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RESEARCH NOTE

# Changes during ripening of papaya fruit in different storage systems

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The ripening stages of the papaya fruit can only be precisely determined by using many parameters on the same fruit. Eight physico-chemical measurements (water content, pH, °Brix, acidity, sugar content, neutral detergent fibre, proteins and minerals) have been obtained for Carica papaya Solo grown in the Canary Islands, during 1 month under different storage conditions (1: room temperature, 25°C; 2: domestic refrigerator, 10°C; 3: control chamber, 12°C and 92% $H_2O$).

Analysis of variance, correlation analysis and principal component analysis (PCA) were used to characterize the ripening process of this fruit. The statistical analysis indicates that pH, and °Brix are indices of the ripening of the papaya fruit.

## INTRODUCTION

Fruits are in constant changes during their life; consequently the characterization of their changes during ripening is essential for nutrient studies. It is well known that fruit is characterized by several physiological processes which can be interdependent and changes must be described by several discriminant parameters (Gortner *et al.*, 1967; Salunke & Desai, 1984; Selvaraj *et al.*, 1982).

This study is aimed at reducing the number of explanatory parameters of the ripening process.

## MATERIAL AND METHODS

### Samples

Carica papaya Solo, cultivated in the Canary Islands, has been analysed. During 1 month, three different batches of fruits (20 fruits each) were stored at: 1, room temperature, 25°C; 2, domestic refrigerator, 10°C; 3, control chamber, 12°C, 92% $H_2O$.

Previous studies were conducted at 7°C storage temperature. The fruits then showed chilling injury symptoms in the first week of storage and signs of decay by a latent infection. For that reason, in this study, the fruits were cleaned with ethanol (80%) before storage.

All the storage experiments have been carried out above 10°C in order to avoid 'chilling injury'. Table 1 shows the number of storage days when sampling was conducted. On each sampling date five fruits were analysed in triplicate. Sample 0 represents the green fruits analysed immediately after receipt. The fruit stored at room temperature ripened quickly and appeared overripe after 30 days storage so we have considered 20 storage days as the full ripening stage.

### Sample preparation

The edible portion of the fruits was considered to be the whole fruit minus peel and seeds. This edible portion from fresh fruit was homogenized; aliquots of homogenate were analysed for: water content (oven at 105°C), titratable acidity (m.22.058 AOAC), total sugar content (sum of glucose, fructose and sucrose) by High Performance Liquid Chromatography (Camara, 1990), nitrogen content by Kjeldahl procedure (m.22052 AOAC), soluble solids (% Brix) and pH.

A portion of the homogenate was freeze-dried; aliquots of it were analysed for mineral content (Torija, 1981) and neutral detergent fibre (Camara, 1990).

### Statistical analysis

*Analysis of variance*

The one-way analysis of variance was applied for analyses of the effect of the ripening process and the

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**Table 1. Number of storage days when the sampling was conducted**

| Sample | System 1 storage days | System 2 storage days | System 3 storage days |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 3 | 3 | 3 |
| 2 | 10 | 7 | 7 |
| 3 | 20 | 17 | 17 |
| 4 | — | 30 | 30 |

storage conditions on the papaya composition. All the analytical results (triplicates of each sample) were used to conduct analysis of variance. The Fisher statistic ($F$ value) obtained from our data and compared with a critical value ($F_c$ at the 95% confidence level) shows the significance of the ripening process and influence of storage conditions on the papaya composition changes (Lebart, 1985; Peña, 1987).

*Correlation analysis*

The correlation analysis procedure generates a matrix of correlation for a set of observed values. The mean values shown in Table 2 were used to conduct this analysis.

Correlation analysis provides a preliminary view of the relationships among variables, and the results can be used for some procedures such as Principal Component Analysis. The coefficient values fall between −1 and +1. A positive correlation indicates that the variables vary in the same direction while a negative correlation indicates that the variables vary in the opposite direction.

Considering as statistically significant those correlations with a significance levels $p < 0.05$ (based on the student's $t$ distribution), with a confidence level of 95%, statistically independent variables have an expected correlation of zero (Lebart, 1985; STSC, 1986).

*Multivariate principal component analysis (PCA)*

The data analysis method allows a global study of the criteria which describe the ripening process. The purpose of the PCA method is to reduce the number of explanatory variables of the experimental results by finding linear combinations of those variables that explain most of the variability. PCA is based on the correlation analysis mentioned above, and is computerized in the statgraphic program (Lebart, 1985; STSC, 1986; Fils-Lycaon *et al.*, 1988).

## RESULTS AND DISCUSSION

Table 2 shows the mean value of three analyses ($X$) and the standard deviations $n - 1$ (SD) of the results of this experiment.

The analysis of variance results are shown in Tables 3 and 4. Table 3 shows the influence of the ripening process on papaya composition changes.

In order to determine if there are statistical differences between the two refrigeration storage systems applied (systems 2 and 3), we have applied the analysis of variance with two factors (ripening process and storage conditions influence). The results are shown in Table 4.

When the $F$ statistic value obtained from our data is less than the critical statistic value ($F_c$), this means no statistical significance (95% or 97·5% confidence level).

Table 3 shows that fruits stored in a domestic refrigerator (system 2) undergo statistically significant composition changes during the ripening process.

**Table 2. Composition of papaya fruit during ripening (g/100 g of fresh fruit)**

| | Days | Water | | pH | Acidity | | °Brix | Sugars | | FND | | Proteins | | Minerals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $X$ | SD | | $X$ | SD | | $X$ | SD | $X$ | SD | $X$ | SD | $X$ | SD |
| System 1 | | | | | | | | | | | | | | | |
| | 0 | 89·98 | 1·30 | 5·89 | 0·53 | 0·06 | 10 | 3·80 | 0·00 | 1·43 | 0·14 | 0·86 | 0·03 | 0·79 | 0·01 |
| | 3 | 88·98 | 0·14 | 5·80 | 0·39 | 0·02 | 8 | 3·26 | 0·37 | 1·30 | 0·04 | 0·85 | 0·10 | 0·86 | 0·01 |
| | 10 | 89·79 | 0·40 | 5·80 | 0·34 | 0·03 | 9 | 3·57 | 0·06 | 1·20 | 0·03 | 0·81 | 0·03 | 1·08 | 0·01 |
| | 20 | 88·26 | 0·18 | 4·55 | 1·04 | 0·02 | 12 | 3·85 | 0·16 | 1·15 | 0·04 | 0·58 | 0·14 | 1·07 | 0·07 |
| System 2 | | | | | | | | | | | | | | | |
| | 0 | 89·98 | 1·30 | 5·89 | 0·53 | 0·08 | 10 | 3·80 | 0·00 | 1·43 | 0·14 | 0·86 | 0·03 | 0·79 | 0·01 |
| | 3 | 89·48 | 0·00 | 5·67 | 0·47 | 0·01 | 10 | 4·12 | 0·13 | 1·40 | 0·08 | 0·68 | 0·04 | 0·56 | 0·04 |
| | 7 | 89·56 | 0·04 | 5·73 | 0·39 | 0·03 | 12 | 6·02 | 0·24 | 0·99 | 0·08 | 0·62 | 0·07 | 0·71 | 0·03 |
| | 17 | 91·08 | 0·14 | 5·77 | 0·41 | 0·01 | 12 | 5·06 | 0·01 | 2·00 | 0·01 | 0·45 | 0·03 | 0·65 | 0·03 |
| | 30 | 88·09 | 0·04 | 4·62 | 0·79 | 0·03 | 14 | 4·79 | 0·01 | 1·84 | 0·01 | 0·58 | 0·03 | 1·01 | 0·10 |
| System 3 | | | | | | | | | | | | | | | |
| | 0 | 89·98 | 1·30 | 5·89 | 0·53 | 0·08 | 10 | 3·80 | 0·00 | 1·43 | 0·14 | 0·86 | 0·03 | 0·79 | 0·01 |
| | 3 | 90·47 | 0·10 | 5·74 | 0·55 | 0·01 | 9 | 3·27 | 0·13 | 0·98 | 0·06 | 0·61 | 0·06 | 0·68 | 0·00 |
| | 7 | 89·53 | 0·13 | 5·57 | 0·44 | 0·12 | 9 | 3·68 | 0·04 | 1·62 | 0·03 | 0·60 | 0·17 | 0·72 | 0·03 |
| | 17 | 90·60 | 0·03 | 5·91 | 0·53 | 0·04 | 13 | 3·67 | 0·40 | 1·77 | 0·06 | 0·54 | 0·01 | 1·04 | 0·01 |
| | 30 | 89·50 | 1·27 | 5·33 | 0·46 | 0·03 | 13 | 3·94 | 0·07 | 1·51 | 0·06 | 0·44 | 0·01 | 0·81 | 0·03 |

$X$, medium value of three analyses; SD, standard deviation $n - 1$.

**Table 3. Analysis of Variance. Influence of the ripening process on papaya composition changes**

| | System 1 | System 2 | System 3 |
|---|---|---|---|
| Acidity | $F$ 3,4 = 77·00 | $F$ 4,5 = 28·39 | $F$ 4,5 = 0·90 |
| Water | $F$ 3,4 = 2·60 | $F$ 4,5 = 6·73 | $F$ 4,5 = 0·78 |
| Minerals | $F$ 3,4 = 30·95 | $F$ 4,5 = 21·77 | $F$ 4,5 = 97·85 |
| Proteins | $F$ 3,4 = 4·42 | $F$ 4,5 = 24·40 | $F$ 4,5 = 7·25 |
| Sugars | $F$ 3,4 = 3·56 | $F$ 4,5 = 76·46 | $F$ 4,5 = 3·47 |
| NDF | $F$ 3,4 = 5·00 | $F$ 4,5 = 45·60 | $F$ 4,5 = 85·83 |
| | $F_c$ 3,4 = 6·59 | $F_c$ 4,5 = 5·19 | $F_c$ 4,5 = 5·19 |

**Table 4. Analysis of Variance. Influence of refrigeration storage conditions (Systems 2 and 3) on papaya composition changes**

| | Acidity | Water | Minerals | Proteins |
|---|---|---|---|---|
| $F$ 1,4 = | 3·91 | 1·14 | 0·44 | 0·54 |
| | Sugars | NDF | °Brix | pH |
| $F$ 1,4 = | 7·98 | 0·14 | 1·45 | 1·05 |

$F_c$ 1,4 = 7·7 (95% confidence level)
$F_c$ 1,4 = 12·2 (97·5% confidence level)

Table 4 shows no statistically significant differences between systems 2 and 3.

The correlation matrix (Table 5) between variables shows significant correlations between: pH and titratable acidity, water and pH; days storage and °Brix and finally between storage and pH.

The correlation coefficient between sugars and °Brix ($r$ = 0·5492) with a significance level 0·0644 cannot be considered to be statistically significant at the 95% confidence level $p < 0·05$. That means °Brix cannot be assumed to be the same as the sugar content in this fruit.

Figure 1 shows the PCA, based on the correlation mentioned above, obtained from our data; the lines intersecting at (0,0) represent the experimental variables, the length of each vector is proportional to its contribution to the principal components. The first two axes of the mainplane represent 69% of the variance of the system. The percentage of variance explained by each component is shown in Table 6.

Table 7 shows the correlation coefficients of the variables with the first two axes; the values in each column give the weights of the linear combination forming each principal component. The first main

**Table 5. Correlation matrix between variables analysed**

| | Water | Acidity | pH | Minerals | Proteins | Sugars | °Brix | NDF | Days |
|---|---|---|---|---|---|---|---|---|---|
| Water | 1·0000 | | | | | | | | |
| | (12) | | | | | | | | |
| | 0·0000 | | | | | | | | |
| Acidity | −0·5992 | 1·0000 | | | | | | | |
| | (12) | (12) | | | | | | | |
| | 0·0395 | 0·0000 | | | | | | | |
| pH | 0·7937 | −0·8560 | 1·0000 | | | | | | |
| | (12) | (12) | (12) | | | | | | |
| | 0·0021 | 0·0004 | 0·0000 | | | | | | |
| Minerals | −0·4056 | 0·4559 | −0·4198 | 1·0000 | | | | | |
| | (12) | (12) | (12) | (12) | | | | | |
| | 0·1908 | 0·1364 | 0·1743 | 0·0000 | | | | | |
| Proteins | −0·1611 | −0·2132 | 0·3366 | 0·1286 | 1·0000 | | | | |
| | (12) | (12) | (12) | (12) | (12) | | | | |
| | 0·6170 | 0·5059 | 0·2846 | 0·6903 | 0·0000 | | | | |
| Sugars | −0·0192 | −0·0516 | −0·1339 | −0·2693 | −0·3954 | 1·0000 | | | |
| | (12) | (12) | (12) | (12) | (12) | (12) | | | |
| | 0·9529 | 0·8735 | 0·6781 | 0·3973 | 0·2033 | 0·0000 | | | |
| °Brix | −0·1560 | 0·4374 | −0·5169 | 0·2762 | −0·7079 | 0·5492 | 1·0000 | | |
| | (12) | (12) | (12) | (12) | (12) | (12) | (12) | | |
| | 0·6283 | 0·1551 | 0·0853 | 0·3849 | 0·0100 | 0·0644 | 0·0000 | | |
| NDF | 0·1894 | −0·0264 | −0·0635 | 0·0228 | −0·4224 | 0·1435 | 0·4564 | 1·0000 | |
| | (12) | (12) | (12) | (12) | (12) | (12) | (12) | (12) | |
| | 0·5555 | 0·9350 | 0·8446 | 0·9439 | 0·1713 | 0·6564 | 0·1358 | 0·0000 | |
| Days | −0·3231 | 0·4400 | −0·6754 | 0·4584 | −0·6918 | 0·2329 | 0·8288 | 0·4786 | 1·0000 |
| | (12) | (12) | (12) | (12) | (12) | (12) | (12) | (12) | (12) |
| | 0·3056 | 0·1523 | 0·0159 | 0·1339 | 0·0127 | 0·4663 | 0·0009 | 0·1154 | 0·0000 |

Coefficient (sample size) significance level.

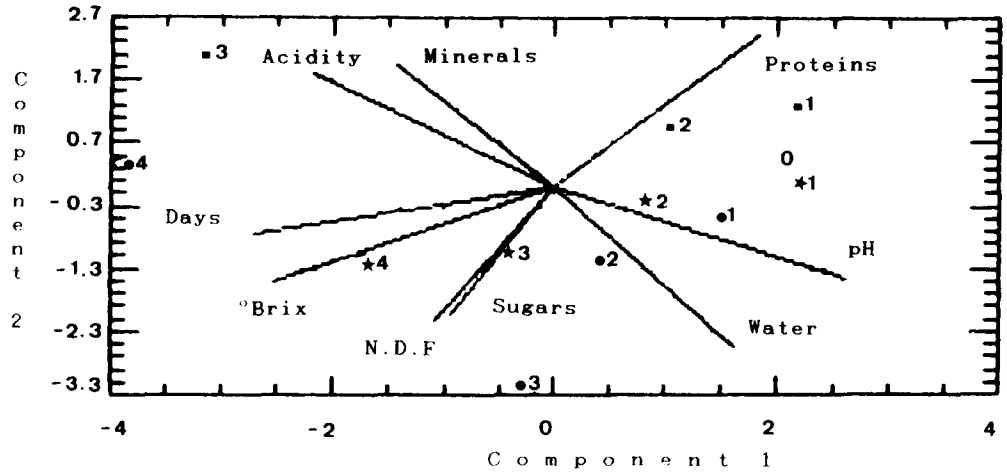


**Fig. 1.** Principal components analysis of the composition of papaya fruit during ripening. Biplot of first two principal components. (■, System 1; ●, system 2; ★, system 3).

component is closely related, negatively and positively, to the number of days storage, pH, °Brix and the titratable acidity.

The second main component is connected with the water content, nitrogen levels, neutral detergent fibre and sugar content. So the first main component represents the ripening period and the variables that could define it in papaya fruit.

Unripe fruits show high levels of proteins; finally overripe fruits show low pH and the highest values of soluble solids.

**Table 6. Percentage of variance explained by each component**

| Component number | Percentage of variance | Cumulative percentage |
|---|---|---|
| 1 | 43·938 23 | 43·938 23 |
| 2 | 25·422 80 | 69·361 03 |
| 3 | 12·191 40 | 81·552 43 |
| 4 | 6·983 01 | 88·535 44 |
| 5 | 6·005 86 | 94·541 30 |
| 6 | 3·729 69 | 98·270 99 |
| 7 | 1·171 11 | 99·442 10 |
| 8 | 0·529 00 | 99·971 10 |
| 9 | 0·028 90 | 100·000 00 |

**Table 7. Correlation coefficients of the variables with the two principal components (× 1000)**

| Variables | Component 1 | Component 2 |
|---|---|---|
| Water | 270·163 | −443·262 |
| pH | 438·094 | −250·965 |
| °Brix | −426·765 | −265·278 |
| Acidity | −367·578 | 311·117 |
| Proteins | 307·401 | 419·184 |
| Minerals | −240·174 | 338·548 |
| Sugars | −158·526 | −357·187 |
| NDF | −182·026 | −372·484 |
| Storage days | −455·413 | −129·279 |

## CONCLUSIONS

The analyses of variance applied show significant changes in papaya composition in the fruits stored in a domestic refrigerator (10°C), and no significantly different effects between the two refrigeration storage conditions applied (systems 2 and 3) on the papaya composition during ripening. For that reason, and considering the previous studies, we can consider the optimum storage temperature for papaya fruit to be 8–12°C, and never less than 7°C in order to avoid chilling injury.

The correlation analysis and PCA show that pH and °Brix values are closely related to number of storage days so we can consider both as indices of the ripening of papaya fruit.

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