Quality Attributes of Milano Salami, an Italian Dry-Cured Sausage

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Among dry-cured sausages produced in Italy, Milano salami is one of the most widespread. The purpose of the present work was to examine a wide range of analytical parameters to describe the chemical and physical characteristics of a set of 37 Milano salamis. Principal component analysis has been adopted, and the most relevant variables have been selected. Only 6 of 19 variables (L^*, modulus, pH, NaCl/moisture, moisture/protein, lactic acid) were used in the final chemometric model. The first two principal components were significant according to double cross validation and accounted for 84.8% of sample variance. A correlation ($p < 0.001$) between principal component scores and sensory ratings, given by a panel of selected assessors, was obtained. On the basis of the correlation with sensory preference scores, the quantitative descriptive analysis profiles and quality scores for each sample were computed.

Keywords: *Quality attributes; dry-cured sausages; texture; principal component analysis*

INTRODUCTION

International trade requires, for traditional and local products in particular, both strict respect of safety criteria and preservation of the peculiar characteristics of the product.

Dry-cured sausage is a traditional cured-meat product of Italy and is produced according to different methods in different regions of the country. Among dry-cured sausages, Milano salami is the most widespread.

A voluntary standard for Milano salami has been recently issued by the Ente Nazionale Italiano di Unificazione (UNI, 1993). It defines processing technology and a few chemical and microbiological characteristics that appear to be inadequate to describe Milano salami properly.

An analysis of food sciences and technology abstract references from 1964 to 1994 revealed a number of studies concerning the microbiological aspects of maturation and safety, while the chemical and physical characteristics of salami and their influence on consumer perception of quality have been rarely investigated (Acton and Dick, 1976; Paneras et al., 1984; Genigeorgis et al.; 1986; Zabeo et al., 1993; Dellaglio et al., 1995).

The purpose of the present work was to suggest a procedure for the identification of the main quality characteristic of Milano salami by means of multivariate statistical techniques.

The correlation between analytical characteristics and the sensorial score of preference and the attribute "aged taste", given by a panel of assessors, was also investigated.

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MATERIALS AND METHODS

Samples. Chemical, physical, and sensory analyses were performed on 37 Milano salamis. The dry-cured sausages (mean weight, 3.5 kg; mean age, 3.5 months), produced and marketed by the largest Italian manufacturers, were purchased on the market. All analyses were performed and completed within 10 days after purchase. Samples were coded with a letter and a number, the former showing the manufacturer, the latter the number of the sample purchased from the same manufacturer.

Chemical Analysis. Moisture, total protein, fat, and sodium chloride were determined according to AOAC Methods 950.46, 928.08, 960.39, 971.27, respectively (AOAC, 1990). The nitrogen to protein conversion factor was 6.25. Sample preparation, before NaCl titration according to AOAC, was carried out by suspension and gentle shaking for 45 min of about 2 g of thoroughly minced sample in 40 mL of distilled water at 55 °C. pH was measured directly by insertion of a combination electrode type Xerolyt (lot 406-M6-DXK-S7/25; Ingold Messtechnic AG, Urdof, Switzerland) both in the core and in the outer parts of halved sausages; mean values are reported. Soluble nitrogen, to evaluate proteolysis index (soluble nitrogen/protein), was measured according to the procedure described by Careri et al. (1993).

Organic acids were determined by HPLC using an Aminex HPX-87H column (Bio-Rad Laboratories, Hercules, CA) and following the method proposed by Virgili et al. (1991). Collagen was measured according to the Codex method (ISO, 1978).

Chemical analysis results represent the mean of three replicates.

Physical Analysis. The evaluation of the mechanical properties was performed with an Instron Universal Testing Machine, Model 4301 (High Wycombe, England), supported by SERIE IX Automated Materials Testing System software (Instron Corp., 1990).

Single and cyclic compression tests were carried out at the constant cross-head speed of 20 mm/min with an anvil 8 cm in diameter on samples previously kept for 60 min at 5 °C, wrapped in aluminum foil. A minimum of five assays were repeated for each test on each sample (25 mm diameter, 15 mm thick) obtained from the central part of salami slices. The Dixon test was applied to exclude anomalous values (Taylor, 1987).

Modulus, an index of samples hardness, was computed on the linear part of the compression curve between 2 and 4 N as the ratio between stress and relative deformation. Results are expressed as newtons per square centimeter.

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Elasticity index was found by performing four cyclic compressions between 0.5 and 30 N and is defined as the ratio between displacements recorded during the fourth and the first compressions.

Color was measured by a tristimulus color analyzer (Chroma Meter CR-210, Minolta, Japan) with standard illuminant C and using CIE, L^*, a^*, b^*, color space equations. Color analyses measuring area was 50 mm diameter, thus enabling readings to be averaged over a relatively wide area. Measurements were carried out immediately after slicing. Five assays were repeated on different portions of a 10 mm thick slice.

Sensory Evaluation. The panel was composed of 17 selected assessors, well acquainted with sensory testing, but not specifically trained on salami evaluation. Two preliminary sessions were performed to instruct the panel. Panelists were asked to score the attribute "aged taste" on a 1−7 anchored scale. The reference corresponding to the maximum intensity of the attribute (score 7) was a 10-month-old salami, pH 5−5.5, salt content 5−5.5%. Panelists were also asked to express their preference by scoring the samples with a 1−7 scale on which 1 corresponded to "dislike very much" and 7 corresponded to "like very much". Three to four samples were evaluated in each session. Each panelist received two 1 mm thick slices of each sample on plastic plates coded with three-digit random numbers. Sessions were performed under natural light at a room temperature of 20 ± 2 °C. Water and unsalted bread were allowed between samples.

Data Analysis. Correlations between all analytical parameters and their significance levels were computed with the Pearson correlation matrix. Cluster analysis was also performed on variables (SYSTAT, 1990).

Principal component analysis was applied by using PARVUS, version 1.2, after autoscaling of the data matrix, with NIPALS algorithm. Double cross validation was carried out by diagonal cancellation matrix with 15 cancellation groups; results are expressed as the ratio between prediction residual error sum of squares and residual square error (PRESS/RSE). Correlation between principal component scores and sensory attribute "aged taste" and preference scores was performed by multiple linear regression. Residual variance in prediction is computed after cross validation with MULTIREP program (PARVUS, 1990).

The quality characteristics of dry-cured sausages were described by using the graphic display of results of the quantitative descriptive analysis (QDA) method (Stone et al., 1974). In the proposed QDA profile each axis represents a chemical or physical parameter as described by Molnar (1983) and by Pompei and Lucisano (1991). Axes are oriented so that quality increases toward the outer end of the axis. A quality score was then computed for each sample as the sum of the normalized values for each parameter considered for the QDA profile. Different formulas were used according to the value that the quality parameter assumes to express best quality. All parameters considered were given the same importance, and therefore all axes had the same length and contributed to the quality score to the same extent (Molnar, 1983; Pompei and Lucisano, 1991).

RESULTS AND DISCUSSION

Analytical results of the 37 samples are reported in Table 1 as mean value, minimum, maximum, and standard deviation (SD). Individual data for each sample are available by request to the authors.

With reference to the UNI standard, shown in Table 2 (UNI, 1993), data may be discussed as follows: only four of the examined samples show pH values lower than the fixed limit, these values never being lower than 4.8. All samples fall within the limit for protein content and moisture/protein and fat/protein ratios and can be considered to be Milano salami according to the standard. It is worthwhile to notice the wide range of moisture and fat contents that might be accepted for these products on the UNI standard basis.

Table 1. Mean, Minimum, Maximum, and Standard Deviation (SD) of Determined Variables on 37 Milano Salamis

variable	mean	minimum	maximum	SD
pH	5.38	4.79	6.11	0.27
moisture (g/100 g)	36.25	24.01	46.42	5.69
protein (g/100 g)	25.76	20.90	35.60	3.26
fat (g/100 g)	32.71	21.44	41.60	4.34
soluble N (g/100 g)	4.42	3.17	5.69	0.62
collagen (g/100 g)	2.23	1.56	3.76	0.48
NaCl (g/100 g)	4.70	3.03	6.14	0.63
NaCl/moisture	0.13	0.07	0.25	0.04
collagen/protein	0.09	0.06	0.13	0.02
fat/protein	1.29	0.82	1.82	0.23
moisture/protein	1.44	0.67	2.08	0.34
soluble N/protein	0.17	0.14	0.21	0.02
lactic acid (g/100 g)	1.21	0.71	1.96	0.30
acetic acid (g/100 g)	0.13	0.05	0.26	0.06
L^*	47.23	39.37	52.40	2.70
a^*	22.09	18.16	23.31	1.03
b^*	6.33	5.08	7.44	0.59
modulus (N/cm^2)	38.48	10.61	68.61	16.94
elasticity index	0.44	0.25	0.57	0.06
"aged taste" score	4.34	2.71	6.30	0.93
preference score	4.08	2.33	5.46	0.72

Table 2. UNI Standard Values for Milano Salami

variable	limit	variable	limit
pH	>5.2	fat/protein	<2.0
protein	>20%	moisture/protein	<2.3
collagen/protein	<0.12		

Only one sample shows a collagen/protein ratio higher than 0.12.

Cluster and correlation analyses of all variables reported in Table 1, except sensory attribute "aged taste" and preference score, were performed to investigate their relationships. Of the original 19 parameters, moisture, protein, fat, soluble N, collagen, and NaCl were correlated ($p < 0.001$) with the ratios calculated between them and provided the same information.

A preliminary principal component (PC) analysis carried out on the 19 parameters confirmed these relationships. Therefore, to find the quality parameters relevant for the classification of Milano salami, PC analysis was carried out on a matrix of 13 parameters, excluding those variables used to calculate ratios, and 37 objects. PCA allows us, by calculating new variables called principal components, which are a linear combination of analytical parameters (original variables), to identify the direction of maximum variability of data. Principal component determination is considered good if the first components take into account a large amount of total data variability.

The first two principal components (PC1 and PC2) were significant, according to double cross validation (PRESS/RSE <1), and accounted for 49.2% of variance (Table 3).

Table 3 reports variable loadings on the first two components and the variance explained by both components. Some of the considered parameters, having low loadings and low explained variance, contribute to the model description to a lesser extent.

Variables having explained variance on the first two components lower than 60% were considered not relevant and were not included in the final PC analysis. Accordingly, six remaining variables were selected.

Principal component analysis carried out on the six variables selected (pH, L^*, modulus, lactic acid, moisture/protein, NaCl/moisture) accounts, with the first two PCs, for a variance of 84.8%. The first two PCs were

Table 3. Loadings on the First Two Principal Components and Variance Accounted for the 13 Variables Considered

variable	loading PC1	loading PC2	explained variance (%)[a]
NaCl/moisture	0.471	−0.001	88.06
moisture/protein	−0.459	0.021	83.96
modulus	0.400	0.261	79.89
*L**	−0.404	0.048	65.54
lactic acid	0.010	0.573	79.52
acetic acid	−0.061	0.485	58.45
pH	0.210	−0.462	68.83
soluble N/protein	−0.149	0.217	20.18
collagen/protein	−0.127	−0.245	20.90
*b**	−0.215	0.217	26.87
*a**	−0.129	−0.245	8.96
elasticity	0.229	0.485	20.92
fat/protein	−0.207	−0.014	17.12
explained variance (%)	30.57	18.60	49.17

[a] Sum of the variance explained on the first two components.

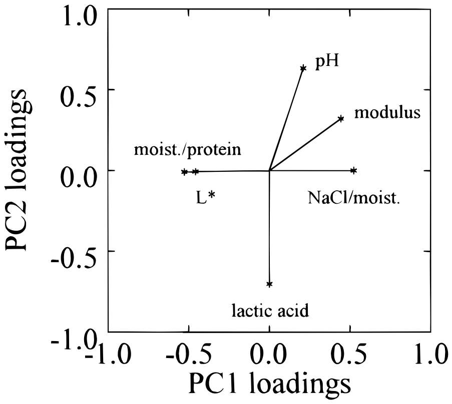

Figure 1. Loadings on the PC1−PC2 plane of the six selected variables.

significant by double cross validation (PRESS/RSE <1). For each variable, the variance explained by PC1 and PC2 was greater than 70%.

Figure 1 shows the variables' positions on the PC1 and PC2 plane. The first principal component is related to the ripening degree, which increases for lower values of moisture/protein and *L** and higher values of modulus and NaCl/moisture.

Along the second principal component, variability is essentially related to lactic acid and pH. Lactic acid represents the main metabolic product in the fermentation process, while the pH increase during ripening is due to complex chemical and biological modifications such as NH_3 and peptide production (Cantoni et al., 1976).

To further investigate the suggested correlation between the principal components and degree of ripening of salami, a multiple linear regression was performed by assuming scores of the two significant PCs as independent variables, while sensory scores for the attribute "aged taste" were the dependent variable. The overall correlation is significant ($p < 0.001$) due to the strong correlation between the first PC and the sensory score. Cross validation, computed with 10 cancellation groups, gives a residual variance of 27.8%, indicating that the first two components explain 72.2% of the variance of the sensory score in prediction.

The distance-weighted least-squares (DWLS) smoothing algorithm (SYSTAT, 1992) has been adopted to show the actual correlation between principal component scores and the sensory scores for the attribute "aged taste". The projection of the surface upon the PC1−PC2 plane results in the "iso-aging" curves shown in Figure 2, in which the 37 samples are plotted on the PC1−PC2 plane. Samples C1, K2, K3, and J2 are samples rated more "aged", while on the left side of the PC1−PC2 plane are located the less "aged" samples.

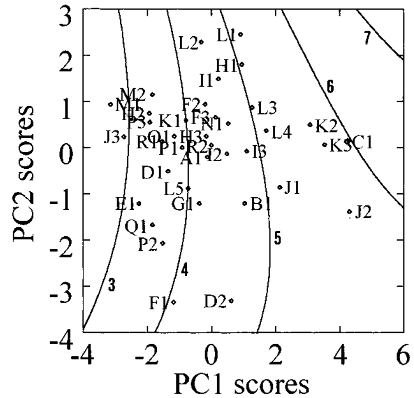

Figure 2. Scores of the 37 Milano salami samples on the PC1−PC2 plane computed from the six selected variables; lines represent the projection of the DWLS smoothing surface on the PC1−PC2 plane (ripening degree increases from 3 to 7).

Table 4. Loadings on the First Two Principal Components and Variance Accounted for the Five Variables Proposed by UNI Standard

variable	loading PC1	loading PC2	explained variance (%)[a]
protein	−0.616	−0.019	92.61
moisture/protein	0.530	0.010	68.57
collagen/protein	0.142	0.904	88.74
pH	−0.377	0.424	53.20
fat/protein	0.420	0.034	43.17
explained variance (%)	48.77	20.49	69.26

[a] Sum of the variance explained on the first two components.

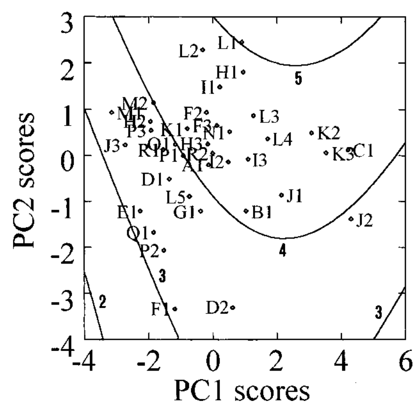

Figure 3. Scores of the 37 Milano salami samples on the PC1−PC2 plane computed from the six selected variables. Isopreference lines increase in preference from 2 to 5.

For comparison to the six selected parameters, a PC analysis was carried out by using the parameters indicated by UNI standard for the chemical characterization of Milano salami.

Variable loadings on the first two components and variance accounted for by each variable are reported in Table 4. The model accounts for 69.3% of sample variance. Only the first component is significant according to double cross validation, and it is related with protein content, pH, and moisture/protein ratio primarily.

Due to the higher variance accounted for and the better interpretation of data structure, the proposed model based on pH, lactic acid content, moisture/protein,

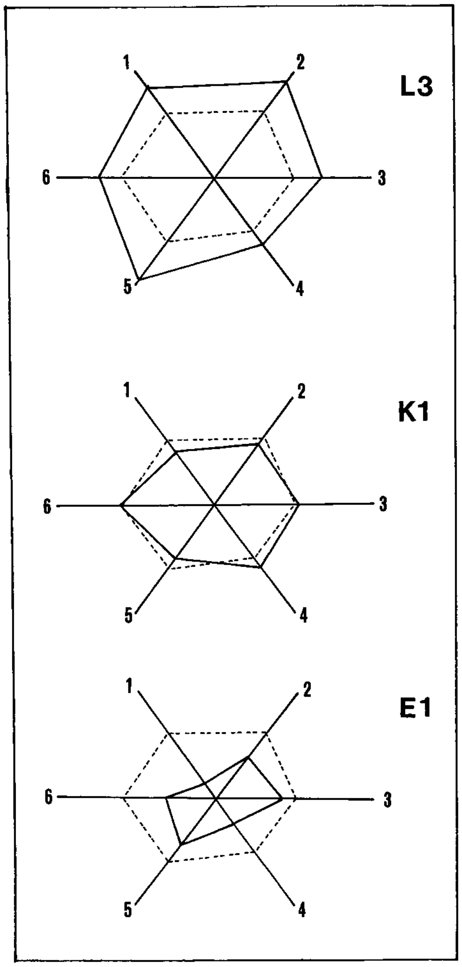

Figure 4. Quantitative descriptive analysis (QDA) profiles of three Milano salamis: L3, high quality; K1, intermediate quality; E1, low quality. Each sample is compared with the average quality score sample (dotted line). 1 = moisture/protein; 2 = NaCl/moisture; 3 = pH; 4 = lactic acid; 5 = modulus; 6 = L^*.

NaCl/moisture, L^*, and modulus must be preferred. The PC analysis shows that texture and color, quantified by means of modulus and L^*, are of great significance. The UNI standard considers these parameters only in descriptive and not quantitative terms.

The relative unimportance of the fat/protein and collagen/protein ratios, when PC analysis is carried out on the original set of variables (Table 3), can be explained by considering that these ratios are controlled by composition requirements.

A linear correlation between the first two component scores and the sensory preference scores was searched for. Sensory preference is positively related ($p < 0.001$) to the PC1 and PC2 obtained as a multiple linear correlations of the six selected parameters.

The linear multiple correlation between principal component scores and preference scores is described by the equation

$$\text{sensory pref} = 4.09 + 0.157(\text{PC1}) + 0.272(\text{PC2})$$

indicating that the samples located on the PC1−PC2 plane in the area identified by positive PC1 and PC2 values are those having higher preference scores.

Linear correlation between sensory preference score and individual quality characteristics, selected by the principal component analysis, is much less significant than the correlation between sensory judgment and the first two components.

The DWLS smoothing algorithm (SYSTAT, 1992) has been adopted to show graphically this correlation. The projection of the surface upon the PC1−PC2 plane originates the "isopreference" curves shown in Figure 3. This figure enabled us to identify a direction of preference. Samples with the highest preference scores show values slightly higher or lower than the mean for parameters related to ripening (modulus, L^*, NaCl/moisture, moisture/protein), but preference decreases as the product becomes too ripe (high value of modulus and NaCl/moisture). This is in agreement with the general belief of producers that higher preference is attributed to medium-aged Milano salami. Higher pH values and less lactic acid are also related to better preference in Figure 3.

In the proposed QDA graphical display of results, axes were oriented according to this information. For moisture/protein and L^*, best quality corresponded to a value lower than average. This value was quantified as the average − 1 SD. For NaCl/moisture and modulus best quality corresponded to a value higher than average that was quantified as average + 1 SD. With these assumptions the outer end of the axes that describe the above-mentioned parameters are equal to mean value respectively plus or minus 1 SD. For pH, best quality was related to high values of the parameter (outer end of the axis equal to mean + 3 SD). For lactic acid, the

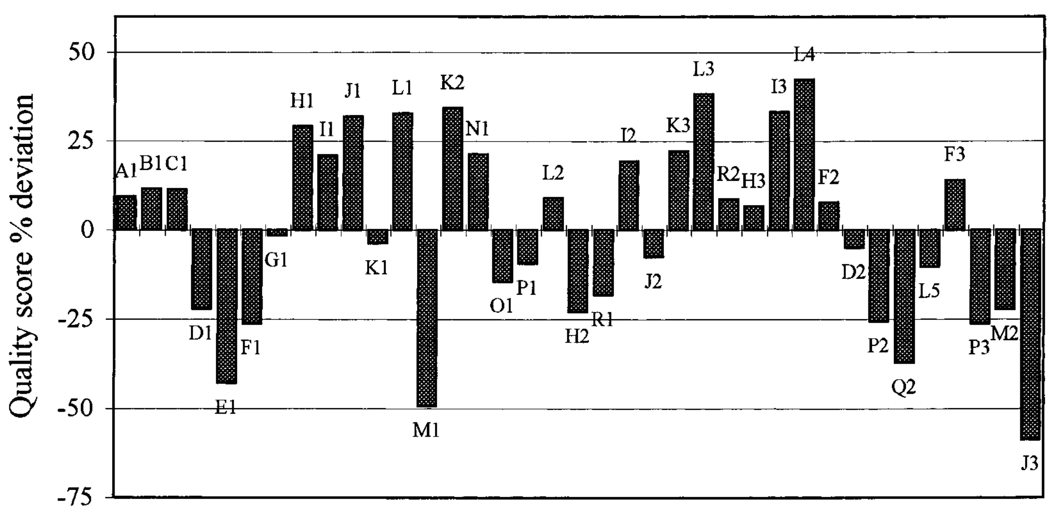

Figure 5. Percentage deviation from the mean of the quality scores of the 37 Milano salami samples.

positive correlation with sensory preference was noted for low values (outer end of the axis equal to mean − 3 SD).

Figure 4 shows the QDA profiles of three samples compared to the sample of average quality. The sample L3 profile is always outside the average quality profile, showing high-quality characteristics, while sample K1 and E1 profiles are, respectively, close to and inside the average quality profile, showing average and low-quality characteristics.

A quality score has been computed for each sample. These scores are shown in Figure 5 as percentage deviation from the average quality score. Samples with high quality scores are in the high-preference area of Figure 3, while low-quality scores are obtained for samples in the low-preference area. A certain degree of constancy in the quality of the production is shown by different producers. For example, producers I and L, with the exception of sample L5, are always above the mean quality score, while producers M and P are always well below.

In conclusion, the proposed approach allows the identification of the most significant parameters that describe Milano salami. A strong relationship exists between sensory preference and parameter selected by PCA, i.e., L^* value, modulus, pH, protein/moisture, NaCl/moisture, and lactic acid content. Manufacturers' attention should be focused on these parameters to obtain traditional products of good quality. Particular attention should be given to physical properties. The evaluation of a larger number of samples will allow better definition of the range of variation for significant parameters.

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