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Quality evaluation of tomato pulp

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The physicochemical properties of tomato pulp (i.e. crushed, diced or chopped tomatoes with about 30% tomato juice as packing medium) and the contribution of various analytical parameters to some sensory attributes were evaluated. In addition, discriminant analysis was used to obtained a sensory classification model based solely on physical and chemical parameters.

INTRODUCTION

Despite an extensive market for tomato pulp in many countries this product is rather neglected in the technical and scientific literature. In particular, there are few indications as to the parameters worth considering when assessing the quality of tomato pulp (commercial definition: crushed, diced or chopped tomatoes with about 30% tomato juice as packing medium). Generally, tomato pulp is examined by the tests normally carried out on peeled tomatoes.

Some countries do not even mention this product in food regulations. The Food and Drug Administration (USA) in 1964 gave the following definition of canned tomatoes (extended also for tomato pulp), which was modified in 1980:

(a) The fruit (drained weight of not less than 66% of the capacity of the container) prepared from mature tomatoes conforming to the characteristics of the fruit *Lycopersicum esculentum* P. Mill, of red or reddish varieties. The tomatoes may or may not be peeled, but shall have the stems and calicies removed and shall have been cored.

(b) The packing media may be: (i) the liquid draining from the tomatoes during or after peeling or coring, (ii) the liquid strained from the residue from preparing tomatoes for canning consisting of peels and cores with or without tomatoes or pieces thereof, (iii) the liquid strained from mature tomatoes (tomato juice), (iv) tomato paste, or tomato puree.

(c) One or more of the following safe and suitable ingredients may be used: (i) calcium salt in a quantity reasonably necessary to firm the tomatoes (or pieces), (ii) organic acids for the purpose of acidification, (iii) salt.

This work is an attempt to develop an objective method for evaluating tomato pulp quality as a substitute for sensory assessment, which is too often considered the definitive one. An investigation into the most significant correlations between some typical sensory variables and the physical and chemical parameters is therefore necessary.

The first aim of this study was to determine the contribution of each physical and chemical variable to sensory quality. Since many variables were involved, principle components analysis (PCA), a multivariate technique, was applied.

The function of PCA is first to indicate relationships among groups of variables in a data set, and second to show relationships between objects. The data matrix can be visualized as describing a multi-dimensional space, with one dimension for each variable, and each sample can be represented as a point in the space. If n variables have been measured, the raw data matrix represents an n-dimensional space, and a full display of the space requires a number of dimensions equal to the lesser of the number of variables and one less than the number of objects.

PCA proceeds by searching for linear combinations of variables with account for the maximum possible proportion of variance in the original data. If two or more variables are strongly correlated, then the majority of the variance in the data can be explained by drawing a new axis through the centre of the group observations, so that sum of squared residual distances

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is a minimum. The remaining proportion of variance in the data can be then explained by constructing a second new axis, orthogonal to the first. In the new system of coordinates the variables are given a loading coefficient proportional to their relative importance.

The possibility was then evalulated of classifying the analytical results on the basis of the sensory scores obtained from discriminant analysis. The essential purpose of discriminant analysis is classification of an item into one of the several mutually exclusive groups on the basis of its measured response variables. It is thus of especial value to predict the class to which unknown samples belong. The basic concept of linear discriminant function is that, through a transformation of the measured variables to a new scale, a linear combination of the variables could be found such that the mean distance between classes would be maximized.

This form of discriminant analysis is closely related to the method of regression analysis. Whereas regression analysis uses a weighted combination of continuous quantitative scale, discriminant analysis uses a weight combination of the quantitative variables to predict the discrete class to which an item belongs.

The general form of the discriminant function is given by

$$L = a_1x_1 + a_2x_2 + ...+ a_px_p$$

where L is a weighted linear composite score. The objective in employing linear discriminant analysis is to find the set of a_s (i.e. weights) which will result in the group differences being as dramatic as possible. This maximises the ratio of the between-group variability to the within-group variability of L.

Success in being able to discriminate between the groups depends upon the ratio of the between-group variability to the within-group variability.

MATERIALS AND METHODS

Sample preparation

Eight of the leading companies were asked to supply 50 kg of tomato pulp packed in 450-g cans and belonging to the same production batch. Preliminary tests (control of conformity to Italian regulation that is the most complete) had shown that these samples were representative of the products on the market, a fact subsequently confirmed by repeating the analyses on other samples.

Chemical and physical analysis

For each brand, subsequently marked by letters, the following determinations were performed (Porretta, 1991):

- Drained weight, i.e. all of the product that remains after 30 s draining on sieve with holes of 2·8 mm × 2·8 mm, was determined following the Italian Official Methods of Analysis (Ministero dell'Agricoltura e delle Foreste, 1989).
- Total acidity (as citric acid monohydrate, g per 100 g of total solids) was measured by titrating the slurry with 0·1 N NaOH to pH 8·1 with an automatic titrator; pH was measured with a pH-meter, and total solids (TS) content by oven drying at 70°C at reduced pressure following the Italian Official Methods of Analysis (Ministero dell'Agricoltura e delle Foreste, 1989).
- Colour was determined on the vacuum-sealed homogenized product, using a model XL 800 colorimeter from Gardner Laboratory Division (Bethesda, MD, USA) with the C-C.I.E. illuminant and the BCR (Community Bureau of Reference, Brussels) reference tile (L = 25·8; a_L = 33·9; b_l = 14·8; a_L/b_L = 2·29) (Kent & Porretta, 1990).
- Consistency was measured using a Bostwick consistometer (Rossi & Catelli, Parma, Italy) by measuring the flow (cm) of the undiluted juice (Bostwick S) and pulp (Bostwick P), in 30 s.
- Volatile acidity (g of acetic acid per kg TS), sodium chloride (g/kg TS) and pectins (pectic acids, pectates, protopectins, expressed as the monohydrate of galacturonic acid, g/kg TS), all determined following the Official Italian Methods of Analysis.
- Soluble solids (SS (%)) were checked on the homogenized product using an RFM81 digital refractometer (Bellingham & Stanley Ltd, Tunbridge Wells, Kent, UK). The colour of serum (browning index) was measured spectrophotometrically as absorbance at 420 nm on the filter-aid filtrate from a homogenized slurry of the whole product diluted to 2·5° Brix.
- D- and L-lactic acid (mg/kg), glutamic, citric monohydrate and acetic acid (g per kg TS) were all determined by enzymic analysis (Boehringer, Mannheim, Germany). 5-hydroxymethyl,2-furfuraldehyde (HMF), fructose and glucose were determined by HPLC (Model 712 automatic sample injection module with a 10-μl injection loop, Waters Associates, Milford, MA, USA) using HPLC grade solvents (Carlo Erba, Milan, Italy) and water (Baker, Deventer, Holland). In particular, HMF was determined as reported previously (Porretta & Sandei, 1991), using a Radial-Pack C-18 column (250 mm × 4 mm i.d., mean particle diameter 10 μm, Merck, Darmstad, Germany), with water–methanol (90:10 (v/v)) as eluent monitored at 285 nm.
- For sugar determinations, an NH_2 column (mean particle diameter 10 μm, Merck, Darmstad, Germany) was used with acetonitrile–water (80:20 (v/v)) as eluent and a differential refractometer (Model 410, Waters Associates, Milford, MA, USA) as detector. In both cases the flow rate was 1·5 ml/min and the injection volume 10μl of the filter-aid filtrate from homogenized slurry of the whole product.

Peak areas were obtained with an integrator.

- Diacetyl (mg/kg) was determined by the following method (IFFJP, 1984). 50 g of tomato pulp diluted in the 1:4 (w/w) ratio were distilled at the temperature required to collect 25 ml of distillate in 5 min. 10 ml of this distillate were mixed with 5 ml of a 5% α-naphthol (w/v) solution in isopropanol and 2 ml of a solution of 40 g of potassium hydroxide and 0·3 g of creatine in

Table 1. Results of the physicochemical and sensory analyses along with descriptive statistics and one-way ANOVA results.

	Acetic acid, g/kg TS	Glutamic acid, g/kg TS	Diacetyl, mg/kg	AMC, g/kg	Glucose, g/kg TS	HMF, mg/kg	AIS, g/kg	Pectic acids, g/kg TS
Range	2·60	30·37	7·60	0·69	206·70	4·36	396·30	20·00
Minimum	0·40	21·30	0·00	0·01	90·80	0·00	408·89	12·00
Maximum	3·00	51·65	7·60	0·70	297·50	4·36	805·22	32·00
Mean	1·40	33·79	1·81	0·19	141·50	0·79	594·00	20·00
SD[a]	0·30	8·02	2·34	0·19	44·50	1·60	100·12	6·00
Median	1·10	31·75	0·66	0·11	131·20	0·00	593·10	16·00
F ratio[a]	4·01*	42·7*	11·0*	5·01*	5·44*	2·90 n.s.	11·1*	19·3*
	Pectates, g/kg TS	Protopectins, g/kg TS	Drained weight, %	Bostwick pulp	Bostwick juice	L	a_L	b_L
Range	31·00	5·00	31·80	7·00	8·50	3·41	7·91	1·82
Minimum	7·00	2·00	64·80	0·00	1·00	23·57	23·91	12·76
Maximum	39·00	7·00	96·60	7·00	9·50	26·98	31·82	14·58
Mean	17·00	4·00	79·65	3·77	5·57	25·71	29·70	13·87
SD[a]	8·00	1·20	9·35	2·20	2·60	0·92	2·05	0·21
Median	16·00	4·00	77·66	4·25	6·50	25·95	30·36	13·97
F ratio[a]	32·2*	5·4*	29·1*	9·7*	13·5*	4·14*	5·25*	3·87*
	a_L/b_L	pH	Volatile acidity, g/kg TS	Total acidity, g/kg TS	Sodium chloride, g/kg TS	Fructose, g/kg TS	Total solids, g/kg	Colour of serum
Range	0·52	0·34	56·50	41·70	107·72	189·20	42·40	0·17
Minimum	1·84	4·12	0·90	49·80	6·14	94·50	50·00	0·19
Maximum	2·36	4·46	57·41	91·50	113·87	283·70	92·40	0·36
Mean	2·14	4·30	20·80	67·20	31·80	151·00	71·00	0·22
SD[a]	0·12	0·30	15·37	9·90	28·17	45·80	11·90	0·04
Median	2·17	4·30	13·21	66·30	22·56	135·60	68·80	0·26
F ratio[a]	5·00*	9·00*	118*	32·6*	3174*	419*	108*	5·18*
	L-Lactic acid, g/kg	D-lactic acid, g/kg	Soluble solids, g/kg	Citric acid, g/kg TS	Acidity (sensorial)	Natural taste (sensorial)	Colour (sensorial)	Viscosity (sensorial)
Range	0·53	0·64	41·00	89·65	8·00	8·00	8·00	8·00
Minimum	0·00	0·00	45·00	20·51	1·00	1·00	1·00	1·00
Maximum	0·53	0·64	86·00	110·16	9·00	9·00	9·00	9·00
Mean	0·16	0·11	64·00	55·82	5·20	4·60	6·50	5·15
SD[a]	0·17	0·17	11·90	16·64	2·25	1·10	3·00	2·34
Median	0·07	0·04	62·30	55·91	5·50	5·40	5·50	5·45
F ratio[a]	14·9*	9·90*	178*	230*	9·28*	2·61 n.s.	20·1*	19·18*

[a] Between groups.
*$p \leq 0{\cdot}05$.
n.s. = Not significant.

Table 2. Correlation matrix of the analytical data

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1·00												
2	−0·37	1·00											
3	0·12	−0·67	1·00										
4	0·49	−0·77	0·61	1·00									
5	0·23	−0·73	0·86	0·61	1·00								
6	0·47	−0·60	0·35	0·93	0·27	1·00							
7	−0·48	0·57	−0·31	−0·60	−0·42	−0·52	1·00						
8	0·74	−0·50	−0·12	0·57	0·07	0·64	−0·63	1·00					
9	0·68	−0·54	−0·10	0·63	0·08	0·70	−0·67	0·99	1·00				
10	−0·17	0·57	−0·46	−0·27	−0·19	−0·25	0·48	−0·19	−0·21	1·00			
11	0·61	−0·52	−0·04	0·38	0·13	0·38	−0·67	0·88	0·85	−0·43	1·00		
12	0·08	−0·16	0·19	0·32	0·54	0·12	−0·47	0·09	0·13	0·40	−0·04	1·00	
13	0·00	−0·13	0·13	0·41	0·43	0·29	−0·45	0·13	0·20	0·45	−0·06	0·96	1·00
14	0·64	−0·51	−0·05	0·39	0·11	0·40	−0·69	0·89	0·86	−0·43	1·00	−0·04	−0·06
15	0·16	−0·13	0·04	0·41	−0·26	0·62	−0·53	0·35	0·42	−0·53	0·31	−0·19	−0·04
16	0·05	−0·61	0·04	0·39	0·39	0·29	−0·32	0·44	0·50	0·07	0·39	0·44	0·48
17	0·61	−0·77	0·34	0·86	0·32	0·89	−0·63	0·83	0·86	−0·48	0·72	−0·03	0·06
18	0·84	−0·55	0·10	0·62	0·26	0·62	−0·36	0·87	0·83	−0·09	0·72	−0·02	0·00
19	0·20	0·21	−0·49	−0·25	−0·29	−0·18	0·56	0·23	0·15	0·52	0·12	−0·31	−0·30
20	0·58	−0·39	0·09	0·39	0·25	0·35	−0·02	0·62	0·55	0·07	0·58	−0·18	−0·17
21	0·35	−0·13	0·36	0·26	0·26	0·20	0·31	0·08	0·01	0·08	0·07	−0·34	−0·33
22	−0·57	−0·45	0·36	0·09	0·33	−0·03	0·24	−0·34	−0·27	−0·19	−0·28	−0·05	−0·02
23	−0·22	−0·11	0·07	−0·12	0·04	−0·14	0·71	−0·32	−0·33	0·16	−0·45	−0·33	−0·34
24	−0·51	−0·30	0·01	−0·01	0·32	−0·17	−0·02	−0·09	−0·03	0·19	−0·02	0·44	0·44
25	−0·43	−0·16	0·34	0·37	0·27	0·33	−0·45	−0·17	−0·05	−0·10	−0·18	0·52	0·64
26	0·56	−0·46	0·14	0·22	0·17	0·17	−0·68	0·63	0·58	−0·69	0·88	−0·16	−0·26
27	−0·03	0·38	−0·29	−0·67	−0·41	−0·61	0·71	−0·32	−0·42	−0·02	−0·20	−0·73	−0·84
28	−0·28	0·62	−0·34	−0·66	−0·64	−0·49	0·83	−0·55	−0·60	0·09	−0·53	−0·75	−0·75
29	0·92	−0·53	0·43	0·51	0·46	0·39	−0·42	0·57	0·50	−0·36	0·55	−0·02	−0·15

Drained weight, delta Bostwick, L, a_L, b_L, a_L/b_L, pH soluble solids, total solids, colour of serum, fructose, D-lactic acid, diacetyl, acetylmethylcarbinol, volatile acidity, total acidity, NaCl,

100 ml of water. The mixture was left to stand for 15 min and then stirred for a few seconds. The same test was repeated on 10 ml of water (blank). Absorbance was read at 545 nm. Finally, diacetyl level was calculated from the difference in absorbance (Abs.) between the sample and the blank and by means of a calibration equation

$$\text{Conc.} = 11{\cdot}76\ \text{Abs.} - 0{\cdot}68 \qquad (R = 0{\cdot}99)$$

derived using standards of known concentrations (Conc.).

- Acetylmethylcarbinol (AMC) (mg/kg) was determined by repeating the spectrophotometric reading at 545 nm on the same sample left to stand for an hour and the content was calculated from the difference in absorbance by means of the equation

$$\text{Conc.} = 1{\cdot}03\ \text{Abs.} + 0{\cdot}01 \qquad (R = 0{\cdot}99)$$

- Alcohol-insoluble solids (AIS) (g/kg TS) were determined by the following method. A solution (10 ml) prepared with homogenized pulp and 95% ethanol (1 : 3 (w/w)) were filtered through a Millipore vacuum system with a 0·45-μm HA-type filter. The residue was dried to constant weight in a laboratory desiccator.

Sensory analysis

Sensory tests were carried out by a 7-member panel selected and trained in tomato products in assessing acidity, natural taste (characteristic flavour), colour (homogeneity of redness) and viscosity on a 1–9 (nil to extreme) category scale. Each attribute is related to hedonic assessment as follows: acidity (1 = not sour at all; 9 = sour), naturalness (1 = taste very similarly to the fresh one; 9 = taste very different from the fresh one), viscosity (1 = solid phase completely separated from the liquid phase; 9 = very consistent product). The attributes used by the panel derived from the main objective to obtain a general evaluation of the product.

Assessors were selected from a group of people consisting of experts (6) on the products and consumers (6) by progressively excluding those (2 experts and 3 consumers) who were not able to consistently recognize the characteristics required. In each session, two single samples were given in random order; samples were assessed at 50°C under artificial daylight illumination (Thorn fluorescent 40 W tubes, 900 lux).

Five panel replications were carried out on each sample.

Statistical analysis

Five replications were carried out for each experiment. Data were processed by: analysis of variance (one-way ANOVA, using the LSD test with 95% confidence limit) and discriminant analysis with the One-way and Discriminant sub-programs of SPSS-PC (SPSS-PC, 1975) respectively; Principal Components Analysis with

($p \leq 0{\cdot}05$) for the research of linear interdependence.

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1·00															
0·34	1·00														
0·35	−0·20	1·00													
0·73	0·53	0·40	1·00												
0·73	0·08	0·32	0·80	1·00											
0·12	−0·54	0·12	−0·05	0·46	1·00										
0·57	−0·21	0·27	0·56	0·87	0·69	1·00									
0·07	−0·22	−0·23	0·24	0·51	0·51	0·77	1·00								
−0·33	−0·28	0·53	−0·02	−0·27	−0·12	−0·15	−0·13	1·00							
−0·47	−0·55	0·14	−0·16	0·00	0·46	0·15	0·28	0·65	1·00						
−0·07	−0·44	0·84	−0·11	−0·20	0·00	−0·09	−0·38	0·71	0·24	1·00					
−0·19	0·46	0·23	0·08	−0·42	−0·79	−0·55	−0·46	0·24	−0·42	0·33	1·00				
0·88	0·36	0·05	0·54	0·48	−0·14	0·35	0·04	−0·32	−0·52	−0·22	−0·18	1·00			
−0·20	−0·43	−0·48	−0·43	−0·09	0·54	0·14	0·32	−0·01	0·53	−0·32	−0·83	−0·03	1·00		
−0·52	−0·15	−0·68	−0·54	−0·37	0·33	−0·17	0·20	−0·03	0·49	−0·45	−0·53	−0·36	0·85	1·00	
0·57	0·05	−0·09	0·59	0·77	0·12	0·61	0·51	−0·37	−0·09	−0·47	−0·44	0·62	0·08	−0·23	1·00

L-lactic acid, glucose, citric acid, acetic acid, glutamic acid, alcohol insoluble solids (AIS), pectic acids, pectates, protopectins, acidity (sensorial), naturalness (sensorial), viscosity (sensorial)

Statgraphics (STSC, 1991); correlation analysis using Statpak with 95% confidence limit (NWA, 1984).

RESULTS AND DISCUSSION

Linear correlations

The results of the physical, chemical and sensory analyses are given in Table 1. The same data were subjected to linear regression analysis (Table 2) to ascertain the interdependence between the significantly different sensory characteristics and the chemical and physical ones ($P \leq 0{\cdot}05$). Neither the attribute 'homogeneity of redness' nor the HMF content were considered at this stage, as the former showed no significant difference among the various samples and the latter was absent in all samples except two.

The mostly interesting significant linear correlations established between the sensory attributes and the physical and chemical parameters were those between 'viscosity' and the drained weight ($R = 0{\cdot}92$) and between 'naturalness' and the pH value ($R = 0{\cdot}83$).

Other significant correlations normally found in physicochemical tomato data evaluation, were those between soluble solids or total solids and fructose, glucose, glutamic acid, between L, b_L and a_L (or a_L/b_L) and glutamic acid, between alcohol-insoluble solids (AIS) and soluble solids, total solids, glutamic acid, drained weight and pectates, and finally between acetic acid and volatile acidity.

The correlation between the sensory attributes 'acidity' and 'naturalness' ($R = 0{\cdot}85$) is quite unusual, which would lead to the consideration that their use has sometimes been improper (notwithstanding statistically significant differences); some assessors could have exchanged naturalness for acidity (or *vice versa*).

Principal components analysis

The results obtained by applying regression analysis only account of a small part of the overall variation. For this reason, the data of Table 1 were subjected to principal components analysis (PCA), a multivariate technique especially effective when the variables are numerous.

PCA used the parameters to build a new system of coordinates in which the variables are given a loading coefficient proportional to their relative importance (Table 3).

The graph showing the scores of the first two components (the explained percentage of which is 61, while the total variance accounts for in the first 3 PCs is 70%) built on all the normalized variables is shown in Fig. 1. It is interesting to note that the pH association is especially important regarding 'natural taste', as has already been shown by linear regression analysis.

It should be noted that the consumer usually prefers,

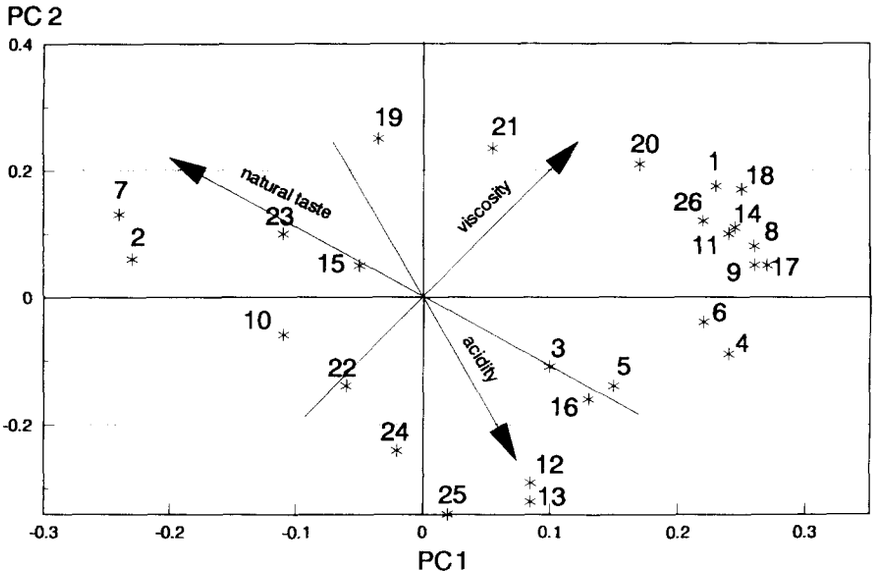

Fig. 1. plot of the physical, chemical and sensory variables on the plane of the first two principal components. The variences accounted for in the first three principal components are respectively PC1 = 37%, PC2 = 23%, PC3 = 12%.

for this type of product, the addition of a little citric acid, normally used to avoid too severe heat treatments.

As Fig. 1 shows, two colorimetric parameters, L and b_L (3 and 5) are also associated with the perception of 'natural' taste; acetic acid (16) negatively affects both 'natural' and 'acid' taste.

Table 3. List of the variables and their coordinates (PC loadings) on the plane of the first two principal components

Variable	PC1	PC2
(1) Drained weight (%)	0·23	0·18
(2) Delta Bostwick	−0·25	0·06
(3) Colour C-CIE L	0·10	−0·11
(4) Colour C-CIE a_L	0·24	−0·09
(5) Colour C-CIE b_L	0·15	−0·14
(6) Colour C-CIE $a_L \backslash b_L$	0·22	−0·04
(7) pH	−0·24	0·13
(8) Soluble solids	0·26	0·08
(9) Total solids	0·26	0·05
(10) Colour of serum	−0·11	−0·06
(11) Fructose	0·24	0·10
(12) D-lactic acid	0·09	−0·29
(13) L-lactic acid	0·09	−0·32
(14) Glucose	0·25	0·11
(15) Citric acid	−0·05	0·05
(16) Acetic acid	0·13	−0·16
(17) Glutamic acid	0·27	0·05
(18) Alcohol-insoluble solids (AIS)	0·26	0·08
(19) Pectic acids	−0·04	0·25
(20) Pectates	0·17	0·21
(21) Protopectins	0·06	0·24
(22) Diacetyl	−0·06	−0·14
(23) Acetylmethylcarbinol	−0·11	0·10
(24) Volatile acidity	−0·02	−0·24
(25) Total acidity	0·02	−0·34
(26) Sodium chloride	0·22	0·12
Sensory variables		
(27) Acidity	−0·15	0·31
(28) Natural taste	−0·21	0·22
(29) Viscosity	0·21	0·15

In some products, acetic acid was present in such a quantity as to almost certainly indicate that the raw tomatoes used were undergoing spoilage. Regarding the different contributions of other analytical parameters to 'acid' taste, D- and L-lactic acids (12 and 13) and total acidity (25) are fundamental in that they accelerate the onset of defects connected with it. Citric acid (27), which—in the graph—is in an intermediate position between 'natural' and 'acid' tastes, confirms the preference for slightly acidified products.

The contribution both to 'natural' and 'acid' taste by the acetylmethylcarbinol (23) resulting from sugar breakdown is instead quite singular. In fact, this compound, as opposed to its direct degradation product (diacetyl, 22), seems to have a positive effect on the formation of the previously mentioned tastes. It must be stated that the values of acetoin determined were very low (0·01–0·07 g/kg).

The 'sweetish' taste, which is typical of this compound when present at low levels, had in this case an enhancing effect on these tastes. As to the attribute 'viscosity', the greatest contribution was made by protopectins. Drained weight and alcohol-insoluble solids (pectins, fibre: cellulose, hemicellulose, lignin) were likewise important. At present, in several European countries as in the USA, drained weight is one of the very few parameters taken into account at a legislative level to evaluate the consistency of peeled tomatoes (what holds for this product is usually applied also to tomato pulp).

In the case, the first principal component can be defined as the component 'quality', and in fact shifts towards higher PC1 values determined the success of the product.

Classification

Cluster analysis revealed that the eight different brands formed three very distinct groups on the basis of the

variables examined. Three classes were then formed based on the sensory analysis scores: class 1 included the samples with scores between [1 and 3] (poor), class 2 between (3 and 6) (fair) and class 3 between [6 and 9] (excellent) (square brackets indicate inclusion, round brackets exclusion of the extreme).

All the significantly different variables were first included in discriminant analysis and then eliminated one by one according to the successive step method, which makes it possible to select the variables (arranged in order of significance) on the basis of the increase in separation between the groups. Finally, One-Way ANOVA selected the variables significantly different ($P \leq 0.05$) from brand to brand, i.e. drained weight, Bostwick consistency (pulp and juice), colorimetric parameters (L, a_L, b_L, a_L/b_L), pH, soluble solids, total solids content, colour of serum, fructose, acetic acid, glutamic acid, alcohol-insoluble solids (AIS), pectic acids.

Discriminant analysis

Discriminant analysis gave two significant functions permitting all the samples examined (40) to be correctly classified ($P \leq 0.01$).

Classification analysis was subsequently applied to another twelve commercial samples for which the 'belongingness' class was predicted on the basis of the afore-mentioned physical and chemical parameters. The model developed made it possible to correctly classify 10 samples ($P < 0.01$), while two samples were placed in class 2 instead of class 3 with a rather low significance ($P = 0.6$). These two samples with $P = 0.4$ really belong to the correct class (3).

Figure 2 shows the scatterplot of all the classes for all the samples examined as identified by the two discriminant functions. This figure permits determination of the partially misclassified cases (i.e. the ones that fall into different group regions).

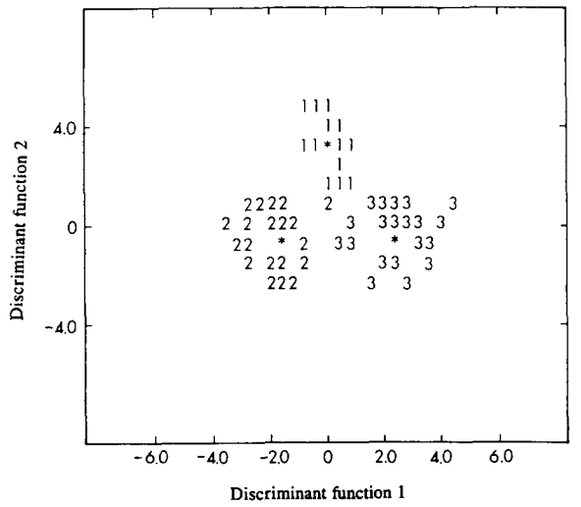

Fig. 2. Discriminant analysis scatterplot of the values of the two discriminant fuction scores for each case of the three classes. Cases are identified by their group number: 1 = poor class, 2 = fair class, 3 = excellent class. The average score for each group (centroid) is indicated by an asterisk.

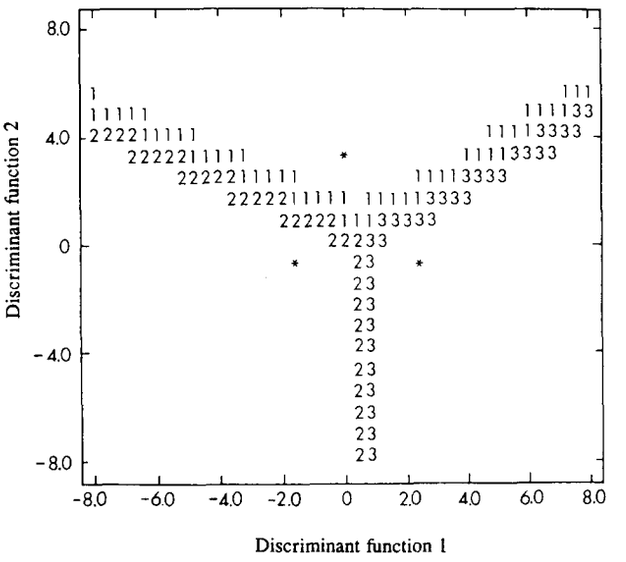

Fig. 3. Discriminant analysis classification map (territorial map). The three groups are well separated. No group falls into the classification region of another group.

The discriminant functions calculated are:

y_1 = 2·52 drained weight
+ 0·48 Bostwick consistency (pulp)
+ 2·82 Bostwick consistency (juice) − 0·36 L
− 2·61 a_L + 3·10 b_L + 0·74 pH + 0·42 SS
+ 1·09 TS − 0·97 colour of serum − 0·95 fructose
−1·22 acetic acid + 2·70 glutamic acid

y_2 = −0·89 drained weight
+ 0·07 Bostwick consistency (pulp)
+ 0·81 Bostwick consistency (juice) − 0·20 L
− 0·90 a_L + 1·58 b_L − 0·37 pH + 3·55 SS
+ 0·15 TS + 0·006 colour of serum − 2·40 fructose
− 0·37 acetic acid + 0·38 glutamic acid.

The territorial map relative to the three classes shown in Fig. 3 illustrates the situation in which both functions contribute to the three groups' separation and the distribution of the discriminant function scores. In this case, no group falls into the classification region of another one. The average score for each group (centroid) is indicated on the plot by an asterisk.

The territorial map is particularly useful for predictive purposes. In fact, by inserting the values of analytical determinations into the two discriminant functions, the coordinates (x by the 1st function and y by the second one) of other samples and therefore their belonging group (prediction) are obtained.

CONCLUSIONS

Principal components analysis made it possible to find out to what extent the different components contributed to the basic sensory properties, while discriminant analysis was used as a classification method for this type of product for which there are few references.

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