The relationship between total phenolic concentration and the perceived style of extra virgin olive oil

Richard Gawel [1,*] and **Deborah A. G. Rogers** [2]

[1] Recognose Pty Ltd, PO Box 487 Unley, South Australia, Australia, 5061

[2] The Olive Press, 24724 Arnold Drive, Sonoma, CA, USA, 95476

[*] Corresponding Author Richard Gawel, email: rg@aromadictionary.com

This is the authors version. A full text version can be found at:

http://grasasyaceites.revistas.csic.es/index.php/grasasyaceites/article/view/560/574

SUMMARY

The relationship between total phenolic concentration and the perceived style of extra virgin olive oil

The degree of bitterness and pungency of a virgin olive oil largely defines its style, and therefore how it is most appropriately used by consumers. In order to assess how Australian olive oil producers interpret the style of their oils, 920 Australian virgin olive oils were classified by their producers as either being mild, medium or robust in style. Although in general, the classifications by producers were associated with the oils' total phenolic concentration, significant variability in phenolic concentration within each style category was observed. The perceived styles of a subset of these oils were further assessed by panels of expert tasters. The expert panels were more discriminating when assigning oils to style categories based on total phenolic levels. The producers and the expert panels were in moderate agreement with respect to oil style, with the interpretation of what constitutes a mild oil being the most contentious.

KEYWORDS: olive oil style, phenolics, taster agreement

1. INTRODUCTION

Virgin olive oil (VOO) is the only edible fat that is naturally both flavoursome and rich in phenolics. A substantial body of evidence now exists that the VOO phenolics confer anti-inflammatory and antioxidant activity which protects against cardiovascular disease and some cancers (reviewed in Tripoli *et al.,* 2005). Nowadays, many health conscious consumers are aware of the perceived health benefits of VOO, and for this reason, they prefer them to other edible fats. If olive oil producers believe that consumers consider 'perceived healthfulness' to be the primary quality attribute of VOO, then it follows that they should attempt to maximise their oil's phenolic level by applying appropriate olive growing and extraction practices.

However, the concentration of phenolics in olive oil also fundamentally affects its taste by contributing to its overall bitterness and pungency (Guitierrez *et al*., 1989; Andrewes *et al*.; 2003). The level of these taste attributes in a VOO in turn determines how it is best used (Cerretani *et al*., 2007). For example, intensely bitter and pungent VOO's are best suited to preparing strongly flavoured foods, while those low in bitterness and pungency best complement delicately flavoured foods. Presumably this is because intensely

bitter olive oils can overpower the flavour nuances of lightly flavoured foods, and conversely, the character contributed by an oil low in bitterness and pungency will be largely inconsequential to an intensely flavoured food.

With this differentiation in mind, Australian VOO producers commonly use a simple style classification system which relates specifically to the combined level of bitterness and pungency displayed by the oil. VOO's are classified as being 'mild', 'medium' or 'robust' depending on whether they are perceived to have a low, medium or high combined level of bitterness and pungency. Before a producer can make recommendations as to how their oil can be most appropriately used in the kitchen they must be able to interpret its style. Such decisions about style take on commercial significance as consumer perceptions of product quality could be jeopardised if incorrect usage recommendations are made by the producer. This work investigates the relationship between total phenolic concentration of extra virgin olive oil and the interpretation of their style by olive oil producers and expert olive oil tasters.

2. METHODS AND MATERIALS

2.1. Sensory Style Determination

Data for this study were collected from producers presenting their current season extra virgin olive oils at the annual Royal Perth (n=387) and Australian National (n=533) Extra Virgin Olive Oil Competitions from 2005 to 2007. Producers exhibiting their oils in each competition were requested to indicate at the time of entry whether, in their opinion, the oils were 'mild', 'medium' or 'robust' in style. The exhibitors were guided in their assessment by a broad definition of style which was provided on the entry form. The mild, medium and robust styles were defined as "those displaying a low, medium and high level of bitterness and/or pungency respectively".

In addition, for the oils exhibited in the Royal Perth Show, panels of three experienced oil judges were given a set of 25 oils and were asked to arrive at a consensus view as to which style class each oil belonged. All the judges were formally trained in olive oil tasting methods including the assessment of bitterness and pungency intensity, had between 5 and 7 years of oil show judging experience, and had tasted oils regularly in a professional capacity.

2.2. Phenolic Concentration

The total phenolic levels were determined within a fortnight of being judged. 10 g of oil was dissolved in 50ml of hexane and extracted three times with 80% aqueous methanol. The extract was then made up to 100ml with water and left to stand overnight. 5 mls of water and 0.5 mls of Folin–Ciocalteau reagent were added to a 1 ml aliquot of the extract and shaken and left to stand for 3 minutes. 1 ml of saturated Na_2CO_3 was then added and shaken before standing for 1h at room temperature. The absorption was read at 725 nm using a UV spectrophotometer, and calibrated with the absorbance of caffeic acid prepared in the same way resulting in concentrations given as mg total phenolics/kg oil expressed as caffeic acid equivalents.

2.3. Statistical Analysis

Style class membership as determined by the olive oil producers was related to total phenolics using binary discrete choice modeling using a logit function. Agreement between producers and expert panels with respect to olive oil style was assessed using Cohen's weighted □ (Cohen, 1968) with weightings of 0.8 and 0.2 for situations where the experts disagreed with the producers on one (mild-medium and medium-robust) or two (mild-robust) style categories respectively. Differences in the mean phenolic level attributed to different style categories by the producers were determined using a one sample t test.

A significance level of 5% was used throughout. All statistical analyses other than Cohen's weighted □ were conducted using MINITAB 14.0 (Minitab Inc, State College, PA, USA). The weighted □ statistic and confidence interval were calculated using a Microsoft Excel routine.

3. RESULTS AND DISCUSSION

3.1. Producer assessment of style and phenolic concentration

Figure 1 shows the distribution of phenolic concentrations for olive oils classified by their producers as either being mild, medium or robust in style. The mean phenolic level of oils classified by producers as being robust (mean=299, se=7.3) were significantly higher ($p<0.001$) than those classified as medium (mean=235, se=4.0), which in turn were significantly higher ($p<0.001$) than those classified as being mild in style (mean=182, se=7.2). This strongly indicates that the phenolic concentration in the olive oils influenced the style as perceived by producers. Given that perceived bitterness and pungency has been shown by others to strongly correlate with total phenolic concentration (Beltrán *et al.,* 2007; Siliani *et al.,* 2006), this suggests that these two attributes are major determinants of olive oil style as perceived by Australian olive oil producers.

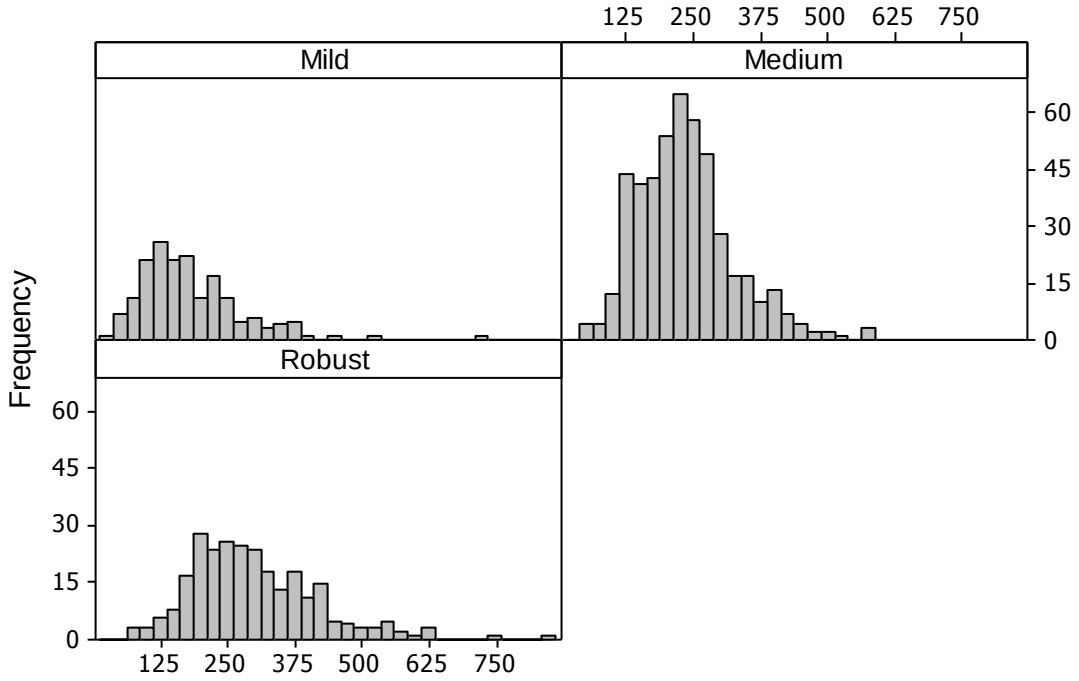

Figure 1: Distribution of phenolic concentration classified by producers as mild, medium or robust(n=920)

A significant overlap in the phenolic distributions between the different style categories was observed (Figure 1). This may have been due to a number of factors. Firstly, as the oils were sourced from climatically diverse regions, it is likely they would have displayed different fatty acid profiles, a factor which has recently been shown to influence the perception of olive oil bitterness and pungency (Garcia-Mesa *et al.,* 2008). However, it is likely that variations in the oil matrix would have had only a minor influence on perceived style given the reported size of this effect.

On the other hand physiological differences between individuals would have likely played a far greater role in taster perception of oil style. Large variations between individuals have been observed in their perception of bitter tastes. Delwiche *et al.* (2001) for example, reported between-subject differences in the perceived suprathreshold intensities of a variety of chemically diverse bitter compounds of up to two orders of magnitude. Furthermore, individuals vary substantially in their relative sensitivities to different bitter stimuli (Delwiche *et al.,* 2001; Yokomukai *et al.,* 1993). Every extra virgin olive oil contains a unique mix of different phenolic species, with each species eliciting different degrees of bitterness and pungency (Gutiearrez-Rosales *et al.,* 2003; Andrewes *et al.,* 2003). Therefore individual differences in bitterness perception could in part explain the observation that oils with widely different phenolic levels were

classified into the same style class by different individuals. Furthermore, as the producers assessed the style of their oil based on the combined percept of bitterness and pungency, it is likely that differences existed between individuals with respect to how they internally summed the intensities of the two percepts in arriving at an overall style classification.

3.2. Agreement between olive oil producers and experts

The agreement between the producers of the olive oils and the expert panels with respect to stylistic interpretation is given in Table 1. The judging panels agreed with the producers in their assessment of style in the majority (55.6%) of cases, and only strongly disagreed (mild versus robust) with the producers assessment in only 23 cases (5.9%). Cohen's weighted □ was 0.426, while being highly statistically significant ($p<0.001$) suggests that the agreement between producers and experts was only moderate (using the criteria of Landis and Koch, 1977).

Table 1: Agreement between expert panels and producers regarding olive oil style.

Producers Style Assessment	**Expert Panel's Style Assessment**			
	Mild	**Medium**	**Robust**	**Total**
Mild	36 (110, 6)	25 (203, 12)	7 (361, 17)	68 (170, 11)
Medium	40 (124, 6)	109 (223, 6)	45 (325, 12)	194 (226, 7)
Robust	16 (173, 13)	49 (237, 11)	60 (367, 14)	125 (291, 11)
Total	92 (127, 5)	183 (223, 5)	112 (350, 9)	387

Means and standard errors or total phenol concentrations of each category given in parenthesis.

Disagreement between producers and experts was most pronounced when interpreting the mild category, with producers concurring with the experts in only 37% of cases. The mean phenolic level of oils classified by the expert panels as being mild (127 mg/kg) was significantly lower than the mean phenolic level of oils considered to be mild by the producers (170 mg/kg) ($p<0.001$) again suggesting that the producers in general were less likely to classify their oils as being mild compared with the experts.

Sinesio *et al.* (2005) showed that both bitterness and pungency decreased with storage duration which may explain the greater propensity of the expert panels to classify the oils as mild, as they tasted the oils after the producers made their assessment. However, this is unlikely to have been a major influence as the maximum time difference between when a producer may have assessed the style and the judge would be approximately 4 months (i.e the maximum time between harvest and when the oils were judged). Di Giovacchino *et al.* (2002) found that even under poor storage conditions (unlike those experienced by the oils assessed in this study), the phenolic concentration of unopened bottles of two types of EV olive oil declined over a 5 month period by only around 7%, a result if replicated here, would be insufficient to explain the level of disagreement between producers and experts as to the interpretation of what constitutes a mild oil.

It is worth noting that the context in which producers and experts assessed style was different. The experts were presented with a set of 25 olive oils in a single session. They were then asked to arrive at a consensus opinion as to the style of each of the oils. That is, in the experts' circumstance, the set of oils acted as their own frame of reference which allowed the panels to compare and contrast the bitterness and pungency of the oils being presented. On the other hand, the producers did not have comparative benchmarks available

when they arrived at a style classification for their oil. The experts therefore may have been subject to the range effect (Parducci, 1965) whereby tasters given a large set of samples have the natural propensity to spread their ratings across the entire range (mild through robust) particularly when there would have been an expectation that samples of different styles would be presented to them. The producers on the other hand would not have been subjected to these effects due to their 'point' classification of one, or (at most) a small number of oils. Some producers may have also avoided designating their oils as mild as they may have felt that this may have connotations of lower quality and potentially shorter shelf life. However, this possibility was not investigated in this study.

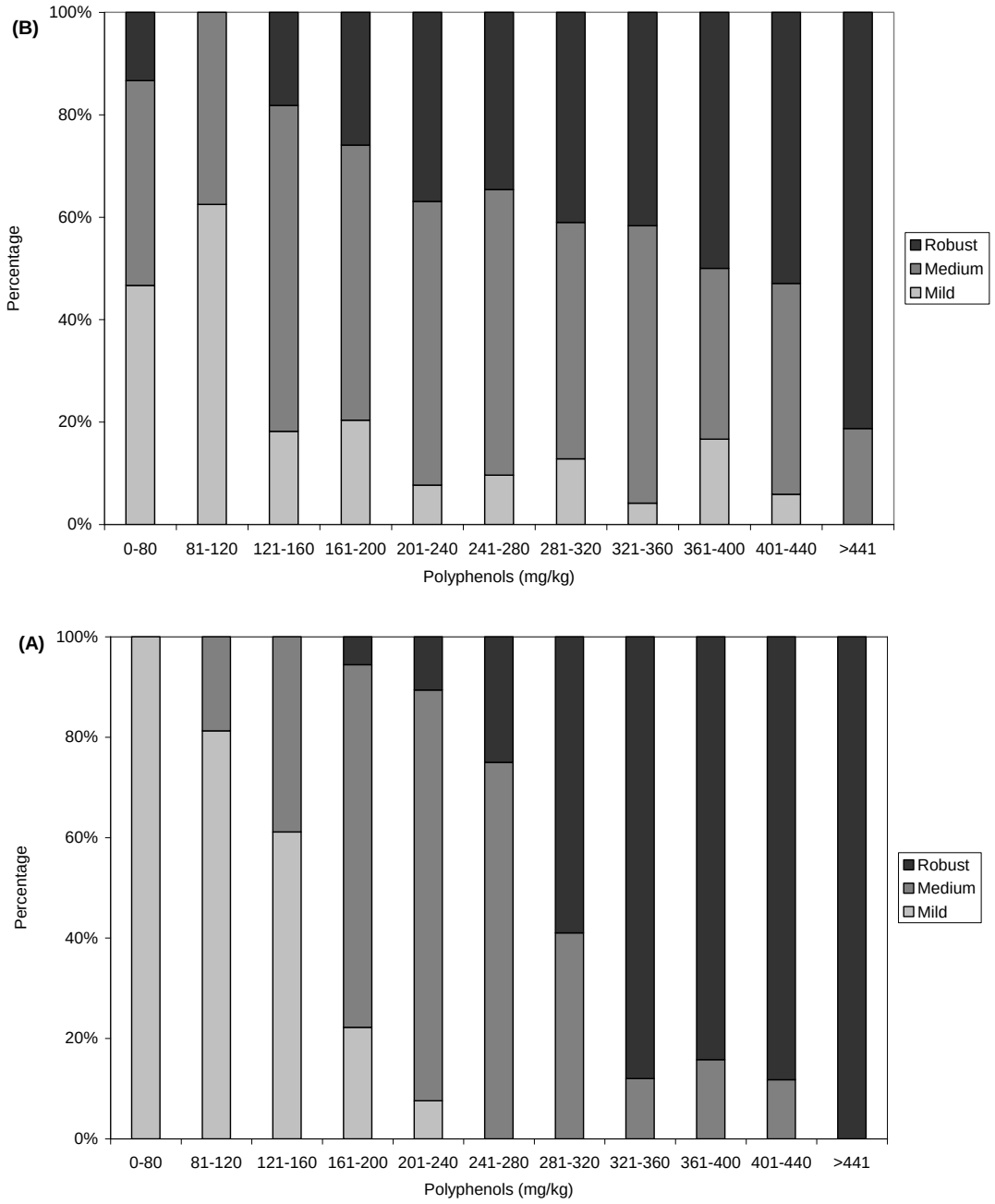

Figure 2: : Proportion of VOO's classified as being mild, medium or robust in style as a function of their total phenolic concentration: (A) Expert panels: (B) Producers (n = 387).

The experts were more definitive in their style classification than were the producers. Fore example, Figure 2 shows that unlike the producers, the expert panels classed all the oils in the lowest 5% total phenolics (under 80 mg/kg) as mild, and all oils in the top 5% (above 440 mg/kg) as robust. Furthermore, the change in the proportion of oils being classified as a function of phenolic level was steeper for the expert panels suggesting that their opinions regarding style were more strongly influenced by changes in phenolic level. This was supported by the significantly higher discriminant function coefficients for the experts as compared with producers suggesting that the expert panels were more discriminating when assessing style based on phenolic level (Table 2). The expert panels may have been more discriminating either because of their greater experience in both assessing the intensity of bitterness and pungency and equating that intensity to a particular style, or because they arrived at a conclusion regarding style by panel consensus rather than an individual opinion. Consensus evaluation by panels of three expert wine judges has recently been shown to result in greater consistency when categorising red wine on the basis of overall quality (Gawel and Godden, 2008).

Table 2: Binary logistic regression coefficients (x 10^{-3}) of style classification modeled on total phenols.

	Producers	**Expert Panels**	**p**
Mild vs (Medium + Robust)	9.96	39.02	<0.001
Robust vs (Mild + Medium)	7.20	23.70	<0.001
Mild vs Robust	13.03	51.89	<0.001

4. CONCLUSIONS

VOO is unique amongst all edible oils. While other edible oils are chosen primarily on their ability to transfer heat during cooking without excessive smoking, VOO is a flavoursome ingredient which has the potential to complement the aroma and taste of food. Whether the dish will be improved by the use of any particular VOO depends on its freshness and on whether the oil is of an appropriate style. These results suggest that a significant degree of variability exists between Australian producers with respect to their interpretation of VOO style. In some cases this could conceivably lead to inappropriate recommendations being made as to the best use of the product. In particular, the apparent reluctance by some producers to classify their oils as mild, may lead some of their customers to unreasonably expect that the oil will have a significant taste impact on their food. Before deciding on the appropriate style of their oil, producers should consider both the opinions of other experienced tasters, and also the results of analytical measures relating to overall bitterness and pungency such as total phenolic concentration. By doing so, they are likely to enhance their ability to consistently interpret the style of their oil, and as a result should be in a position to give better advice to consumers as to how their oils are best used.

ACKNOWLEDGEMENT
The authors thank the Australian Olive Association and the Western Australian Olive Council Inc for freely contributing the data reporting olive oil style and phenolic level.

REFERENCES

Andrewes P, Busch JLHC, De Joode T, Groenewegen A, Alexandre H. 2003. Sensory properties of virgin olive oil phenols: Identification of deacetoxy-ligstroside aglycon as a key contributor to pungency. *J. Agr. Food Chem*. **51**, 1415-1420

Beltrán G, Ruano MT, Jiménez A, Uceda M, Aguilera MP. 2007. Evaluation of virgin olive oil bitterness by total phenol content analysis. *Eur. J. Lipid Sci. Tech*. **108**, 193-197.

Cerretani L, Biasini G, Bonoli-Carbognin M, Bendini A. 2007. Harmony of virgin olive oil and food pairing: A methodological proposal. *J. Sens. Stud*. **22**, 403-416.

Cohen JA. 1968 Weighted kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. *Psychol. Bull*. **70**, 213–220.

Delwiche JF, Buletic Z, Breslin PAS. 2001. Covariation in individuals'sensitivities to bitter compounds: Evidence supporting multiple receptor/transduction mechanisms. *Percept. Psychophys*. **63**, 761-776.

Di Giovacchino L, Mucciarella MR, Costantini N, Ferrante ML, Surricchio G. 2002. Use of Nitrogen to improve stability of virgin olive oil during storage. *JAOCS* **79**, 339-344.

Garcia-Mesa JA, Pereira-Caro G, Fernandez-Hernandez A, Civantos CGO, Mateos R. 2008. Influence of lipid matrix in the bitterness perception of virgin olive oil. *Food Qual. Prefer*. **19**, 421-430.

Gawel R, Godden PG. 2008. Evaluation of the consistency of wine quality assessments from expert wine tasters**.** *Aust. J. Grape Wine R*. **14**, 1-8.

Gutierrez F, Albi MA, Palma R, Rios JJ, Olias JM. 1989. Bitter taste of virgin olive oil: Correlation of sensory evaluation and instrumental HPLC analysis. *J. Food Sci*. **54**, 68-70.

Gutierrez-Rosales F, Riaos JJ, Goamez-Rey MA. 2003. Main phenols in the bitter taste of virgin olive oil. Structural confirmation by on-line high-performance liquid chromatography electrospray ionization mass spectrometry. *J.Agr. Food Chem*. **51**, 6021-6025.

Landis JR, Koch G. 1977. The measurement of observer agreement for categorical data. *Biometrics* **33**, 159–174.

Parducci A. 1965. Category judgment: A range-frequency model. *Psychol. Rev*. **72**, 407–418.

Siliani S, Mattei A, Benevieri LB, Innocenti B, Zanoni B. 2006. Bitter taste and phenolic compounds in extra virgin olive oil: an empirical relationship. *J. Food Quality* **29**, 431-441.

Sinesio F, Moneta E, Esti M. 2005. The dynamic sensory evaluation of bitterness and pungency in virgin olive oil. *Food Qual. Prefer*. **16**, 557-564.

Tripoli E, Giammanco M, Tabacchi G, Di Mago D, Giammanco S, La Guardia M. 2005. The phenolic compounds of olive oil: structure, biological activity and beneficial effects on human health. *Nutr. Res.Rev*. **18**, 98-112.

Yokomukai Y, Cowart BJ, Beauchamp GK. 1993. Individual differences in sensitivity to bitter-tasting substances. *Chem. Senses* **18**, 669-681.