PAPER

RELATIONSHIP BETWEEN SENSORY RESULTS AND COMPLIANCE SCORES IN GRATED PARMIGIANO-REGGIANO CHEESE

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ABSTRACT

The regulations for Protected Designation of Origin require a certification body to verify compliance with the provisions of the product specification. The grated Parmigiano-Reggiano is evaluated with a scorecard containing 21 quantitative descriptors and 4 qualitative evaluations of compliance with the regulations. To better understand the relationship between sensory compliance and quantitative descriptors we have tested 24 samples of grated Parmigiano-Reggiano. Correlations and Partial Least Squares gave us a better understanding of compliance evaluation. The work allowed us to define the most important descriptors in relationship with compliance and showed that it is possible to predict compliance values using descriptor values.

- Keywords: sensory analysis, Parmigiano-Reggiano, grated cheese, compliance score -

INTRODUCTION

Worldwide the generic term used to describe products attributed to a defined region is products with a Geographic Indication (GI) as for example Darjeeling tea in India, Tequila spirit in Mexico or Napa Valley wines in USA. Within the European Union (EU), Protected Geographical Indication (PGI) is applied to products whose characteristics originate mainly, but not exclusively, from a particular region (e.g. Scottish farmed salmon, Bayonne ham, Turron de Alicante), whereas Protected Designation of Origin (PDO) have proven characteristics resulting solely from the region of production (i.e. Parma Ham, Isigny butter, Valencia rice). Cheese is the most important PDO product.

The European regulations on quality schemes for agricultural products and foodstuffs number 2081 of 1992, number 506 of 2006 and the latest number 1151 of 2012 provide for product specifications to include organoleptic characteristics. In the EU database DOOR, the so called "single document" for each PGI and PDO product gives general information about the characteristics of the product and it's processing (EUROPEAN COMMISSION DOOR, 2013). These regulations require a certification body to verify compliance with the provisions of the product specification (OFFICIAL JOURNAL OF THE EUROPEAN UNION, 2012). Since an organoleptic specification is included in the product description, compliance indicates agreement with the registered specification.

Testing for compliance with the registered organoleptic specification is different from sensory quality control. The latter is less demanding since production conditions are tightly controlled within a food processing plant and consequently food attributes are relatively stable.

GI is always connected to the artisanal process with the product being produced in many small scale plants with different conditions of production i.e. source of raw material, climatic condition, production equipment, operation of this equipment, packaging of the product, management of the product prior to distribution, etc. Such heterogeneity makes for problems in defining the characteristic in the official production standard, hence the official sensory definitions tend to be general and thus not precise.

Sensory properties define the distinctiveness of the product at the moment of consumption. For GIs many different sensory characteristics have to be measured in order to allow both control of the process and certification.

Within Europe, there is no unanimity in how sensory properties should be evaluated; in most cases there is expert evaluation that is not easily translated into sensory analysis. When a sensory panel is employed there are many different approaches to panel composition, the scorecard and to the presentation of the results of the data analysis.

The compliance evaluation of a GI has something in common with quality control judgments made by product experts on the conformity with pre-defined sensory characteristics. Compliance is an assessment of how "typical" the product is of the GI. This is different from quality as perceived by consumers. A product can be compliant with the specification ('typical' of the GI) but might be considered poor quality by consumers who do not know and appreciate the qualities of this GI. On the other hand a product could be found to be of good quality by consumers but not compliant with the specification of the GI.

Sensory evaluation of cheeses is also employed to evaluate compliance with pre-established sensory specifications. Thus it is used both in quality control (in cheese producing companies) and in scoring compliance (for GIs).

The most common system of organoleptic evaluation by a control body is that using the traditional method of forming an overall quality score by summing up the scores on number of characteristics (BODYFELT, 1988). Another system of quality scoring of some attributes (appearance, consistency, odour/flavour) is detailed by the norm ISO 22935-3/IDF 99-3 "Milk and milk products – Sensory analysis" part 3 (INTERNATIONAL STANDARD ORGANISATION 2009, KRAGGERUD *et al.*, 2012). A further method with some differences from the above is used for the Spanish PDO cheese Idiazabal which uses a scorecard with 8 parameters (4 appearance, 1 texture, 1 odour, 1 taste and 1 aftertaste) each with a compliance score and hence a total compliance score (PÉREZ-ELORTONDO, 2007). For this cheese compliance is determined with a decision tree. Yet another system of quality scoring for compliance is used by the Italian Parmigiano-Reggiano PDO cheese. The scorecard (GARAVALDI *et al.*, 2010) contains attributes for compliance as well as Quantitative Descriptive Attributes (QDA). A compliance score is derived for each of 4 properties (appearance, odour, taste and texture). The Italian Asiago PDO cheese is evaluated with a 6-attributes (colour, "holes", sweet, salty, sour, bitter) QDA scorecard with quality ranges (ZANNONI and MARANGON, 2011), i.e. should the intensity of the perceived attribute be out of the range specified for any one of the characteristics then the product is not compliant.

Availability of funds, technical support, the interests of producers and market requirements are all factors, which affect the method chosen to score compliance. There is no general agreement on how to tackle this most important problem; the choice of approach is currently determined by the specific requirements of each GI.

The only nation where there is uniformity in

sensory evaluation of GIs is France. The Institute for the Designation of Origin (INAO, 2008) has given guidance notes for the organization and operation of sensory panels for all PDO/PGI products. In practice for French Appellation d'Origine Protegée (AOP) PDO cheeses a common system of evaluation is a total compliance score (CANTAL, 2011) (SALERS, 2011) (PICODON, 2008) (ABONDANCE, 2010) (FOURME D'AMBERT, 2008) derived from the sum of compliance scores of 3 parameters (appearance, texture and taste).

From those examples, it is evident that there are four types of methods to evaluate the compliance of GI with their specifications. The most common is to give a total score indicating the deviance from pre-established sensory specification (CANTAL, 2011) (SALERS, 2011) (PICODON, 2008) (ABONDANCE, 2010) (FOURME D'AMBERT, 2008) as indicated by the ISO norm 22935-3. Another method employs a quality score for every parameter (PÉREZ-ELORTONDO *et al.*, 2007).

A less common method (ZANNONI and MARANGON, 2011) employs a QDA scorecard with quality (or compliance) ranges for every attribute. A fourth model (GARAVALDI *et al.*, 2010) employs a compliance score for visual, odour, texture and taste together with a QDA with 24 descriptors.

Parmigiano-Reggiano is one of the most popular Italian cheeses, with Protected Designation of Origin (PDO) from 1954 (from 1996 in EU). The most common end use of this cheese is grated over pasta. The increasing success in foreign markets and customer demand for convenience has led to an increasing proportion of the cheese being grated before being packaged in a modified atmosphere prior to distribution.

The grated cheese comes from Parmigiano-Reggiano PDO wheels, which are cut into large pieces, grated by a grating machine and then transferred by a conveyor belt to a packing machine. The process of grating/packaging lasts only few minutes. The quality of the final products depends not only on the quality of the original cheese, but also on the operation of the grating process (Fig. 1).

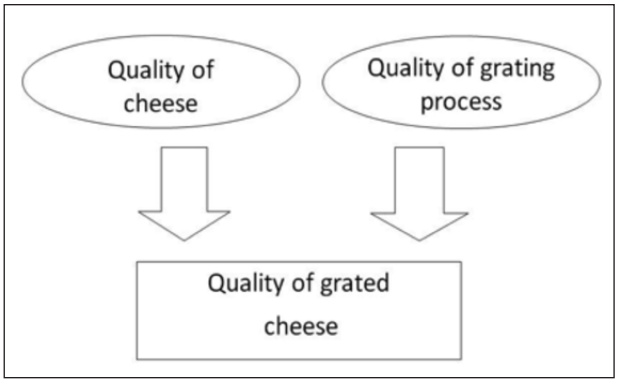

Fig. 1 - Determinants of grated Parmigiano-Reggiano quality.

For the product to be marketed as grated Parmigiano-Reggiano cheese, it must be certified by the official control body, Organismo Controllo Qualità Produzioni Regolamentate (OCQPR), for compliance with the Parmigiano-Reggiano regulations. These state that in the grated form the product must keep the characteristics of the original cheese (ZANNONI, 2007). The sensory analysis used by the certification body, for assessing the compliance of grated Parmigiano-Reggiano has been used since 2002. The scorecard for grated Parmigiano-Reggiano has been evaluated in a previous paper (ZANNONI and HUNTER, 2013).

Bearing in mind that there is no unanimity on how the compliance evaluation of GIs is carried out, this paper contributes to knowledge of the relationship between compliance and quantitative descriptors, using grated Parmigiano-Reggiano cheese as an example.

MATERIALS AND METHODS

Samples

The regulations for Parmigiano-Reggiano cheese state that the cheese can be grated only in a plant, located in the production area of the cheese, operating as prescribed by the regulations. Moreover the producer has to be authorized and regulated by the control body OCQPR. The minimum age of the product is 12 months but a maximum age is not defined.

Twenty four samples of grated Parmigiano-Reggiano, each from a different processor, were collected. Four hundred grams for each sample were collected in the production plant in four 100g bags under modified atmosphere.

Sample preparation

Each of 24 samples was divided in two parts (sub-samples of two 100g bags) for sensory analysis; the products were identified with letters A – X. Thus 48 sub-samples were evaluated by the panel. In each tasting session four sub-samples were evaluated. Order of presentation for each assessor was defined by sets of 4x4 Latin squares. Samples were refrigerated to between 2 and 8°C and their temperature was raised to 13°C temperature during the evening before tasting. The samples were served at room temperature raising the tasting temperature of the samples to approximately 16°C. Each panellist was served with 20 g sub-sub-samples on a plastic Petri dish.

Scorecard

For evaluating the sensory compliance of PDO

Table 1 - Correlations of each variable of each modality with the appropriate Compliance variable.

a) Variables of Colour modality correlated with Compliance - visual variable.

Variable	Mean	Corr	Prob
Colour Intensity	3.19	0.04	ns
Brown	0.07	-0.44	0.014
Lemon yellow	0.09	0.19	ns
Other colours	0.08	-0.45	0.013

b) Variables of Appearance modality correlated with Compliance - visual variable.

Variable	Mean	Corr	Prob
Particles size	3.29	-0.05	ns
Large grains	0.31	-0.84	<.001
Long threads	0.49	-0.47	0.009

c) Variables of Odour modality correlated with Compliance - odour variable.

Variable	Mean	Corr	Prob
Odour Intensity	3.56	0.06	ns
Rancid	0.53	-0.57	0.001
Rind	0.76	-0.39	0.028
Sour	0.23	-0.16	ns

d) Variables of Texture modality correlated with Compliance - texture variable.

Variable	Mean	Corr	Prob
Degree of Solubility	3.90	0.92	<.001
Dryness	0.83	-0.81	<.001
Rind particles	0.62	-0.72	<.001
Sandy	0.63	-0.61	0.001

e) Variables of Aroma/taste modality correlated with Compliance - aroma/taste variable.

Variable	Mean	Corr	Prob
Aroma/Taste Intensity	4.31	0.37	0.036
Salty	0.60	0.11	ns
Pungent	0.77	-0.04	ns
Sour	0.70	-0.07	ns
Rancid	0.89	-0.63	<.001
Rind	1.11	-0.66	<.001

Parmigiano-Reggiano grated cheese with the regulations, the designated control body Organismo Controllo Qualità Produzioni Regolamentate (OCQPR), uses a "mixed" scorecard, with both descriptive and compliance scores (ZANNONI and HUNTER, 2013). The quantitative descriptive part of the scorecard has 21 descriptors; a 1-7 scale for 5 attributes (colour intensity, odour intensity, aroma/taste intensity, particle size and degree of solubility). For the 16 descriptors connected to defects a 1-4 scale is used because it is more acceptable to the panellists. In addition the scorecard has an additional 4 qualitative evaluations of compliance for visual, odour, texture and aroma ("back of the nose" odour)/taste using a 1-7 scale with 1 minimum and 7 maximum score.

Panel

The nine panellist were aged between 34 and 69 years and had from 5 to 18 years experience of sensory analysis of Parmigiano-Reggiano cheese.

Statistical data analysis

The univariate (one variable at a time) analysis of this data is fully described in Zannoni and Hunter (2013). The starting point for the analysis described in this paper is the 24 Sample means from this analysis.

The scorecard presents 4 modalities: Visual (Colour plus Appearance), Odour, Texture and Aroma/Taste with a compliance score. For each of these modalities the individual variables have been correlated with the relevant compliance score (Table 1a-e).

Note that for Colour (but not Appearance), Odour, Texture and Aroma/Taste there is an intensity measurement followed by some descriptors related to defects.

The next step in the analysis is to "predict" each of the four compliance scores from all the other sensory data. For each of the four Compliance Scores there are twenty one possible explanatory factors and yet only twenty four sample values. In such circumstances multiple regression analysis is known to be problematic. One solution to this problem is to use principal components regression (PCR). First the explanatory data is summarised by the principal components scores on the much smaller number of principal dimensions (typically 2, 3 or 4), which summarise the data, and these scores are then used in the regression instead of the initial data. The multiplier for each variable of the initial data can be obtained using the regression coefficients plus the loadings of the initial data on the relevant dimension. However, we have chosen to use Partial Least Squares (PLS) regression, which has many similarities with PCR. PLS (MARTENS and NAES, 1989) is an iterative technique and has been found to produce more effective prediction equations in most circumstances.

The number of (PLS) dimensions (1, 2, 3....) was determined by the computationally intensive technique of cross-validation. A value of Predictive Residual Error Sum of Squares (PRESS) was calculated by taking each unit of data in turn and forming a prediction equation from the remaining units of data using 1, 2, ... dimensions. Ostens (OSTENS, 1988) test of significance was used to judge how many PLS di-

Table 2a - Predicting each of the Compliance variables in turn from the total Sensory Data.

Variable	COMPLIANCE			
	VISUAL	ODOUR	TEXTURE	AROMA/TASTE
Mean	4.96	4.55	4.68	4.38
No of PLS dimensions	2	1	3	2
% Variance accounted for PRESS	76.7	28.4	91.4	73.6
Predictive Error Sum of Square	2.858	2.125	1.708	2.229
Standard error of prediction	0.345	0.298	0.267	0.305

mensions (Table 2a) were required. Once the number of dimensions were determined the predictive equations were found (Table 2b). The Genstat (VSN International) statistical package was used.

RESULTS

In previous work (ZANNONI and HUNTER, 2013) the scorecard was evaluated by fitting a mixed model to each attribute and by using Generalised Procrustes Analysis for each modality. The results showed good discrimination between samples and good agreement between assessors.

Correlations

The correlations of descriptors scores for each sample with the corresponding compliance score e.g. odour intensity, rancid, rind, sour correlated with odour compliance. Table 1 shows that 13 out of the 21 descriptors

Table 2b - Predictive equations for the Compliance variables from PLS, the predicted Compliance Scores are calculated using the equation: Predicted Score = Const + $Coeff^{1}$ * Colour Intensity (Colour) + ……+ $Coeff^{n}$* Descriptor n …+ $Coeff^{21}$* Rind (Aroma Taste) (n = 1….21).

n		VISUAL		ODOUR		TEXTURE		AR./TASTE	
		Const 4.58	%Y 76.7	Const 4.42	%Y 28.4	Const 3.58	%Y 91.4	Const 3.61	%Y 73.6
	Colour	Coeff	%X	Coeff	%X	Coeff	%X	Coeff	%X
1	Colour Intensity	0.021	0.9	0.012	1.3	-0.02	50.3	0.029	1.9
2	Brown	-0.024	15.4	-0.005	16.3	-0.022	22.3	-0.017	14.2
3	Lemon yellow	0.019	1.2	-0.002	0.0	-0.011	7.6	-0.014	8.1
4	Other colours	-0.013	11.5	-0.001	6.4	-0.002	19.4	-0.004	5.9
	Appearance								
5	Particles size	-0.066	10.3	0.013	14.7	-0.052	82.2	0.032	15.0
6	Large grains	-0.401	67.3	-0.025	20.8	-0.229	70.4	-0.117	21.6
7	Long threads	-0.213	44.0	-0.026	29.0	-0.134	37.1	-0.137	37.1
	Odour								
8	Odour Intensity	-0.010	5.3	0.002	1.4	-0.037	21.0	-0.014	1.7
9	Rancid	-0.044	14.6	-0.028	21.4	-0.055	18.0	-0.121	20.6
10	Rind	-0.142	51.9	-0.024	64.6	-0.171	60.3	-0.106	62.5
11	Sour	-0.039	0.4	-0.01	0.6	-0.030	10.7	-0.005	0.8
	Texture								
12	Solubility	0.184	53.2	0.046	61.2	0.391	84.3	0.226	76.6
13	Dryness	-0.101	43.0	-0.021	56.3	-0.248	83.2	-0.116	68.9
14	Rind particles	0.016	93.6	-0.035	56.7	0.004	99.6	0.010	99.1
15	Sandy	0.059	28.0	-0.017	45.8	-0.117	55.7	-0.096	50.9
	Aroma_Taste								
16	Aroma/Taste Intensity	0.059	9.7	0.013	6.5	0.114	26.6	0.058	15.6
17	Salty	0.021	5.6	0.002	0.6	0.047	24.5	0.019	2.0
18	Pungent	-0.002	3.2	-0.008	0.5	0.057	9.0	-0.006	2.9
19	Sour	-0.001	1.3	-0.008	0.3	0.037	3.5	-0.012	0.3
20	Rancid	-0.038	23.6	-0.032	35.4	-0.092	25.5	-0.146	35.0
21	Rind	0.016	93.6	-0.035	56.7	0.004	99.6	0.010	99.1

were significantly correlated with the relevant compliance variable. The only significant positive correlation is that of *Solubility.* Negative correlations were found, in descriptors (with a 4-points scale) considered defects: *Large grains, Long threads, Rancid Odour, Rind odour, Dry, Rind particles, Sandy, Rancid Aroma, Rind Aroma*. It is interesting to note that some of these descriptors *Large Grains, Long threads, Rind particles, Rind Aroma* are influenced by processing conditions. *Large grains* and *Long threads* are determined by the grating conditions i.e. type of grating surface, pressure applied. *Rind particles* and *Rind Aroma* are determined by the percent of rind in the cheese used for grating.

Partial Least Squares (PLS)

PLS has been used to predict each of the Compliance variables in turn from all the sensory data.

The percent variance explained for the PLS correlations showed very good results for Texture 91.4% (with 3 dimensions) and for Visual and Aroma/Taste (76.7 and 73.6 % respectively, both with 2 dimensions). The results for Texture probably occurred because this modality is very strongly positively correlated with *Solubility* and strongly negatively correlated with *Dryness*, *Rind particles* and *Sandy*. The rather disappointing results for Odour (28.4% of variance explained) showed the difficulties the panel had with this modality.

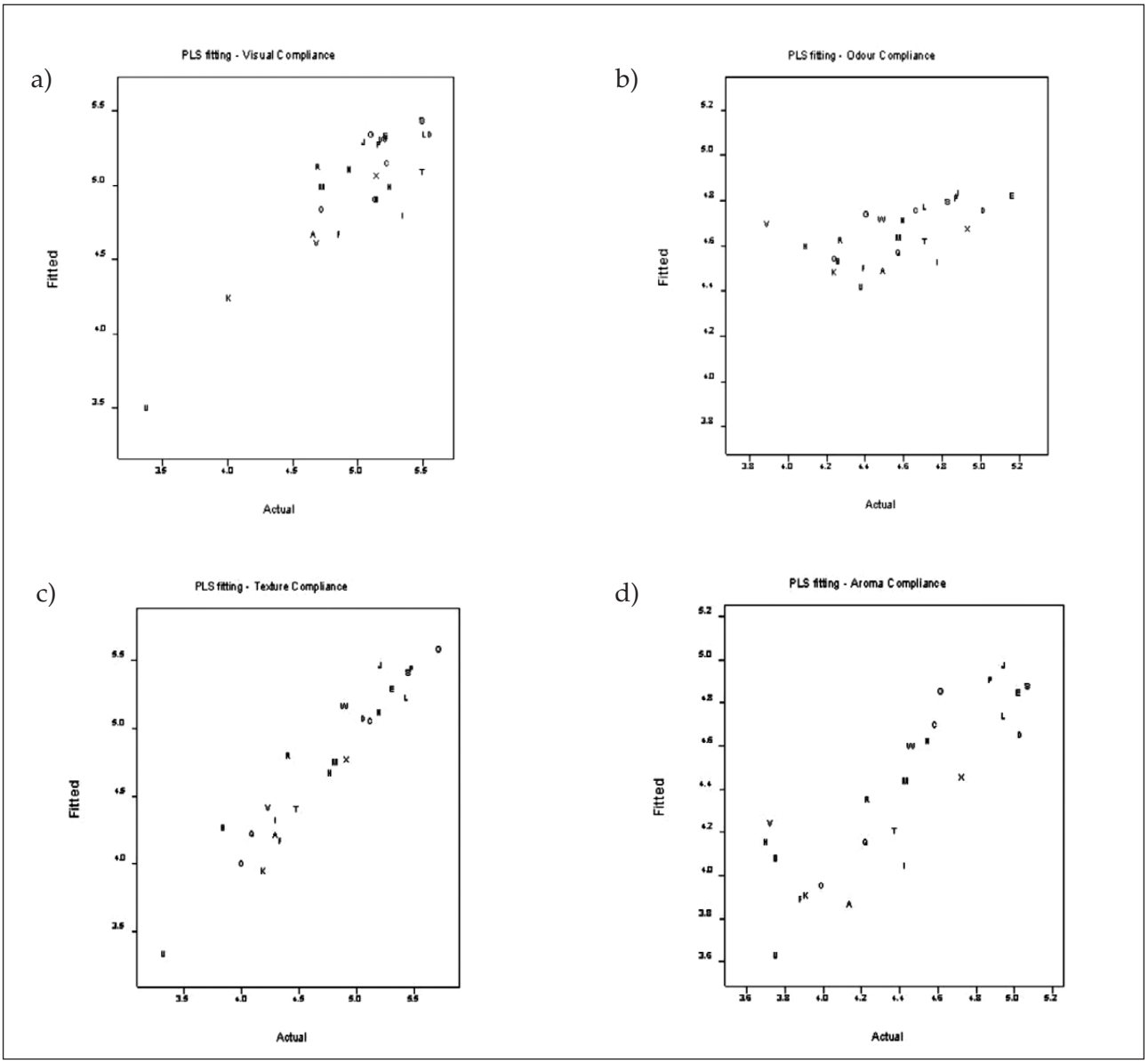

Fig. 2 - a,b,c,d : PLS: relationship between actual and predicted compliance data for each modality (visual, odour, texture, aroma). Letters represents the samples.

The equations for predicting each of the Compliance scores from all the individual descriptors allows the importance of every descriptor to be better judged. Correlations among the descriptors not directly related to a Compliance Score is logical because when we run a PCA with all the data the 4 compliances show their relationships being grouped together in an area opposed to that of descriptors considered defects which are grouped together even though they belong to different modalities. This makes sense because in cheese the presence of one defect always involves other defects. For instance if we find *Rind odour* this is an odour defect but also a texture one (i.e. *low Solubility*) and of aroma/taste (*Rind aroma* and often *Rancid*).

In predicting the ***visual compliance*** the most important predictors are *Rind aroma* and the presence of *Rind particles* in texture. Both are related to *Large grains* which is the visual descriptor correlated with the presence of rind in the grated cheese. Colour is of minimal importance in this prediction.

The most important predictor of ***odour compliance*** by far was *Rind odour* followed by other rind descriptors in other modalities.

In case of ***texture compliance*** we have the contribution of an important very large positive correlation (*Solubility*) and three substantial negative correlations (*Dryness, Rind particles, Sandy*) to the prediction.

The ***aroma/taste compliance*** is predicted mostly by the descriptor *Rind* in aroma/taste, texture and odour. This value seems to depend slightly more than the others on the quantity of cheese rind present in the samples.

The Fig. 2 shows relationships between actual and predicted compliance. It is evident that three of the four modalities are closely predicted.

CONCLUSIONS

In evaluating compliance of a PDO/PGI, it is clear that compliance cannot be separated from the descriptors. It is also true that compliance could be the results of the interaction of many sensory perceptions, not all of which are present in the scorecard. Nevertheless the scorecard has been refined by long experience in order to find the most important perceptions connected to the definition of the desired quality of the product.

PLS has allowed a better understanding of compliance evaluation of grated Parmigiano-Reggiano cheese and has confirmed the usefulness of the scorecard for official control.

Three important points come out from this work:

The most important descriptors in relationship with compliance were found to be concerned with the presence of rind in samples. The regulations allow a maximum of 18 % of rind by weight in grated cheese. The sensory control has been shown to be effective in finding rind in the product. An increase in the amount of rind causes a decrease in the sensory quality with clear disadvantages for consumers.

It is possible to satisfactorily predict compliance values using descriptor values with the exception of odour.

The compliances results expressed in a numeric manner are a practical way to show the sensory quality of this PDO cheese thus allowing its employment by the official certification body.

Another important finding of this work is the importance of descriptor *Solubility* ("positive" descriptor) in the quality assessment of a product that is normally spread over warm pasta.

Negative descriptors were, mainly descriptors connected to an excess of rind: *Large grains, Rind odour, Presence of Rind particles* and *Rind aroma.*

Extra cheese ring is readily available in plants for vacuum packed sliced Parmigiano-Reggiano because the ring flat parts of the wheel are removed before slicing the wheels into 200 or 300 g pieces. This work showed that one of the most important quality problem influencing the compliance score was the addition of extra quantities of cheese ring not belonging to the original wheels.

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