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Methodological development for sensory evaluation of product presenting biological variability: a case study on apple

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Introduction

- Assessment of the sensory qualities of fruits and vegetables is of major interest for growers, retailers and industries

- Development of adapted sensory methodologies in the 1970s and 1980s
  (Heintz and Kader, 1983; Stevens and Albright, 1980; Williams and Carter, 1977)

- Working with fresh plant material poses special problems:
  - Changes of the characteristics with time
  - Non availability of suitable reference samples
  - Heterogeneity/biological variability of the plant material

A Challenge

"Real variation within a given genotype may make differences among genotypes more difficult to detect"

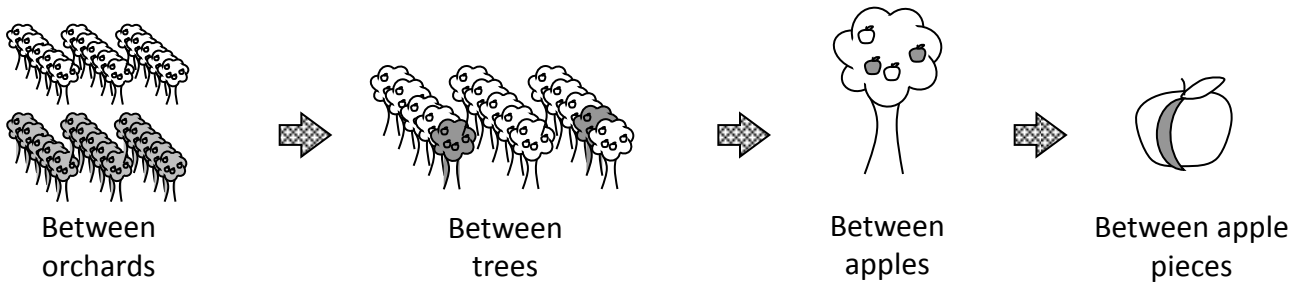
" One of the challenges in sensory evaluation of fruit is product variability "

Hampson et al., 2000

The heterogeneity of plant material in a commercial batch

- Difficulties still emphasised in fruits and vegetables studies
  (Allais and Létang, 2009; Azodanlou et al., 2003; Cetinkaya et al., 2006; Le Moigne et al., 2008; Lonchamp et al., 2009; Sousa et al., 2007)

- In studies on apples, related to variations in sensory properties within a cultivar and even within a piece of fruit
  (Dever et al., 1995; Hampson et al., 2000; Harker et al., 2003; Harker et al., 2005; Seppä et al., 2012; Symoneaux et al., 2002; Vaysse et al., 2006; Watada and Abbot, 1985)



- However, majority of sensory studies only deal with the assessor source of variation through the assessor effect and the product x assessor interaction term

Objectives

To observe fruit-to-fruit variability occurring within a commercial batch in sensory results

To compare 2 models of analysis of variance (ANOVA) taking the fruit-to-fruit variability into account or not

To recommend a methodology to get more reliable sensory results for products presenting variability

Data structure

- 19 assessors with 60 hours training
- 7 sensory attributes for texture and taste (the main drivers of preferences in apples (Daillant-Spinnler et al., 1996))
  - Crunchiness
  - Firmness
  - Crispness
  - Juiciness
  - Fondant
  - Acidity
  - Sweetness

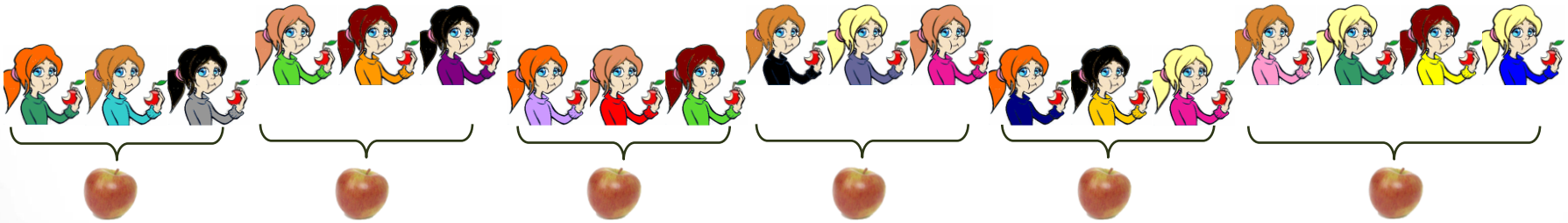
- 3 cultivars : Ariane, Braeburn and Pink Lady®



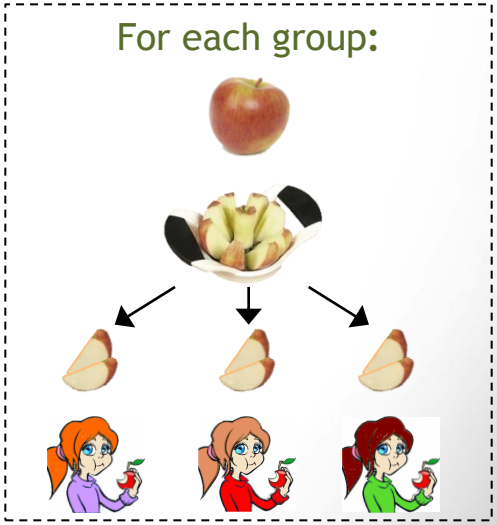
- 3 random replicates

Apples were shared by several assessors

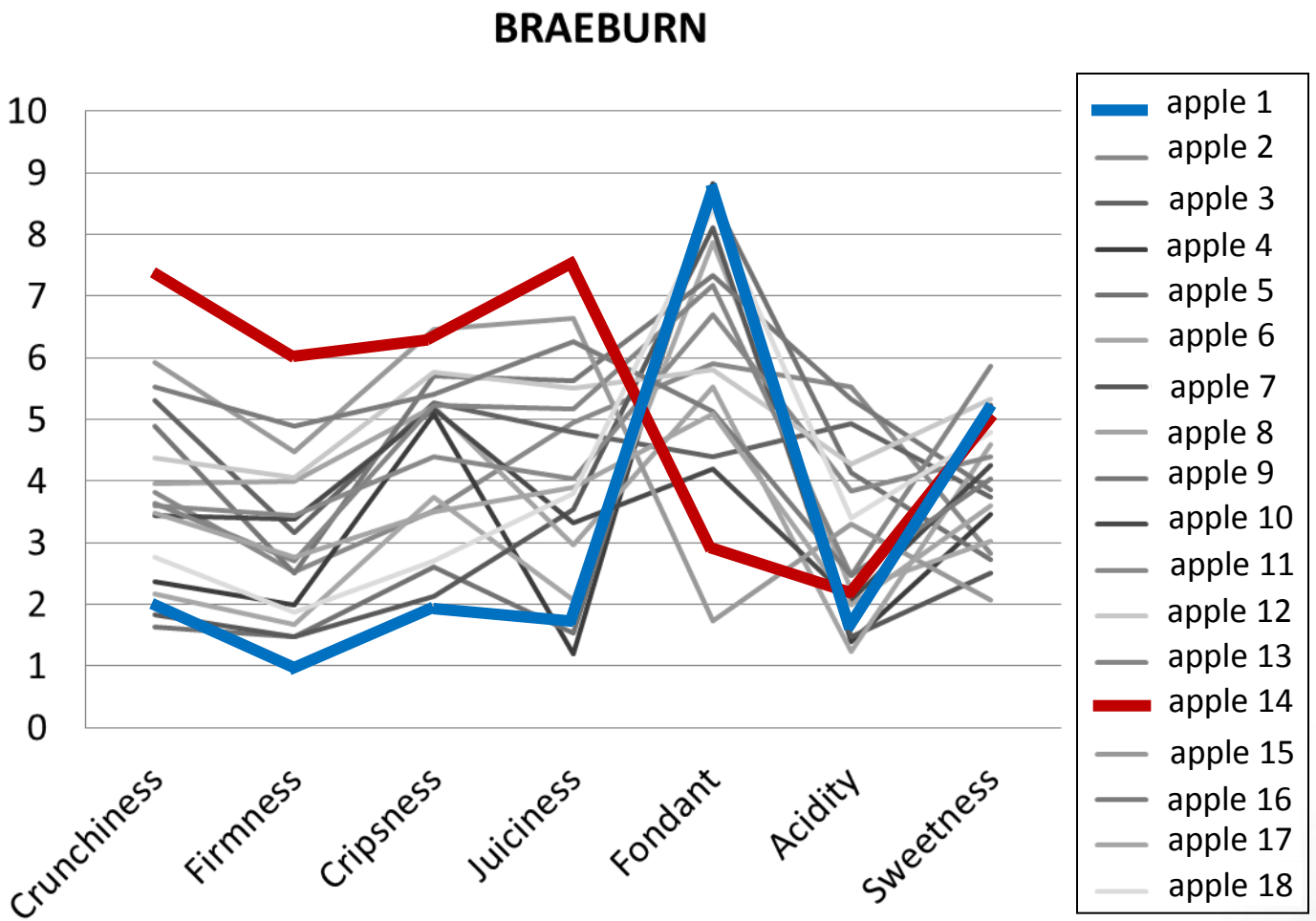
- To observe the fruit-to-fruit variability : apples were cut and several assessors (3-4) tasted the same apple
  - The panel was divided into 6 groups



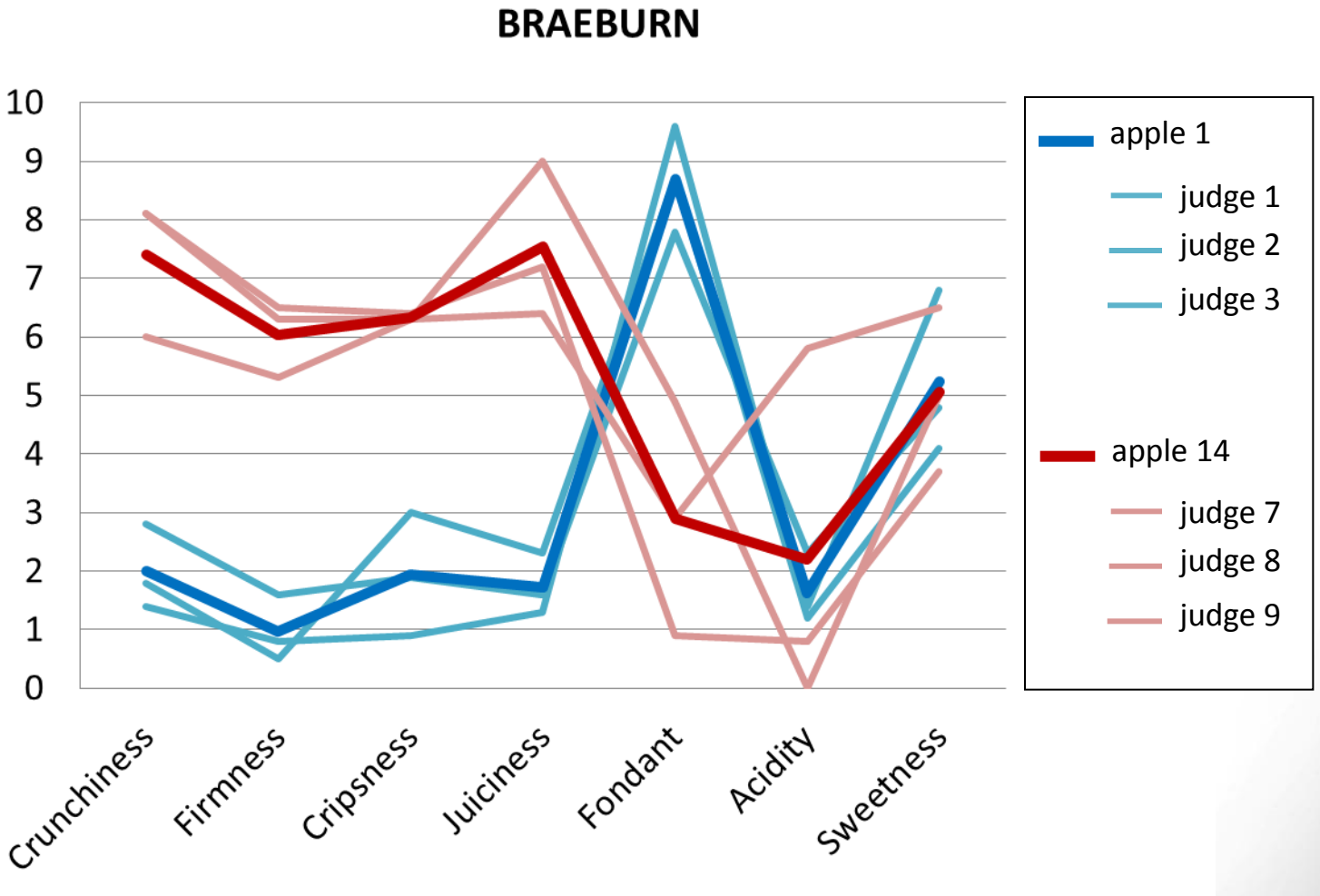
- X 3 replicates
- ➡ A total of 18 apples for each cultivar



Mean scores vary with the apples



Assessors who tasted the same apple agree



Accounting for fruit-to-fruit variability in data analysis

- Standard analysis : mixed model (Næs, Brockhoff & Tomic, 2010)

$$X_{ijk} = Cultivar_i + Assessor_j + Cultivar : Assessor_{ij} + \varepsilon_{ijk}$$

where ε_{ijk} *~N(0,* σ^2 *),* $Assessor_j$ *~N(0,* $\sigma^2_{Assessor}$ *) and* $Cultivar:Assessor_{ij}$ *~N(0,* $\sigma^2_{Cultivar:Assessor}$ *); all terms are independent*

- Mixed hierarchical model including fruit effect

$$X_{ijkl} = Cultivar_i + Assessor_j + Cultivar : Assessor_{ij} + \boldsymbol{Fruit}_{l(i)} + \varepsilon_{ijkl}$$

where ε_{ijlk} *~N(0,* σ^2 *),* $Assessor_j$ *~N(0,* $\sigma^2_{Assessor}$ *),* $Cultivar:Assessor_{ij}$ *~N(0,* $\sigma^2_{Cultivar:Assessor}$ *) and* $Fruit_{l(i)}$ *~N(0,* σ^2_{Fruit} *) ; all terms are independent*

Accounting for fruit-to-fruit variability in data analysis

- Mean Squares (MS) : to observe changes in MS distribution when fruit is added

$$MS = \frac{(x_{i\ldots} - \bar{x}_{\ldots})^2}{I - 1}$$

- Contribution to variance : to evaluate the part of variability of each factor

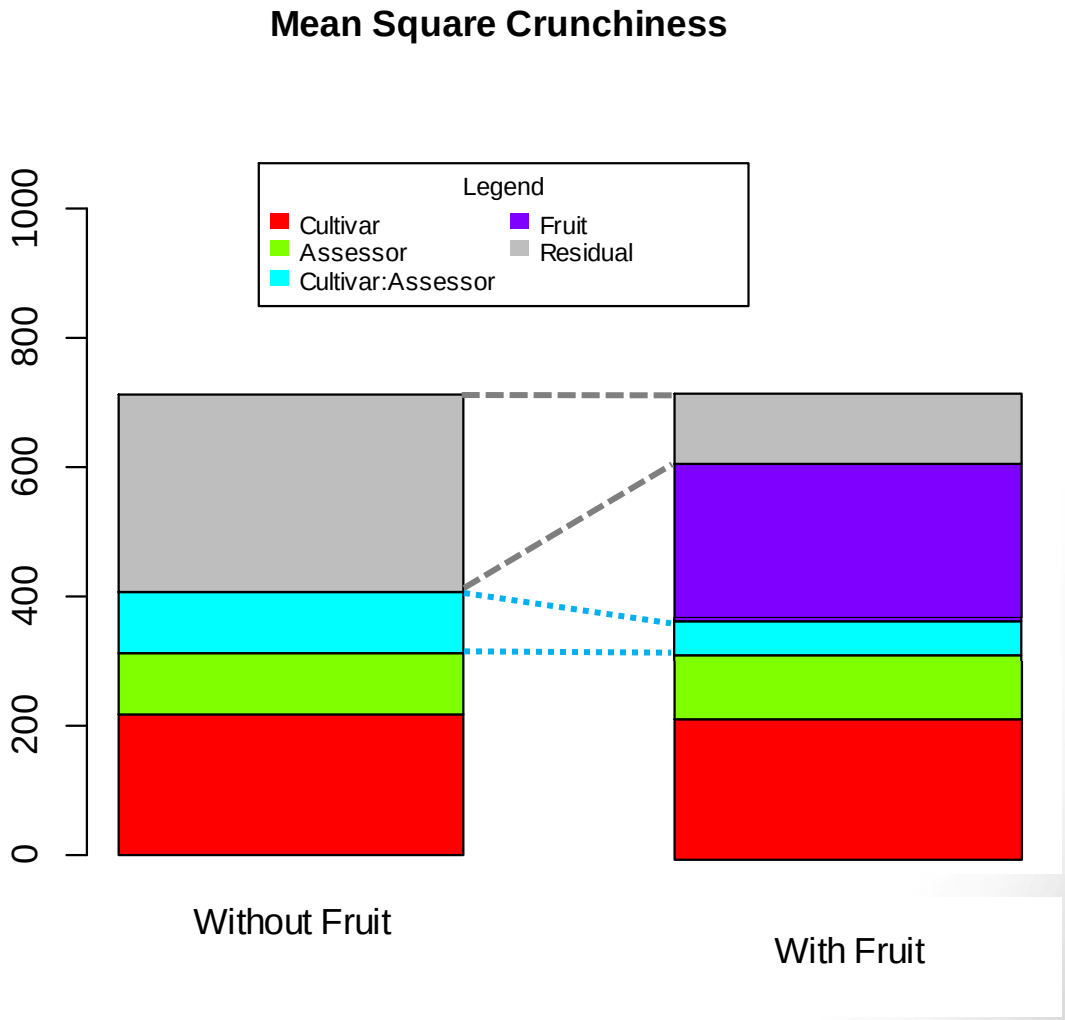
$$Contribution\ to\ variance = \frac{Variance\ component_k}{\sum_k Variance\ component_k}$$

- Discrimination between cultivars (*p*-values of cultivar effect)

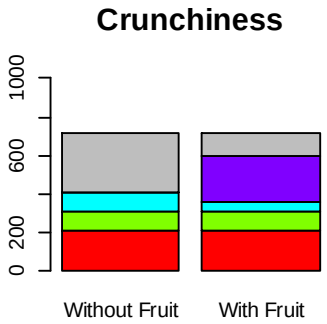
- Analysis were done with the lmerTest package (Kuznetsova, Brockhoff & Christensen) - R software, version 2.14.2

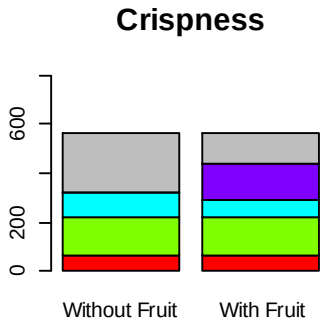
Decrease of the interaction term MS and the residual MS

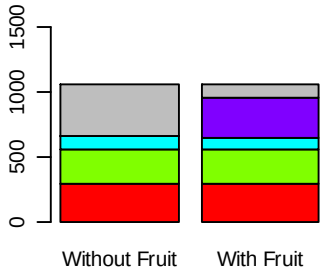
- Adding fruit effect implies
  - A decrease of Cultivar : Assessor interaction MS
  - A decrease of Residual MS

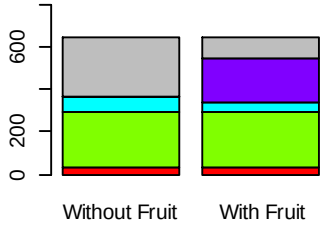


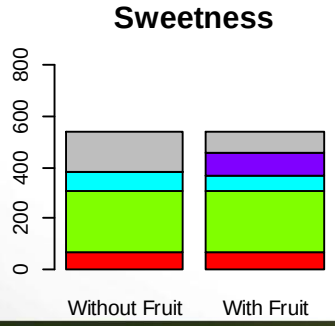
Decrease of the interaction term MS and the residual MS



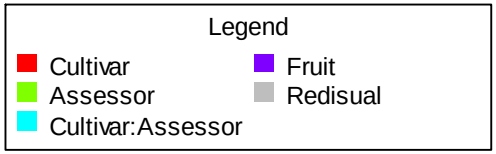




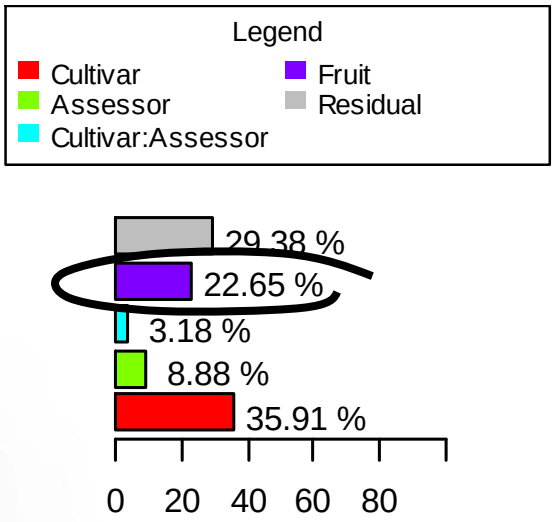


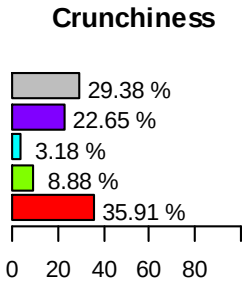


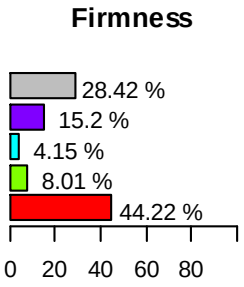
Comparison of mean squares with and without fruit effect

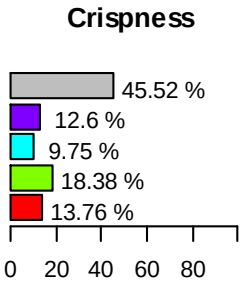


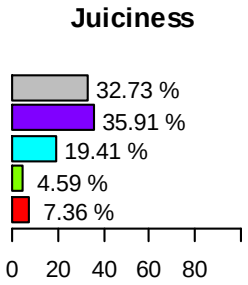
A large contribution of the fruit

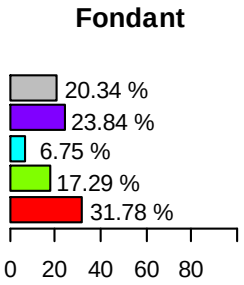


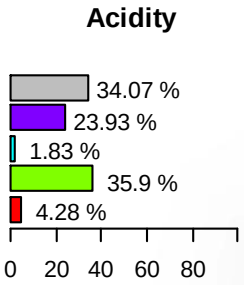




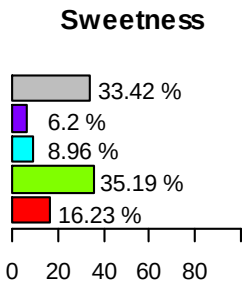


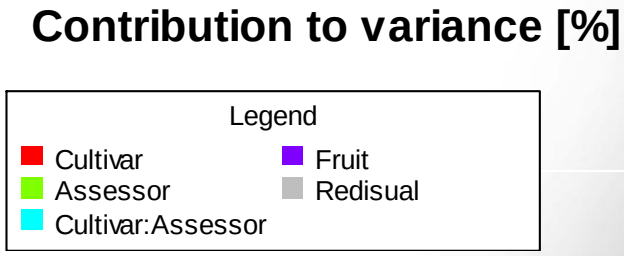






- The fruit contribution is large
- Except for Sweetness
  - Large assessor contribution

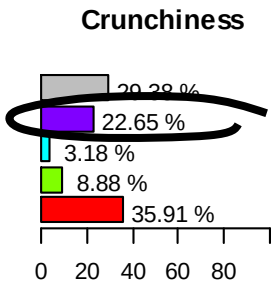


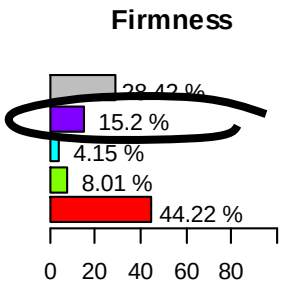


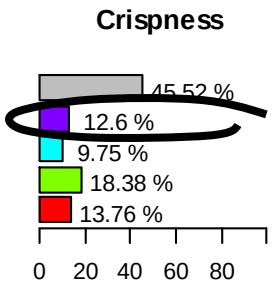
A large contribution of the fruit

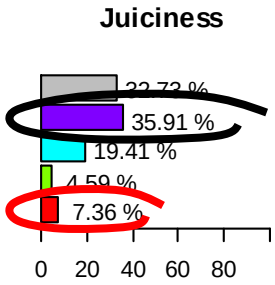
- The fruit contribution is
  - Larger than the Assessor contribution and Cultivar : Assessor contribution for Crunchiness, Firmness, Juiciness and Fondant
  - At least larger than Assessor contribution for Crispness and Acidity
  - Larger than Cultivar effect for Juiciness and Acidity

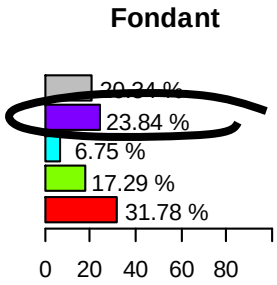
➡ Real variation within a given cultivar may make differences among cultivars more difficult to detect

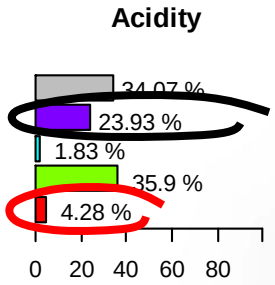


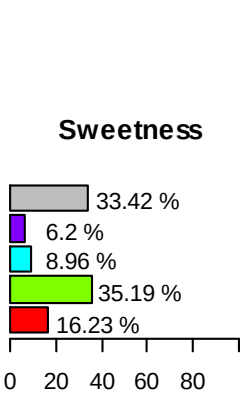


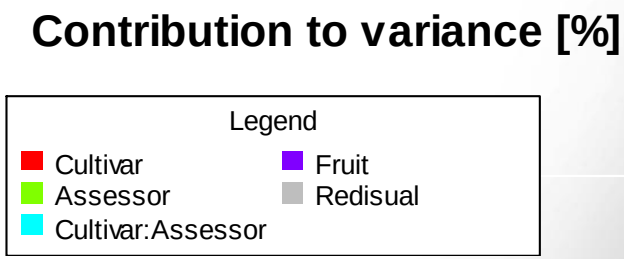












The inclusion of fruit effect may change the conclusions

Standard analysis : mixed model

Significance levels for the sensory evaluation of the three apple cultivars

	Crunchiness	Firmness	Crispness	Juiciness	Fondant	Acidity	Sweetness
Cultivar	0.000***	0.000***	0.000***	0.001***	0.000***	0.003***	0.000***
Assessor	0.028	0.001	0.000	0.380	0.000	0.000	0.000
Cultivar:Assessor	0.999	1.000	0.304	0.053	0.996	1.000	0.185

Mixed hierarchical model including fruit effect

Significance levels for the sensory evaluation of the three apple cultivars

	Crunchiness	Firmness	Crispness	Juiciness	Fondant	Acidity	Sweetness
Cultivar	0.000***	0.000***	0.000***	0.065 NS	0.000***	0.047 *	0.000***
Assessor	0.000	0.000	0.000	0.382	0.000	0.000	0.000
Cultivar:Assessor	0.409	0.274	0.118	0.000	0.026	0.711	0.185
Fruit	0.000	0.001	0.065	0.000	0.000	0.000	0.137

Conclusion

- The fruit-to-fruit variability is an important characteristic of a batch
- Adding the fruit effect in the analysis makes sense
- Adding the fruit effect in the analysis can imply changes in conclusions
  - E.g. erroneous conclusion about the improvement of a product
- Recommendations
  - Collecting data : Each piece of fruit should be shared by several assessors
  - Analysing data : Hierarchical mixed ANOVA including fruit effect should be applied
- Perspective
  - Mixed Assessor Model

Thank you for your attention

Special thanks to the panelists,
Corinne Patron and
Isabel Saillard