# TOOLS OF SENSORY ANALYSIS APPLIED TO APPLES

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The use of senses in judging food quality is part of our daily actions of eating. Sensory science is used to understand consumer preferences, to measure the components of taste and texture, and to predict eating quality with instrumental measurements. Sensory scientists use a whole array of tools to describe and evaluate quality, or changes in quality of a product over time. Consumer tests give information on the acceptance of a product. In 1997, at this meeting, we showed how consumers could differentiate apples harvested at different maturity stages. Consumer preference of apples in air storage indicated which harvest date was optimum for a mid- or long-term storage of 'Gala', 'Braeburn', and 'Fuji'. Today, we will present two examples of the use of instrumental measurement to understand two important factors of apple quality: flavor, and texture.

## IDENTIFICATION OF COMPOUNDS CONTRIBUTING TO 'GALA' AROMA

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Aroma, taste and flavor attributes are customarily explained by the interaction of chemical compounds with taste or olfactory receptors. Aroma perception is the result of volatile compounds stimulating olfactory receptors. Volatile compounds produced by 'Gala' apples were isolated and injected into a gas chromatograph for separation and identification. Two detectors were used: the chemical detector - flame ionization or mass spectrometer-, and the human detector - the nose (Figure 1). As the human subject sniffs the effluents of the gas chromatograph, he/she responds to the stimuli of individual odor-active compounds. The subject is trained to recognize odor-active compounds, identify them with his/her own descriptor, and rate the perceived intensity by moving a cursor on a sliding scale from 0 (no odor) to 15 (extreme odor intensity). This time-intensity method has been named "osme", from the Greek word "odor".

The human subject output is an aromagram, and the peaks produced by the odor active compounds are compared with the peaks produced by the chemical detector, the FID (Figure 2). For example, on Figure 2, two peaks, #4 and #20, were produced by 'Gala' apples in large amounts. Both resulted in high odor intensities recorded by the human subject on the aromagram. Those peaks correspond to butyl acetate and hexyl acetate, respectively, with a solvent-like or gala aroma. On the other hand, peak #6 is very small on the chemical detector, it is produced in small amounts; it has nevertheless an important odor-activity, with an odor intensity of 5 on the 15-point scale, and a sweet, strawberry-like odor. This compound is ethyl-2-methyl butyrate. Peak #5 on the aromagram, with an odor-intensity of 7, is even not detected by the FID. We suspect it is a sulfur-containing compound because it has a distinctive skunk odor, and sulfur compounds usually have very low odor-thresholds. Finally, on the same graph, the FID detected a compound produced in large amounts (no number on the chromatogram); this is farnesene, and it has no odor-activity in the amount injected in the GC. Compounds with an odor-activity identified in 'Gala' apple are listed in Table 1.

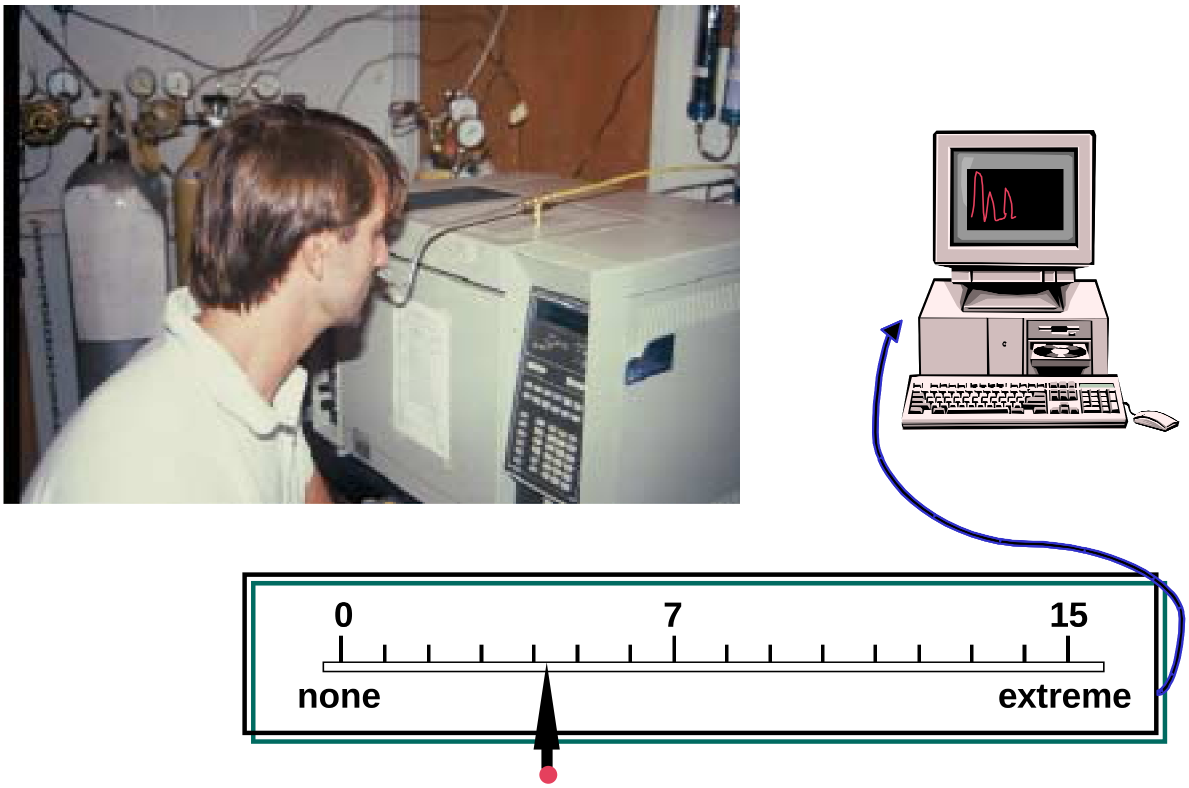


**Figure 1.** Set-up for "osme" analysis.

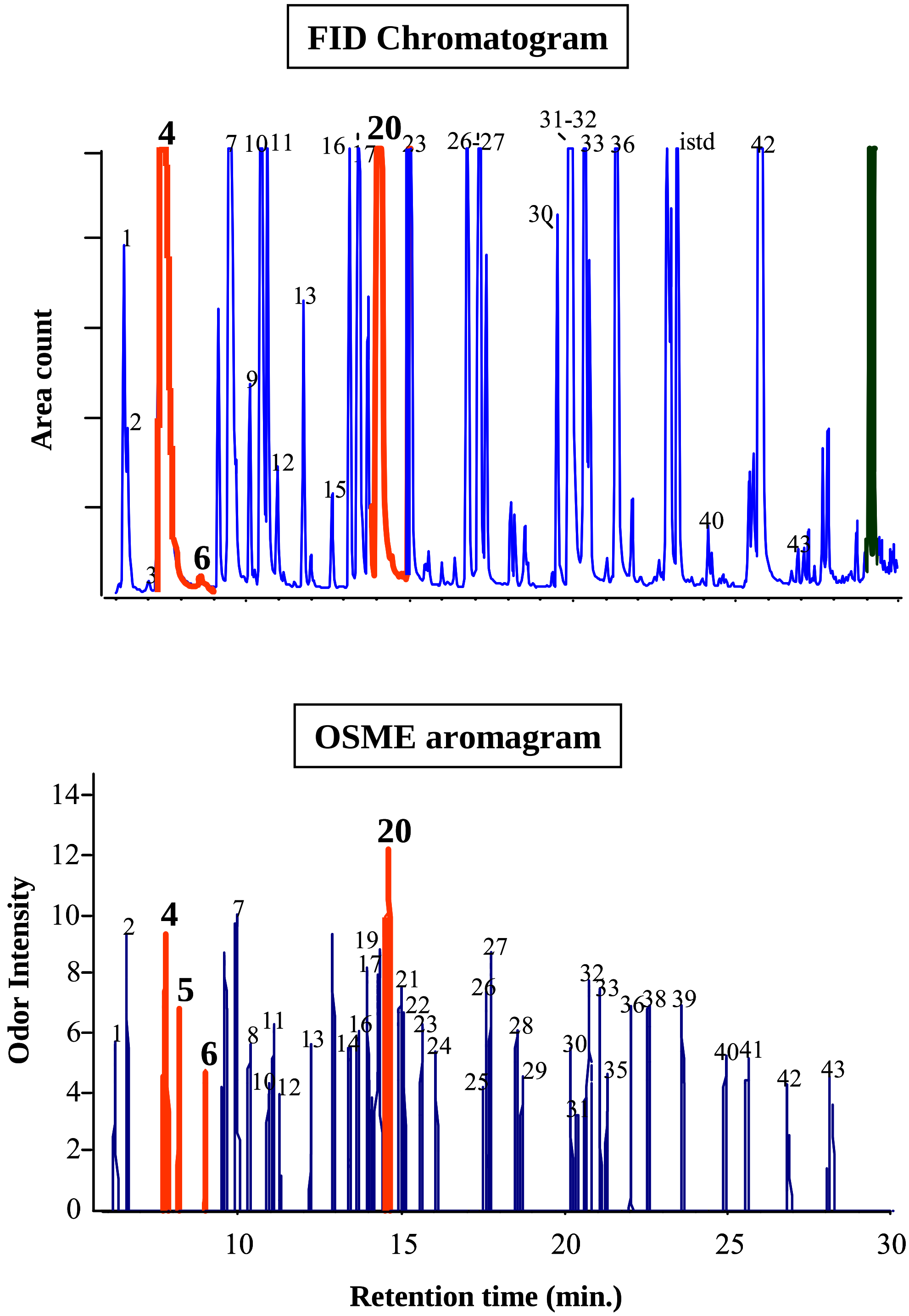


**Figure 2:** Chromatogram obtained with the flame ionization detector (top), and aromagram obtained with the human subject detector (bottom) of 'Gala' apple at harvest.

**Table 1.** Odor-active compounds found in 'Gala' apple by using "osme."

| | Descriptor | Compound | Perceived intensity (0 to 15) |
|---|---|---|---|
| **Fruity** | "Gala", ripe, pear | hexyl acetate | 12.05 |
| | Nail polish | butyl acetate | 10.60 |
| | Solventy | 2-methyl butyl acetate | 9.91 |
| | Sweet strawberry | ethyl-2-methyl butyrate | 8.06 |
| | Sweet fruity | methyl-2-methyl butyrate | 7.95 |
| | Very sweet, strawberry | propyl-2-methyl butyrate | 7.04 |
| | Fruity, apple | butyl-2-methyl butyrate | 6.30 |
| | Gala | pentyl acetate | 6.06 |
| | Grapejuice | β-damascenone | 5.21 |
| | Apple, grapefruit | hexyl-2-methyl butyrate | 5.15 |
| | Green apple | butyl hexanoate[b] | 4.57 |
| | Apple | hexyl butyrate[b] | 1.86 |
| | Apple | hexyl propanoate | 3.76 |
| | Fruity, tape | 6-methyl-5-hepten-2-one | 3.51 |
| | Rotten apple, cheesy | butyl butyrate | 2.22 |
| | Fruity | unknown[c] | 1.88 |
| **Other Descriptors** | Floral | unknown[c] | 3.67 |
| | Anise, licorice | 4-allylanisole | 7.69 |
| | Watermelon | unknown[c] | 7.38 |
| | Cucumber | unknown[c] | 2.68 |
| | Mushroom | 1-octen-3-ol | 4.62 |
| | Cat urine, mushroom | unknown[c] | 4.08 |
| | Nutty, mushroom[a] | hexyl tiglate | 1.66 |
| | Adhesive | unknown[c] | 4.15 |
| | Adhesive or musty | unknown[c] | 2.68 |
| | Skunk, rubber | no peak | 8.40 |
| | Oatmeal, skunky | no peak | 3.21 |
| | Dusty/musty | no peak | 2.31 |
| | Metallic, skunk | no peak | 1.25 |

a: at or below odor threshold. Perceived sporadically.
b: peaks co-elute on the FID, but perceived separately by the panelists
c: correspond to peaks detected by FID, but no satisfactory match was found in the NIST library

The aroma profile of 'Gala' apples after three weeks from harvest ("fresh") was compared with the aroma profile of apples stored in air and in CA. Reduction of volatile production in CA storage and corresponding odor activities allowed deduction of those compounds dominant in fresh 'Gala' apples. Hexyl acetate, butyl acetate and 2-methyl butyl acetate, with apple and solvent-like aromas were the compounds with the highest perceived intensity for fresh apples, but decreased significantly in CA-stored apples. Butyl-2-methylbutyrate and hexyl-2-methylbutyrate had a typical apple aroma in fresh apples, but were almost not perceived in CA-stored fruit. Methyl-2-methylbutyrate, ethyl-2-methylbutyrate and propyl-2-methylbutyrate had a very strong sweet, berry-like aroma, and were still well perceived in CA-stored apples. We believe those compounds contribute to the background sweet aroma of apples. Finally, compounds that did not have an apple aroma were only perceived in fresh apples. Those were β-damascenone (grape juice), 4-allylanisole (anise), 1-octen-3-one (mushroom), and two unknown compounds with watermelon and skunk odors.

Like all gas-chromatography and olfactometry methods, "osme" only gives information for individual compounds. When in mixtures, odor-active compounds may interact with each other by odor enhancement, suppression or addition. For this reason, another experiment was designed to evaluate mixtures of the compounds found to be odor-active for 'Gala' apple, and compare those mixtures with apples. This experiment showed that hexyl acetate, butyl acetate, hexanal, 2-methyl butyl acetate, and methyl-2-methyl butyrate were necessary to be in the mixture to impart 'Gala' aroma.

Compounds contributing to 'Gala' aroma were added to a storage room as liquids in a pilot study. The compounds volatilized, and were absorbed by the apples in the room. Fruitiness of treated apples was enhanced and perceived by a taste panel two and three weeks after treatment and removal from storage.

## CONCLUSIONS

Gas chromatography and sensory analysis by olfactometry are powerful tools to measure and identify aroma-active compounds in a food system. Aroma-active compounds are currently used in processed foods as natural flavorings. A new use of natural flavorings can be aroma enhancement of apples stored in CA prior to packing. The right proportion of aroma-active compounds must be determined for each variety; more research needs to be done to fine-tune the conditions of volatile application.

## REFERENCES

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## APPLE PREFERENCE RELATED TO FIRMNESS: A CONSUMER STUDY

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Instrumental analysis is usually faster, more reproducible and easier to implement than sensory analysis. Apple firmness is commonly measured with the Magness Taylor penetrometer, and measurements correlate positively with perceived firmness by consumer or trained panels. However, Magness Taylor is a destructive measurement. Research for non-destructive instruments that could be installed on a packing line is under way (see Dr. Reed's presentation). The objectives of the present study were to understand the relationship between measurements from a non-destructive firmness acoustic device, and consumer preference relative to firmness.

1. Can consumers distinguish texture and firmness differences between two levels of firmness index (FI) values?
2. Is there a level of firmness acceptance associated with a range of FI values, or a specific FI value?
3. Is there a difference in consumer response to apples grouped by FI values between 'Golden Delicious' and 'Red Delicious'?

### METHODS

'Golden Delicious' and 'Red Delicious' were grouped into four firmness classes based on non-destructive firmness measurements with an acoustic device on the day of testing.

For 'Golden Delicious', the firmness classes were:

- A = 15 to 17 FI
- B = 19 to 21 FI
- C = 23 to 25 FI
- D = 27 to 29 FI

For 'Red Delicious', the firmness classes were:

- A = 10 to 13 FI
- B = 15 to 18 FI
- C = 20 to 23 FI
- D = 25 to 28 FI

Apples were presented to each panelist in pairs, without cutting. All combinations of the six possible pairs of the four firmness levels were presented in a balanced incomplete block design. Each panelist saw all four firmness levels presented in two sets out of the six possible pairs: A/B, A/C, A/D, B/C, B/D, and C/D. Panelists were presented either: A/B and C/D, A/C and B/D, or A/D and B/C. 'Golden Delicious' was tested on February 9th, 1998, and 'Red Delicious' was tested on February 10th, 1998.

Panelists were asked to bite into each apple and answer the following questions for each pair of apples:

1. Which apple do you prefer?
2. Which texture do you prefer?
3. Which apple is firmer?
4. Is firmness of sample xxx acceptable/ not acceptable?
5. Is firmness of sample yyy acceptable/not acceptable?
6. Comments

Data were analyzed by using the table of critical numbers for the one-sided paired comparison test for difference (Meilgaard et al., 1991).

## RESULTS

### *Differences between levels of firmness*

For Red Delicious apples, there were significant differences for overall preference between all pairs of firmness levels except between level B (15 to 18 FI) and C (20 to 23 FI) (Figure 3). Panelists could discriminate between all levels of firmness and significantly preferred the texture of firmer apples (Figures 4 and 5). The choice for texture preference followed closely what was considered the firmer apple.

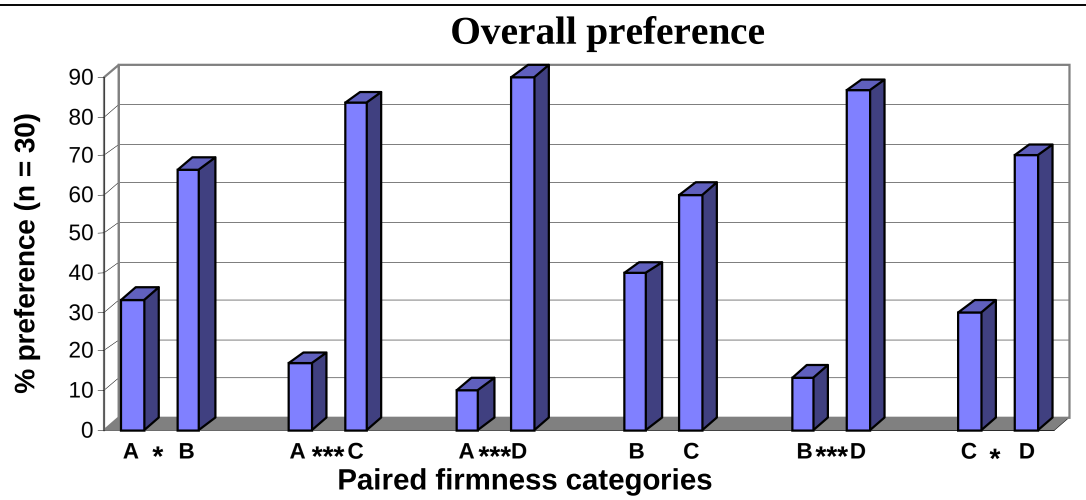


**Figure 3**. Paired comparison results for 'Red Delicious' apple: overall preference.

For Golden Delicious, there were no significant differences between levels A and B (16 FI and 20 FI) and between levels C and D (24 FI and 28 FI) for overall preference, texture preference and firmness intensity (Figures 6, 7, and 8). When A was compared to C and D, and B compared to C and D for overall preference, the firmer apples were significantly preferred (Figure 6). Panelists could discriminate firmer apples based on FI and preferred the texture of firmer apples (Figures 7 and 8).

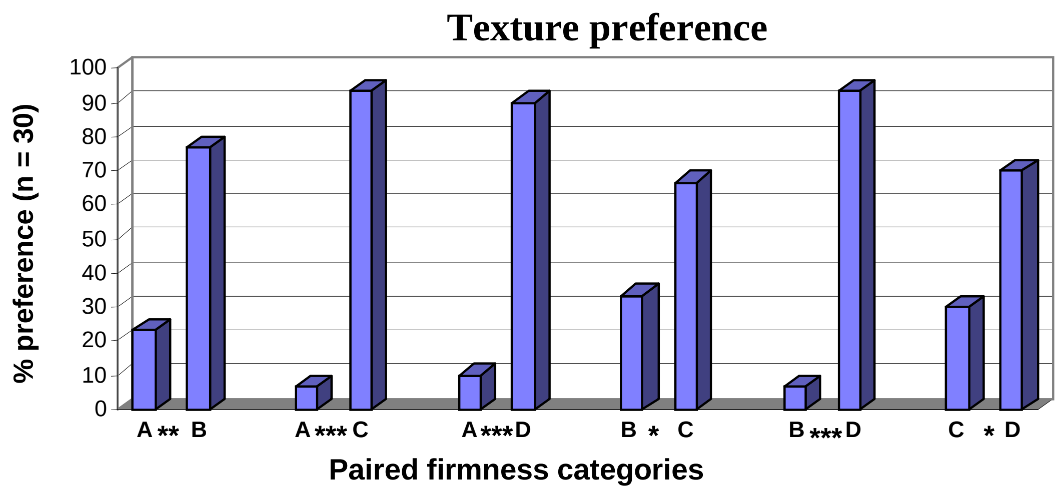


**Figure 4**. Paired comparison results for 'Red Delicious' apple: texture preference.

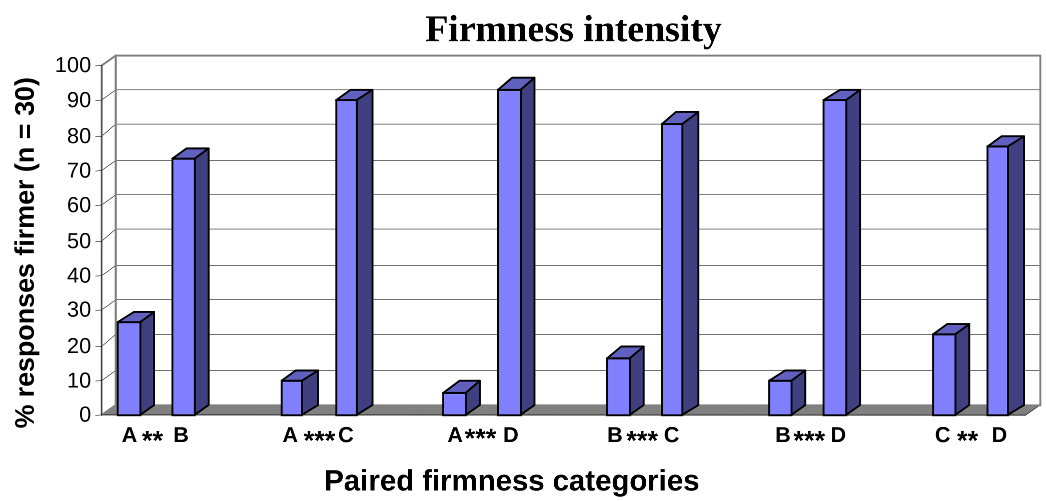


**Figure 5**. Paired comparison results for 'Red Delicious' apple: firmness intensity.

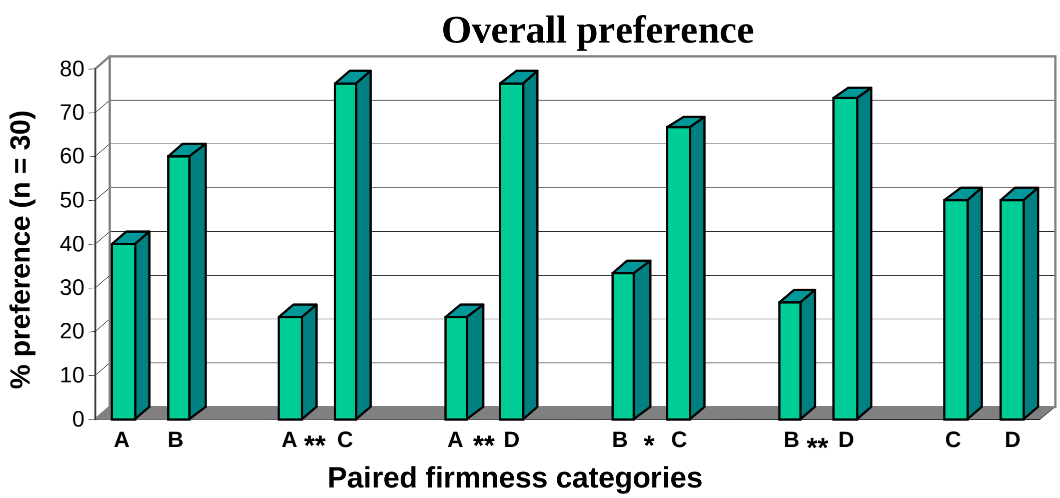


**Figure 6**. Paired comparison results for 'Golden Delicious' apple: overall preference.

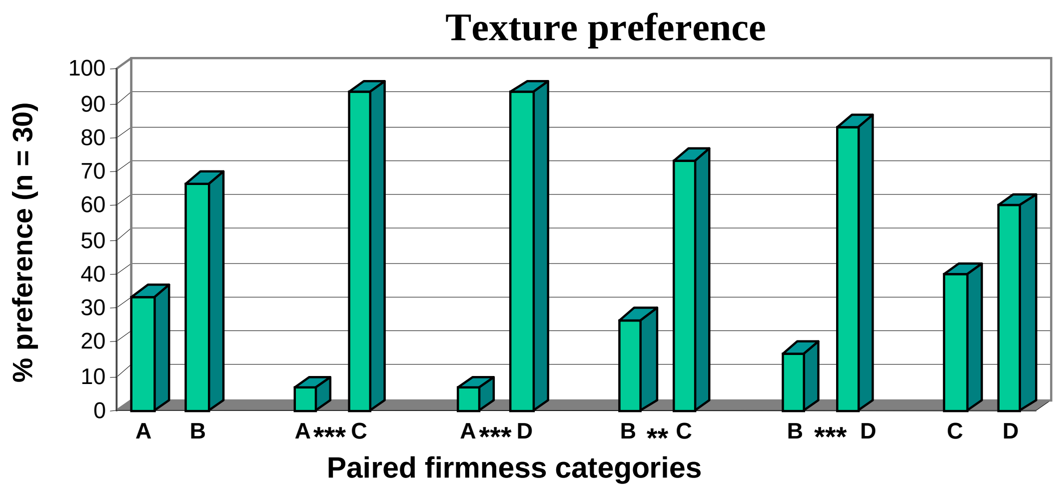


**Figure 7**. Paired comparison results for 'Golden Delicious' apple: texture preference.

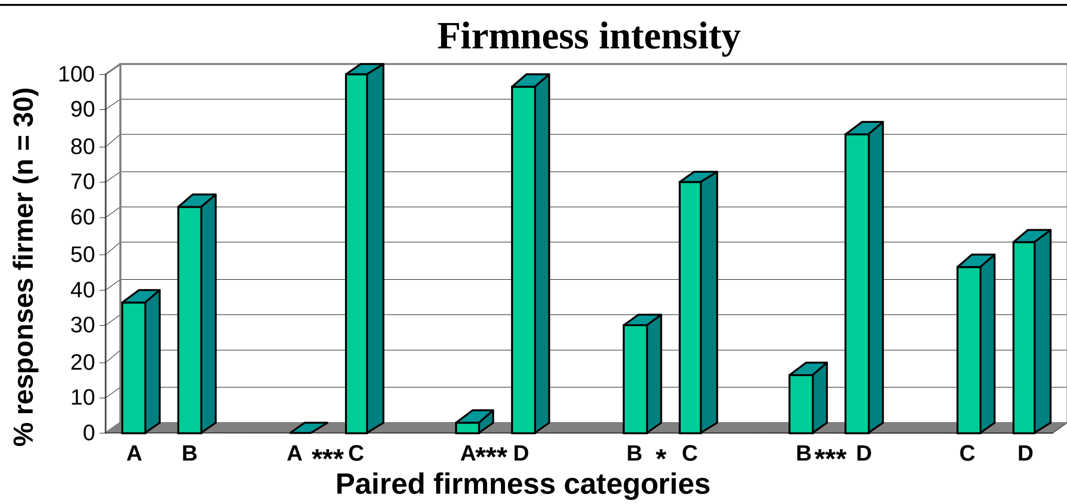


**Figure 8**. Paired comparison results for 'Golden Delicious' apple: firmness intensity.

***Firmness acceptance***

75% of the panelists rejected Red Delicious apples at 10 to 13 FI (level A), 44% rejected apples at 15 to 18 FI (level B) and 28% rejected apples at 20 to 23 FI (level C) (Figure 9). Overall, for Red Delicious, only apples above 25 FI were accepted.

Most of the Golden Delicious apples that were rejected for firmness belonged to the A and B levels of firmness, 16 FI and 20 FI respectively (Figure 10). Overall, apples with an FI value above 23 (C and D levels) had an acceptable firmness: 10% of C level (23 to 25 FI) and 4% of D level (27 to 29 FI) apples were rejected for firmness (Figure 10).

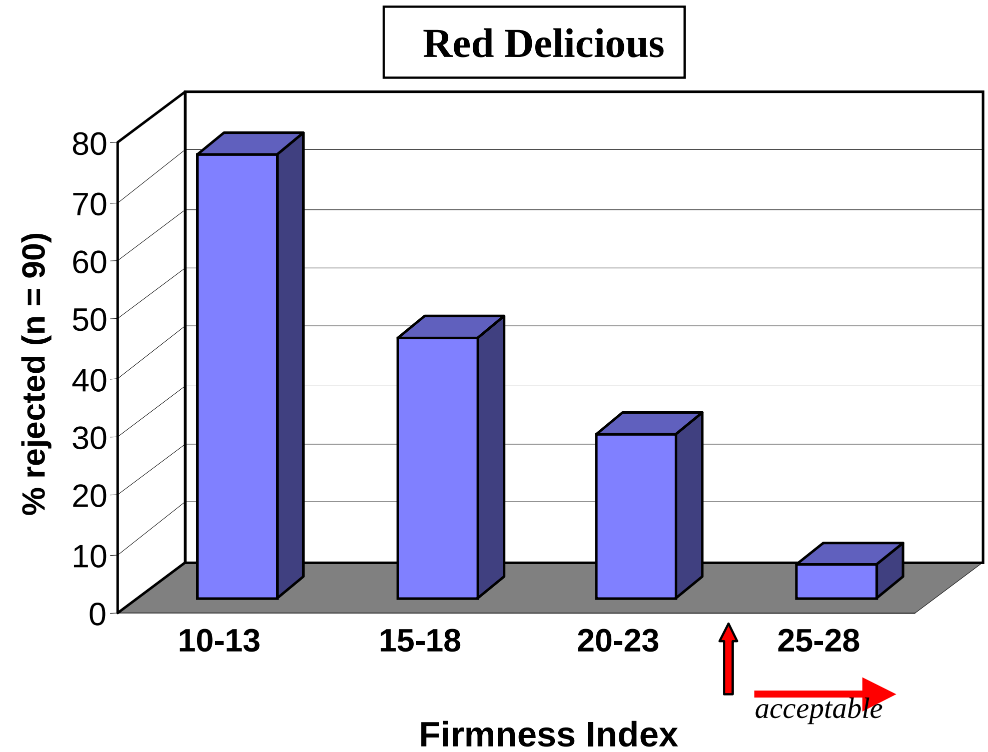


**Figure 9.** Firmness acceptance by firmness index as measured with acoustic device.

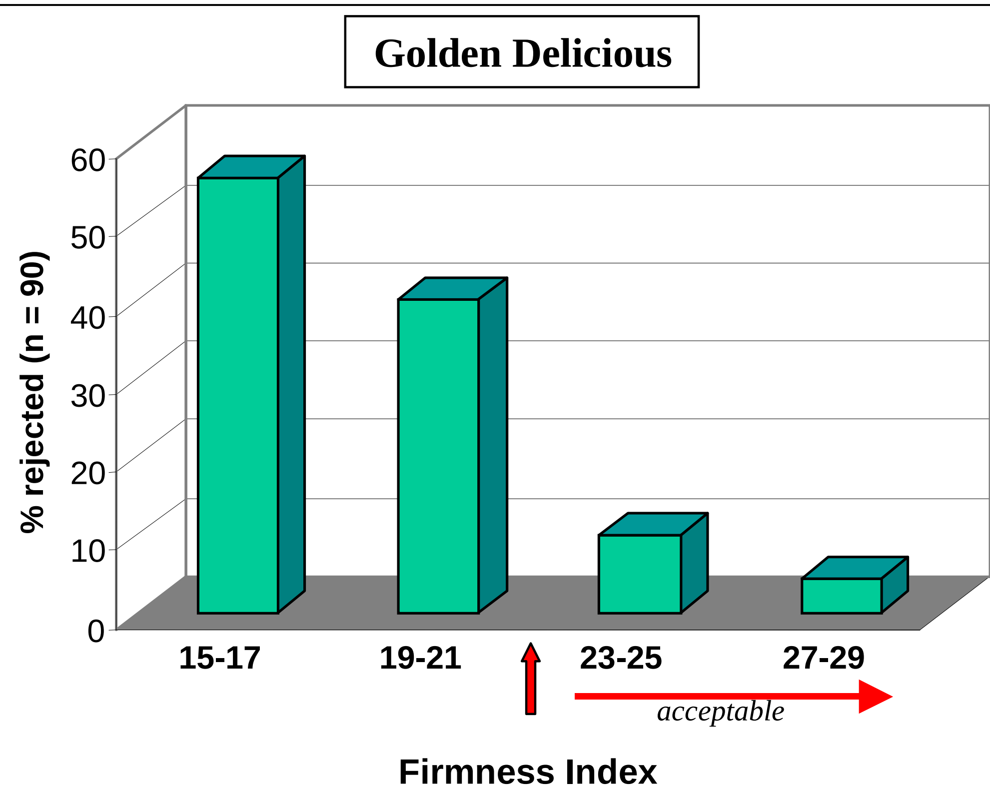


**Figure 10.** Firmness acceptance by firmness index as measured with acoustic device.

***Comparison between Golden and Red Delicious:***

Firmness grouping was defined by 3 units of FI values for Golden Delicious and 4 units of FI for Red Delicious. The wider range of firmness for Red Delicious might explain the better discrimination for firmness intensity between the different levels of firmness. It seems that the value of 23 to 25 FI was the minimum critical value for apple acceptance. 90% of Golden Delicious apples were accepted at 23 to 25 FI. Only 70% of Red Delicious apples were accepted at 20 to 23 FI, and more than 90% apples were accepted at 25 to 28 FI.

***Panelist comments:***

The most often used attribute for Red Delicious apples was “mushy”. Except the firmest apples (level D), all levels were qualified as mushy and not firm enough. Apples with the D level of firmness were generally preferred to the other samples. The flavor of apples with the A level of firmness was often liked. A few panelists mentioned that flavor was more important than taste for them, and some panelists did not like any of the apples presented to them.

For Golden Delicious, most of the comments were about contrasting taste with firmness. Panelists generally liked firm, crunchy apples with a sweet and slightly sour taste. Many panelists commented that the softest apples (levels A and B) had a better taste, more flavor and were sweeter than the firmer apples (level C and D), but had an unacceptable firmness. Overall, apples from the level C were preferred more often than level D apples (the firmest level) because they thought those apples had a good combination of flavor and texture. A few panelists liked the firmer apples regardless of the taste. Three panelists disliked apples from the firmest level because they were too hard. A few panelists also did not like any of the apples presented to them because they were not firm enough.

## CONCLUSIONS

Consumers could distinguish between levels of firmness as defined by the acoustic device. The difference was more obvious for Red Delicious apples that were classified by groups of 4 units of FI than for Golden Delicious apples grouped by units of 3 FI. Golden Delicious apple firmness was accepted at FI above 23, and Red Delicious apple firmness was accepted at FI above 25. In an earlier study, we found that Gala apples had an unacceptable texture below 22 FI. However, the texture of Fuji apples was rejected only below 16 FI. The questions asked to the panelists were not as direct for Gala and Fuji apples.

## REFERENCES

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