Comparative Study of *Selva* and *Camarosa* Strawberries for the Commercial Market

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ABSTRACT: *Selva* and *Camarosa* strawberry varieties were characterized chemically and physically. The importance of keeping the stem until processing, the influence of different transport periods under refrigerated conditions, the effects of freezing and exposure to air of damaged surfaces were evaluated. During freezing, losses of ascorbic acid, sucrose, fructose and glucose were reported for both varieties. However, keeping the stem intact minimizes the losses of ascorbic acid in frozen fruits. The exposure to air of cut surfaces affects ascorbic acid content of fresh fruits, with the highest losses reported in *Camarosa*. *Selva* showed properties important for commercial use, as compared to *Camarosa*, with regard to a higher resistance to thawing and higher contents of total phenolics, total protein, and ascorbic acid.

Keywords: strawberries, freezing, organic acids, mechanical resistance, water loss

Introduction

CONSUMERS DEMAND HIGH QUALITY JAMS with excellent natural flavor, color, and whole fruit content. Strawberry (*Fragaria x ananassa Dutch*.) is one of the most perishable fruits, susceptible to mechanical injury, physiological deterioration and decay, due to fungal action, mainly grey mold rot (caused by *Botrytis cinerea*).

The basic quality of the fruit depends on the interaction of many factors including climate, soil fertility, pest and pathogen control, harvesting time, quality of harvest (fruit integrity, bruising, cutting, for example), and prestorage treatments (Sistrunk and Morris 1985, McLellan 1996).

Preharvest factors affecting postharvest quality of berry crops were studied (Prange and others1997), concluding that most quality parameters are genetically based, so genetic selection is important when specific characteristics are needed (Shaw 1990). Some other studies were made about postharvest strawberry quality, such as the effects of ozone treatment (Pérez and others 1999), the package influence during storage (Sanz and others 1999), and the influence of the atmosphere composition during storage on color stability (Holcroft and Kader 1999). Color stability of strawberry fruit jams, made from frozen strawberries, was shown to be affected by cultivar and storage temperature of the final product (Garcia–Viguera and others 1999). Nevertheless, no studies were found on the appropriateness of *Selva* strawberries for industrial processing in the fruit puree and jam industry.

Strawberry fruit jams are extremely important in the fruit jams industry because they account for most of the sales. The products that can be made from strawberry jams are extraordinarily different from one another; thus, strawberries have to be prepared in many different ways, such as cut size (from 3 mm cubes for some pulps to 25 mm cubes to other fruit preparations) and sugar, color, and flavor additions.

Frozen berries are commonly used for commercially processed jams. The freezing process influences the final quality of the fruit (Suutarinen and others 2000). In fast-freezing, there is insufficient time to remove the water from the cell through osmosis. The cell contents under-cool, and ice forms within the cell. In slow-freezing, there is enough time to remove the appropriate amount of water from the cell and ice does not form within the cell, but outside. On thawing, this may be a source of drip loss and may explain why slow-frozen fruits often have higher rates of drip loss then fast-frozen fruits (Reid 1996).

Evaluating the effects of transportation conditions (including refrigeration and freezing), and analyzing the injuries suffered by the strawberries and their effect on the mechanical and nutritional properties of each variety of strawberries, are the main concerns of the fruit jam industry. The Portuguese fruit jam industry uses mainly 2 strawberry varieties: *Selva*, grown in Portugal, and *Camarosa*, imported mostly from Spain.

The main objectives of this study were to characterize chemically and physically 2 strawberry cultivars (CV) that are used in the Portuguese fruit jam industry; to test the importance of keeping the strawberry stem until the jam is made; to evaluate the influence of different transportation periods under refrigerated conditions on physical-chemical properties of the fresh strawberries; to study the effects of freezing on physical-chemical properties of *Selva* and *Camarosa* strawberries; to determine the effect of exposure of damaged surfaces to air (such as by cutting) for different periods on physical-chemical properties of fresh strawberries; and to compare the resistance to freezing/thawing of the 2 strawberry varieties in order to evaluate each CV for different commercial products.

Materials and Methods

IN ORDER TO SIMULATE THE CONDITIONS OF commercial processing, several situations were tested (Figure 1). *Selva* and *Camarosa* strawberries were harvested in Bragança (Portugal) and Huelva (Spain), respectively, and transported to the laboratory under refrigerated conditions (4 °C). The fruits were sorted on arrival to eliminate damaged fruits and to select for uniform color and maturation degree (Wang and Lin 2000).

Analyses were conducted 48 and 72 h after harvesting to check the influence of refrigerated storage time on fruit quality (Boyette and others 1989).

For processing, stems have to be removed. Therefore, after harvesting, the fruit stems were either immediately cut (strawberries without stem) or left intact to be cut in the factory (strawberries with stem). Therefore, samples with and without the stem were tested.

Another commercial procedure is to cut

the fruits into pieces (usually from 3 to 18 mm) so they can be further processed. This cutting operation may be performed at different times prior to additional handling. In order to simulate the cutting operation, fresh strawberries were cut into slices of variable size and left, at room temperature, in contact with air for 5 and 30 min before the analyses were performed.

Whole fresh strawberries, with and without stem, were frozen at –18 °C and analyzed after a 6-mo storage period.

The dripping volume after thawing, which is an important parameter that indicates the fruit's resistance to freezing/thawing, was determined for the 2 varieties tested.

Three replications were made for each parameter and the results presented are mean values with the respective standard deviation.

Determination of pH and total acidity (TA)

pH and TA were determined according to the AOAC 942.15 method (AOAC 1997).

Determination of total solids (TS), volatile solids (VS) and ash

Samples of approximately 30 g were placed in an oven at 105 °C to constant weight, to determine total solids. After that, they were placed at 505 °C for approximately 1 h to determine ash (the remnant) and volatile solids content (the difference between TS and ash).

Determination of organic acids

For the quantification of organic acids, strawberries were blended until forming a puree. Commercial enzymatic kits were used to determine malic acid (kit Boehringer nr 139068), ascorbic acid (kit Boehringer nr 409677), and citric acid (kit Boehringer nr 139076). The kits were obtained from Boehringer, Manheim, Germany. In the case of ascorbic acid determinations, the fruit puree was centrifuged and the supernatant was used, to avoid interferences with the detection method. For each parameter an appropriate dilution was used in ultra-pure water.

Determination of sugar

For the determination of sugars, a puree was prepared as previously described for organic acids determination. This puree was then filtered through a membrane (0.2 mm pore size) and diluted when necessary. Sugars (sucrose, glucose, and fructose) were quantified by HPLC (Chrompack, Middleburg, The Netherlands) using a refractive index (RI) detector (JASCO 830–RI Intelligent RI Detector, Jasco, Tokyo, Japan) and a PL Hi-Plex Ca Column. The eluent was sterilized ultra-pure water. The analyses were made at an elution rate of 0.6 mL/min and an oven temperature of 85 °C. The retention times of sucrose, glucose and fructose were, respectively, 11.67, 13.86, and 16.95 min.

Determination of protein

Protein concentration was measured in the strawberry puree previously described, before and after dialysis, according to the method described by Bradford (1976), using the Pierce (Rockford, Ill., U.S.A.) Coomassie protein assay reagent with crystalline BSA as the standard protein.

Dialysis was conducted by placing approximately 20 mL of sample into a dialysis membrane of 20 kDa molecular weight cutoff and leaving it for 18 h at 4 °C in distilled water.

Determination of fat

Fat was determined according to the AOAC 983.23 method (AOAC 1997).

Determination of lignin and cellulose

Lignin determination was made according to the AOAC 949.04 method (AOAC 1997).

Cellulose was determined following the Portuguese standard NP 1005 (1974).

Determination of anthocyanins and total phenolic compounds

The method described by Riberau–Gayon (1982) was the one used for anthocyanins determination.

Total soluble phenolics in the fruit extracts were determined using the Folin–Ciocalteau reagent according to the method of Slinkard and Singleton (1977).

Determination of drip loss

Drip loss is defined as the liquid volume (in mL) lost per 100 g of frozen fruits during thawing. The after-thaw volume was determined after 4 h equilibration at room temperature. Drip loss was calculated by averaging the percentages of liquid losses for each of the 3 replicates made and for each CV.

Statistical analysis

In order to determine whether the differences found in the various physical-chemical properties analyzed were significant or not, 2-way analysis of variance (ANOVA) was performed at both 5 and 10% significance levels.

Considering all the combinations of conditions tested in the present work (please refer to Figure 1), it was possible to establish

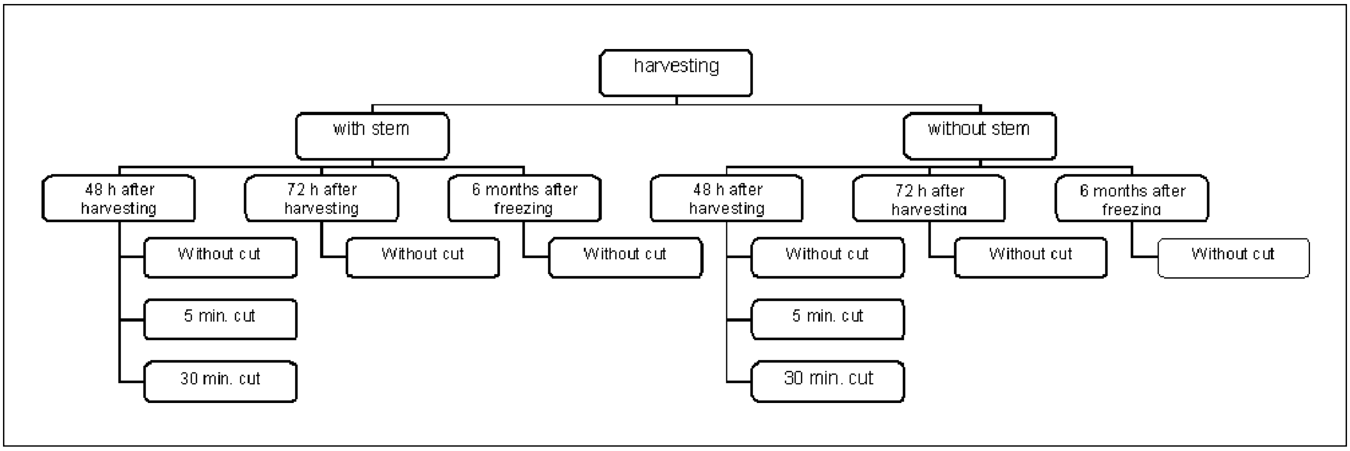

Figure 1—Conditions tested for each variety of strawberries

Table 1—Analytical results for *Camarosa* and *Selva* whole strawberries 48 and 72 h after harvest, with or without stem.

Parameters		*Camarosa* 48 h	*Camarosa* 72 h	*Selva* 48 h	*Selva* 72 h
Total solids ($g/_{100}g_{fruit}$)	With stem	8.79±0.12	8.21±0.18	13.78±0.18	12.38±0.13
	Without stem	9.12±0.20	9.02±0.27	12.69±0.08	12.73±0.04
Ash ($g/_{100}g_{fruit}$)	With stem	51.0±4.0	42.0±3.0	50.0±4.0	41.0±1.0
	Without stem	0.48±0.01	0.50±0.04	0.33±0.01	0.34±0.01
Celullose ($g/_{100}g_{fruit}$)	With stem	2.33±0.29	1.78±0.28	2.14±0.14	2.05±0.19
	Without stem	1.90±0.13	1.79±0.14	1.98±0.09	1.92±0.70
pH	With stem	3.70	3.53	3.67	3.67
	Without stem	3.66	3.64	3.73	3.73
Titrable acidity ($V_{NaOH,\ 0,1M}$/100 g)	With stem	113.3	125.5	105.5	93.1
	Without stem	119.5	119.8	95.6	89.8
Total phenolics (mg/g_{fruit})	With stem	6.139±0.048	6.659±0.249	10.510±0.361	9.162±0.169
	Without stem	6.357±0.294	6.450±0.637	9.831±0.189	8.549±0.181
Antocyanins ($mg/100\ g_{fruit}$)	With stem	41.067±0.908	39.560±3.045	29.992±0.916	30.845±0.140
	Without stem	48.190±1.424	48.190±1.424	29.981±0.982	29.465±0.429
Citric acid (mg/g_{fruit})	With stem	7.469±0.868	7.342±0.832	4.417±1.704	7.255±0.644
	Without stem	7.648±0.253	8.087±0.429	5.194±0.378	5.354±0.303
Malic acid (mg/g_{fruit})	With stem	1.313±0.015	1.201±0.146	ND	ND
	Without stem	1.171±0.066	0.961±0.015	ND	ND
Ascorbic acid (mg/g_{fruit})	With stem	0.313±0.033	0.246±0.046	0.301±0.010	0.336±0.002
	Without stem	0.355±0.011	0.088±0.022	0.380±0.046	0.285±0.083
Sucrose (mg/g_{fruit})	With stem	5.317±0.000	5.132±0.141	7.416±0.120	3.628±0.011
	Without stem	9.091±0.000	8.561±0.074	5.826±0.202	3.632±0.217
Fructose (mg/g_{fruit})	With stem	27.835±0.016	24.792±0.713	62.719±5.894	46.379±1.076
	Without stem	30.739±0.033	31.112±2.634	55.124±4.256	46.590±4.832
Glucose (mg/g_{fruit})	With stem	34.736±0.002	28.382±0.486	86.433±4.548	68.614±6.953
	Without stem	35.378±0.059	31.220±3.719	67.580±1.111	69.345±13.341

ND - not determined

4 sets of tests to allow comparisons both within the same variety (when subjected to different storage conditions and cutting times) and between the 2 varieties under study (for fresh and frozen fruits). A 1st set of tests was performed to compare, for each variety, 3 different treatments (48 h, 72 h after harvesting, and 6 mo frozen) and 2 different blocks (with and without stem). A 2nd set of tests was performed, also for each variety, to compare 2 different treatments (5 min and 30 min cut) and the same 2 different blocks (with and without stem). The 3rd and 4th sets of tests were performed in order to compare the physical-chemical properties of the 2 varieties in fresh and frozen strawberries, respectively and the previously mentioned blocks.

Results and Discussion

THE COMPLETE SET OF RESULTS IS PRESENTed in Table 1 to 4.

Freezing caused an increase in humidity and, consequently, a decrease in total and volatile solids. This is mainly caused by atmospheric water condensation and freezing on the fruits' surfaces during the freezing process. The freezing process causes damages in vegetable tissues (Reid 1996), raising the free water content (Figure 2 and 3). However, the results of analysis of variance show that the differences found were not significant both at 5 and 10% significance level. As no significant differences were found for fresh strawberries, for simplicity, the figures represent the averaged results for fresh fruits (48 h and 72 h after harvest, with and without cut, with and without stem).

The fat content of *Selva* strawberries is nearly half of that of *Camarosa*, but these values are too low to be relevant when considering its use on commercial products. (Figure 4)

Considering the total phenolics content, no significant differences were found in *Selva* strawberries for all the conditions under study (Figure 1). The same was generally valid for *Camarosa* berries. When comparing the 2 varieties, *Selva* strawberries show a higher (30%) content of total phenolics, which can act as a natural antioxidant agent. This difference is significant at 10% significance level ($p = 0.066$). Considering the contents of anthocyanins, *Selva* CV shows a lower content (28% less) than *Camarosa*, but the differences were found to be not significant at the studied levels ($p > 0.1$). These compounds are responsible for the red color of the fruits, but, for the particular application sought in the present study (industrial use), the color is a secondary parameter once artificial colorants are always added to the products.

The balance among organic acids and sugars determines strawberry flavor (Peréz and others 1999). Of the whole set of experiments made, and concerning the citric and malic acid content of the fruits, the only significant differences ($p < 0.1$) where found when comparing frozen berries from the 2 varieties under study (*Camarosa* has a higher citric acid and lower malic acid content than *Selva*).

Ascorbic acid (vitamin C) is present in strawberries, giving an added value to this fruit due to its important nutritional properties. This acid is quite unstable, thus it can be an indication of fruit freshness. In fruit juice processing, as well as in fruit purees and jams preparation, ascorbic acid can suppress browning by avoiding the oxidation of polyphenols to o–quinones that, through polymerization, form brown pigments (Sawamura and others 1994).

In fresh whole *Camarosa* and *Selva* strawberries, no differences ($p > 0.1$) were found in ascorbic acid levels when comparing the fruits 48 h and 72 h after harvesting, both with and without the stem.

In fresh *Camarosa* strawberries, the exposure of cut surfaces to air induced losses of ascorbic acid as high as 50% after only 5 min, although after 30 min the losses were not significantly higher ($p > 0.1$). *Selva* showed increasing losses, but they did not exceed 26% of the initial value.

Table 2—Analytical results for *Camarosa* and *Selva* strawberries 5 and 30 min after cutting, with or without stem.

		Camarosa		*Selva*	
Parameter		5 min after cut	30min after cut	5 min after cut	30 min after cut
pH	With stem	3.58	3.64	3.72	3.73
	Without stem	3.49	3.54	3.74	3.72
Titrable acidity ($V_{NaOH,\ 0,1M}$/100 g)	With stem	120.1	119.3	99.7	105.3
	Without stem	135.9	115.1	94.1	96.6
Total phenolics (mg/g_{fruit})	With stem	6.439±0.035	6.799±0.059	9.264±0.098	9.260±0.614
	Without stem	6.772±0.057	6.188±0.598	9.013±0.358	9.210±0.520
Antocyanins (mg/100 g_{fruit})	With stem	43.745±1.094	42.042±5.607	27.919±0.083	31.119±8.218
	Without stem	45.783±2.380	40.227±0.113	29.799±1.108	27.739±0.742
Citric acid (mg/g_{fruit})	With stem	8.365±0.398	7.700±0.108	4.203±0.341	3.909±0.530
	Without stem	8.851±0.217	7.598±0.470	3.989±0.568	3.614±0.417
Malic acid (mg/g_{fruit})	With stem	1.326±0.026	1.258±0.033	ND	ND
	Without stem	1.011±0.041	0.966±0.007	ND	ND
Ascorbic acid (mg/g_{fruit})	With stem	0.175±0.023	0.180±0.020	0.301±0.010	0.267±0.021
	Without stem	0.163±0.018	0.168±0.006	0.326±0.068	0.245±0.004
Sucrose (mg/g_{fruit})	With stem	6.008[a]	4.161±0.101	6.386±0.168	6.167±0.022
	Without stem	6.043[a]	6.044±0.022	5.864±0.728	6.085±0.074
Fructose (mg/g_{fruit})	With stem	26.854[a]	28.042±0.078	72.054±4.343	58.055±1.988
	Without stem	25.282[a]	26.837±0.089	61.312±2.093	57.245±2.275
Glucose (mg/g_{fruit})	With stem	30.774[a]	31.977±0.115	86.412±2.348	71.934±1.253
	Without stem	25.282[a]	28.377±0.574	74.890±4.094	69.988±2.102

ND – not determined
[a] These values correspond to a single determination, therefore no SD was calculated.

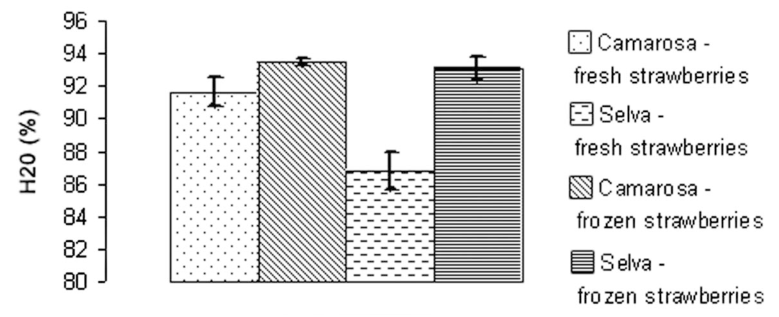

Figure 2—Moisture content (H_2O) of fresh and frozen strawberries

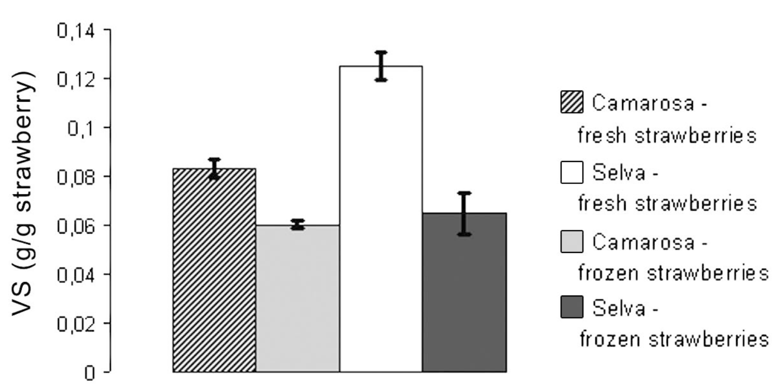

Figure 3—Volatile solids (VS) content of fresh and frozen strawberries

The amount of ascorbic acid is significantly higher (up to 2-fold, p = 0.047) in frozen *Selva* strawberries when compared with the *Camarosa* variety, suggesting advantages of the former in terms of better resistance to oxidizing agents during processing, as well as an increase in the final product shelf life, reducing the need to add preservatives. For strawberry purees and jams, mainly frozen fruits are used. In fact, the freezing process induced a loss of more than 60% of total ascorbic acid in *Camarosa* strawberries with stem and more than 80% when the stem has been previously removed. The corresponding values in *Selva* were lower (22% and 49%, respectively, for strawberries with and without stem).

The results above are summarized in Table 4 and show that keeping the stem can be of extreme importance to the retention of ascorbic acid in frozen fruits (significant differences, p = 0.092, were found when comparing *Selva* and *Camarosa* varieties). In fact, the procedure of removing the stem immediately after harvesting is common, but, to our knowledge, the effects of this procedure in the final quality of the fruits have never been demonstrated before.

The liquid volume lost by 100 g of fruit (drip loss) is an important parameter for industrial processing, not only because it allows to evaluate the quality of the process of freezing/thawing, but also allows to determine the loss of mechanical resistance during these stages, due to cell wall breakage by ice crystals (Reid 1996). Mean values of drip loss after thawing are pre-

Table 3—Analytical results for *Camarosa* and *Selva* whole strawberries after 6 mo of freezing, with or without stem.

Parameters		*Camarosa*	*Selva*
Total solids ($g/_{100}g_{fruit}$)	With stem	6.39±0.09	6.36±0.50
	Without stem	6.68±0.05	7.4±0.59
Ashes ($g/_{100}g_{fruit}$)	With stem	0.46±0.02	0.46±0.63
	Without stem	0.52±0.0003	0.34±0.02
pH	With stem	3.46	3.58
	Without stem	3.50	3.52
Titrable acidity ($V_{NaOH,\ 0,1M}$/100 g)	With stem	119.05	89.09
	Without stem	105.64	86.62
Total phenolics (mg/g_{fruit})	With stem	8.929±0.027	9.606±0.028
	Without stem	8.325±0.052	7.739±0.102
Antocyanins (mg/100 g_{fruit})	With stem	39.363±0.419	25.104±0.052
	Without stem	61.363±1.676	28.993±0.210
Citric acid (mg/g_{fruit})	With stem	9.233±0.538	5.190±0.088
	Without stem	9.265±0.846	6.147±0.145
Malic acid (mg/g_{fruit})	With stem	1.309±0.195	6.353±0.697
	Without stem	1.181±0.024	4.920±0.457
Ascorbic acid (mg/g_{fruit})	With stem	0.113±0.015	0.234±0.009
	Without stem	0.063±0.010	0.168±0.008
Sucrose (mg/g_{fruit})	With stem	0.0±0.0	3.034±0.060
	Without stem	0.0±0.0	2.785±0.021
Fructose (mg/g_{fruit})	With stem	20.146±0.494	33.587±0.449
	Without stem	16.748±0.970	32.830±0.369
Glucose (mg/g_{fruit})	With stem	19.433±0.256	35.630±0.101
	Without stem	21.953±0.668	33.788±0.357

sented in Figure 5. *Selva* strawberries present by far the lowest drip loss during thawing, which is in agreement with its higher content in lignin (Figure 6), indicating a higher mechanical resistance. Further, the lower drip loss during thawing determined for *Selva* variety also helps to explain the lower losses of ascorbic acid detected, after 6 mo of storage at –18 °C, when compared to *Camarosa* variety (Nunes and others 1998).

Selva strawberries also show a higher protein content, which can be considered as a nutritional advantage when comparing with the other varieties. On the other hand, *Selva* and *Camarosa* strawberries have approximately the same amount of peptides smaller than 20 kDa, since the decrease of total proteins after dialysis with a 20 kDa MWCO membrane was approximately the same (Figure 7). This means that *Selva*'s higher protein content is due to high-molecular-weight molecules, usually the ones with higher biological activity.

The total sugar content decreases in fresh fruits only slightly until 72 h after harvesting, but after freezing, sucrose disappeared and glucose and fructose decreased about 50% and 65%, respectively, for both varieties. This can be explained by fermentation processes that may occur during freezing/thawing with concomitant consumption of sugars. In fact, although ethanol and aldehydes were not determined, some off odors started to be apparent and gas disengagement was visible in thawed strawberry puree.

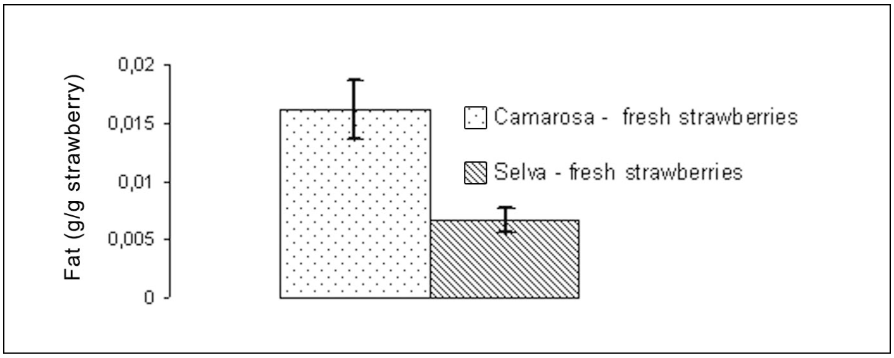

Figure 4—Fat content of fresh strawberries

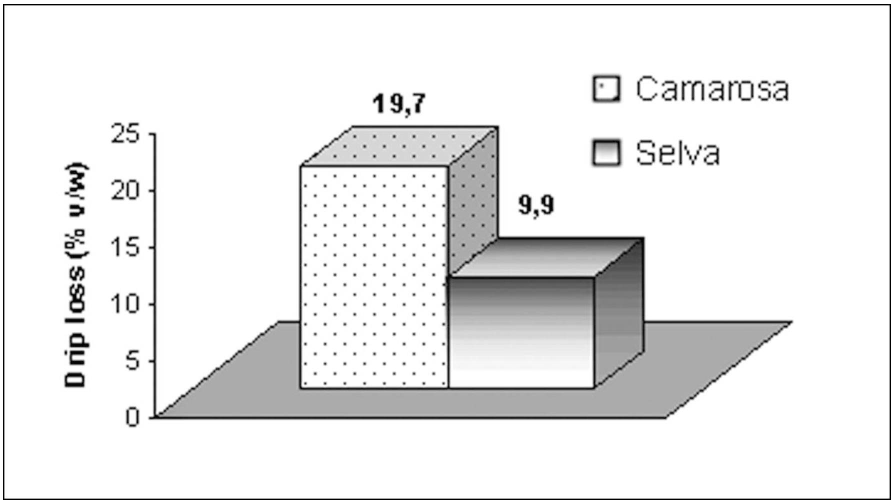

Figure 5—Drip loss of the 2 cultivars of strawberries after thawing

Conclusion

For both varieties, the results suggest that until 72 h after harvest, under refrigerated conditions, there is no deterioration of the main physical-chemical parameters of both the whole and cut fresh fruits.

As compared with *Camarosa* strawberries, several physical-chemical properties were highlighted for *Selva* with regard to resistance to thawing, higher levels of total phenolics, total protein, and ascorbic acid content. For the latter parameter, keeping the stem was found to be advantageous when using frozen fruits.

The presented results clearly demonstrate there are advantages associated with the use of *Selva* strawberries for commercial purposes.

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Table 4—Ascorbic acid losses for *Camarosa* and *Selva* strawberries, with or without stem.

Ascorbic acid losses (%)		*Camarosa*	*Selva*
After 5 min. cut	With stem	44%	0%
	Without stem	54%	1,5%
After 30 min. cut	With stem	42%	11%
	Without stem	52%	26%
After 6 mo frozen	With stem	64%	22%
	Without stem	82%	49%

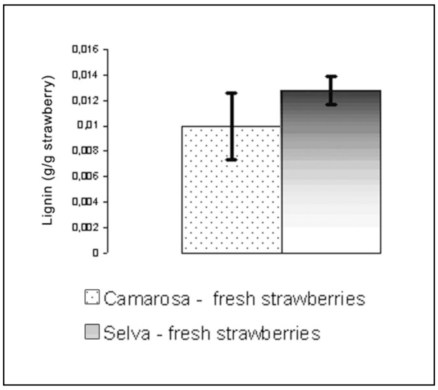

Figure 6—Lignin content of fresh and frozen strawberries

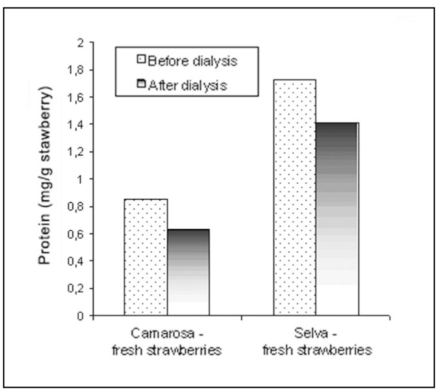

Figure 7—Total protein content of fresh and frozen strawberries, before and after dialysis

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