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Alternative sanitation techniques applied to minimally fresh industrially processed cherry and plum salad

A.M. Fernández-León[1], F. Cañada-Cañada[1], S. Nogales-Delgado[1], J. Delgado-Adámez[1], D. Bohoyo-Gil[1], M.F. Fernández-León[2]

[1]*CICYTEX-Instituto Tecnológico Agroalimentario (INTAEX), Gobierno de Extremadura, Avda Adolfo Suarez, S/N, 06071 Badajoz, Spain.*

[2]*Centro para la Calidad de los Alimentos, Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA), Campus Universitario Duques de Soria, c/José Tudela s/n, 42004 Soria, Spain.*

Abstract: *A comparative study on different sanitation methods on the quality decay of fresh industrially processed cherry ('Ambrunés') and plum ('Suplum eleven') salad is presented. The fruit was processed in a cleaning room, under usual and controlled conditions in a fresh cut industrial plant, using the following steps: reception, cutting, washing, draining and packaging. Processed salad was packaged in thermally sealed polypropylene basket using passive modified atmosphere. During a storage period of 10 days at 4 ºC, sensory attributes, functional content and microbial counts analysis were performed. It was concluded that the combinated use of UV-C radiation and 10.0 g/l ascorbic acid was effective in reducing the microbial counts, maintaining the antioxidant compounds and the sensorial quality of the product during the 10 days at 4 ºC.*

Keywords: *antioxidant compounds, fresh-cut, industrial practices, quality attributes salad, UV-C radiation.*

I. INTRODUCTION

Ready to eat fresh fruit has become an important area of potential growth in the fast expanding produce industry [1] presumably due, in part, to their characteristics of freshness, low caloric contents, commodity to be used and an active promotion of fruits and vegetables as basic components of a healthy diet. Nevertheless, it is well known that minimal processing alters the integrity of the fruit and induce surface damages increasing lightly the tissue respiration and leading biochemical deteriorations [2, 3].

In order to decrease microbial contamination, the fresh-cut industry commonly uses sodium hypochlorite as disinfection agent but by-products such as trihalometanes and chloramines are potentially harmful for humans, so must be studied alternative disinfectant agents [4]. One alternative disinfectant agents is ultraviolet-C (UV-C) light, is easy to use and lethal to most types of microorganisms [5].

Fruits are considered a natural source of antioxidants, including anthocyanins and polyphenols [6], compounds that can reduce the risk of degenerative diseases caused by oxidative stress, such as cancer, cardiovascular disease and stroke [7]. Red fruits, including sweet cherries and plum, are rich in these types of compounds.

The main purpose of this work was to evaluate whether cherries and plums salad could make an acceptable fresh-cut product. It was considered interesting to determine how the production chain, and the alternative sanitation techniques used, affect the microbial growth, sensory and functional quality of fresh fruit salad.

II. MATERIALS AND METHODS

Plant material

The samples of sweet cherry (*Prunus avium* L.) 'Ambrunés' were obtained of Valle del Jerte (Cáceres, Spain) and the cultivar of plum (*Prunus salicina* Lindl), 'Sumplum eleven', a red flesh variety, was harvested in Finca La Orden-Valdesequera (Badajoz, Spain) were carefully selected for uniform size and colour as well the absence of damage and defects. Samples were taken and transported to INTAEX under refrigeration conditions.

Minimal processing

The processing was realized in the clean room (Temperature 8 ºC). The steps of processing were: a) Reception; b) Cutting: plums were sliced manually and cherries are mechanically; c) Washing: industrial washing equipment, model Camel (Turatti, Italy) coupled with an ultraviolet system of six lamps (Montagna, Italy). The following treatments (Ti) were applied: T0- water (control), T1- the ascorbic acid concentration used in the water was 10.0 g/l and T2- 10.0 g/1 ascorbic acid and UV-C radiation; d) Draining: the slice plums and cherries were drained using an industrial drying tunnel (Domino Junior Laboratorio, Turatti, Italy); e) Packaging: the same number of pieces of cherries and plums were placed in a polypropylene (PP) basket and thermally sealed with the PP film to generate a passive modified atmosphere (MAP) with the respiration of the

product. An industrial packaging, model Verpakungs-Systeme (Western, Germany) was used; f) Storage: Packaged samples were stored at 4 ºC in refrigeration for up to 10 days to simulate shelf life conditions.

Total soluble solids, titratable acidity and pH

Total soluble solids (TSS), titratable acidity (TA) and pH were measured for each independent homogenate (n = 4), obtained from fresh salad fruit and homogenized. TSS were measured by refractometry using an RE40 refractometer (Mettler Toledo, S.A.E., Spain), results are expressed as ºBrix. TA and pH were determined using DL50 Graphix automatic titrator (Mettler Toledo, S.A.E., Spain). The maduration index was calculated as the ratio between TSS and TA. Results were expressed as g malic acid/100g fresh weight (fw).

Colour

The flesh colour of cherries and plums were measured using a CR-200 tristimulus colorimeter (Minolta, Japan). Chromatic analyses were conducted in accordance with the CIE (Commission Internationale de l'Eclairage) system. Values of L*, a* and b* were used to define a three-dimensional colour space. The hue angle (h*), calculated as arctg (b*/a*), expresses the colour nuance. Each datum represents the average of 4 measures taken at equidistant points on the equatorial region of the respective fruit. The colorimeter was calibrated on a standar white tile.

Total phenolic content, anthocyanin pigments and antioxidant activity

Total phenolic content (TPC) was extracted from 5 g of homogenate (n=4). The colorimetric reaction was developed by using Folin-Ciocalteau reactive. After one-hour reaction, absorbance was measured at 760 nm with a UV-2401 PC spectrophotometer (Shimadzu Scientific Instruments, USA). TPC was quantified by an external standard method using gallic acid and expressed as mg galic acid/100 g fresh weight [8].

Anthocyanins were extracted from 10 g of homogenate in 50 ml acidic methanol solution (0.2% HCl) (n=4) and evaluated by chromatography [9]. The quantification was carried out by the external standard calibration method, using cyaniding 3-O-rutinoside as standard and expressed as mg cyaniding 3-O-rutinoside/100 g fresh weight.

For determining the total antioxidant activity (TAA) 20 µl of salad juice obtained from salad homogenate was placed in a spectrophotometric cuvette, and 1 ml of the radical cation ABTS (2-2'-azinobis(3-ethylbenzoithiazolone 6-sulphonate) was added (n=4). The initial absorbance value at 730 nm was then compared with the absorbance obtained after 20 min of reaction. The TAA was expressed as mg Trolox/100 g fresh weight [10].

Microbiological analyses

Microbiological analysis was carried out following ISO 4833 and ISO 7954 international standards (ISO 7954 1988; ISO 4833 1991). All samples were done in triplicate and their results were expressed as log CFU/g.

Sensory evaluation

Sensory quality was evaluated by a semi-trained panel consisting of eight members. Each panellist was given several pieces from each basket. The samples were coded with random three-digit numbers to mask the treatment identity in order to minimize subjectivity and to ensure test accuracy. All quality evaluations were performed in a sensory room.

Statistical analysis

For statistical studies, SPSS 18.0 software was used (SPSS Inc., Chicago, IL, USA). Correlations were estimated with the Pearson test at $p<0.05$ significance level. Data are expressed as means ± S.D. and were analyzed using a one-way analysis of variance (ANOVA). When ANOVA detected significant differences between mean values, means were compared using Tukey's test.

III. RESUSLTS AND DICUSSION

Total soluble solids (TSS), titratable acidity (TA), pH and maturation

The results for total soluble solids (TSS), titratable acidity (TA), pH, and maturation index are presented in Table 1.

Table 1: Total soluble solids (TSS), titratable acidity (TA), pH and maturation index (TSS/TA) of fresh cut salad fruit.

Storage	Treatment	TSS[1]	TA[2]	pH	TSS/TA
Day 0	T0	17.17a ± 0.21	1.02b ± 0.00	3.34a ± 0.00	16.83a ± 0.24
	T1	16.27b ± 0.42	0.92c ± 0.03	3.35a ± 0.02	17.62a ± 0.52
	T2	15.53c ± 0.06	1.17a ± 0.03	3.13b ± 0.04	13.25b ± 0.31
Day 1	T0	17.50a ± 0.26	1.03b ± 0.05	3.34a ± 0.05	17.02a ± 0.92
	T1	15.33b ± 0.23	1.09b ± 0.04	3.16b ± 0.02	14.08b ± 0.46
	T2	14.33c ± 0.06	1.20a ± 0.02	3.01b ± 0.01	11.98c ± 0.20
Day 3	T0	18.30a ± 0.40	1.04a ± 0.01	3.33a ± 0.01	17.66a ± 0.56
	T1	16.60b ± 0.00	0.93b ± 0.03	3.28a ± 0.02	17.92a ± 0.58
	T2	15.87c ± 0.12	0.94b ± 0.03	3.29a ± 0.02	16.82a ± 0.36
Day 7	T0	16.70a ± 0.10	0.80a ± 0.01	3.55a ± 0.01	20.88b ± 0.39
	T1	15.23c ± 0.12	0.67b ± 0.02	3.55a ± 0.02	22.86a ± 0.87
	T2	16.37b ± 0.06	0.77a ± 0.00	3.47b ± 0.01	21.26b ± 0.36
Day 10	T0	17.67a ± 0.06	0.67a ± 0.02	3.53a ± 0.02	26.25a ± 0.85
	T1	16.37c ± 0.06	0.61a ± 0.03	3.48a ± 0.05	26.87a ± 1.23
	T2	16.60b ± 0.00	0.67a ± 0.06	3.46a ± 0.07	25.03a ± 2.23

(1) ºBrix; (2) g mallic acid/100 g fresh weight. In each column, for each storage date, the same letter in superscript indicates that there is no significant difference ($p > 0.05$). Mean of 4 independent replicates.

There were some significant differences in TSS between the treatments applied. The control sample (T0) showed higher values with respect to T1 and T2. Values are slightly lower for the two treatments applied, and they increase slightly with storage days.

TA ranged with levels fluctuating from one storage day to the next and pH varied between the limits pH 3 to 5. Organic acids play an important role in the flavour of fruit, a sensory attribute that is determined by the ratio of sugar to acid, maturation index (TSS/TA) increased. There were some significant differences and a clear tendency to greater values with increasing maturity, agree that found values for TSS and TA. The values for TSS and acidity found in this study are similar to others given for those cultivars of fruit, not cut [11, 12].

Colour

In the fresh-cut fruit the consumer detects principally the tonality of the pulp of the fruit rather than the solid colours (a* and b* values) and hue angle (h*) is the parameter that determines acceptance or rejection of the produce.

The value obtained for the hue angle parameter (h*) of the flesh of plum and cherry are given in Figure 1. In general, hue angle (h*) showed increase from day 0 to day 10 of storage, for all applied treatments, but the greatest increase was from day 7, especially for T0 and T1, so we can conclude that for T2 the pigments conservation is better. This can be because ascorbic acid is a widely used antioxidant whose reductory action against quinones and diphenols prevents browning of minimally processed fruit as it produces only colourless derivatives [13].

The great increase in the hue angle (h*), possibly indicating a reduction of anthocyanins, as we can see in Table 2. In the case of cherry, there were not some significant differences in h* between the treatments applied and storage days. The values for h* found in this study are similar to others given for this cultivars of fruit, at 4-5th ripening stages [12].

Total phenolic content, anthocyanin pigments and antioxidant activity

Phenolic and anthocyanin contents and total antioxidant activity (TAA) are shown in Table 2. The phenolic content is high in all days of storage studied, but from day 7, a great decrease in this content was observed. Similar behaviour was found for anthocyanin content and TAA. Maybe this decrease during storage period at 4 ºC using passive modified atmosphere, is due to an increasing surface area contact with oxygen as a result of cutting and this had an effect on the activity of the major enzymes involves in the functional compounds degradation.

The values for phenolic and anthocyanin content found in this study are similar to values of others authors [11, 12]. The TAA values are lower than those obtained for the same whole cultivars by the same authors.

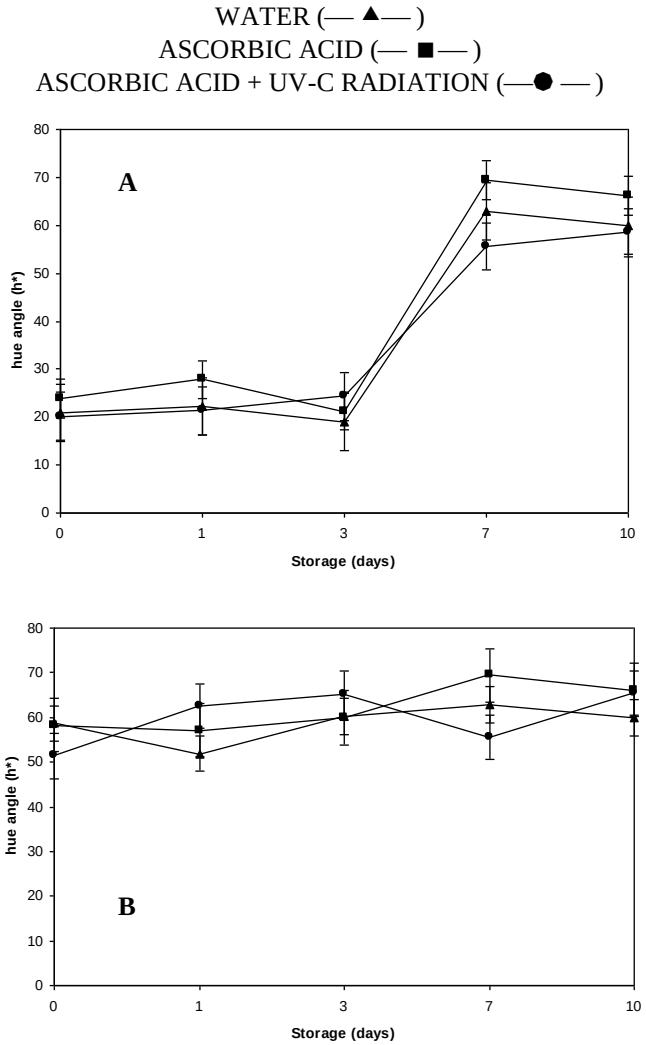

Figure 1: Evolution in hue angle (h*) of plum (A) and cherry (B) separately, using different washing treatments.

Table 2: Total phenolic content (TPC), anthocyanin pigments and antioxidant activity (TAA) of fresh cut fruit salad throughout the storage.

Storage	Treatment	TPC[1]	Total anthocyanins[2]	TAA[3]
Day 0	T0	118.49c ± 2.71	29.71b ± 1.01	217.94b ± 16.19
	T1	124.33b±2.74	16.97c ± 0.78	279.63a ± 21.30
	T2	178.30a ± 1.94	35.39a ± 1.70	275.10a ±10.80
Day 1	T0	85.88c ± 5.34	7.42c ± 0.77	272.43a ± 13.99
	T1	110.60b ± 3.76	12.53b ± 0.27	283.97a ± 10.18
	T2	160.76a ± 4.87	25.36a ± 1.02	239.66b ± 6.69
Day 3	T0	89.70c ± 1.37	14.62b± 0.69	283.95a ± 9.57
	T1	109.25b ± 1.62	13.74b ± 1.21	277.04a ± 4.09
	T2	159.84a ± 1.75	26.68a ± 2.92	283.68a ± 2.78
Day 7	T0	82.99b ± 4.10	8.90b ± 0.18	215.25a ± 15.70
	T1	103.09a ± 7.86	11.01a ± 1.22	237.65a ± 11.19
	T2	96.74a ± 4.61	8.23b ± 0.44	230.87a ± 12.02
Day 10	T0	84.78c ± 3.18	10.43a ± 0.52	218.28b ± 10.21
	T1	107.40a ± 2.83	9.22b ± 0.35	265.54a ± 7.72
	T2	101.33b ± 2.57	8.94b ± 0.45	226.62b ± 15.75

(1) mg gallic acid /100 g fresh weight; (2) mg cyaniding-3-O-rutinoside/100 g fresh weight; (3) mg Trolox/100 g fresh weight. In each column, for each storage date, the same letter in superscript indicates that there is no significant difference ($p > 0.05$). Mean of 4 independent replicates.

Microbiological assessment

The effects of the different sanitizing treatments on microbial growth from fresh cut salad fruit was carried out. In all treatments, microbial growth increased when time of storage extended. However, the T2 treatment reduced the microbial count more than T0 y T1. For the mesophilic growth, after 10 days of storage, T2 reduced the mesophilic growth by 1.15 log CFU/g compared with the control (T0). At day 0, psychrotrophic counts of fresh-cut plum and cherry washed with ascorbic acid + UV were less than 2 log CFU/g. This initial value provided a lower phychrotropic load at day 10. After 10 days of storage at 4 ºC, psychrotrophic growth in T2 was 2.60 log CFU/g and in the control (T0) 3.59 log CFU/g (i.e. a 1.0 log CFU/g reduction using T2). For the moulds and yeast growth after 10 days of storage, there were not some significant differences in between the treatments applied. The values in this study are similar to others given for fresh processed lettuce [14] where they applied directly UV radiation on the product and concluded that UV-C effect not depends on the dose.

To evaluate the effect of UV radiation on microbial growth of washing water, with the objective to see the possibility of reusing this water, the analysis of this water before and after washing the fruit was carried out. The Figure 2 shows how to use UV radiation (T2) produces lower microbial load that T1 at beginning and at end of the process, so that it can be concluded that the use of UV causes a microbial reduction in washing water, with possibility of reuse this water with the consequent minimization of water consumption and decrease in the wastewater discharge rates in the food industry, producing a good environmental impact.

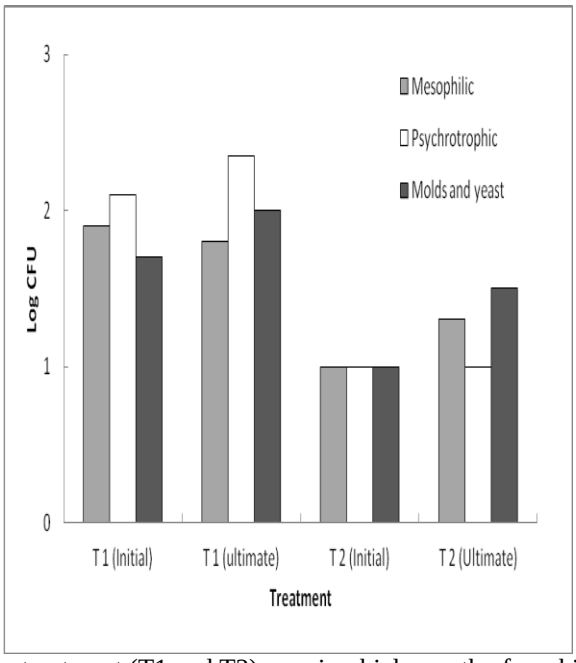

Figure 2: Effects of sanitizing treatment (T1 and T2) on microbial growth of washing water, before (initial) and after (ultimate) the processing of fruit salad.

Effect of washing treatment on sensory quality

The visual quality was excellent after washing for all treatments, and promotion of browning was not observed for any washing solutions. No significant differences in the initial visual quality were observed among the treatments. These samples maintained the full typical aroma, which was not affected by the different washings. Off-odors were not detected in washed samples with different solutions at any storage time. Sample textures slightly decreased during storage, but no differences were observed between the applied treatments.

IV. CONCLUSION

The present study suggest that whether cherries and plums salad could make an acceptable fresh-cut product and determine how the production chain and the alternative sanitation techniques used, affect the microbial growth, functional and sensory quality of fresh processed fruit salad, in order to find environmentally alternatives to the chlorine traditionally used in the food industry. Samples were directly processed in our fresh-cut processing line and cleaning room, which gives more accurate and realistic information about the quality of these commercial products. It was concluded that the combinated use of UV-C radiation and 10.0 g/l ascorbic acid was effective in reducing the microbial counts, maintaining the antioxidant compounds and the sensorial quality of the product during the 10 days at 4 ºC. This treatment could be a good substitute of use of sodium hypochlorite and alternative technique for minimizing water consumption in the food industry.

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