Influence of the Ecological Cultivation of Strawberries (*Fragaria* × *Ananassa* Cv. Chandler) on the Quality of the Fruit and on Their Capacity for Conservation

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The quality of strawberries cultivated ecologically has been studied and compared to that of conventionally cultivated strawberries. The fruits from the two groups were grown in adjacent plots under identical environmental conditions. The quality parameters analyzed were both physical and chemical. The organoleptic characteristics of both types of fruit have been evaluated by a taste panel. By means of a simulation trial possible differences between changes in the quality of the fruits from each group during transportation and shelf life have been examined. The results show that the ecologically grown fruit had a superior quality to the conventionally grown fruit, the former showing a more intense color, higher sugar, and dry matter contents and better organoleptic characteristics. Ecologically grown fruits had a higher resistance to deterioration during simulated marketing conditions and thus a better degree of conservation.

Keywords: *Fragaria × ananassa; ecological cultivation; quality; conservation*

INTRODUCTION

During the last decade there has been an increase in consumer interest in ecologically cultivated foodstuffs throughout the world. This has been accompanied by an increase in the availability of such foodstuffs on the market. Given this situation, mechanisms have been established for promoting this type of production.

Although some interesting studies exist on the qualitative (Knorr, 1979; Fernandes et al., 1995), nutritional (Lairon et al., 1982; Kopp, 1992; Díez et al., 1995; Auclair et al., 1995; Pérez-Llamas et al., 1996), and organoleptic characteristics (Pettersson, 1978; Hansen, 1981) of ecological agricultural products [see also reviews by Lairon et al. (1984) and by Vogtmann (1983)], they have not been sufficiently contrasted.

The objective of the present study was to characterize the quality of ecologically cultivated strawberries, comparing it with that of strawberries cultivated using conventional methods. In addition, the conservation of the two types of fruits during simulated transportation and marketing conditions was studied.

EXPERIMENTAL PROCEDURES

The experiment was carried out in collaboration with two farmers who used conventional and ecological techniques of cultivation, respectively. The same cultivar, Chandler, was cultivated in adjacent plots of 6 and 4 ha in Almonte, Huelva, Spain, which had identical soil conditions and planting system. Plants were arranged on 50 cm ridges with lines of plants 25 cm apart; the width of the corridor between ridges was 60 cm, thus yielding a density of 73 000 plants/ha. Plants were grown under transparent polyethylene tunnels in both cases. The differences between treatments were exclusively regarding to fertilization and pest management. For the ecological plot a farmyard manure basal dressing (70 000 kg/ha) was applied. Except for this application, fertilization was distributed in both cases by the drop irrigation system: synthetic fertilizers for the conventional plot and humic acids and liquefied poultry manure for the ecological plot, with approximately the same doses of N-P-K (300-100-350). Similarly, chemical pesticides were used in the conventional plot, whereas the ecological plot was treated with pesticides meeting the standards of ecological agriculture. The yield from the conventionally cultivated plot was 37 000 kg/ha and that from the ecologically cultivated plot was 21 000 kg/ha, the labor time on each plot being the same.

A total of 11 random samples were taken at weekly intervals during the months of March, April, and May. Each 4 kg sample was divided in two equal parts, one of which was kept for physical−chemical analysis and the other for sensory analysis. In one harvest (29 March) a 20 kg sample was collected for the conservation study and this was stored in a cold chamber at 1 °C (relative humidity 95%) for 2 days to simulate conditions of transportation to other countries. Subsequently, they were kept for several days at room temperature and at 8 ± 2 °C to simulate the conditions of shelving during marketing.

Twenty fruits were taken from each sample, and their length, width, hardness and color were determined. The length and width were measured in mm using a gauge, the width measurements being taken at the point of greatest equatorial diameter. The weight (g) was determined using a precision balance. Hardness (N/cm^2) was estimated by measuring the resistance to penetration using a Zwick 3300 densimeter (Zwick GmbH, Ulm, Germany) with a 5 mm diameter disk (force required to depress the disk 2.4 mm into the fruit). The color was measured using the $L^*a^*b^*$ color spacing system with a Minolta CR200 chromometer (Minolta Camera Co., Osaka, Japan). Results are expressed in arbitrary units given by the equation $1000a/(L + b)$, which reflects changes of color very well (low or negative values, intense green; high values, 500−600, intense red).

Two determinations of acidity and of sugar content were performed on each sample and three of dry matter and ash content. The vitamin C (ascorbic acid) and Ca, Mg, Fe, Mn, and Cu contents were measured in duplicate. Titratable acidity was obtained with a Crison automatic titrator (Crison Instruments AG, Baar, Switzerland), results being expressed as mL of 0.1 N NaOH required by 2 mL of juice in order to attain pH 8. The sugar content (Brix degrees) was measured using an Atago DBX-55 refractometer (Atago Co. Ltd, Tokyo, Japan). Dry matter (%) was calculated by desiccating samples of approximately 50 g of finely cut fruit in an oven at 110 °C for 45 h. The ash content of each fruit sample was determined by combustion at 450 °C of the dry matter obtained previously

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Table 1. Physical Parameters[a]

date of harvest	length (mm)			width (mm)			weight (g)			color [1000a/(L + b)]			hardness (N/cm^2)		
	C	E	sig	C	E	sig	C	E	sig	C	E	sig	C	E	sig
10/3	45.5	47.4	ns	33.3	32.5	ns	20.4	20.0	ns	473	626	***	47.6	42.4	***
15/3	46.7	46.4	ns	33.4	35.3	*	21.5	22.7	ns	618	653	*	44.4	52.2	***
22/3	44.8	47.0	*	34.0	35.9	*	21.9	25.8	**	515	552	**	42.9	45.1	ns
29/3	45.3	42.7	**	33.8	31.0	**	19.8	16.1	**	511	558	***	33.9	39.0	**
5/4	47.2	45.7	ns	33.0	35.6	*	18.6	21.6	**	507	577	***	46.8	22.7	***
18/4	44.7	37.7	***	32.2	34.6	**	18.2	19.6	ns	586	601	ns	25.3	22.6	ns
24/4	40.0	36.0	***	29.5	33.0	***	14.7	16.8	**	561	570	ns	24.3	33.4	ns
3/5	37.6	40.2	**	30.3	34.9	***	16.7	17.0	ns	577	589	ns	21.3	25.3	*
10/5	36.7	40.7	***	31.3	34.6	***	15.3	18.9	***	597	621	*	18.9	13.0	***
17/5	36.5	37.8	ns	32.2	30.3	*	17.2	15.7	ns	557	559	ns	20.7	38.0	***
23/5	34.6	37.2	***	27.6	28.8	ns	12.1	12.7	ns	508	599	***	33.7	23.7	***
$\bar{x}$	41.4	41.7	ns	31.9	33.2	ns	17.6	18.5	ns	545	591	**	33.3	32.3	ns

[a] Note: C, conventional cultivation; E, ecological cultivation; sig, significance (ns, not significant; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$).

Table 2. Chemical Parameters[a]

date of harvest	acidity (mL 0.1 N NaOH)			sugars (°Brix)			ascorbic acid (mg/L)			dry matter (%)			ashes (%)		
	C	E	sig	C	E	sig	C	E	sig	C	E	sig	C	E	sig
10/3	2.7	2.6	ns	6.8	8.3	***	460	650	*	8.3	8.8	ns	0.8	0.6	*
15/3	2.7	3.0	ns	6.4	7.0	**	580	680	***	7.0	7.9	**	1.0	0.8	ns
22/3	2.6	2.7	ns	6.0	7.0	***	520	630	***	6.6	6.7	ns	1.2	1.2	ns
29/3	2.6	3.0	***	5.7	8.0	***	430	550	**	6.6	7.2	ns	0.8	0.5	*
5/4	2.9	2.1	***	6.3	7.7	***	610	730	**	7.8	9.6	***	0.6	0.8	ns
18/4	2.6	2.5	ns	7.0	7.8	***	620	700	*	6.4	7.3	*	0.6	0.6	ns
24/4	3.1	2.7	**	7.9	7.4	***	790	610	***	9.1	8.5	*	0.9	1.0	ns
3/5	3.4	3.0	***	9.9	9.7	ns	850	800	**	8.7	10.0	*	1.1	0.6	***
10/5	3.2	2.4	***	9.0	9.9	***	830	800	ns	8.5	9.7	*	1.2	0.8	**
17/5	3.0	3.4	**	8.5	9.8	***	880	920	ns	9.7	11.0	***	0.7	0.8	ns
23/5	3.6	2.9	***	9.2	9.9	***	960	880	**	9.9	10.0	ns	1.3	0.8	***
$\bar{x}$	2.9	2.8	ns	7.5	8.4	**	700	720	ns	8.1	8.9	**	0.9	0.8	ns

[a] Note: C, conventional cultivation; E, ecological cultivation; sig, significance (ns, not significant, * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$).

and ground in a porcelain mortar. The ascorbic acid (mg/mL) contained in the juice obtained from the fruits was determined by colorimetric analysis with 2,6-dichloroindophenol as indicator. The mineral contents of both types of fruit were analyzed by atomic absorption with a Perkin-Elmer 3030 spectrophotometer.

Sensory analysis was performed by a panel of 14 tasters specially selected and trained to evaluate the quality of fruits and vegetables. The overall grading of each sample was carried out using a 9-point structured scale (1, worst quality, 9, optimum quality) and that of individual attributes (color, brightness, appearance, odor, hardness, juiciness, acidity, sweetness, and taste) on a 6-point unstructured scale (0, imperceptible, 5, maximum intensity). The commercial losses (percentage of fruits with $^1/_3$ or more of their surface mechanically damaged or rotten) were determined on a sample of 80−90 fruits taken at random. The sensory characteristics and the commercial losses were determined in duplicate.

For the statistical analysis, variance analysis was used (Ruiz-Maya, 1983). Student's *t*-test (Gore, 1953) was used to compare the means obtained for the two cultivations at a same harvest and a paired comparison tests (Gore, 1953; Davies, 1960) was used for the comparison of the overall means taking into account all the harvests.

RESULTS AND DISCUSSION

Table 1 shows the results obtained after measuring the physical parameters. There was no significant difference between the lengths of the fruits from the two groups; on the other hand, a considerable, but not significant, difference between the widths was observed in favor of the ecological strawberries. The smaller width-to-length equality explains the more lengthened aspect of the conventionally grown fruits.

Both parameters tended to decrease with successive harvests. There were no significant differences between the weights of the fruits from the two groups and in both groups the weights diminished in successive harvests. While color and hardness indicate the ripeness of the fruit to a certain degree, these parameters also depend on the variety of the fruit and may be affected by conditions of cultivation. In the present trial, the color remained virtually constant from one harvest to another, but the ecologically grown fruits presented a significantly stronger color ($p < 0.01$) than the conventionally grown strawberries. Fruit hardness tended to decrease in both groups in successive harvests. In six of the 11 harvests the ecologically grown strawberries were firmer than the conventionally grown fruits, while in the other five this tendency was reversed. The overall means of the two groups for this parameter were not significantly different.

Table 2 shows the results of the chemical determinations. There were no significant differences between the mean acidity values of the two types of fruits. The values for acidity in both groups tended to vary irregularly with harvest although there was a slight trend toward increasing acidity. The sugar contents followed similar trends to that of acidity but without such pronounced fluctuations. In all but two samples (24/4 and 3/5) the sugar contents were higher in the ecologically cultivated fruits than in the conventionally grown strawberries. The overall mean for the ecologically cultivated fruits was 8.4° Brix, which was significantly ($p < 0.01$) higher than that of the conventionally grown fruits (7.5° Brix). There were no significant differences between the ascorbic acid contents of the two groups.

The dry matter content of the ecologically grown fruits was higher than that of the conventionally grown fruits in all but one harvests (24/4) and the overall means for

Table 3. Metal Contents[a]

metal	conventional cultivation	ecological cultivation	tabulated values[b]
Ca	27.2 ± 2.8[c]	23.7 ± 2.2[c]	16−30
Mg	10.6 ± 0.9	8.6 ± 0.6	11−20
Fe	639 ± 65	734 ± 72	800−1310
Mn	223 ± 12	193 ± 18	130−250
Zn	62.5 ± 3.6	68.9 ± 4.3	90−270
Cu	7.8 ± 1.4	10.0 ± 2.0	28−170

[a] Ca and Mg expressed in mg/100 g f.w.; Fe, Mn, Zn, and Cu expressed in μg/100 g f.w. [b] Deutsche Forschungsanstalt für Lebensmittelchemie (1994). [c] Mean (n = 33) ± se.

this parameter were consequently significantly different ($p < 0.01$), i.e., 8.9% for the ecologically cultivated groups and 8.1% for the conventionally grown group. The results found here for acidity, sugars, and dry matter find close agreement with those of Fernandes et al. (1995), who also worked with strawberries.

The ash content of both types of fruit fluctuated considerably, and their overall means (0.92% for the ecologically grown group and 0.77% for the conventionally grown group) were not significantly different.

There were no differences between the Ca, Mg, Fe, Mn, Zn, and Cu content of the two groups of fruits (Table 3). In general the content in these metals varied little from one harvest to another. When these values are compared with the reference values published by Deutsche Forschungsanstalt für Lebensmittelchemie (1994), the Ca and Mn contents can be considered relatively normal, those of Mg and Fe slightly low, those of Zn low, and those of Cu very low.

Table 4 shows the values for the sensory attributes and the points assigned for each attribute by the panel. Color and brightness were constant in successive harvests and followed trends similar to those obtained for color using the colorimeter (Table 1). This indicates that the degree of ripeness in each harvest was more or less the same. The panel judged strawberries from the ecological cultivation (except in the case of the 17/5 harvest) to have a more intense brightness than those from the conventionally cultivated group. This was reflected in a significant difference ($p < 0.01$) between the overall means of each group for this parameter. Since the taster cannot appreciate the often minute differences between the lengths and weights of the strawberries, it is the color and the brightness of the fruit which chiefly contribute to their evaluation of appearance. The appearance of the ecologically grown fruits, therefore, was judged to be significantly superior ($p < 0.01$) to that of the other group.

The values corresponding to odor showed a very slight tendency to increase in successive harvests in the conventionally grown group. In all harvests except one (15/3) the odor of the ecologically grown fruits was deemed superior to that of the conventionally grown strawberries, but in only six of the remaining 10 harvests was the difference between the two groups significantly different. Overall, however, the mean evaluation of this parameter for the ecologically grown fruits was significantly higher than that of the conventional strawberries ($p < 0.01$). In general the ecological strawberries were deemed to be moderately odorous (2−3 points out of 5) and the conventionally grown fruits weakly odorous (1−2 points).

The hardness values given by the panel, as in the case of the mechanically measured values using the densitometer (Table 1), were very variable and were not significantly different from one group to another. Despite this finding, the ecologically grown fruits were judged overall to be juicier than the conventionally grown fruits ($p < 0.01$), although the differences between the groups were not significant in every harvest.

Table 4. Organoleptic Parameters[a]

date of harvest	color (scale, 0−5)			brightness (scale, 0−5)			appearance (scale, 0−5)			odor (scale, 0−5)			hardness (scale, 0−5)		
	C	E	sig	C	E	sig	C	E	sig	C	E	sig	C	E	sig
10/3	3.1	4.0	***	2.8	3.7	***	2.9	3.8	***	1.4	3.4	***	3.0	3.0	ns
15/3	3.1	3.2	ns	3.1	3.1	ns	3.1	3.1	ns	2.0	1.8	ns	2.7	3.2	***
22/3	3.3	3.5	ns	2.5	3.2	**	3.3	3.4	ns	1.3	1.6	ns	2.6	2.8	ns
29/3	2.9	3.5	**	2.9	3.2	ns	3.2	3.4	ns	1.2	2.1	**	2.7	2.6	ns
5/4	3.1	3.8	**	3.1	3.4	ns	3.2	3.8	**	1.4	2.9	***	2.9	2.4	***
18/4	3.4	3.8	*	2.9	3.2	ns	3.5	3.6	ns	1.5	3.4	***	2.3	2.0	*
24/4	3.0	3.5	*	3.0	3.2	ns	3.1	3.5	*	1.6	2.5	**	2.6	2.2	*
3/5	3.4	3.5	ns	3.3	3.3	ns	3.4	3.5	ns	2.5	2.7	ns	2.4	2.5	ns
10/5	3.4	3.8	ns	3.2	3.5	ns	3.4	3.8	*	2.1	2.9	*	2.6	2.3	ns
17/5	3.7	3.7	ns	3.5	3.4	ns	3.6	3.6	ns	2.3	2.7	ns	2.6	2.6	ns
23/5	3.1	3.3	ns	2.6	3.0	*	3.1	3.3	ns	2.1	2.2	ns	2.3	2.3	ns
$\bar{x}$	3.2	3.6	**	3.0	3.3	**	3.2	3.5	**	1.8	2.5	**	2.6	2.5	ns

date of harvest	juiciness (scale, 0−5)			acidity (scale, 0−5)			sweetness (scale, 0−5)			taste (scale, 0−5)			overall grading (scale, 1−9)		
	C	E	sig	C	E	sig	C	E	sig	C	E	sig	C	E	sig
10/3	2.8	3.7	***	3.1	2.7	ns	1.5	3.0	***	1.8	3.5	ns	5.2	7.2	***
15/3	3.0	3.0	ns	3.1	2.9	ns	1.8	2.1	ns	2.2	2.4	ns	5.1	5.5	ns
22/3	2.9	3.0	ns	2.9	2.6	ns	1.3	2.1	***	1.5	2.4	ns	4.7	5.8	**
29/3	2.8	3.2	**	2.6	2.2	*	1.5	2.5	***	1.8	2.9	***	4.9	6.2	***
5/4	2.8	3.5	***	2.7	2.1	**	1.6	2.9	***	1.9	3.2	***	5.5	6.9	***
18/4	3.1	3.4	**	2.5	1.9	*	1.9	2.6	**	2.2	3.0	**	5.7	6.7	**
24/4	2.9	3.4	**	3.0	2.0	***	1.5	2.6	***	2.0	2.9	***	5.4	6.5	**
3/5	3.2	3.4	ns	2.5	2.4	ns	2.4	2.7	ns	2.6	3.0	ns	6.1	6.5	ns
10/5	3.0	3.4	**	2.6	2.1	*	1.8	2.8	***	2.2	3.0	***	5.5	7.0	***
17/5	3.1	3.3	ns	2.7	2.5	ns	2.2	2.7	*	2.5	3.0	*	6.1	6.8	*
23/5	2.8	3.2	**	2.8	2.2	**	2.0	2.6	**	2.2	2.9	**	4.9	6.2	***
$\bar{x}$	2.9	3.3	***	2.8	2.3	***	1.8	2.6	***	2.1	2.9	***	5.3	6.5	***

[a] Note: C, conventional cultivation; E, ecological cultivation; sig, significance (ns, not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$).

Table 5. Commercial Losses (%)[a,b]

	8 ± 2 °C			ambient temperature		
days	C	E	sig	C	E	sig
0	0.0	0.0	ns	0.0	0.0	ns
2	0.0	0.0	ns	0.0	0.0	ns
4	11.1	3.5	**	34.2	4.5	**
5	4.8	1.4	*	65.4	21.8	**
7	6.7	1.4	*	78.6	23.6	**
8	16.3	3.7	**	87.0	71.7	*
11	65.7	35.0	***			
12	71.0	33.3	***			
13	89.6	22.6	***			

[a] Note: C, conventional cultivation; E, ecological cultivation; sig, significance (ns, not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$). [b] Fruits with $^1/_3$ or more of their surface mechanically damaged or rotten.

The values obtained for the juiciness of the ecologically grown fruits can be considered very good.

The values for the sensation of acidity and sweetness for both types of strawberry are not those one would expect from the results of chemical analysis (Table 2). This demonstrates the complexity of sensory perception and the interaction of the senses. Thus, while the chemical determinations indicate slightly increasing values for both parameters in successive harvests, the sensory evaluations indicate an even slighter rise in sweetness (the sensation being tempered by the sensation of acidity), and decrease in acidity (counterbalanced even more by the sensation of sweetness). In all the harvests the ecologically grown fruits were sweeter and less acidic than the conventionally grown fruits, the difference between the overall means being highly significant ($p < 0.01$). The values for sweetness corresponded to medium sweet (acceptable) for ecologically grown fruit and low for conventionally grown fruit, while both groups had a medium level of acidity.

For all samples the ecological strawberries were judged to have a more intense taste (about 3 points) than the conventional fruits (about 2 points). The differences between the overall means for the taste evaluations were highly significant ($p < 0.001$) in favor of the ecologically grown fruit.

The overall or absolute score gives an evaluation on a scale of 1−9 of the fruits on the basis of the results of all the parameters considered. This overall score remained more or less constant from one harvest to another in both groups with just a very slight tendency to increase. The values for the ecologically grown strawberries were at all harvests either significantly greater ($p < 0.05$) or highly significantly greater ($p < 0.01$ or $p < 0.001$) than those of the conventionally cultivated fruit. The difference between the two overall means of this absolute score was highly significant ($p < 0.001$). In summary the ecologically grown fruit were superior to those of the conventionally cultivated fruits in all of the sensory qualities assessed and, consequently, in terms of their overall appreciation scores. Hardness was the only parameter for which values in the two groups were similar.

Table 5 shows the commercial losses of strawberries from the two groups in the various stages of their simulated marketing, at 8 ± 2 °C as well as at ambient temperature. As was to be expected, there was a exponential increase in percentage loss with time for both groups, this increase being more pronounced at room temperature. Ecologically grown fruits were more resistant to deterioration than conventionally grown fruits, in agreement with Vogtman (1983) for other agricultural produce. For both groups, unless on sampling days and at the end of the simulated transportation in which the losses yet were zero, at all other stages the losses of conventionally grown fruit were significantly higher than those of ecologically grown fruit. This indicates that ecologically grown strawberries have a conservation capacity higher than the conventionally grown strawberries.

The phsyical parameters determined during the conservation, color and hardness (data not shown), showed similar behavior in both types of strawberries: color remained fairly constant with a tendency to increase in intensity toward the end of the trial and, consequently, the difference of initial color intensity shown the day of the harvest was maintained practically constant during all the period of the conservation; similarly, also throughout the conservation hardness maintained the initial difference observed the day of the harvest. In contrast, storage at room temperature led to a slight loss of hardness of fruits from both groups but was maintained better at 8 ± 2 °C.

The analyzed chemical parameters, acidity and sugar (data not shown), were maintained practically constant during simulated marketing and, therefore, so were their initial differences; there was only a slight tendency for the acidity to increase in conventionally grown fruits at room temperature.

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