# Physicochemical Characterization of Kiwifruit (*Actinidia deliciosa* 'Hayward') from Different European Origins

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**Abstract**

**The objective of this research was to compare physicochemical characteristics of kiwifruits from different countries of origin aiming to associate their characteristics with their origin. Kiwifruits (*Actinidia deliciosa*), 'Hayward', were compared from three European countries: France, Italy and Portugal, considering eight production areas. Quality indicators were evaluated during storage at 2°C under controlled atmosphere at different sampling times: 2, 45, 80, 120 and 155 days. At each time, 35 kiwifruit, from each production area were randomly selected to be analysed in terms of physicochemical characterization. The effect of country of origin was evaluated through 1-factor ANCOVA. Further, data were analysed by means of multidimensional factorial analysis (MFA) and reduced to 3 multidimensional factors, explaining 70% of the variance. Samples from the three different countries were clearly identified along the full experimental period. As major conclusion, through simple physicochemical evaluations by means of adequate statistical analysis, it was possible to discriminate different countries of origin during different storage times.**

## INTRODUCTION

Consumer preference of fruit is strongly influenced by sweetness, acidity and characteristic flavours being determined primarily by the sugar-acid balance with fruit firmness (Marsh et al., 2004; Harker et al., 2009). Consumers consider high quality fruit to be those with nice appearance, high nutritional value and good taste (Crisosto and Crisosto, 2001). Sugar and acid content can differ markedly within families of kiwifruit and a wide variation occurs in perception of sweetness and acidity (Marsh et al., 2006).

A rapid loss of starch and increase in soluble solids content provides one of the main criteria for harvest of fruit in New Zealand, but fruit also accumulate acids during growth to produce the characteristic acidity in 'Hayward' fruit (Okuse and Ryugo, 1981).

The most widely grown kiwifruit crop is the *Actinidia chinensis* var. *deliciosa* (*Actinidia delicosa*), 'Hayward'. Its commercial growing has spread to many countries because of its distinctive characteristics, such as size, uniformity and postharvest quality (Esti et al., 1998).

There is limited information on the relationship between consumer preference or acceptance and chemical composition of ripe fruit (Crisosto and Crisosto, 2001).

The main objective of this research was to compare physicochemical characteristics of kiwifruits from different European countries aiming to have a first

insight on the association between their characteristics and the country of origin.

## MATERIALS AND METHODS

Kiwifruits (*Actinidia deliciosa*), 'Hayward', from three European countries: France, Italy and Portugal were evaluated between December and May 2007. Portuguese kiwis were collected at harvest from six different producers at two regions and French and Italian kiwifruits were bought directly at the importer/distributor and considered to come from single producers. All fruits were stored at 2ºC under controlled atmosphere with humidified air flushed through potassium permanganate to absorb ethylene. For each of the eight producers, samples were drawn at five sampling times: 2, 45, 80,120 and 155 days of storage. To facilitate data analyses kiwifruits were grouped in three groups according to country of origin (Portugal - PT, France - F and Italy - IT). At each time, 35 kiwifruit, from each production area were randomly selected for analysis. Physicochemical characterization was performed in terms of firmness, colour, soluble solids content, pH, sugar content and titratable acidity.

Firmness was measured using a texturometer (TA.XT plus, Stable Micro Systems, with a load cell of 2000 g. A plane cylindrical probe with a 2.0 mm diameter was used at a constant velocity of 0.5 mm/s until a perforation of 10 mm was reached. Firmness was measured on slices of 15 mm taken at the equatorial zone of each fruit. Ten fruits from each production area and storage time were measured.

### Colour

Ten fruits from each production area and storage time were measured. Kiwifruits were cut at the equatorial zone and colour was measured in the pericarp zone. Colour was measured by using a colorimeter (Minolta CR - 300, Minolta Corp., Ramsey, New Jersey, USA) using the CIE- $L^*a^*b^*$ system. Hue angle = $\tan^{-1}(b^*/a^*)$ and Chroma = $(a^{*2}+b^{*2})^{1/2}$ were calculated (Francis, 1970).

### Total Soluble Solids (TSS) Content and pH

Kiwifruit were cut and squeezed through gauze, and non diluted juice was collected. The SSC was measured using a hand held refractometer (model Atago - ATC1, Atago Co. Ltd., Tokyo, Japan) at 20ºC and expressed as fresh weight (%). The pH was measured using a pH probe (Hanna Instruments, model HI 99163. 3 fruits from each production area and storage time were used.

### Sugar Content

The measurement of sugar content was performed by distillation and titration according to the procedure described NP 1420 (IPQ. 1987). Results were expressed in w/w % - g glucose/100 g kiwifruit. Three replicates for each production area were performed at each sampling time.

### Titratable Acidity

Titratable acidity was determined according to NP 1421 (IPQ. 1977). Results were expressed as % of malic acid. Three fruits from each production area and storage time were used.

Additionally, a sensory panel of 12 trained assessors was used to perform an initial characterisation of kiwifruits from different origins.

### Statistical Analysis

The *SPSS* v. 16 for Windows was used for statistical analysis of data. A 1-factor ANCOVA (Neter et al., 1996) for country of origin, with storage time as covariate, was applied to different quality indicators, followed by Post-hoc when significant differences were identified. All tests were performed at a 95% confidence. Colour data were reduced through Principal Component Analysis (PCA) at each sampling time. Further, full aggregated data from the eight producers were analysed by means of multidimensional

factorial analysis (MFA) using XLSTAT 2008 software (Addinsoft, SARL, UK).

## RESULTS AND DISCUSSION

At the initial sensorial characterisation, significant differences were found between Portuguese kiwifruits, from both regions, and fruits from Italy and France, namely Italian kiwifruits that were at an advanced stage of maturity (Fig. 1), with a marked decreased astringency and acidity and generally more appealable.

In terms of firmness, significant differences were found on the first moment of evaluation (Table 1). Portuguese fruits were firmer confirming the more immature phase. During storage, these differences became smaller; nevertheless, Portuguese samples remained firmer (Fig. 2). No significant differences were observed on pH value of kiwifruits from different origins during storage (Fig. 3 and Table 1). The total soluble solids content (TSS) of Italian kiwifruits was higher than for those from other origins throughout storage. However, TSS of Portuguese kiwifruits increased with storage time, thus decreasing the initial differences observed (Fig. 4 and Table 1). Significant differences on sugar content were observed along storage time (Table 1). The observed increase in sugar content during storage is probably determined by the loss of water from the fruits (Fig. 5). No significant differences were observed on acidity of kiwifruits from different origins during storage (Fig. 6 and Table 1). The Italian kiwifruits showed the highest sweet/acid ratio at the initial evaluation, nevertheless this difference faded away during storage (Fig. 7). Statistically significant differences were found between acidity and brix/acid ratio of kiwifruits 'Hayward' from different countries of origin (Table 1).

Regarding colour evaluation, Principal Component Analysis (PCA) reduced the results into a two-dimensional space representing between 90-99% of the data variability. Biplots from PCA (Fig. 8) further illustrate the results from ANCOVA (Table1), showing that Portuguese kiwifruit were characterized by a more green and intense colour. French fruits yielded higher luminosity and hue angle, while Italian kiwifruits showed a decrease in the luminosity with storage time.

Multidimensional factorial analysis (MFA), applied to aggregated data from quality indicators for kiwifruit 'Hayward from all eight producers, throughout storage, reduced data to 3 multidimensional factors, explaining 70% of the variance (Figs. 9 and 10). Quality indicators, at each sampling time tended to project closely, particularly firmness, sweet/acid ration and sugar content (Fig. 9).

Samples from the three different countries were clearly identified along the full experimental period (Fig. 10). Particularly regarding Portuguese samples, those from region one - PT1 (producers a, b and c) yielded smaller inter production area variability than samples from region two - PT2 (producers a, b and c) throughout the entire period.

As major conclusion, through simple physicochemical evaluations and by means of adequate statistical analysis, it was possible to discriminate different countries of origin throughout different storage times.

The main limitation of this work was due to the initial different stage of maturity of kiwifruits from Portugal obtained from producers directly at harvest and Italian and French kiwifruits bought at commercial maturity, which did not allow for more extensive conclusions concerning country of origin.

Further comparisons demand for integrated research warranting the use of fruits from different countries of origin harvested at similar maturity levels and stored at identical conditions.

## ACKNOWLEDGEMENTS

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## Literature Cited

Crisosto, C.H. and Crisosto, G.M. 2001. Understanding consumer acceptance of early harvested 'Hayward' kiwifruit. Posth. Biol. Techn. 22:205-213.

Esti, M., Messia, M.C., Bertocchi, P., Sinesio, F. and Moneta, E. 1998. Chemical compounds and sensory assessment of kiwifruit (*Actinidia chinensis*): electrochemical and multivariate analyses. Food Chem. 61:293-300.
Fisk, C.L., Silver, A.M., Strik, B.C. and Zhao, Y. 2008. Postharvest quality of hardy kiwifruit (*Actinidia arguta* 'Ananasnaya') associated with packaging and storage conditions. Posth. Biol. Techn. 47:338-345.
Francis, F.J. 1970. Color Measurement in Plant Breeding. HortSci. 5:102-106.
Harker, F.R., Carr, B.T., McRae, E.A., Wismer, W.V. and Marsh, K.B. 2009. Consumer liking for kiwifruit flavour: A meta-analysis of five studies on fruit quality. Food Qual. Pref. 20:30-41.
IPQ. 1987. NP 1420. Frutos, produtos hortícolas e seus derivados. Determinação dos açúcares totais, dos açúcares redutores e dos açúcares não redutores. Técnica de Luff-Schoorl. Methode de routine.
IPQ. 1977. NP 1421. Géneros alimentícios derivados de frutos e de produtos hortícolas. Determinação da acidez.
Jaeger, S.R., Rossiter, K.L., Wismer, W.V. and Harker, F.R. 2002. Consumer-driven product development in the kiwifruit industry. Food Qual. Prefer. 14:187-198.
Marsh, K., Attanayake, S., Walker, S., Gunson, A., Boldingh, H. and MacRae, E. 2004. Acidity and taste in kiwifruit. Posth. Biol. Techn. 32:159-168.
Marsh, K., Friel, E.N., Gunson, A., Lund. C. and MacRae, E. 2006. Perception of flavour in standardised fruit pulps with additions of acids and sugars. Food Qual. Pref. 17:376-386.
Neter, J., Kutner, M.H., Nachtsheim, C.J. and Wasserman, W. 1996. Applied Linear Statistical Models. 4th ed. Irwin, Chicago, USA.
Okuse, I. and Ryugo, K. 1981. Compositional changes in the developing 'Hayward' kiwifruit in California. J. Am. Soc. Hort. Sci. 106:73-76.

## Tables

Table 1. Results from the application of ANCOVA for country of origin, with storage time as covariate, to different quality indicators of kiwi 'Hayward' from Portugal, France and Italy. Bold p-values indicate a significative effect at a 95% confidence level.

| Quality indicator | *p*-value | | Quality indicator | *p-value* | |
|---|---|---|---|---|---|
| | Country of origin | Storage time | | Country of origin | Storage time |
| *L** | **0.026** | 0.678 | Firmness | 0.062 | **0.005** |
| *a** | **0.003** | **<0.001** | pH | 0.105 | 0.153 |
| *b** | 0.213 | **<0.001** | TSS | 0.134 | 0.098 |
| *Hue angle* | 0.071 | **0.018** | Sugar content | 0.775 | **< 0.001** |
| *Chroma* | 0.091 | **<0.001** | Acidity | **<0.001** | 0.471 |
| | | | Sweet/acid balance | **0.002** | 0.820 |

## Figures

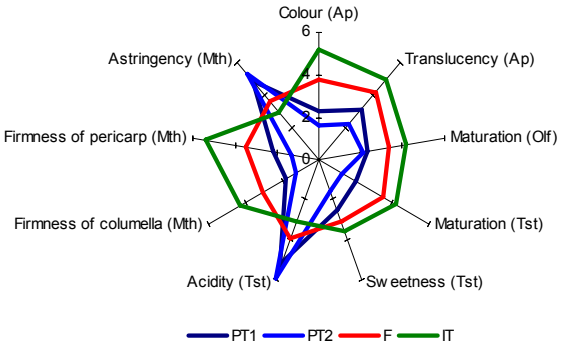


Fig. 1. Initial sensorial characterization of kiwifruits 'Hayward' from different countries of origin (Portugal - PT1 and PT2, France - F and Italy - IT).

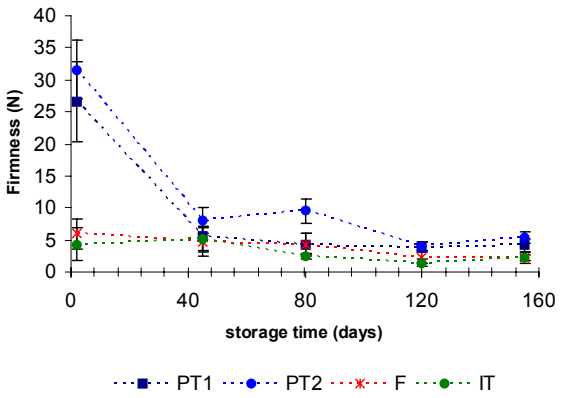


Fig. 2. Firmness of kiwifruits 'Hayward' from different countries of origin: Portugal (PT1 and PT2), France (F) and Italy (IT) during storage.

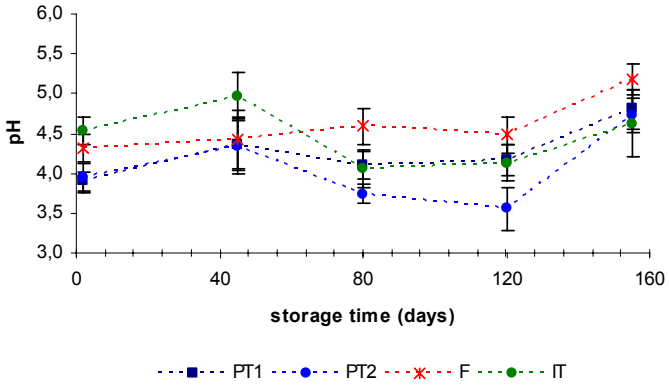


Fig. 3. pH of kiwifruits 'Hayward' from different countries of origin: Portugal (PT1 and PT2), France (F) and Italy (IT) during storage.

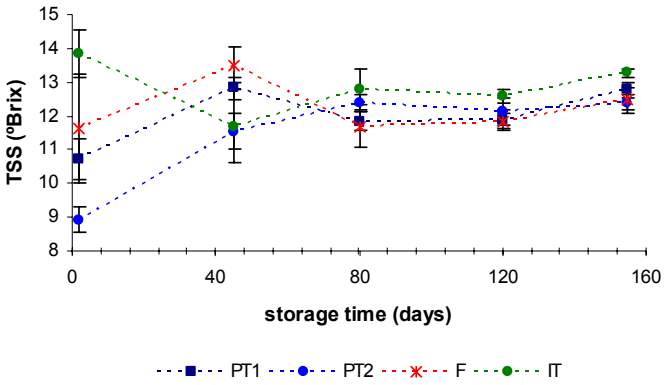


Fig. 4. Total Soluble Solids of kiwifruits 'Hayward' from different countries of origin: Portugal (PT1 and PT2), France (F) and Italy (IT) during storage.

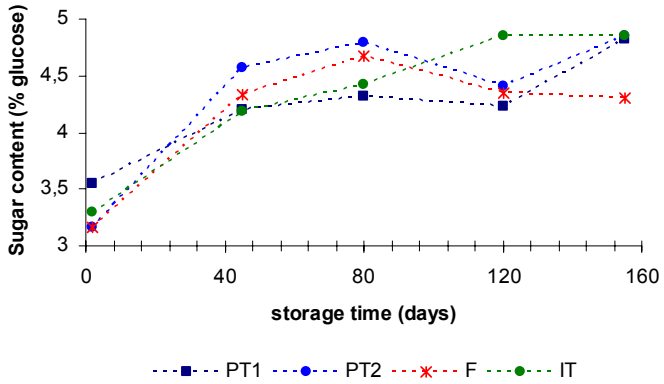


Fig. 5. Sugar content (% glucose) of kiwifruits 'Hayward' from different countries of origin: Portugal (PT1 and PT2), France (F) and Italy (IT) during storage.

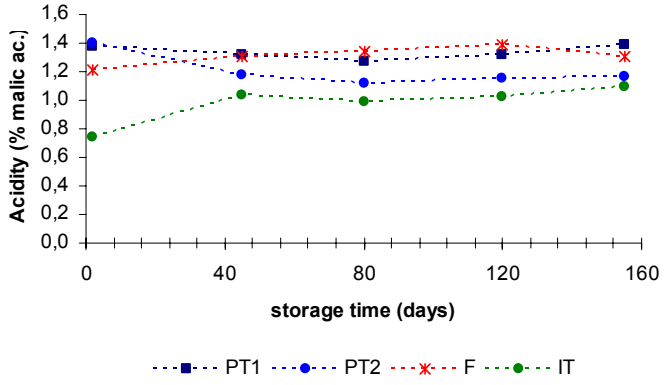


Fig. 6. Acidity (% malic acid) of kiwifruits 'Hayward' from different countries of origin: Portugal (PT1 and PT2), France (F) and Italy (IT) during storage.

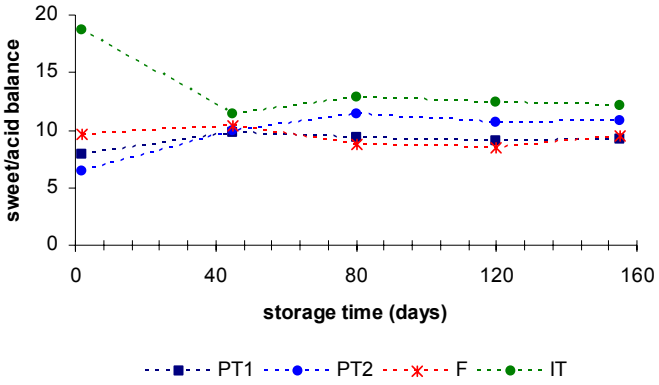


Fig. 7. Sweet/ Acid ratio of kiwifruits 'Hayward' from different countries of origin: Portugal (PT1 and PT2), France (F) and Italy (IT) during storage.

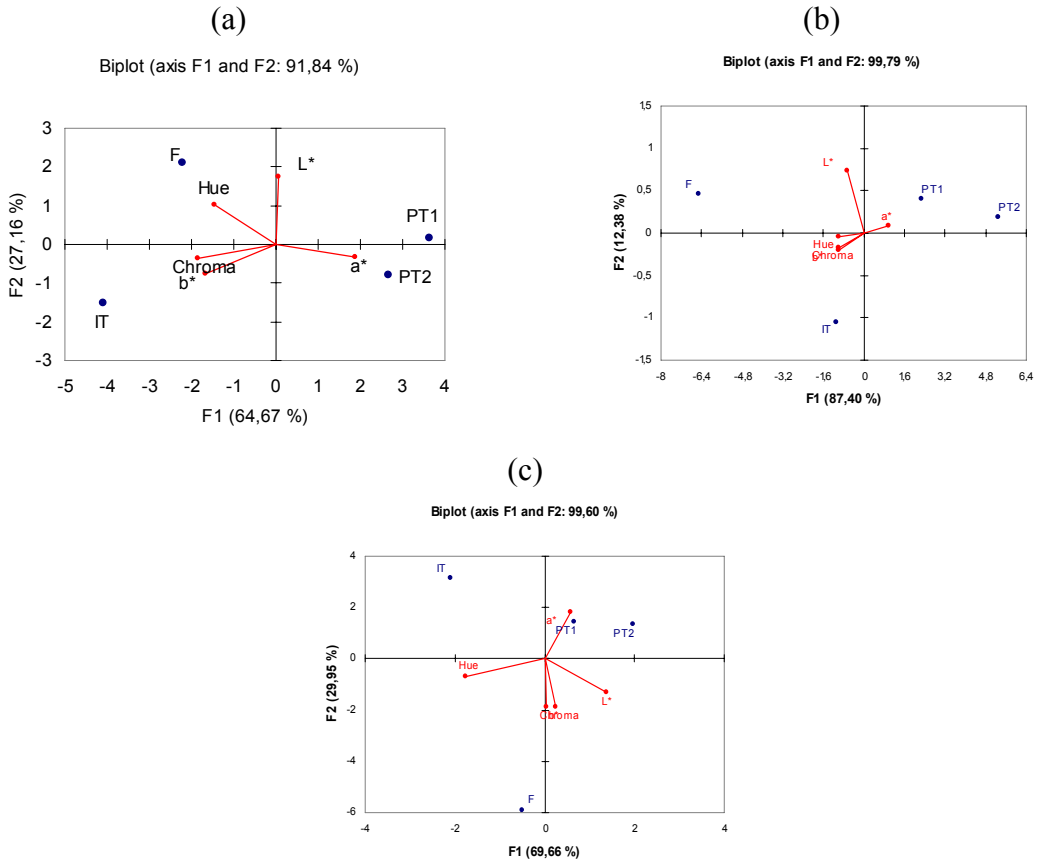


Fig. 8. Biplots from PCA applied to colour measurements taken from kiwifruit's 'Hayward' pericarp from different origins: Portugal (PT1 and PT2), France (F) and Italy (IT), at different storage times: (a) 45 days; (b) 120 days); (c) 155 days.

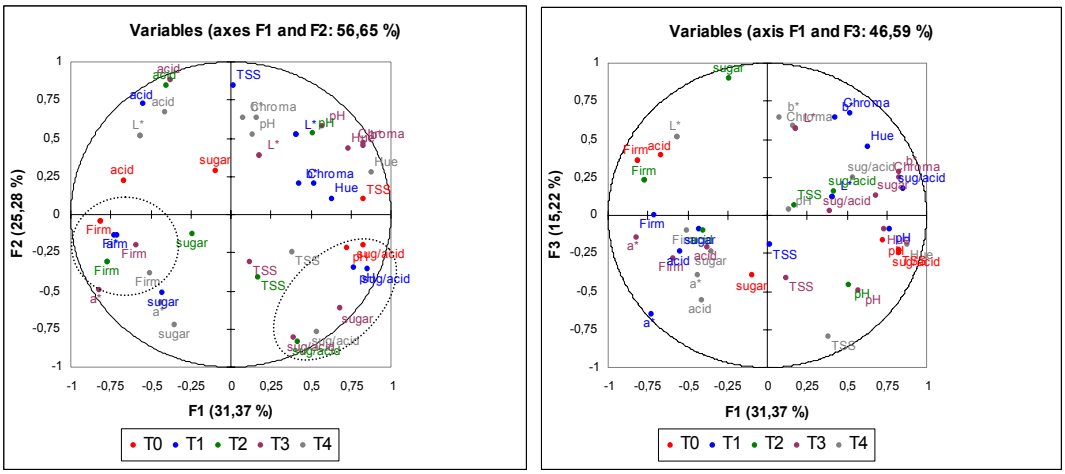


Fig. 9. General projection of different quality indicators onto the 3-dimensional space (F1, F2 and F3, representing 72% of data variability) resulting from the application of MFA to aggregated data on kiwifruit 'Hayward' from eight different producers (six from PT, one from F and one from IT), evaluated at five storage times (T0 - 2 d, T1 - 45 d, T2 - 80 d, T3 - 120 d and T4 - 155 d).

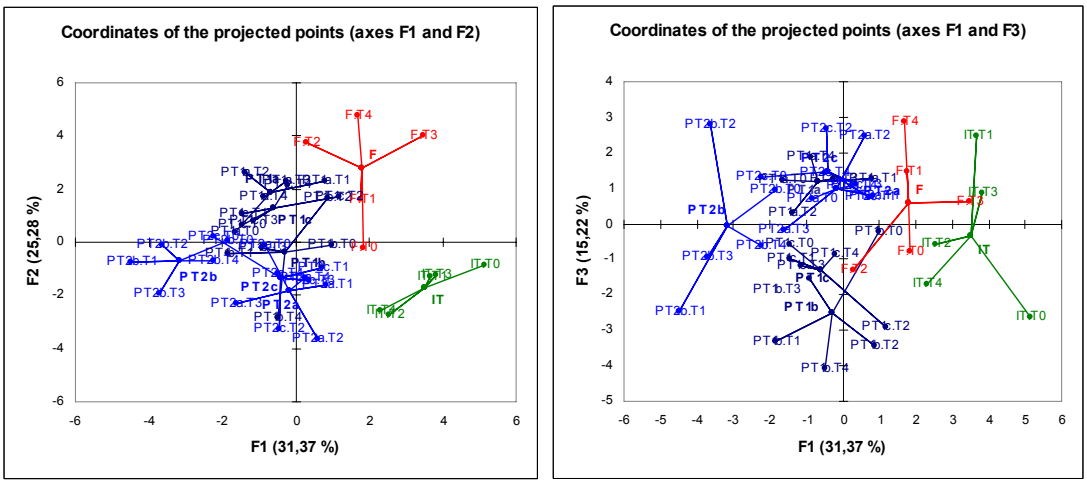


Fig. 10. Projection of overall quality evaluation of kiwifruit 'Hayward' from eight different producers (six from PT - PT1a/b/c, PT2a/b/c, one from F and one from IT), evaluated at five storage times (T0 - 2 d, T1 - 45 d, T2 - 80 d, T3 - 120 d and T4 - 155 d), onto the 3-dimensional space (F1, F2 and F3) resulting from the application of MFA to aggregated data.