - water pressure inside cell to maintain structural integrity

CB can be made to curl when dry and will form a fibrous end product

- Now the results for SC, AV, and CB. All evergreen and all common in Florida landscape.

% Weight loss at 155F



Hygroscopic?
Drying afterwards

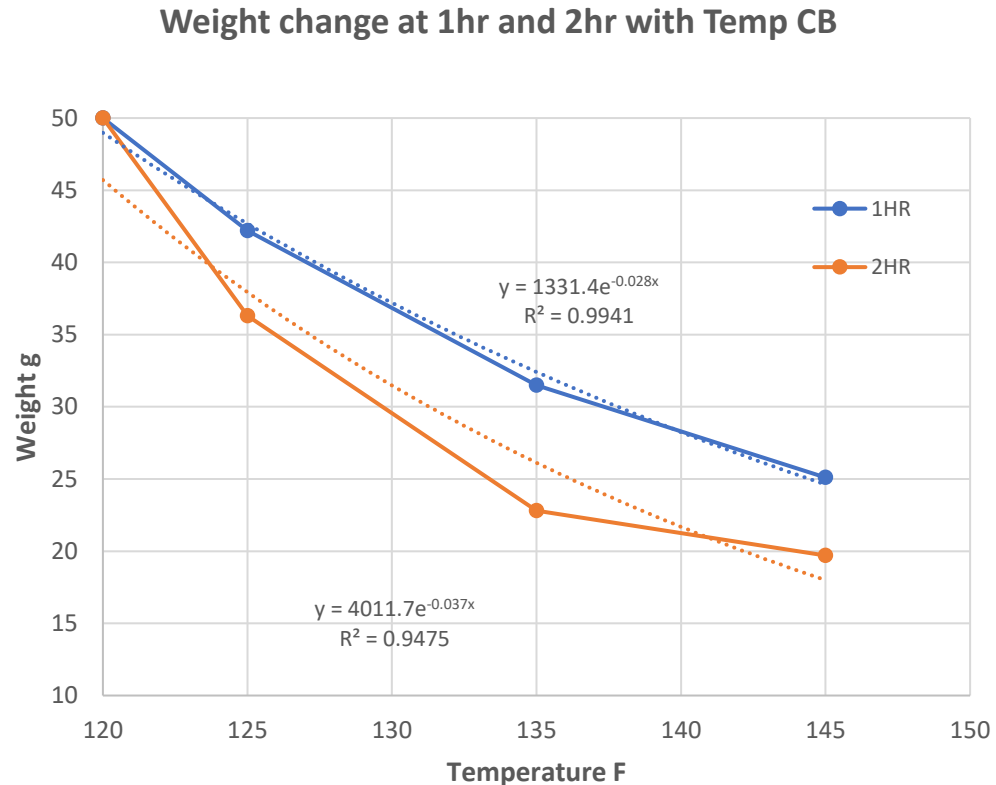


AV



SC

Weight change at 1 hr and 2 hr with temperature for CB



Results as expected with greater weight loss after 2 hr than 1 hr

For modeling:

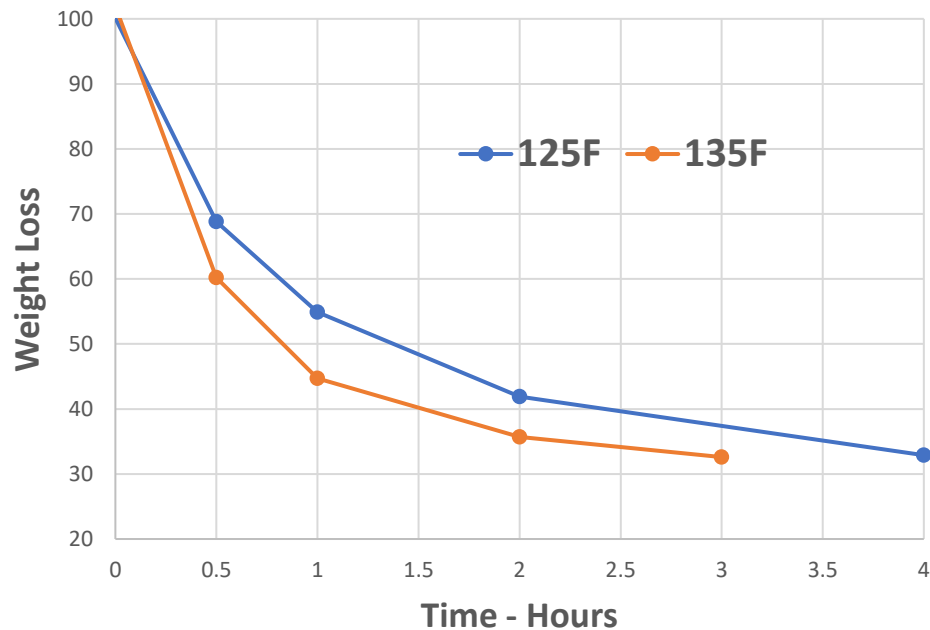
What should be the starting temperature?

What should be the end point?

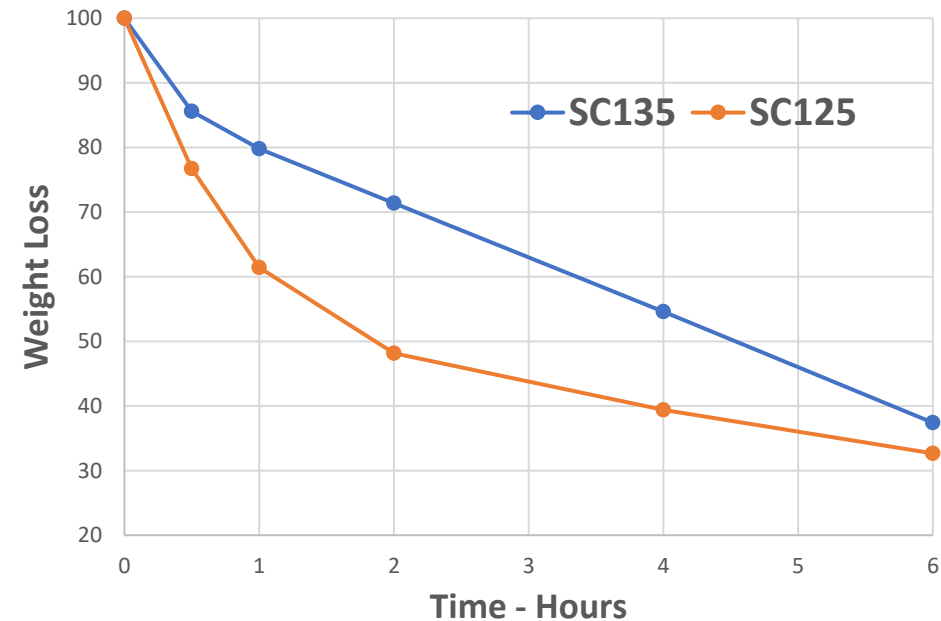
Weight eventually plateaus

- **The weight loss results are not as expected at lower temperatures**
- **Why low temperature? – feasible for solar dehydration**
- **SC loses more weight at 125F than 135F - What happened?**

Weight Loss AV with Temperature

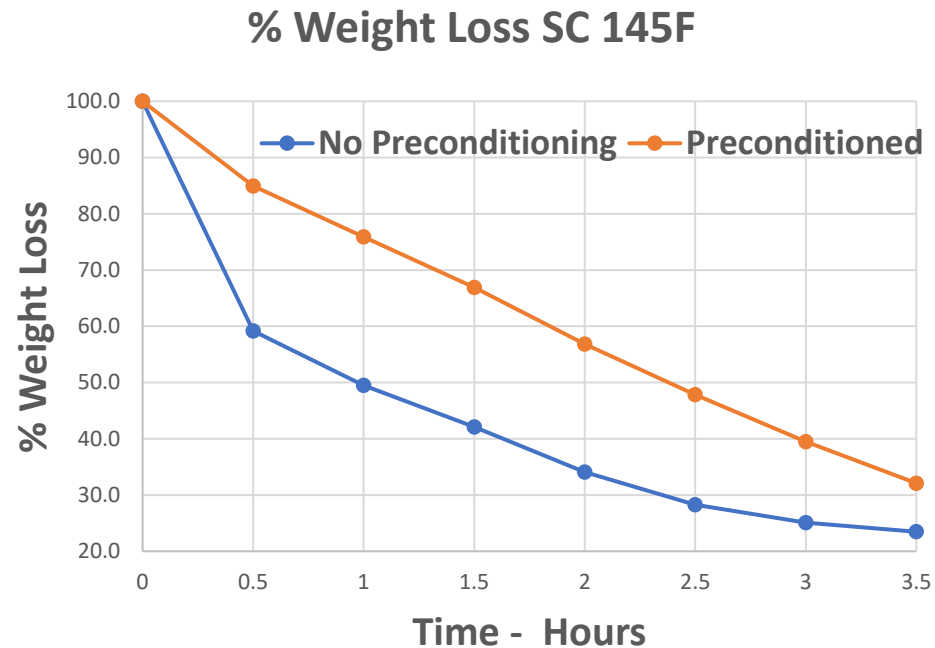


Weight Loss SC with temperature



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- Maybe the leaves are wet with dew, maybe the results will be more consistent bringing the leaves inside and leaving them at room temperature for some period of time. Experiment with “preconditioning”

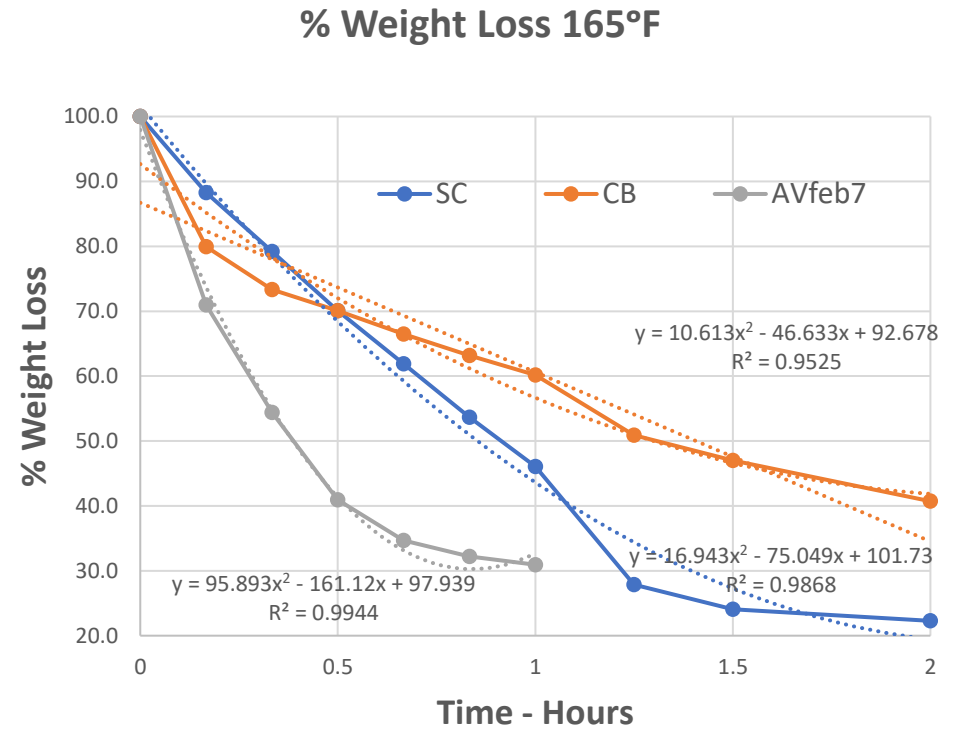
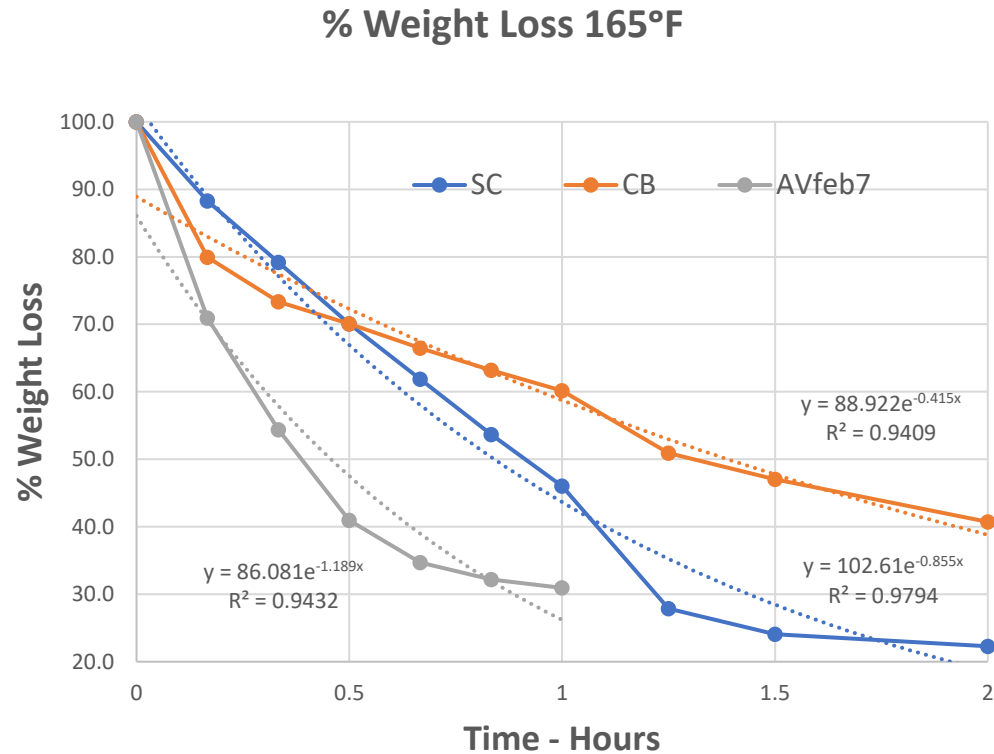


**One hour at 145F weight loss is
50% with no preconditioning
vs 24% with preconditioning**

Hypothesis

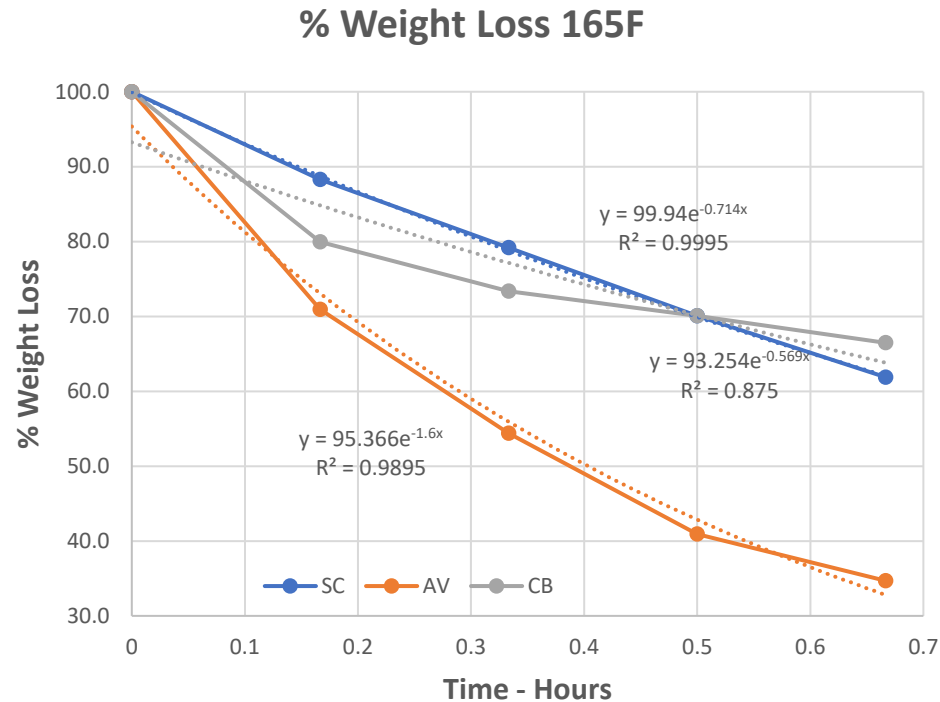
**Plants have a stoma under the leaves which facilitate the transfer of O_2 , CO_2 , and H_2O - transpiration
At lower temperatures plants don't feel the need to “close” the stoma.
Plants can be slow to respond**

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Regression data for SC CB and AV at 165 F. Somewhat better fit for a polynomial equation than an exponential decay

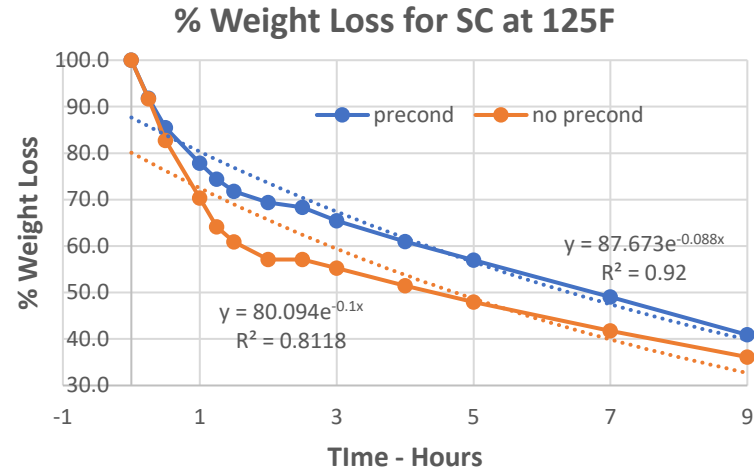
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Are there two mechanism driving the loss of water. The first one a quick initial loss of loosely bound water followed by a slower loss by more tightly bound water?

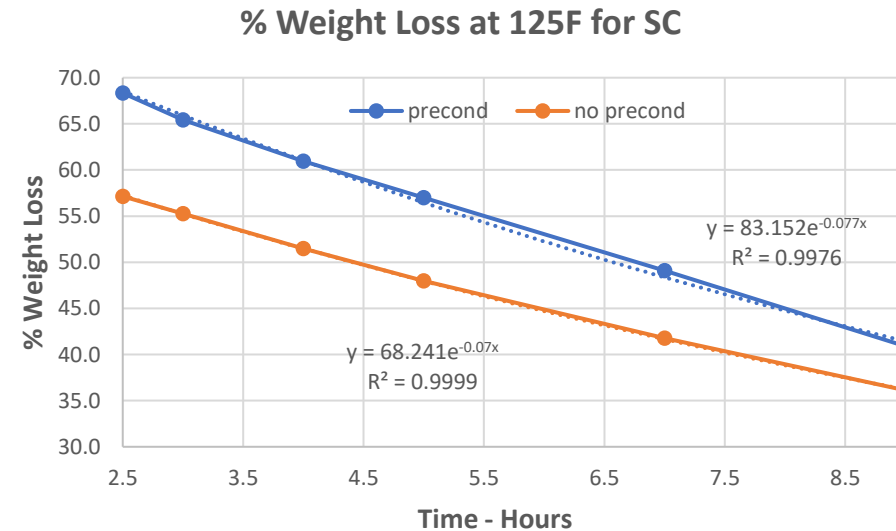
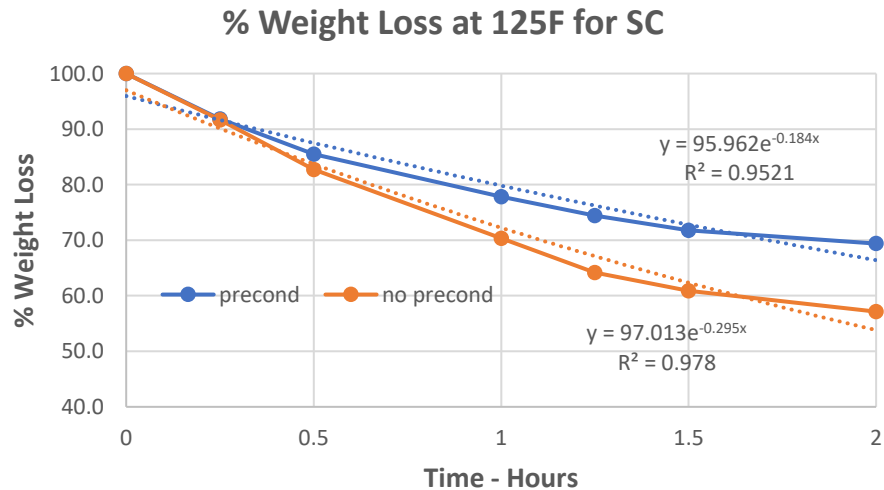
Previous data using only first four points provides a better fit for a first order decay for AV and SC

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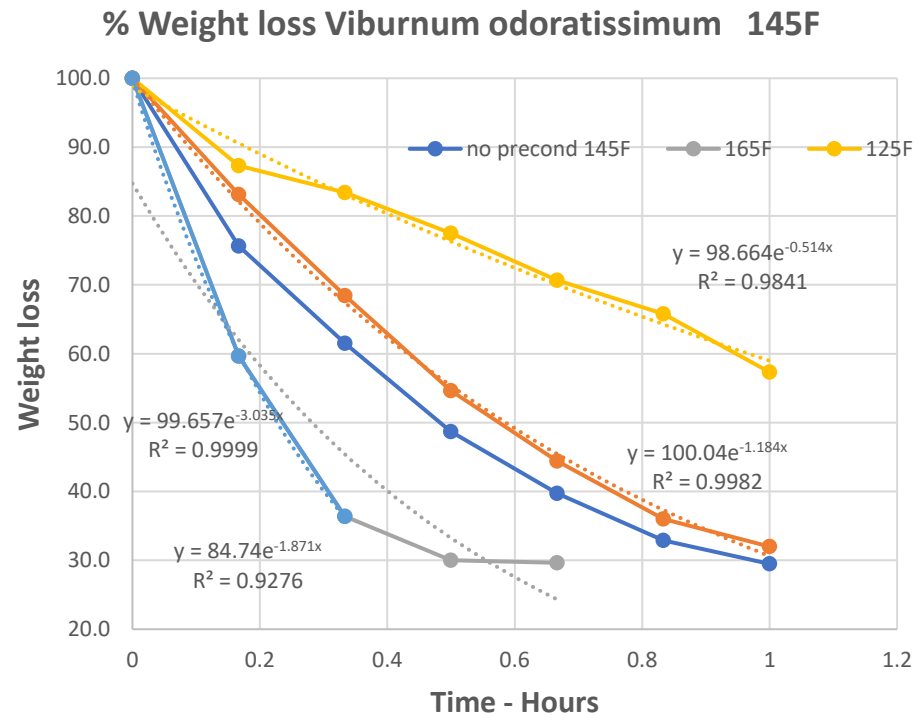


Results for SC at 125F plot and model for full data set and data split into 0 to 2 hours time and 2.5 hours to 9 hours

Much better fit when data is split



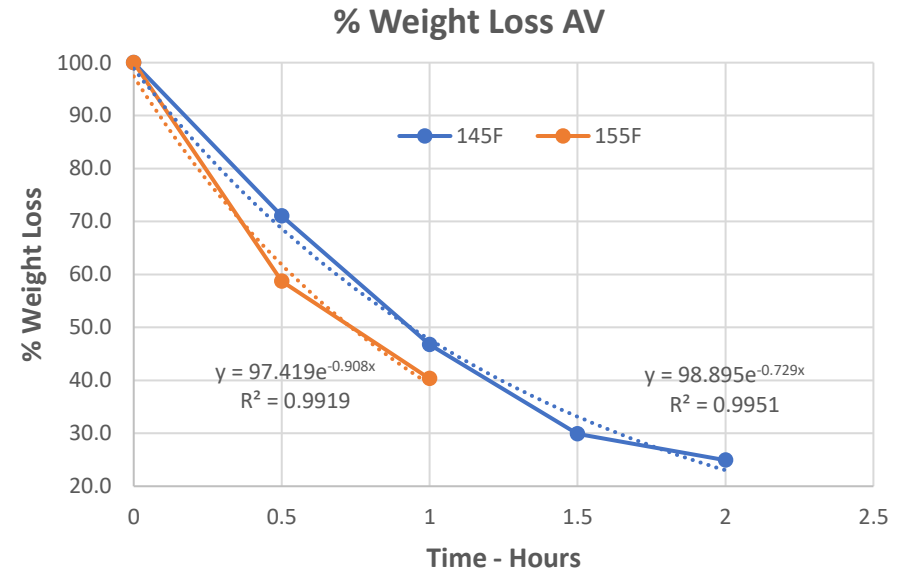
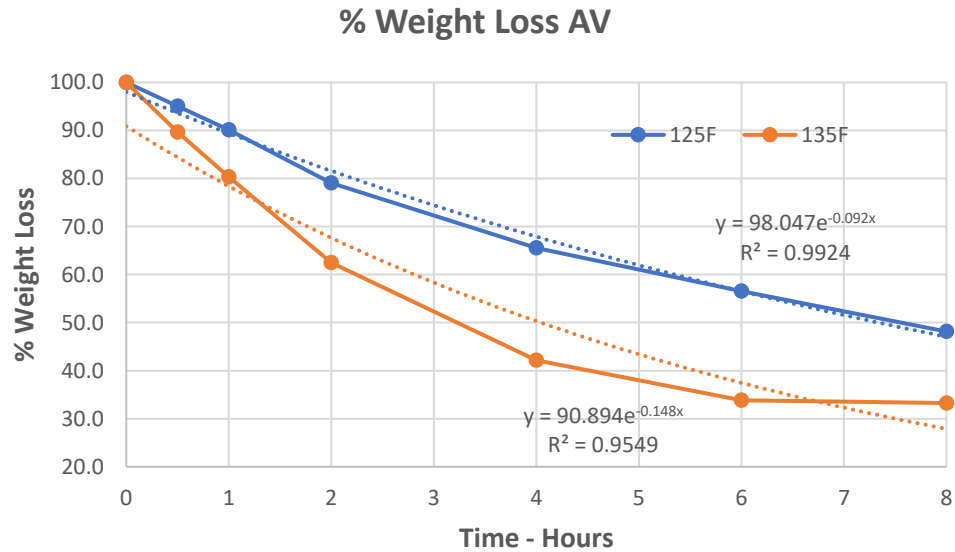
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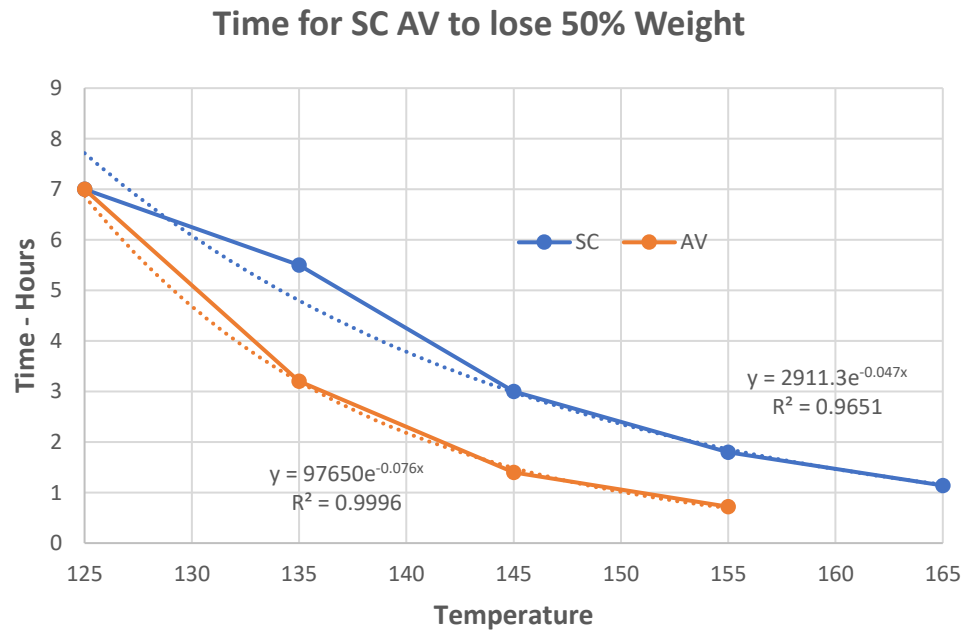
Much better results with plants that lose weight rapidly and don't respond to preconditioning

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Weight loss AV with time for various temperatures

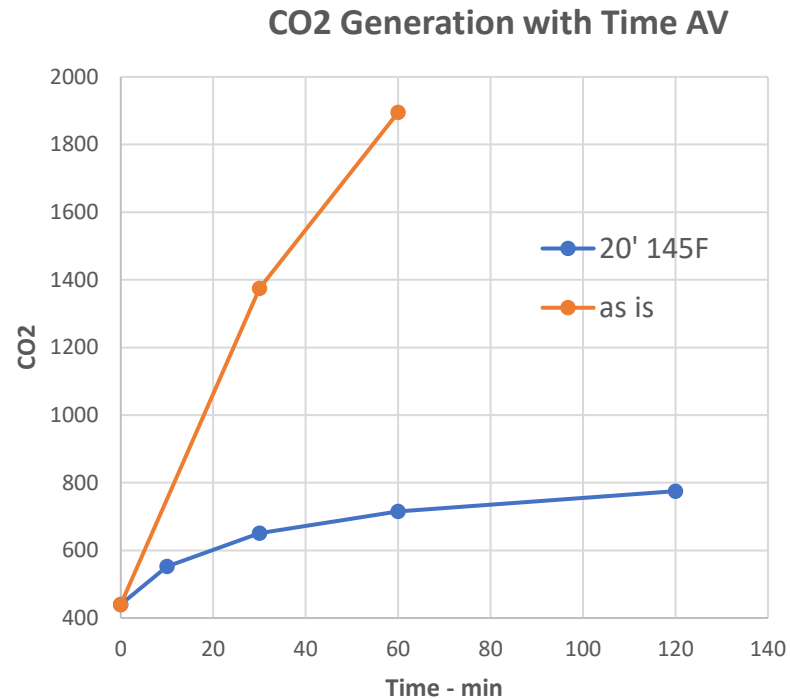


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Use preconditioning data,
closer to reality

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Final step to determine when leaves no longer generate CO_2

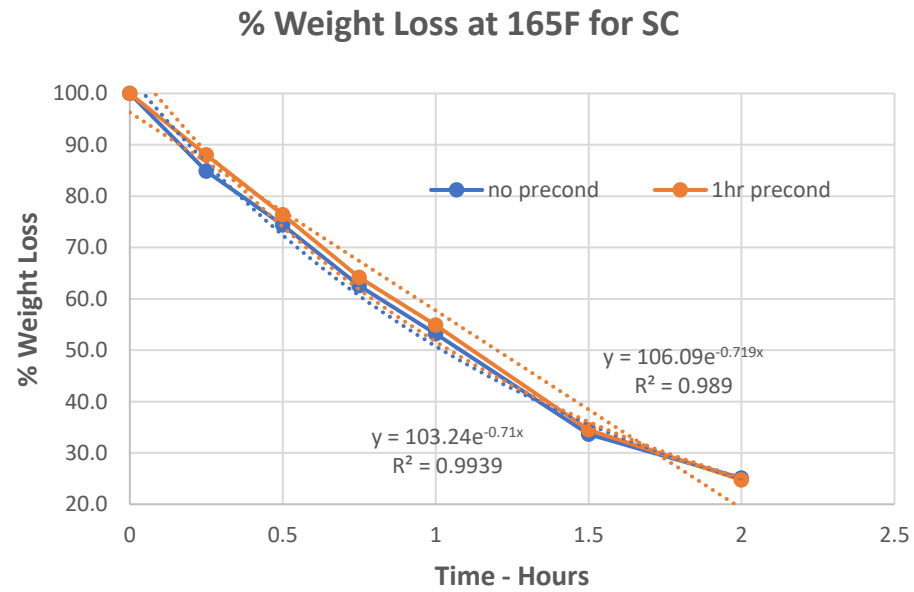
Summary

- Plants leaves can contain 10 to 30 % carbon
- Water can be removed at relatively low temperature and short time
 - 125°F to 165°F between 2 and 8 hours
- Removal of the water does stop leaves from emitting CO₂
- Many questions and topics for study remain
- Freezing the plants changes results drastically
- If nothing else - can we improve marijuana?

**Can we afford to take care of our
environment?**

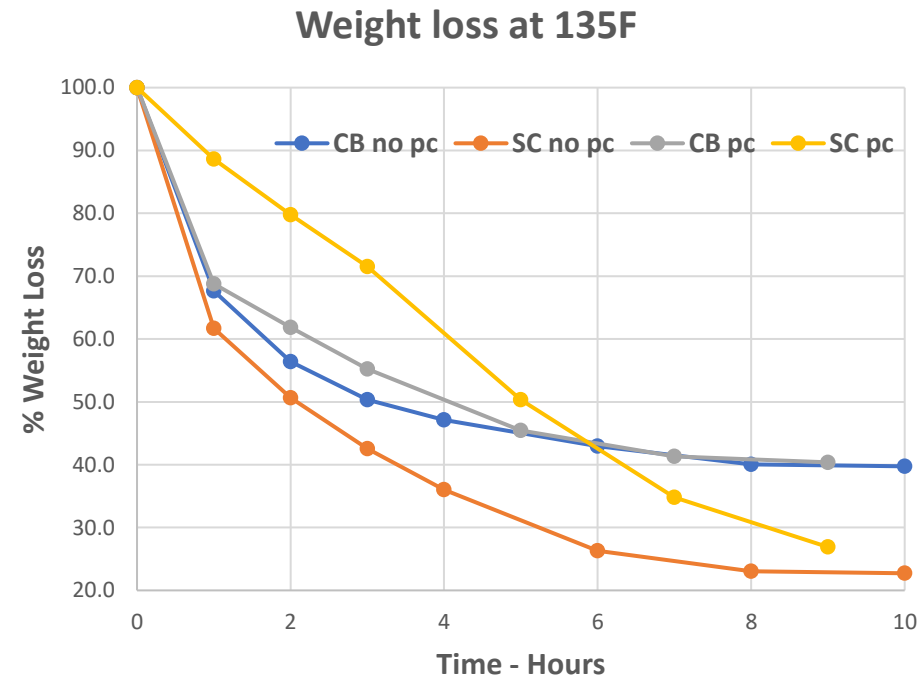
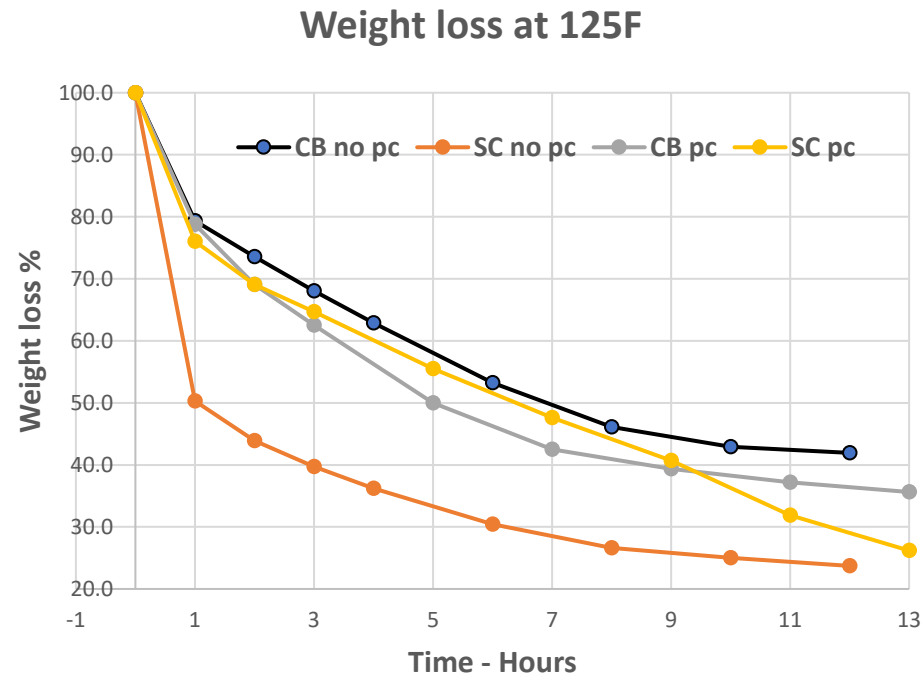
**Can we afford not to take care of our
environment?**

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Feasibility of Carbon Capture from Plants

- Result for CB SC with and without preconditioning



Feasibility of Carbon Capture from Plants

- Results for CB SC with and without preconditioning

