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Influence of postharvest ultrasounds treatments on tomato (*Solanum lycopersicum*, cv. Zinac) quality and microbial load during storage

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ABSTRACT

Whole tomato fruits were treated at ultrasonic power levels from 10% to 100%, and at a constant frequency of 45 kHz, for different times (1–19 min). A central composite rotatable design (CCRD) was applied to optimise ultrasonic treatments for tomato quality (colour, texture and total phenolic content (TPC)) maintenance. According to response surface analysis, the optimal treatment parameters were 55%_10 min, 80%_15 min and 100%_19 min. At these conditions, and especially at higher power levels, a maximum retention of colour and texture, as well as an increase of TPC and microbial reduction were obtained in comparison with untreated fruits during 15 storage days at 10 °C. The ultrasounds treatment was found to be effective in delaying colour development and texture losses, preserving sensorial quality of whole tomato, with increase of TPC and microbial load reduction. Moreover, this postharvest treatment can be used as an alternative for extending fresh fruits shelf-life.

1. Introduction

Ultrasonic (US) fields consist of waves at high amplitude, in frequency generally above 20 kHz, and is a propagation process of mechanical vibration in the medium. US when propagated through a biological structure, induces compressions and depressions of the medium particles and a high amount of energy can be imparted. Depending on the frequency used and the applied sound wave amplitude a number of physical, chemical and biochemical effects can be observed, which enable a variety of applications. In the food industry, the combined mechanical, heating and cavitation effects are used has a cleaning action on surfaces to kill some bacteria, inactivate virus or even damage cell wall of some smaller microbial [1]. The mechanism of microbial inactivation by US is mainly due to thinning of cell membranes, localised heating, production of free radicals (e.g., ˙OH, HOO, and O˙) [2,3] and formation of hydrogen peroxide [4].

The use of US in fresh produce decontamination is relatively recent. Seymour et al. [5], Scouten and Beuchat [6], Huang et al. [7], and Ajlouni et al. [8] used single-frequency ultrasound to decontaminate different fruits and vegetables. Mixed results have been reported, with some authors concluding that one log of additional reduction was achieved, while others reporting no additional reduction. Moreover, the power ultrasound has been reported to enhance certain quality parameters, such as on orange fruit [9], apple cider, milk [10], peanuts [11] and more recently on strawberry fruit postharvest [12].

The efficacy of US treatments can be affected by power level (%), treatment time (min) and temperature (°C) [13,14]. In this case, where several variables may influence the treatment impact, response surface methodology (RSM) can be an effective technique for optimising the process [15]. RSM is a powerful statistical and mathematical tool with the advantage of determining the effects of operational factors and their interactions.

The aim of this study was to optimise the ultrasounds treatments at 45 kHz of constant frequency by response surface methodology on tomato quality (colour, texture and total phenolic content). The impact of three optimal conditions (55%_10 min, 80%_15 min; 100%_19 min) on tomato colour, texture, total phenolic content, sensorial analysis (colour and global acceptability) and microbial load, during 15 days storage at 10° C, was also evaluated.

2. Materials and methods

2.1. Plant material

Tomato (*Solanum lycopersicum*, cv. Zinac) fruits harvested at mature-green maturity stage, with uniform colour (by USDA

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Table 1
Initial tomato quality attributes.

Quality attributes	
Colour parameters	
L^*	45.78 ± 1.00
a^*	−8.81 ± 1.06
b^*	22.05 ± 1.78
°h	111.76 ± 1.92
Texture	
Firmness (maximum force, N)	11.42 ± 2.11
Total phenolic content	
TPC (mg GAE 100 g^{-1})	21.37 ± 0.66
Microbial load	
Mesophilic count (Log_{10} cfu g^{-1})	3.76 ± 0.20
Yeasts and moulds (Log_{10} cfu g^{-1})	2.22 ± 0.10

standard tomato colour classification [16]), size, round shape and without bruises or signs of infection, were obtained from a commercial greenhouse Carmo & Silvério in centre west of Portugal. On arrival to laboratory, fruits were stored overnight in a cooling chamber (at 10 °C) until ultrasounds treatment. Table 1 summarises the initial values of tomato quality attributes.

2.2. Ultrasound treatment

For each ultrasounds treatment conditions and storage day *ca.* 1500 g of tomato fruits were sonicated in an ultrasonic bath at 10 °C ± 0.5 °C (Elma Transsonic Cleaning baths – multiple-frequency units) with 45 L nominal capacity, a constant ultrasound frequency of 45 kHz, and varying the treatment power level and time conditions according to the experimental design presented in Table 2. After treatment, tomato fruits were dried (absorbent paper) and stored at 10 °C, as previously optimised by [17], during 15 days.

2.3. Experimental design

A central composite rotatable design (CCRD) was used to optimise and evaluate the main, interaction, and quadratic effects of sonication conditions (power level: *PL*, and treatment time: *t*) and storage period (*Sp*) on tomato quality. The complete design consisted of three sets of experimental points: (i) a traditional factorial design with 2^k points, k being the number of independent variables (factors) with coded levels +1 and −1; (ii) to account for non-linearity, a star of 2^k points, coded as +α and −α on the axis of the system at a distance of $\alpha = [2^k]^{1/4}$ from the origin; and (iii) two central points to provide an estimate of the lack of fit of the obtained linear statistical model as well as of the pure error of the experiments [18]. The ranges of interest of each independent variable were: power level (*PL*): 10–100%; treatment time (*t*): 1–19 min; and storage period (*Sp*): 1–15 days. Table 2 shows the coded and uncoded matrix of independent variables.

The evaluated quality parameters (dependent variables) were: colour, texture and total phenolic content (TPC).

Table 2
Coded and uncoded matrix of independent variables.

Coded independent variables			Uncoded independent variables		
X_1	X_2	X_3	Powel level (%) (*PL*)	US time (min) (*t*)	Storage period (days) (*Sp*)
1	1	1	82	15	12
1	1	−1	82	15	4
α	0	0	100	10	8
0	0	α	55	10	15
−1	−1	1	28	5	12
0	0	−α	55	10	1
−α	0	0	10	10	8
−1	−1	−1	28	5	4
1	−1	−1	82	5	4
−1	1	1	28	15	12
1	−1	1	82	5	12
0	0	0	55	10	8
−1	1	−1	28	15	4
0	−α	0	55	1	8
0	0	0	55	10	8
0	α	0	55	19	8

2.4. Quality attributes evaluation

2.4.1. Colour

The colour of tomato fruits was evaluated using a tristimulus colorimeter (Minolta chroma Meter, CR-300, Osaka, Japan), measuring the CIEL*a^*b^* parameters. The instrument was calibrated using a white standard tile (L^* = 97.10, a^* = 0.19, b^* = 1.95), and the illuminate C (10° observer). L^* values represent the luminosity of samples (0-black to 100-white), a^* and b^* values indicate the variation of greenness to redness (−60 to +60) and blueness to yellowness (−60 to +60), respectively. From the CIELab coordinates the hue angle (°h = arctg (b^*/a^*)) was calculated. Four determinations for each fruit were performed in equatorial zone. Sixteen measurements were determined for each treatment condition.

2.4.2. Texture

Texture was determined by a penetration test with a Texture Analyzer (TA.HDi, Stable Microsystem Ltd, Godalming, UK), using a 50 N load cell and a stainless steel cylinder probe with a 2 mm diameter. The penetration test was performed at 3 mm s^{-1} of speed and at 7.5 mm of penetration distance in the equatorial zone of the fruits. Force–distance curves were recorded and firmness (maximum peak force (N)) was used as indicator of texture. Sixteen measurements were taken for each treatment condition.

2.4.3. Total phenolic content

Total phenolic content (TPC) was determined using the Folin–Ciocalteu reagent [19]. Samples (10 g) were homogenised in 70% aqueous methanol (10 ml), using a Yellow line DI 25 basic polytron (IKA-Labortechnik, Stauten, Germany), centrifuged (Sorvall RC-5, rotor SS34, DuPont, Wilmington, United States) at 19,000 rpm for 20 min at 4 °C, and the supernatant collected. One hundred microlitre of supernatant was mixed with 5 ml of Folin–Ciocalteu (1/10, v/v) and 4 ml of Na_2CO_3 (7.5%, w/v). The mixture was placed in a water-bath (45 °C for 15 min) and the absorbance measured at 765 nm in an ATI Unicam UV/VIS UV4 spectrophotometer (Unicom Limited, Cambridge, United Kingdom), using gallic acid as a standard. Results (six replicates) were expressed as milligram gallic acid equivalents (mg GAE 100 g^{-1}) of fresh weight.

2.4.4. Sensorial analysis

Analytical-descriptive tests were used to discriminate the sensory quality attributes of untreated (Ctr) and US-treated samples during storage. A panel of 8/10 trained-panellists (members of our Department), who met the basic requirements of sensory sensitivity according to [20] in adequate conditions compliant to [21], identified and distinguished the sensory attributes: colour and global acceptability of samples, using numeric rating scales as follows:

Colour rating system: 1 = green (0% red); 2 = breaker (<10% red); 3 = turning (10% < red < 30%); 4 = pink (30% < red < 60%); 5 = red (60% < red < 90%) and 6 = red (>90% red).