Lab 4: Vegetables and Fruits November 15, 2025

Lab Group 2: Caitlin & Corey

Contact Information:

caitlinkauffman@kings.edu;
coreygustafik@kings.edu

Introduction: Cooking Treatments on Vegetable Pigments

This lab explored how different cooking treatments, such as the length of cooking time, method of cooking, and the addition of an acid or base, influenced pigments and sensory characteristics of chosen vegetables (broccoli, red cabbage, and cauliflower).

Objectives – The purpose of this lab is to:

- Explain the conversion of chlorophyll pigments to pheophytins as a function of time and pH.
- Discuss the effect of various cooking methods (e.g., use of lid, pressure cooker, microwave) on vegetable pigments.
- Determine the effect of the use of a lid and various types of water on the pH of the cooking medium.

Introduction: Cooking Treatments on Vegetable Pigments (Continued)

- Food Science Principles –
  - Different cooking methods used to cook fruits and vegetables affect the taste, texture, flavor, appearance, and overall preference of these food items:
    - An acidic medium delays turgidity losses (softening) but causes color changes in the cooked product.[1]
    - An alkaline medium preserves color in some cases, though color change can occur depending on the cooked fruit or vegetable[1]; an alkaline environment also accelerates turgidity losses.[1]
    - Cooking fruits and vegetables in a liquid enhances the solubility of pectic substances present[1]; this leads to a more tender final product.[1]
  - Pigments are affected by heating, acidity, and alkalinity differently:
    - Chlorophyll is water-soluble and can affect the color of the cooking liquid[1]; extended heating and acidity accelerate its conversion to pheophytin (fruit or vegetable appears an olive-drab color)[1]; chlorophyllin is formed under alkaline conditions (fruit or vegetable appears bright green).[1]

Introduction: Cooking Treatments on Vegetable Pigments (Continued)

- Food Science Principles (Continued) –
  - Pigments are affected by heating, acidicity, and alkalinity differently:
    - Anthocyanins appear red under acidic conditions, purple under neutral conditions, and blue under alkaline conditions[1]; extended heating can cause pigments to appear red or brown in color.[1]
    - Anthoxanthins contribute flavor to some vegetables, such as cauliflower[1]; an acidic pH bleaches any present anthoxanthins, while an alkaline pH leads these pigments to appear light yellow[1]; alkaline conditions contribute to color change in the water (turns yellow due to water-soluble anthoxanthins).[1]

Methods/Procedures

- **Samples:**
  - Broccoli
  - Red Cabbage
  - Cauliflower
- **Procedures:**
  - Wash produce well.
  - Chop into uniform pieces.
  - Use 50 g random pieces for each preparation.
    - Cook the vegetable according to the variation assigned.
    - After cooking, remove the vegetable from the cooking liquid with a slotted spoon and place on a white plate.
    - Evaluate the vegetable in terms of Color, Flavor, Texture, Odor.
    - Pour the cooking liquid into a glass beaker.
    - When cooking liquid has cooled to room temperature, test pH.
    - Evaluate color and clarity of liquid.
    - Record all Data in Table.

Methods/Procedures (Continued)

- **Variations:**
  - Waterless: In a covered, 1 qt saucepan, place 25 mL and 50g vegetable. Boil until tender. Note total time forcooking until tender.
  - Lid on, 5 min: In a covered, 1 qt saucepan, bring 250 mL water to boil; add 50g vegetable. Boil 5 min.
  - Lid on, 15 min: In a covered, 1 qt saucepan, bring 250 mL water to boil; add 50g vegetable. Boil 15 min.
  - Lid off, 5 min: In an uncovered, 1 qt saucepan, bring 250 mL water to boil; add 50g vegetable. Boil 5 min.
  - Lid off, 15 min: In an uncovered, 1 qt saucepan, bring 250 mL water to boil; add 50g vegetable. Boil 15 min.
  - Cold water start, lid off: In an uncovered, 1 qt saucepan, place 250 mL cold tap water and 50g vegetable. Heat uncovered to a boil and continue to boil actively for 5 minutes. Note total time for heating and boiling.
  - Distilled water, lid off: In an uncovered, 1 qt saucepan, heat 250 mL distilled water to a boil. Add 50g vegetable. Boil for 5 minutes, uncovered.
  - Pressure cooker, 2 min: Place 250 mL water and 50 g vegetable in pressure cooker. Follow directions to achieve 15 pounds pressure. Maintain pressure for 2 min. Cool according to directions before opening pressure cooker. Pressure cooker, 10 min: Place 250 mL water and 50 g vegetable in pressure cooker. Follow directions to achieve 15 pounds pressure. Maintain pressure for 10 min. Cool according to directions before opening pressure cooker.
  - Microwave, uncovered: Place 50 g vegetable in a small microwave-safe dish. Add 15 mL water. Cook for 1 min 30 sec, uncovered.

Methods/Procedures (Continued)

- **Variations (Continued):**
  - Microwave, covered: Place 50 g vegetable in a small microwave-safe dish. Add 15 mL water. Cook for 1 min 30 sec, covered.
  - Steamer: Place 50 g vegetable in a covered steamer containing enough water to boil throughout steaming period, but without touching vegetable. Note total time for cooking until tender.
  - 0.3 g Baking Soda, 3 min: In a covered 1 qt saucepan, bring 250 mL water to boil; add 0.3 g Baking Soda and 50 g vegetable. Quickly return to boiling and boil 3 min.
  - 0.3 g Baking Soda, 20 min: In a covered 1 qt saucepan, bring 250 mL water to boil; add 0.3 g Baking Soda and 50 g vegetable. Quickly return to boiling and boil 20 min.
  - 19 mL Vinegar, 3 min: In a covered 1 qt saucepan, bring 250 mL water to boil; add 19 mL Vinegar and 50 g vegetable. Quickly return to boiling and boil 3 min.
  - 19 mL Vinegar, 20 min: In a covered 1 qt saucepan, bring 250 mL water to boil; add 19 mL Vinegar and 50 g vegetable. Quickly return to boiling and boil 20 min.
  - Milk, 3 min: In a covered 1 qt saucepan, bring 250 mL milk to boil; add 50 g vegetable. Quickly return to boiling and boil 3 min.
  - Milk, 20 min: In a covered 1 qt saucepan, bring 250 mL milk to boil; add 50 g vegetable. Quickly return to boiling and boil 20 min.

Broccoli	Waterless	Lid on, 5 min	Lid on, 15 min	Lid off, 5 min	Lid off, 15 min
Which Pigment are you investigating?=	Chlorophyll -->				
pH (of cooking liquid)	null	7.3	7.2	7.6	6.4
Appearance of Cooking Liquid	null	cloudy, yellow	brown	cloudy, light green	very clear, golden brown
Vegetable Color	null	floret- dark green; stalk- light green	floret- dark green; stalk- bright green	floret- pale green; stalk- bright green	floret- dark green; stalk- pale green
Texture	tender, 3	soggy, 1	mush, 1	watery, 2	moist, 2
Flavor	strong, 1	light, 3	watery, 2	crummy, 1	strong raw taste, 1
Odor	potent, 1	null	null	watered down, 2	watered down, 2
Overall Rating (Scale of 1-5)	3	2	1.5	2	3
Explanation of Observations	minimal water for flavor compounds to be lost in; short cooking time prevents mushy texture	flavor compounds lost in water	longer cooking time (in water) leads to a soft texture and watery flavor; lid on promotes chlorophyll conversion to pheophytin	lid off maintains vibrant colors; flavor compounds lost in water	longer cooking time leads to darker, less bright coloring; cooking for a long time in water explains the watery flavor and waterlogged broccoli (i.e., "moist" texture)
	odor	1=strong/potent/off	3=neutral	5=fresh/pleasant	2=in between 1 and 3; 4=in between
	flavor	1=bad/off, 2=bland	3=acceptable, 4=decent	5=good/delicious	
	texture	1=mushy/soft	3=tender	5=crisp/firm	2=in between 1 and 3; 4=in between

*Notes: Graphs: The cooking Time (x-axis) was a suggestion of how to look at the data (for example, for those w/ 5 vs 15 min), and you could plot different lines for the Lid on vs off, for example. There are several "groups" you could potentially see in here. It doesn't need to be a Line, it could be a Bar -- but what kind of picture(s) would best tell this story? However your Team wishes to look at this is up to the group.

Q: [In the One-Pager's from where were are to take data for the PIGMENTS experiments], What do the x's mean in certain columns of the one-pager that we are using to enter data? Does that mean this data was not collected for these specific samples? Does that mean those data points should be left blank when entering into the Excel sheet? *A: This Depends on the On-Pager Data you're talking about. For instance, in the broccoli experiment, the x means that data was not collected -you could leave those data points blank bc that would mess up a graph or chart by entering text in there. In the cauliflower experiment, the x means that is it a checkmark for that variable.*

Results – Broccoli (Continued)

Cold water start, lid off	Distilled water, lid off	Pressure cooker, 2 min	Pressure cooker, 10 min	Microwave, uncovered	Microwave, covered	Steamer	Baking Soda, 3 min	Baking Soda, 20 min	Vinegar, 3 min
7	7.4	6.8	6.7	null	null	7.6	9.4	9.8	4.1
pale, cloudy yellow floret- dull green; stalk- pale green	pale, cloudy yellow floret- green; stalk- bright green	dark green null	bright "puke" yellow drab green, brownish	none to assess bright green	light yellow-green bright green	clear yellow bright green	yellow-ish null	brownish-olive green null	clear with a hint of green null
soft tops rubber, 4	rubbery, 4	soggy, 1	fall apart, 1	stable, crunchy, 3	mild crunch, 3	soft, 1	mush, 1	very mushy, 1	crunchy, 5
strong, 1	medium, 3	watered down, 2	extreme watered down, 1	strong, 1	burnt, 1	raw, 2	baking soda, 2	strong baking soda, 1	light vinegar, 2
null	raw, 1	faint, 4	very faint, 3	null	faint, 4	med, 3	faint baking soda, 2	watery, 2	light vinegar, 2
1.5	2.5	1.5	1	3	2.5	2.5	1	0.5	1
cooking for longer in cold water dampens color vibrancy and overcooks the broccoli	unfavorable texture changes but better-retained color due to pH of distilled water	pressure cooker allows water to boil at a higher temperature, making the broccoli soggy and watery	color loss, watered-down flavor, and fall-apart/mushy texture with longer cooking time	color, texture, and flavor retained due to short cooking time	steam does not escape as readily, cooking the broccoli through more and trapping odor molecules (leads to a more detectable odor)	longer cooking time makes for softer broccoli	adding a base leads to a softer/more mushy texture; baking soda imparts a "baking soda" flavor onto the broccoli	cooking for longer with a base leads to a very mushy texture and strong baking soda flavor; scent of baking soda becomes less strong over time; pH is much higher than with plain tap water	acids retain texture; the vinegar imparts a "vinegar" flavor onto the broccoli, which increases with cooking time

Vinegar, 20 min	Milk, 3 min	Milk, 20 min
4.6	6.1	6.6
clear with specks of green null	yellow-green null	darker yellow-green null
crunchy moist, 4	mush w/crunch, 2	soggy, 1
med vinegar, 2	creamy, 4	milky, 2
med vinegar, 1	light milk, 2	strong milk, 1
1.5	1	0.5
longer cooking time makes broccoli less crunchy, but texture is still crisp from the acid; stronger vinegar flavor with longer cooking time; pH is much lower than with plain tap water	texture is slightly crunchier due to shorter cooking time; lighter milk flavor and aroma with shorter duration of cooking	pH is generally lower than with tap water; texture is softer and "milky" flavors/scents are more pronounced with a longer cooking time

Results – Broccoli (Continued)

For the Cooking Tx on Pigments Experiments, it is up to you and your Team how you enter, analyze and present the provided Data in your Spreadsheet

https://youtu.be/mRAUnOVWnLk

https://youtu.be/7QbKz8BNsYc

Red Cabbage	Waterless	Lid on, 5 min	Lid on, 15 min	Lid off, 5 min	Lid off, 15 min	Cold water start, lid off	Distilled water, lid off	Pressure Cooker, 2 min	Pressure cooker, 20 min
Which Pigment are you investigating?=	Anthocyanins -->								
pH (of cooking liquid) - *Complete from One-Pager*	6.1	7.2	5.7	6.9	6.5	7.3	6.7	6.6	6.1
Appearance of Cooking Liquid & Vegetable - *Match the Image on the Slide w/ each Treatment (e.g. A, B, C)*	dark purple	blue-purple	violet	blue	dull purple	light blue	light pink	faded purple	dark purple
Vegetable Color - *this is on the "Data Sheet" w/ the pH values*	dark pinkish-purple	purple	heavily-faded purple	pink-purple	faded purple-pink	pink w/ a hint of blue	pinkish purple	faded purple	dark purple
Texture - *can you hypothesize what the result might be for each Tx?*	tender, 3	slightly soft but firm, 4	tender-soft, 2	soft but firm, 4	soft, 2	tender, 3	slightly soft but firm, 4	tender-crisp, 3	mushy, 1
Flavor	n/a								
Odor	n/a								
Overall Rating/acceptability - *convert the Smiley Face Scale into something numerical to analyze (Scale of 1-5)*	4	4	3	4	3	4	3	4	1
Explanation of Observations	tender texture due to moderate cooking time; crispness is preserved but not over-pronounced; lower pH = anthocyanins appear more pink/purple/red	texture is kept firm from short cooking time and organic acids trapped in cooking vessel (lid on); anthocyanins appear more purple with neutral to slightly alkaline pH	slightly soft texture from longer cooking time; lid on contributes to lower pH, explaining violet-colored anthocyanins	short cooking time retains texture; slightly acidic pH explains pink-purple anthocyanins	longer cooking time reduces crispness in cabbage; slightly acidic pH contributes to pinkish-purple anthocyanins	slightly alkaline pH causes anthocyanins to appear more blue; shorter cooking time leads to a soft but crisp texture in the cabbage; high acceptability rating indicates cabbage texture was perceived as pleasant	slightly acidic pH and short cooking time contribute to firm but slightly soft texture; pH explains pinkish colors	slightly acidic pH and short cooking duration produce a crisp product; pressure cooking method makes the cabbage tender	long cooking duration produces mushy cabbage

Microwave, uncovered	Microwave, covered	Steamer	Baking Soda, 3 min	Baking Soda, 20 min	Vinegar, 3 min	Vinegar, 20 min	Milk, 3 min	Milk, 20 min
6.3	6.8	8	9.2	10.1	3.7	error	6.8	6.6
light purple	light purple-blue	clear	light green	medium green/teal	pink	error	white w/ a hint of purple	slightly pink milk
faded purple	dark purple w/ a hint of green	purple	dark green	dark green	pink	error	light purple	faded dark purple
tender, 3	soft, 2	soft, 2	soft, 2	mushy, 1	firm, 5	error* (soft to mushy, 1)	slightly soft but firm, 4	mushy, 1
4	3	1	1	1	1	null	4	2
the acidic pH accounts for the light purple anthocyanins; the final pH, as well as being uncovered during the cooking process, also contribute to the cabbage's doneness and the perceived satisfaction with its texture	the slightly higher pH may explain the hints of blue and green seen in the cabbage cooked under these conditions compared to the cabbaged cooked uncovered in the microwave (even though both are acidic); the trapped steam cooks the cabbage more than when uncovered, so the texture is softer	the cooking method of steaming and the alkaline pH explain the soft, undesirable texture of the cabbage	the addition of baking soda (basic) explains the alkaline pH and, consequently, the greenish anthocyanins; it also explains the soft texture, even with a short cooking duration	the longer cooking time explains/would explain a mushier texture; the baking soda creates an alkaline cooking environment that contributes to this softness and causes anthocyanins to appear more green/teal in color	vinegar (acidic) contributes to a firm texture in the cooked cabbage; the acidic pH causes the anthocyanins present to appear bright pink	We would predict the pH to be highly acidic, the anthocyanins to appear pink to red in color, and the final texture to be soft, due to the extended cooking time (despite being cooked in an acidic solution)	milk is slightly acidic, and with a short duration of cooking time, the cabbage is likely to be slightly soft but firm; the anthocyanins leach into the milk, turning it slightly purple; the pH is close to neutral, which explains the purple color of the anthocyanins	the slightly lower, more acidic pH explains the pink tint to the milk; the longer cooking time contributes to the cabbage's soggy/mushy texture

For the Cooking Tx on Pigments Experiments, it is up to you and your Team how you enter, analyze and present the provided Data in your Spreadsheet

https://youtu.be/mRAUnOVWnLk

https://youtu.be/Kxj9eT-T7Z4

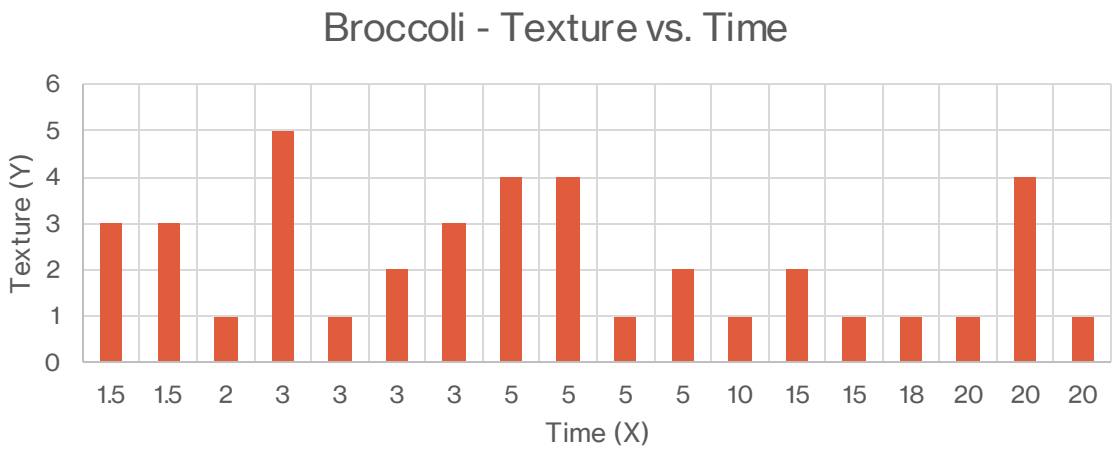
Cauliflower	Waterless	Lid on, 5 min	Lid on, 15 min	Lid off, 5 min	Lid off, 15 min	Cold water start, lid off	Distilled water, lid off
Which Pigment are you investigating?=	Anthoxanthins -->						
pH (of cooking liquid) - *Complete from One-Pager*	null	6.2	6.1	6.5	6.5	6.3	6.3
Appearance of Cooking Liquid	null	clear	clear	clear	clear	clear	clear
Appearance of Vegetable	rusty orange/brown, crisp/intact	light yellow, fibrous/intact	yellow, crisp/intact/fibrous	light yellow, mushy/soft	yellow, crisp/intact	white, crisp/intact/fibrous	white, crisp/intact/fibrous
Vegetable Color - - *Complete from One-Pager*	rusty orange/brown	light yellow	yellow	light yellow	yellow	white	white
Texture	crisp, 5	crisp, stringy, 4	crisp, stringy, tender, 3	mushy, 1	crisp, 5	crisp, stringy, 4	crisp, stringy, 4
Flavor	garden, 4	watery, 2	flavorful, 5	watery, 2	bland, 3	watery, 2	bland, 3
Odor	null	null	garden, 4	null	null	null	null
Overall Rating/acceptability (1-5)	3	5	3.5	4	3.25	3.75	3.25
Explanation of Observations	cooking for a relatively short period of time without water contributes to the orange/brown color of the cauliflower and the crisp texture	cooking in water contributes to the "watery" flavor of the cauliflower; the slightly acidic pH and short cooking time leave the cauliflower with a crisp texture	the longer cooking time contributes to the darkening from light to regular yellow; the slightly acidic pH slows the softening of the cauliflower, while the longer cooking time promotes it - this leads to cauliflower with a tender texture	cooking the cauliflower in water contributes to the "watery" flavor; the texture is not what we would expect it to be	the longer cooking time explains the darkening color of the cauliflower; the texture is not what we would expect it to be	a "watery" flavor might be expected with a longer cooking time; the texture is not what we would expect it to be; the slightly acidic pH helps keep the cauliflower white	a shorter duration of cooking explains the crisp texture; the bland flavor may be accounted for by the cooking method and liquid used (distilled water); the slightly acidic pH helps keep the cauliflower white
	odor	1=strong/potent/off	3=neutral	5=fresh/pleasant	2=in between 1 and 3; 4=in between 3 and 5		
	flavor	1=bad/off, 2=bland	3=acceptable , 4=decent	5=good/delicious			
	texture	1=mushy/soft	3=tender	5=crisp/firm	2=in between 1 and 3; 4=in between 3 and 5		

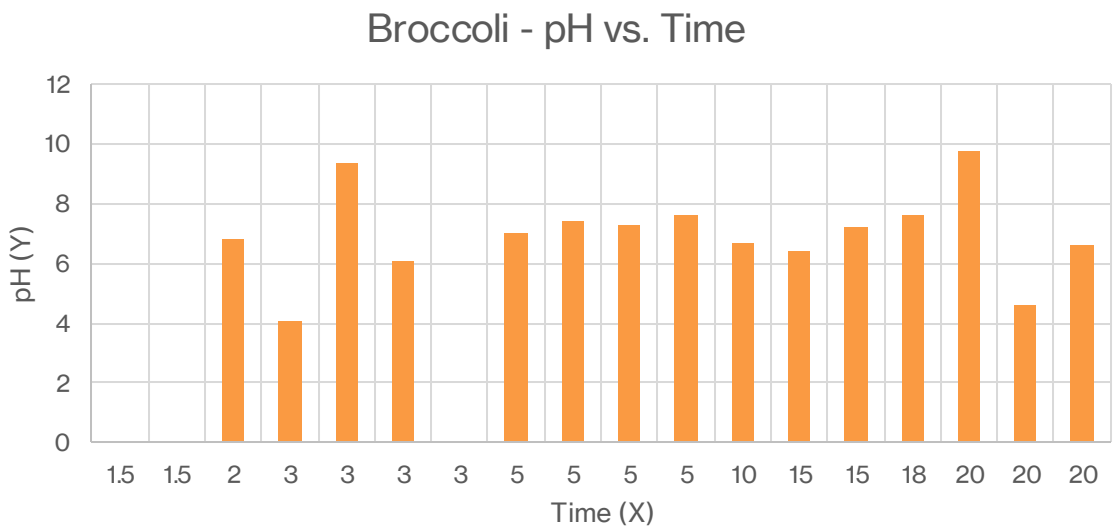
Results – Cauliflower (Continued)

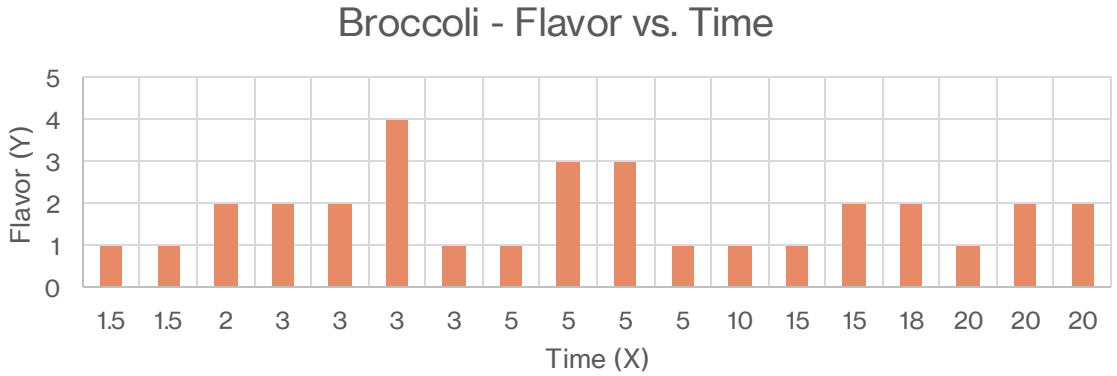
Pressure Cooker, 2 min	Pressure cooker, 10 min	Microwave, covered	Microwave, uncovered	Steamer	Baking Soda, 3 min	Baking Soda, 20 min	Vinegar, 3 min	Vinegar, 20 min
6.3	5.6	null	null	8.1	9.2	9.1	3.5	3.3
clear	clear	null	null	clear	yellow	golden, brown-yellow	clear/pale white	opaque/off-white
yellow-white, mushy/soft	white, mushy/soft	yellow, fibrous/intact	solid yellow, fibrous/intact	light yellow-white, crisp/intact	yellow-green, crisp/intact	yellow w/ a hint of green, mushy/soft	white, crisp/intact	white, mushy/soft
yellow-white	white	yellow	solid yellow	light yellow-white	yellow-green	yellow w/ a hint of green	white	white
mushy, 1	mushy, 1	stringy, 4	stringy, 4	crisp/tender, 3	crisp, 5	mushy, 1	crisp, 5	mushy, 1
garden, 4	strong, 1	garden, 4	strong, 1	bland, 3	bitter, 1	flavorless, 3	metallic, 1	vinegar, 1
null	null	garden, 4	garden, 4	null	bitter, 1	null	vinegar, 1	vinegar, 1
0.5	0	3	1.5	4.5	3.25	0	0	0.25
pressure cooker allows water to boil at a higher temperature, leading to overcooked and mushy cauliflower (despite the slightly acidic pH)	cooking for a longer duration leads to mushy cauliflower (despite an acidic pH); the acidic pH helps the cauliflower retain its white color	covering the cauliflower in the microwave traps more organic acids, which may explain the lighter yellow color compared to the uncovered microwaved cauliflower; cooking for a short duration keeps the cauliflower from becoming mushy	leaving the cauliflower uncovered in the microwave may have contributed to the darker yellow color (compared to the former condition); cooking for a short duration keeps the cauliflower from becoming mushy	some of the white color is retained in the cauliflower through steaming with the lid on; the alkaline pH contributes to the remaining shift in color from white to more yellow	the short cooking duration left the cauliflower with a crisp texture; the addition of baking soda raised the pH (alkaline), leading to a change in the color of the cauliflower from white to yellowish-green; the baking soda also contributed to the bitter flavor and odor detected by the experimenters	the longer cooking time and addition of a base (baking soda, alkaline) led to mushy cauliflower; the pigments (anthoxanthins) appeared more yellow for the same reasons	the addition of an acid (vinegar) lowered the cooking solution's pH, causing the cauliflower to appear bright white; this (in combination with the short cooking duration) contributed to the cauliflower's crisp texture; the unpleasant flavor and vinegar-y scent can be attributed to the addition of vinegar as well	the addition of an acid and subsequent low pH contribute to the retention of the white color in the final cooked cauliflower; the long cooking time caused the cauliflower to become mushy, as well as taste and smell strongly of vinegar

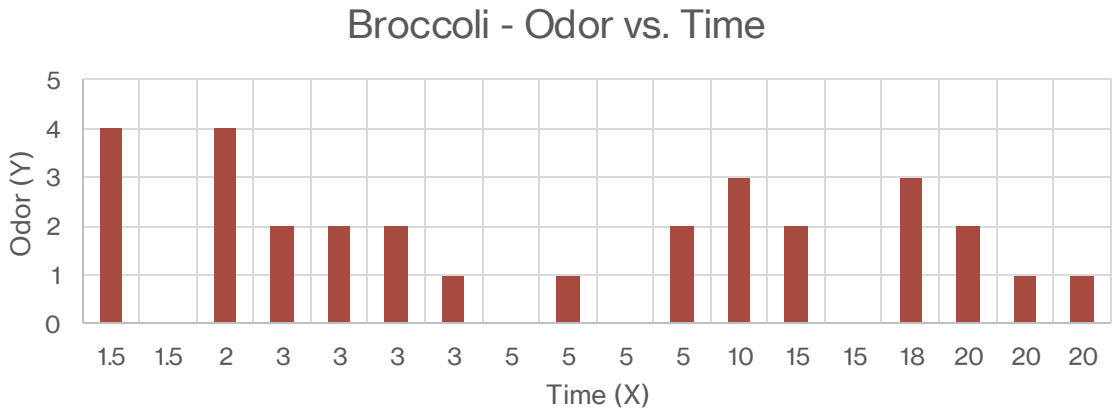
Milk, 3 min	Milk, 20 min
5.6	5.6
white (milky)	white (milky)
light green, crisp/intact	off-white/hint of yellow, intact
light green	off-white/hint of yellow
crisp, 5	tender, 3
milky, 2	milky, 2
milky, 2	milky, 2
2	2.25
the slight acidity (acidic pH) of the milk contributed to the crisp texture of the cauliflower, as well as the color change from white to light green; the shorter cooking duration helped retain the crisp texture of the cauliflower; the milky flavor and aroma can be explained by the use of milk as the cooking liquid	the longer cooking duration led to a more tender texture in the cauliflower; the slight change in color can be attributed to the acidic pH from the milk, which may also explain why the cauliflower was not overcooked despite the extended cooking time; the milky flavor and odor can be attributed to the milk used for cooking

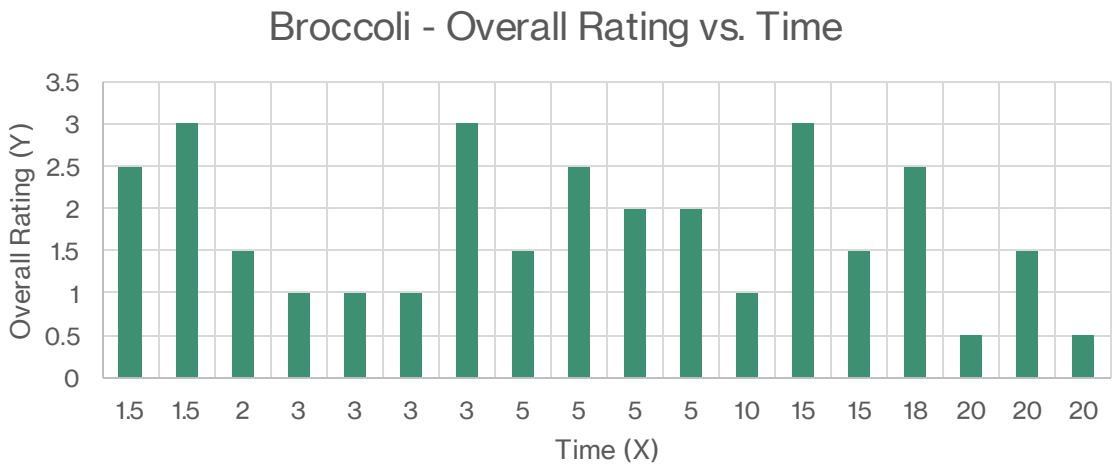
Results – Cauliflower (Continued)



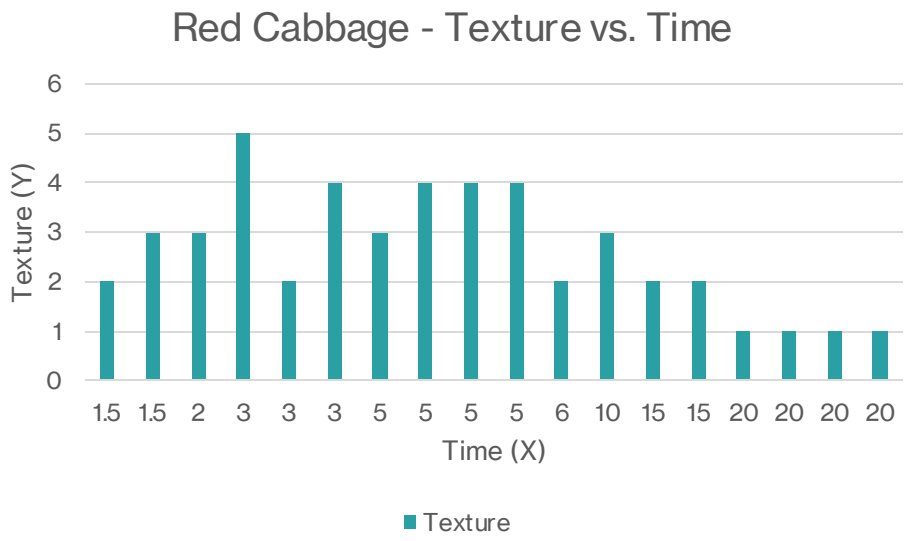


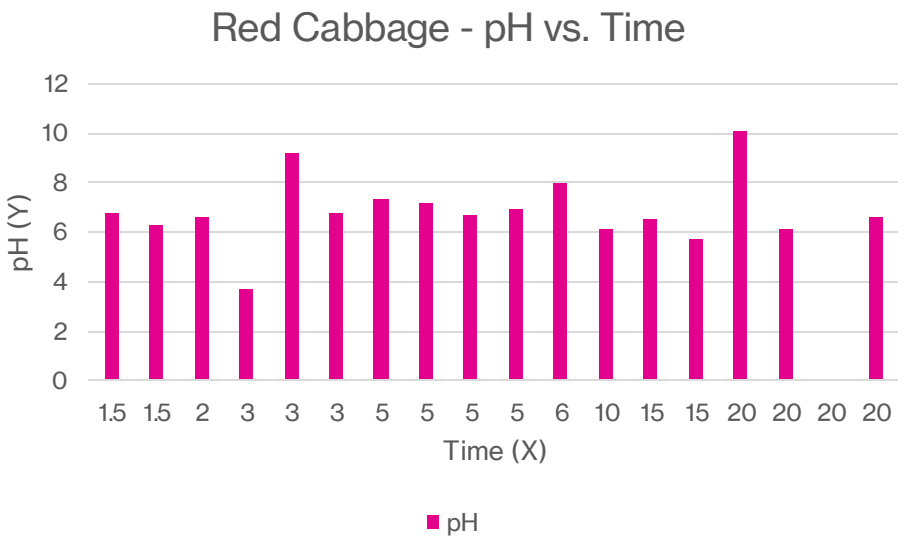


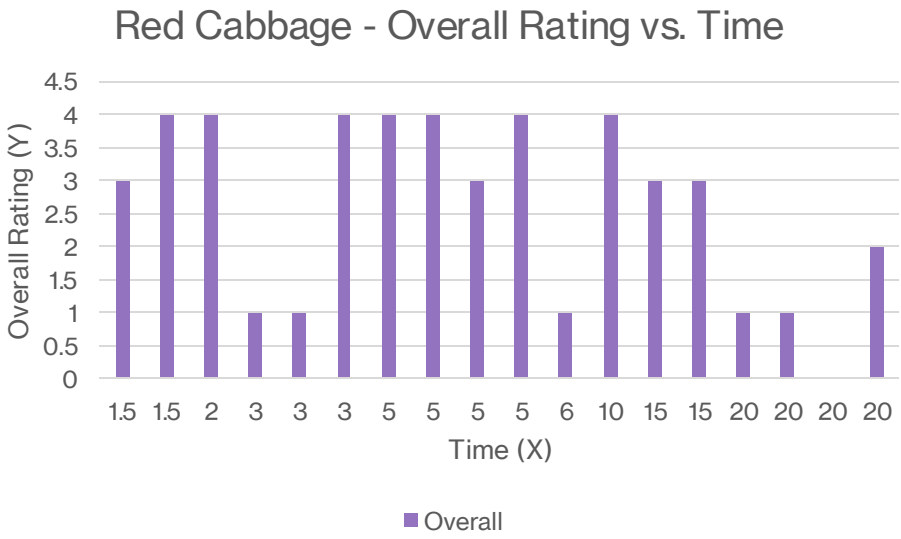




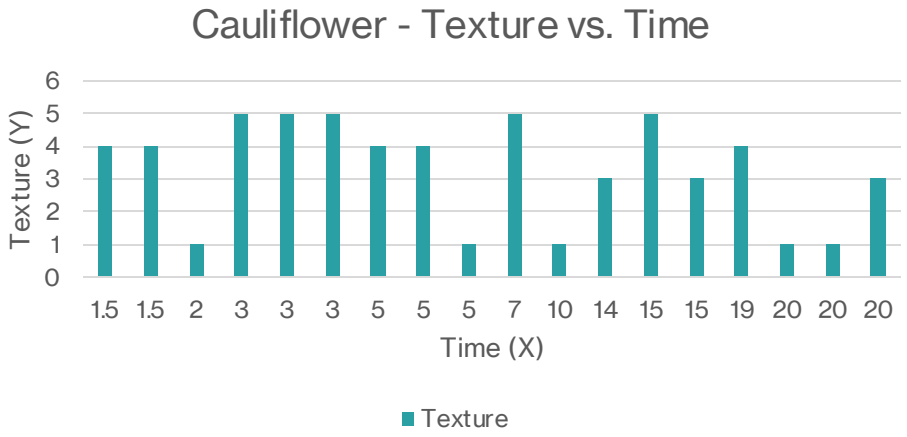
Results – Broccoli (Continued)

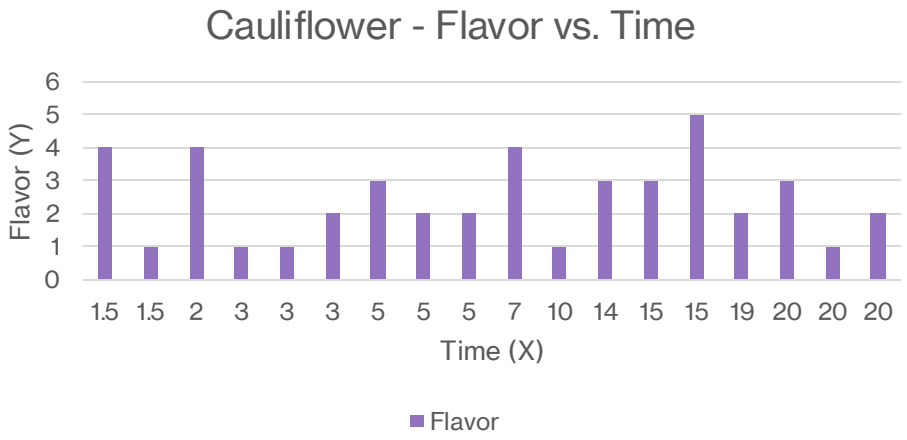


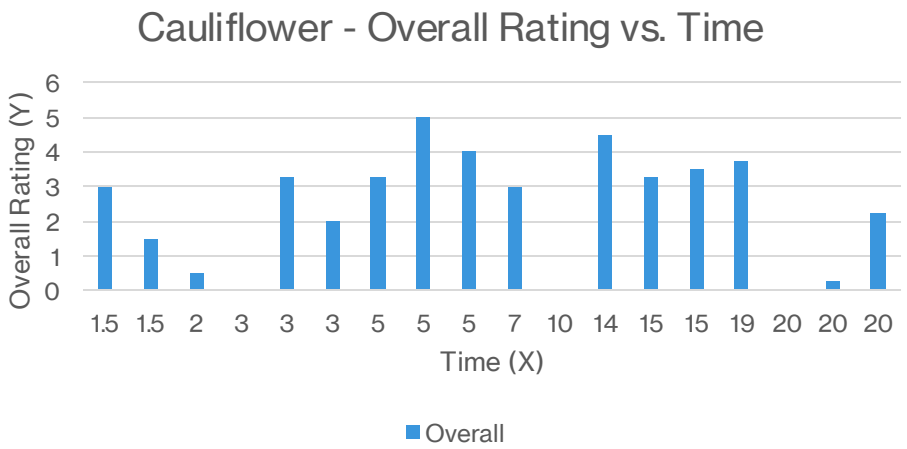


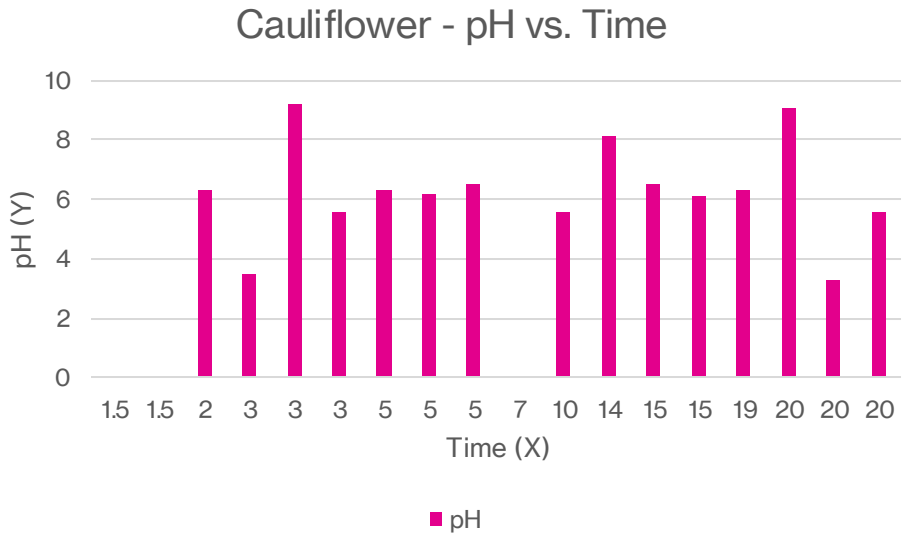


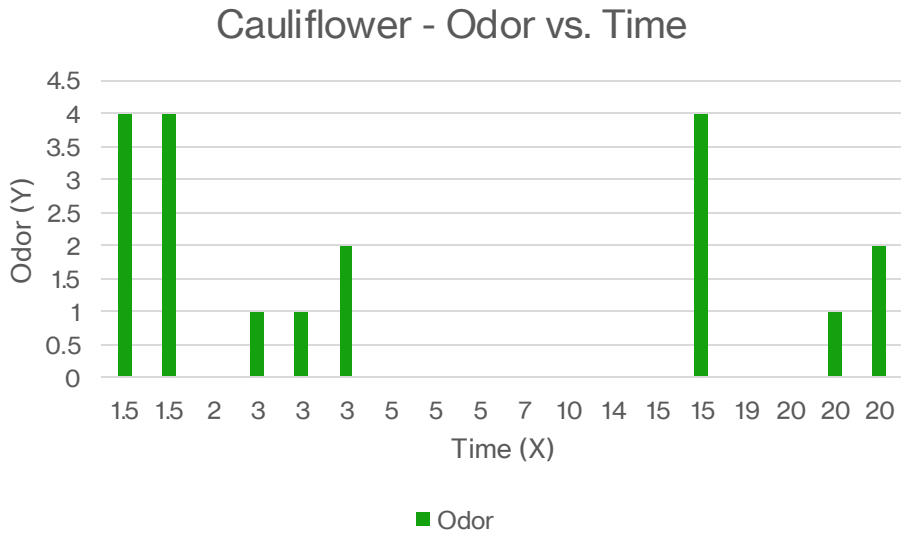
Results – Red Cabbage (Continued)











Results – Cauliflower (Continued)

Discussion – Analysis of Results

- Conclusions From and Interpretations of the Results:
  - Generally speaking, texture became softer over time for most vegetables tested. Acid slowed this softening to some extent, but after a certain point, softening will happen regardless of the presence of an acidic medium.
  - pH was relatively stable over time across all three vegetables, with outliers generally resulting from the addition of an acid or base rather than occurring due to extended cooking time. Small changes in pH occurred due to the release of organic acids from vegetables; the magnitude of this effect changed depending upon whether a lid was used during the cooking process.
  - Odor was generally perceived as less pleasant over time for broccoli (not including variations that added an acid or base to the cooking liquid); cauliflower exhibited a similar trend, but only some variations were noted to have an odor at all.
  - Flavor perception depended more on the cooking method and liquid than the amount of time the vegetable was cooked; however, it was generally perceived as less pleasant over time for broccoli, not exceeding a "2" after 5 minutes of cooking. The flavor of cauliflower generally appeared to be perceived as more pleasant over time, up to a certain point – flavor perception also likely depends on the vegetable and the person tasting it!
  - Overall rating depended on the cooking method and liquid but generally decreased once 20 minutes of cooking time had passed. Cauliflower may be an exception; ratings were highest (and more stable between 3 and 19 minutes of cooking time) but were lower from 1.5 to 2 minutes as well as at 20 minutes.

Discussion – Analysis of Results (Continued)

- Conclusions From and Interpretations of the Results (Continued):
  - Chlorophyll, pH, and time: Broccoli became a duller green over time, and the presence of acid accelerated this. A higher (more alkaline) pH made the broccoli appear bright green, but only up to a certain point. Cooking anything for too long, regardless of the presence of a base, will lead to color deterioration.
  - Cooking methods and vegetable pigments: Most vegetable samples examined in this experiment exhibited expected changes in color –
    - The chlorophyll in broccoli was converted to pheophytin and appeared more olive-like in acidic mediums and over longer cooking times. It appeared brighter green (as chlorophyllin) in basic mediums.
    - Anthocyanins appeared blue/green/teal when red cabbage was cooked under basic conditions, purple when conditions were neutral, and red/pink when conditions were acidic.
    - Anthoxanthins appeared bright white under acidic conditions and yellow under basic conditions.

Discussion – Analysis of Results (Continued)

- Why Did We Get These Results?
  - Effects on texture – Turgidity is lost with longer cooking times[1]; addition of a base accelerates softening, while addition of an acid slows it.[1]
  - Effects on color – Pigments react differently under various pHs and cooking conditions.
  - Effects on odor – Odor molecules may be trapped when vegetables are cooked with a covering on the cooking vessel; addition of an acid or base (or ingredient other than water, such as milk) will make for more complex aromas; more odor molecules may escape with steam and be lost as cooking time lengthens.
  - Effects on flavor – Flavor molecules may be leached out into the cooking liquid, leading to a less flavorful product when: (A) plenty of liquid is present, (B) the cooking vessel is uncovered, so compounds can escape with steam, and (C) the vegetable is cooked over a longer period of time, maximizing losses into the surrounding area.
  - The role of pH – pH of the cooking liquid is affected by the addition of an acid or base to the medium, as well as whether a lid is covering the cooking vessel. This is because organic acids leach out from the cooked vegetable into the surrounding liquid, lowering the pH.[1] Whether these acids escape into the air or condense with the water vapor and reenter the cooking medium depends on the presence or absence of a lid/covering. Water can become more acidic with longer boiling times, but the changes are slight.[2] The magnitude of this change may explain why pH appeared relatively stable over time.
- Explanation of Differences/Limitations:
  - Subjective interpretation of the results by the reporters; misinterpretations made by the experimenters; differences in adherence to the procedures across vegetable experiments; certain vegetables and fruits may behave differently depending on ripeness, compounds present, etc.

Discussion – Summary of What We Learned

- We learned that:
  - Texture is impacted by acidic or basic cooking conditions, as well as cooking time.
  - Flavor depends upon the cooking method and liquid but can be decreased over longer cooking times as phytonutrients and other flavor compounds leach into the surrounding environment.
  - Odor molecules can be trapped when a cooking vessel is covered, exhibiting a stronger scent once the lid is removed. Odor molecules may be lost over longer cooking times, weakening any perceived aroma.
  - pH changes occur due to the addition of an acid or base to the cooking medium but can also take place when a lid traps organic acids from vegetables in the cooking vessel. Time can affect the pH of boiling water, but only slightly.
  - Color changes occur in relation to pH changes and over longer cooking times.

Discussion – How We Met the Objectives

- Explain the conversion of chlorophyll pigments to pheophytins as a function of time and pH.
  - We met this by explaining the observations noted in the Broccoli lab and highlighting these relationships in our discussion.
- Discuss the effect of various cooking methods (e.g., use of lid, pressure cooker, microwave) on vegetable pigments.
  - We met this by explaining how the use of a lid impacts pH, and, therefore, the color of the final cooked vegetable (and cooking liquid).
- Determine the effect of the use of a lid and various types of water on the pH of the cooking medium.
  - We met this by explaining how the addition of an acid or base, as well as the use of a lid, affect the pH of the cooking medium.

Discussion – Conclusion: Take-Home Message

Pigments in fruits and vegetables may appear differently depending on the length of time the product is cooked, the cooking method employed, and the pH of the cooking medium, among other factors.

Works Cited

1. DellaValle DM. Week 4. Fruits and Veggies! Hyperlinked lecture slides. ND 608. King's College; November 10, 2025. Moodle. Accessed November 16, 2025.
2. Zha Y, Cao B, Ni L, Huang Y. Effects of boiling and storage on water quality of tap water, spring water, and bottled water. *Water*. 2025;17(9):1330. doi:10.3390/w17091330