# Predictive Models of Leafy Greens Sensory Attributes

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## Abstract

Although USDA Dietary Guidelines recommend increased consumption of a variety of fresh fruits and vegetable for a healthy diet, there are 1000 edible greens and only limited numbers are available commercially. The purpose of this study was utilization of predictive models for flavor, appearance, texture, and overall acceptability of eight specialty leafy greens (amaranth, huazontel, pac choi, tai sai, arugula, mizuna, komatsuna, and red iceberg lettuce) based on their quality attributes (color, texture, soluble solids, and dry weight) and indicators of secondary metabolites (total phenolics and radical scavenging capacity).

Stepwise methods were used to select statistically significant ($\alpha$=0.05) predictor variables (total of 17 attributes), and their parameter estimates (PE) for appearance, flavor, texture, and overall acceptability (response variables) of eight greens which were determined in a sensory trial by panelists (n=96).

Among instrumental measurements, total phenolics (TP) was the only significant predictor of panelists perceived appearance with PE=0.15. TP and L*(Lightness) were the two significant predictors of panelists' perceived flavor (PE=0.04, and PE=0.01, respectively). Similarly, TP and L* were significant predictors of panelists perceived overall acceptability of the greens (PE=0.04 and 0.01, respectively). Predictors of panelists perceived texture were instrumental texture and hue angle (3D calculated color component) with PE=0.01 and 0.33, respectively. As expected overall acceptability scores of the panelists were also significant predictors of both favorable appearance and flavor of the selected leafy greens (PE=0.62 and 1.00, respectively).

Although TP content appears to contribute to sensory attributes of selected leafy greens, and in this study was a predictor for panelists' perceived appearance, flavor, and overall acceptability, the association is not well understood. Lightness color coordinate (L*) was also characterized as a significant predictor of panelists perceived flavor and overall acceptability.

Results of this study, along with other predictive models of leafy greens sensory attributes, may be utilized for prediction of consumer acceptability of specialty leafy greens for marketing considerations.

**Keywords:** Predictive models; specialty leafy greens; quality attributes; indicators of secondary metabolites.

## Selected Leafy Greens

| Leafy Vegetable | Taxa | Genus & species |
|---|---|---|
| **Arugula** | Sputnik | Eruca vesicaria var. sativa |
| **Komatsuna** | Komatsuna | Brassica rapa |
| **Mizuna** | Mizuna | Brassica rapa var. nipposinica |
| **Pac choi** | Bonsai F1, Hybrid | Brassica rapa |
| **Huazontel** | Red Aztec Spinach | Chenopodium berlandieri |
| **Amaranth, Burgundy** | Burgundy Amaranth | Amaranthus hypochondriacus |
| **Chinese Cabbage** | Tai sai | Brassica rapa |
| **Red Iceberg Lettuce** | Red Iceberg Lettuce | Lactuca sativa |

## INSTRUMENTAL ANALYSES

- Total Soluble Solids
- Dry Matter

Indicators of Primary Metabolites

- Total Phenolics
- Radical Scavenging Capacity

Indicators of Secondary Metabolites

- Texture
  - Puncture test (Whole leaves)
  - Rupture test (Shredded leaves)
- Color
  - a*: redness/Greenness
  - b*: Yellowness
  - L*: lightness/Darkness
  - Hue Angle (3D Color): tan-1(b*/a*)
  - Chroma (Saturation): $(a^{*2}+b^{*2})^{1/2}$

Indicators of Quality Attributes



## Instrumental Measurements of the Selected Leafy Greens

TOTAL PHENOLICS CONTENT AND RADICAL SCAVENGING CAPACITY OF THE EIGHT SELECTED LEAFY GREENS (MEANS±SD)*

| | Total Phenolics (mg GAE/100g fresh weight) | Total Phenolics (mg GAE/g dry weight) | Radical Scavenging Capacity (µmole TEAC/100g fresh weight) | Radical Scavenging Capacity (µmole TEAC/g dry weight) |
|---|---|---|---|---|
| Amaranth | 175.94±15.7 † | 17.59±1.6† | 179.58±34.5 † | 4.71±0.9† |
| Huazontle | 130.39±17.2 † | 11.93±1.3 | 221.39±8.3 † | 5.96±0.6† |
| Pac Choi | 113.41±12.1 † | 10.53±0.9† | 126.97±19.3 | 11.29±0.8† |
| Tai Sai | 157.94±8.5 † | 19.19±0.3† | 149.13±12.3 | 3.18±0.9† |
| Arugula | 243.69±80.1 † | 24.47±0.8† | 172.70±23.6 † | 2.89±0.4† |
| Mizuna | 226.39±41.9 † | 19.59±1.2† | 226.93±11.5 † | 5.67±0.5† |
| Komatsuna | 173.27±15.9 † | 16.89±1.1† | 185.31±28.2 † | 4.22±0.4† |
| Red Iceberg lettuce | 91.58±6.9 | 12.82±0.6 | 146.45±17.8 | 10.89±2.1 |

*Values in each column followed by † are significantly different (P=0.05) from the control (Red iceberg lettuce)

DRY WEIGHT, TOTAL SOLUBLE SOLIDS AND TEXTURAL PROPERTIES OF THE SELECTED GREENS (MEANS±SD)*

| | Dry Weight (Per cent) | Total Soluble Solids (°Brix) | Texture (Rupture, mm F, g) | Texture (puncture, mm F, g) |
|---|---|---|---|---|
| Amaranth | 10.08±1.3 † | 6.00±0.8 † | 217.43±11.7† | 131.84±34.3 |
| Huazontle | 11.83± 0.6 † | 6.70±0.7 † | 1986.96±844.2† | 127.66±27.1 † |
| Pac Choi | 9.84±0.7 † | 4.13±0.6 † | 662.90±195.7 | 201.63±17.6 |
| Tai Sai | 8.41±0.3 † | 5.83±0.2 † | 446.13±68.6 | 181.29±32.7 |
| Arugula | 10.18±0.5 † | 6.80±0.3 † | 396.45±61.8 | 201.33±17.9 |
| Mizuna | 11.32±0.6 † | 6.23±1.4 † | 422.36±227.9 | 52.53±27.6 † |
| Komatsuna | 9.95±0.7 † | 8.24±2.28 † | 667.94±256.1 | 195.33±4.6† |
| Red Iceberg lettuce | 3.25±0.2 | 1.90±0.4 | 514.24±190.3 | 181.40±35.3 |

*Values in each column followed by † are significantly different (P=0.05) from the control (Red iceberg lettuce)

## Consumers' Hedonic Perception of the Selected Leafy Greens

| | Appearance | | Flavor | | Texture | | Overall Acceptability | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Amaranth (n=35) | 7.46 | 1.90 | 6.60$^b$ | 2.09 | 7.06$^b$ | 1.80 | 6.89 | 2.21 |
| Huazontel (n=35) | 6.43$^b$ | 2.13 | 6.31$^b$ | 2.32 | 6.79$^b$ | 2.17 | 6.35$^b$ | 2.16 |
| Pac choi (n=35) | 8.20$^a$ | 1.17 | 7.43 | 1.27 | 7.76 | 1.56 | 7.66 | 1.37 |
| Tai sai (n=35) | 8.29$^a$ | 0.89 | 6.66$^b$ | 1.88 | 7.53 | 1.75 | 6.88 | 1.97 |
| Arugula (n=61) | 8.07$^a$ | 1.21 | 5.41$^b$ | 2.69 | 7.61 | 1.66 | 5.98$^b$ | 2.50 |
| Mizuna (n=61) | 8.40$^a$ | 0.81 | 7.15 | 2.05 | 8.03 | 1.18 | 7.46 | 1.76 |
| Komatsuna(n=61) | 8.32$^a$ | 0.99 | 6.80$^b$ | 2.05 | 7.67 | 1.22 | 7.26 | 1.82 |
| Red iceberg lettuce (control) (n=61) | 7.10 | 1.76 | 7.64 | 1.45 | 8.10 | 0.93 | 7.62 | 1.42 |

Values in each column followed by a are significantly higher than control (Red iceberg lettuce)

Values in each column followed by b are significantly lower than control (Red iceberg lettuce)

| | Appearance | | Flavor | | Texture | | Overall Acceptability | |
|---|---|---|---|---|---|---|---|---|
| | %Acceptable* | %Unacceptable** | %Acceptable | %Unacceptable | %Acceptable | %Unacceptable | %Acceptable | %Unacceptable |
| Amaranth | 62.86 | 2.86 | 45.71 | 5.71 | 51.43 | 2.86 | 51.43 | 8.57 |
| Huazontel | 37.14 | 2.86 | 45.71 | 8.57 | 57.58 | 9.09 | 44.12 | 8.82 |
| Pac choi | 88.57 | 0.00 | 54.29 | 0.00 | 71.43 | 2.86 | 64.71 | 0.00 |
| Tai sai | 82.86 | 0.00 | 40.00 | 2.86 | 73.53 | 2.94 | 55.88 | 5.88 |
| Arugula | 80.00 | 1.67 | 22.95 | 21.31 | 72.13 | 3.28 | 31.15 | 14.75 |
| Mizuna | 83.33 | 0.00 | 59.33 | 6.67 | 77.05 | 0.00 | 62.71 | 3.39 |
| Komatsuna | 83.61 | 0.00 | 54.10 | 4.92 | 67.21 | 0.00 | 60.66 | 1.64 |
| Red iceberg | 48.33 | 5.00 | 72.13 | 1.64 | 75.41 | 0.00 | 68.85 | 3.28 |

* Percent of panelists rated the attribute as acceptable or highly acceptable in a 9-point hedonic test.

** Percent of panelists rated the attribute as unacceptable or highly unacceptable in a 9-point hedonic test.

## Predictive Model Equation

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \varepsilon$$

**Response Variable:**
- Appearance
- Flavor
- Texture
- Overall Acceptability

**Parameter Estimate**

**Intercept**

**Predictors:**
- Color (L*, a*, b*, Hue angle, Chroma)
- Texture(Knife-edge, Multipuncture probes)
- Total Soluble Solids
- Dry Weight
- Total Phenolics (Fresh and dry bases)
- Radical Scavenging Capacity
- Sensory attributes

## Results of Association of Panelists' Perception of the Leafy Greens with Instrumental Measurements

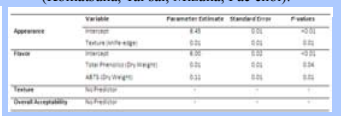
Predictors of panelists-perceived sensory attributes of the eight selected taxa.

| | Variable | Parameter Estimate | Standard Error | P-values |
|---|---|---|---|---|
| Appearance | Intercept | 0.66 | 1.35 | 0.63 |
| | Total Phenolics (Dry Weight) | 0.15 | 0.02 | <0.01 |
| | Overall Acceptability | 0.62 | 0.16 | 0.01 |
| Flavor | Intercept | 0.31 | 0.14 | 0.01 |
| | L* | 0.01 | 0.01 | <0.01 |
| | Total Phenolics (Dry Weight) | 0.04 | 0.01 | <0.01 |
| | Overall Acceptability | 1.00 | 0.02 | <0.01 |
| Texture | Intercept | 7.51 | 0.14 | <0.01 |
| | Hue angle | 0.33 | 0.03 | <0.01 |
| | Texture (knife-edge probe) | 0.01 | 0.01 | 0.02 |
| Overall Acceptability | Intercept | 0.33 | 0.17 | 0.01 |
| | L* | 0.01 | 0.01 | <0.01 |
| | Total Phenolics (Dry Weight) | 0.04 | 0.01 | <0.01 |
| | Flavor | 0.99 | 0.02 | <0.01 |

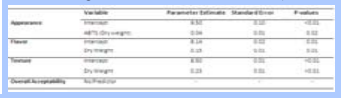
Predictors of panelists' perceived sensory attributes of the greens in the green subgroup (Arugula, Komatsuna, Tai sai, Mizuna, Pac choi).

| | Variable | Parameter Estimate | Standard Error | P-values |
|---|---|---|---|---|
| Appearance | Intercept | 9.04 | 0.00 | <0.01 |
| | Dry Weight | 0.01 | 0.01 | 0.02 |
| | L* | 0.01 | 0.01 | 0.04 |
| | Total Phenolics (Dry Weight) | 0.04 | 0.04 | <0.01 |
| Flavor | Intercept | 12.26 | 0.93 | <0.01 |
| | Total Phenolics (Dry Weight) | 0.27 | 0.04 | 0.01 |
| Texture | Intercept | 7.57 | 0.06 | <0.01 |
| | Texture (knife-edge) | 0.01 | 0.0 | 0.03 |
| Overall Acceptability | Intercept | 11.73 | 0.02 | <0.01 |
| | a* | 0.03 | 0.01 | 0.01 |
| | Total Phenolics (Dry Weight) | 0.22 | 0.01 | <0.01 |

Predictors of panelists' perceived sensory attributes of the Eudwvlfd genus subgroup (Komatsuna, Tai sai, Mizuna, Pac choi).



Predictors of panelists' perceived sensory attributes of the red leafy greens subgroup (Red iceberg lettuce, Amaranth, Huazontel).



## Results and Discussion

**Predictive Models for all Eight Taxa**

× Dry weight total phenolic content appears to be a possible predictor of panelists' perceived appearance, flavor, and overall acceptability.

× Instrumentally measured texture (with knife-edge probe) was a predictor of the panelists' perceived texture.

× Further analysis by dividing the greens into the subgroups provided other predictors for panelists' perception scores; for example, L* for appearance of leafy greens with dominant green color and dry weight ABTS value for Brassica genus subgroups.

**Correlation Results** (Not Shown in Tables)

× Among the panelists' four sets of scores, flavor and overall acceptability were highly correlated ($r$= 0.96, $S$= 0.001) indicating that flavor of the greens is a main contributor of panelists' judgments of overall acceptability.

× Similar results were observed in the red, green, and Eudwvlfd genus subgroups ($r$= 0.97, $S$= 0.01, $r$= 0.98, $S$= 0.001, and $r$= 0.94, $S$= 0.05, respectively).

× Predictably, panelists' flavor scores were highly correlated ($r$= 0.97, $S$= 0.001) with the percentage of panelists rating the product as "highly acceptable and/or acceptable" and negatively correlated ($r$=-0.91, $S$= 0.001) with the percentage of panelists rating the greens as "highly unacceptable and/or unacceptable." Correlations among other panelists' rated attributes were not statistically significant ($S$>0.05).

## Conclusions

It appears that TP content is a major contributor to sensory attributes of selected leafy greens and a significant predictor for panelists' perceived appearance, flavor, and overall acceptability. Lightness color coordinate (L*) were also characterized as a significant predictor of panelists' perceived flavor and overall acceptability.

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