EFFECT OF ULTRASONICATION, THERMOSONICATION AND ULTRAVIOLET IRRADIATION ON THE QUALITY OF STRAWBERIES (*Fragaria anannassa*) AND RED BELL PEPPERS (*Capsicum annuum L.*)

D. M. SANTOS PEDRO, E.M.C. ALEXANDRE, J. FUNDO, T.R.S. BRANDÃO and C. L.M. SILVA [(a)]

(a) LOPA-Laboratory for the Optimization of Food Processes, Escola Superior de Biotecnologia, Universidade Católica Portuguesa, Rua Dr. António Bernardino de Almeida, 4200-072 Porto, Portugal; Fax: +351 225 090 351, www.esb.ucp.pt/lopa, E-mail: clsilva@esb.ucp.pt

ABSTRACT

The objective of this work was to study the effect of ultrasonication, thermosonication and UV-C irradiation on the quality attributes of strawberries (*Fragaria anannassa*) and red bell peppers (*Capsicum annuum*, L.). Thermosonication studies were carried out at 50ºC and 65ºC. Control water treatments at the same temperatures were conducted. The analysed quality factors were colour and texture for both products, in addition to anthocyanins content in the case of strawberries.

Results showed that UV-C constituted a harmless treatment, with little or no effect on color, texture or anthocyanins content. Ultrasonication caused small colour changes and no significant effects on texture of both products. Thermosonication at 65ºC resulted in undesirable changes of color, anthocyanins and texture of strawberries, and color of red bell peppers. When compared to water treated samples, thermosonicated ones showed higher texture retention. This effect was much more pronounced on red bell peppers.

1. INTRODUCTION

Alternative non-thermal technologies constitute emergent challenging methods aiming at reducing pernicious effects of thermal methods, by preserving quality and nutritional attributes of fruits and vegetables, and yielding safe and less-perishable products. The application of ultrasounds and ultraviolet (UV-C) irradiation are examples of non-thermal technologies that may have potential applications in the food industry.

Ultraviolet (UV) light occupies a wide band of wavelengths in the non-ionising region of the electromagnetic spectrum between X-rays (200 nm) and visible light (400 nm) (Hollósy, 2002). The germicidal range is in the region of short-wave UV (UV-C), with wavelenghts between 200 and 280 nm, being the 254 nm the most lethal (Summerfelt, 2003). Exposure to low doses of UV-C has been reported to reduce post-harvest decay of fruits and vegetables (Lu *et al.*, 1987; Erkan *et al.*, 2001; Marquenie *et al.*, 2002; Allende and Artés, 2003), which accredits prospective application of UV-C in the postharvest industry.

Ultrasound is defined as pressure waves with a frequency of 20 kHz or more (Butz and Tauscher, 2002). Ultrasound may be used at frequencies between 20 kHz and 10 MHz. Higher-power ultrasound at lower frequencies (20-100 kHz) has the ability to cause cavitation, which has the capacity to inactivate microbes and enzymes (Knorr *et al.*, 2002, 2004; Piyasena *et al.*, 2003). The conjoint application of mild temperatures may enhance the ultrasonication effect (thermosonication), especially in terms of product's safety (Mason *et al.*, 1996, Lopéz-Malo *et al.*, 2005), with minor changes in terms of quality parameters, when compared to conventional thermal methods.

The objective of this work was to study the effect of ultrasonication, thermosonication and UV-C irradiation on the quality attributes of strawberries (*Fragaria anannassa*) and red bell peppers (*Capsicum annuum*, L.).

2. MATERIALS AND METHODS

Strawberries (*Fragaria anannassa*) and red bell peppers (*Capsicum annuum*, L.) were acquired in a local market. They were pre-washed and carefully soaked with an absorbant towel. Strawberries were used either as whole, for ultrasonication and thermosonication studies, or cut into two equal halves, for the UV-C irradiation treatments or texture analysis studies. Red bell peppers were cut into pieces of 1x2 cm for all treatments.

UV-C treatments were carried out in an UV-C chamber that was designed by Universidade do Algarve (EST-Ualg, Faro, Portugal). Samples were carefully placed in petri plates and submitted to a bank of four germicidal UV lamps (TUV G30T8, 16 W, Philips, peak emission at 254 nm) for 2 minutes, at an average intensity of 12,36W /m^2. The intensity of flux of lamps and dose of exposure (*time* x *intensity*) were continuously measured using an UV digital photometer (DO 9721 Delta Ohm).

Ultrasonication and thermosonication treatments were carried out in an ultrasound machine (Bandelin Sonorex RK 100H) operating at 32 kHz. Samples were treated for 2 minutes at 20˚C (ultrasonication), and 50˚C and 65˚C (thermosonication). Control water treatments at the same temperatures were also performed.

The quality factors analysed were colour and texture for both products, in addition to anthocyanins content in the case of strawberries. At least 4 replicates of at least 30 samples each were analyzed.

Colour was measured using the Hunter (L, a and b) scale, with a colorimeter (CR-300, Minolta). The total colour difference (TCD) was the parameter considered for evaluation of colour. The TCD quantifies the overall colour difference of a given sample (L,a,b) when compared to a reference sample (L_o, a_o, b_o), according to equation (1) (Drlange, 1994):

$$TCD= [(L-L_o)^2+(a-a_o)^2+(b-b_o)^2)]^{1/2} \quad (1)$$

being index "$_o$" indicative of initial reference values of fresh product.

Anthocyanins were assayed by a spectrophotometric procedure (spectrophotometer UV-1601, Shimadzu). Results were obtained in terms of monomeric pigment anthocyanin (pelargonidin 3-glycoside).

Texture analysis was conducted in a texturometer (TA-XT2plus, TA Instruments) equipped with a 5 kg force cell. Compression mode tests (30% deformation, 1mm/s velocity) were performed using a 10 mm or a 36 mm diameter cylindrical probe for red bell peppers or strawberries, respectively. Hardness values were registered as the maximum force observed during compression of samples.

The experimental results were compared by analysis of variance (two-way ANOVA, Analysis Tool Package, Excel 2000, Microsoft®, USA).

3. DISCUSSION

Results of strawberries and red bell peppers quality are, respectively, presented in tables 1 and 2. The overall colour difference was judged according to the TCD reference table, as stated by Drlange (1994).

For both products, irradiation with UV-C light constituted the most harmless treatment, with little changes on colour and texture (hardness).

Table 1. Results for colour, hardness and anthocyanins of strawberries (*Fragaria anannassa*) treated by ultraviolet radiation (UV-C), ultrasonication (US 20ºC), thermosonication (US 50ºC and US 65ºC) and water (W 20ºC, W 50ºC and W 65ºC).

Treatments	Color (TCD[a,c])	Hardness (normalized values[b,c])	Anthocyanins (normalized values[b,c])
UV-C	1,562 ± 0,829	1,025 ± 0,206	0,888 ± 0,076
US 20ºC	2,626 ± 0,235^{z,y}	0,999 ± 0,070^{p}	1,082 ± 0,083^{x}
W 20ºC	2,864 ± 0,355^{z,v}	0,763 ± 0,129^{p}	1,250 ± 0,010^{x}
US 50ºC	4,620 ± 0,463^{y}	0,919 ± 0,246^{p}	0,866 ± 0,180^{x}
W 50ºC	3,084 ± 0,243^{v,s}	0,827 ± 0,154^{p}	0,945 ± 0,080^{x}
US 65ºC	6,387 ± 0,610^{w}	0,640 ± 0,233^{t}	0,835 ± 0,351^{y}
W 65ºC	4,347 ± 0,416^{s}	0,279 ± 0,079^{t}	0,756 ± 0,112^{y}

[a] TCD – Total Color Diference
[b] normalized values in relation to untreated samples
[c] values in the same column followed by a different letter are significantly different (P>0,05)

After ultrasonication (US 20ºC) samples showed distinct colour in relation to fresh. However, this effect was very small when compared to the effect of thermosonication, especially at 65ºC. At this temperature, thermosonication caused great differences on the colour of samples. Water treatments carried out at the same temperature showed very similar results, which suggests that the effect on colour is due to the temperature effect, and not exclusively to the sonication of samples.

Table 2. Results for colour and hardness of red bell peppers (*Capsicum annuum*) treated by ultraviolet radiation (UV-C), ultrasonication (US 20ºC), thermosonication (US 50ºC and US 65ºC) and water (W 20ºC, W 50ºC and W 65ºC).

Treatments	Color (TCD[a,c])	Hardness (normalized values[b,c])
UV-C	1,344 ± 0,853	0,971 ± 0,306
US 20ºC	4,778 ± 1,307^{w}	1,146 ± 0,451v
W 20ºC	3,051 ± 1,034^{x}	1,070 ± 0,414^{v}
US 50ºC	5,528 ± 1,856^{w}	1,214 ± 0,500^{v}
W 50ºC	3,144 ± 1,000^{x}	0,910 ± 0,420^{v}
US 65ºC	6,572 ± 1,770^{z}	1,076 ± 0,480^{v}
W 65ºC	7,487 ± 1,525^{y}	0,587 ± 0,282^{p}

[a] TCD – Total Color Diference
[b] normalized values in relation to untreated samples
[c] values in the same column followed by a different letter are significantly different (P>0,05)

In the case of strawberries a slight decrease in anthocyanins content was observed at higher temperatures, which may be related with observed total colour differences.

Interesting results were obtained in relation to the products hardness. In the case of strawberries (table 1), samples turned softer with increasing of temperature. However, the decrease of hardness was much more pronounced on the water treated. In the case of red bell peppers (table 2), softening of samples was only observed for water treated samples at 65ºC. These results suggest that, somehow sonication of samples (at the used frequency), even when coupled with temperature, seems to preserve the structure of vegetable tissues, preventing them from texture loss when higher temperatures are used.

4. CONCLUSIONS

UV-C constituted a harmless treatment, with little or no effect on colour, texture or anthocyanins content. Ultrasonication caused small colour changes and no significant effects on texture of both products. Thermosonication at 65ºC caused significant changes on colour of strawberries and red bell peppers. When compared to water treated samples, thermosonicated ones showed higher texture retention. This effect was much more pronounced on red bell peppers.

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REFERENCES

Allende A. and Artés, F. (2003). UV-C radiation as a novel technique for keeping quality of fresh processed Lollo Rosso letuce. *Food Res. Int.*, 36(8):739-756

Butz., P. and Tauscher, B. (2002). Emerging technologies: Chemical aspects. *Food Res. Int.*, 35(2-3):279–284

Drlange (1994). Color Review. Drlange Application Report, no. 8.0.e. USA

Erkán, M., Wang, C.Y. and Krizek, D.T. (2001). UV-C radiation reduces microbial populations and deterioration in *Curcubita peppo* fruit tissues. *Env. Exp. Bot.*, 45(1):1-9

Hollósy, F. (2002). Effects of ultraviolet radiation on plant cells. *Micron*, 33(2):179-197

Knorr, D., Ade-Omowaye, B.I. and Heinz, V. (2002). Nutritional improvement of plant foods by non-thermal processing. *Proc. Nut. Soc.*, 61(2):311-318

Knorr, D., Zenker, M., Heinz, V. and Lee, D.-U. (2004). Applications and potentials of ultrasonics in food processing. *Trends Food Sci. Technol.*, 15(5):261-266

Lopéz-Malo, A., Palou, E., Jiménez-Fernández, M., Alzamora, S.M., Guerrero, S. (2005). Multifactorial fungal inactivation combining thermosonication and antimicrobials. *J. Food Eng.*, 67(1-2):87-93

Lu, J.Y., Stevens, C., Yakabu, P., Loretan, P.A., and Eakin, D. (1987). Gamma, electron beam and UV radiation on control of storage roots and quality of Walla Walla onions. *J. Food Proc. Preserv.*, 12:53-62

Marquenie, D., Michiels, C.W., Geeraerd, A.H., Schenk, A., Soontjen, C., Van Impe, J.F. and N icoläi, B.M. (2002). Using survival analysis to investigate the effect of UVC and heat treatment on storage rot of strawberry and sweet cherry. *Int. J. Food Microbiol.*, 73(2-3):187-196

Mason, T.J., Paniwnyk, L. and Lorimer, J.P. (1996). The uses of ultrasound in food technology. *Ultrason. Sonochem.*, 3(3):S253-S260

Piyasena, P., Mohareb, E. and McKellar, R.C. (2003). Inactivation of microbes using ultrasound: a review. *Int. J. Food Microbiol.*, 87(3):207-216

Summerfelt, S.T. (2003). Ozonation and UV irradiation – an introduction and examples of current applications. *Aquac. Eng.*, 28(1-2):21-36