Quality attributes and shelf-life of vacuum packaged potato strips *(Solanum tuberosum)* as affected by edible coatings, thermal and non-thermal treatments

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Abstract

The aim of this work was to investigate the effect of using ultrasound or edible coating as a possible alternative to blanching on the quality of vacuum-packaged potato strips. The treatments assessed were blanching (85ºC, 3.5 min), coating with 2 % alginate and sonicating (42 kHz, 5 min) in an ultrasonic bath containing a 2 % citric acid solution. Vacuum-packaged samples were stored up to 12 days at 3 ±1ºC. The pH, polyphenol oxidase (PPO) activity, sugars and microbial load were assessed. Also, the colour, shear-force and dry matter of the treated and fried potato strips as well as the oil adsorption and acrylamide after frying were evaluated. The PPO activity of the treated samples was not significantly different over time ($p>0.05$). The treatments applied did not affect the attributes of the fried potato strips over time; there were no significant changes in oil absorption, acrylamide content or colour ($p>0.05$). However, the visual quality of sonicated packaged potato strips was significantly better than that of the other treatments after storage. The loss of the texture of blanched potatoes was remarkable ($p<0.05$) before and after frying. Sonicated samples maintained mesophilic bacteria counts better than blanched and alginate coated vacuum-packaged potato strips.

Keywords: ultrasound, blanching, PPO, alginate, French fries.

1. Introduction

Several treatments have been used to replace the current methods of prolonging shelf life and reducing the loss in quality of fresh-cut products. Blanching is a method that is commonly used in minimally processed potatoes to prevent enzymatic browning by inactivating polyphenol oxidase, promoting a more uniform colour after frying, limiting oil absorption and improving texture (Severini, Baiano, De Pilli, Romaniello, & Derossi, 2003; Moreira, Castell-Perez, & Barrufet, 1999). However, it is also known that this thermal treatment could lead to a loss of firmness and a loss of other attribute, such as nutrients, flavour and colour (Alvarez, Canet, & Tortosa, 2001).

The use of edible coatings and non-thermal technologies, such as ultrasound, can be a good alternative to avoid or minimize this loss of quality. Studies involving the use of ultrasound for mango juice showed improvements in the carotenoid content and phenolic compounds, in addition to a reduction in the microbial load (Santhirasegaram, Razali, & Somasundram, 2013). These authors also stated that this treatment is a good alternative to a thermal treatment and indicates the combination with other thermal and non-thermal technologies. Ultrasound has been shown to reduce the loss of firmness of kiwifruit (Meng, Zhang, & Adhikari, 2014) and plum fruit during storage (Chen & Zhu, 2011). Similarly, Amaral, Benedetti, Pujola, Achaerandio, & Bachelli (2015) applied ultrasound to vacuum-packaged potatoes and found that this treatment affected the tuber microstructure, but did not affect the firmness, and no changes were observed in colour. The activity of PPO and POD decreases when ultrasound (40 kHz) is combined with ascorbic acid (1%) in fresh-cut apples stored for 12 days at 10ºC (Jang & Moon, 2011). However, the effectiveness of ultrasound varies according to the frequency and power used, type of microorganism and enzyme, pH, temperature, and fruit or vegetable to which it is applied (Bilek & Turantaş, 2013; São José et al., 2014).

However, edible coatings are widely used in industry for whole and fresh-cut products to preserve quality. Alginate has been used to reduce weight loss and microbial load in carrots (Amanatidou, Slump, Gorris, & Smid, 2000), to maintain the quality and prolong the shelf life of fresh-cut apples (Rojas-Graü et al., 2007), and to reduce the stress of failure and browning during the storage of fresh-cut mangoes (Chiumarelli, Ferrari, Sarantópoulos, & Hubinger, 2011). Therefore, the association of alginate and nanomaterials can exhibit beneficial effects on the quality of shiitake mushrooms during

extended storage (Jiang, Feng, & Wang, 2013). Therefore, non-thermal processing technologies and edible coatings could be alternatives to thermal processing methods, but specific studies are needed for each product. For this reason, the aim of this work is to evaluate the effects of alginate and the combined use of ultrasound and citric acid as alternatives to blanching on the quality attributes of minimally processed potatoes and fried potatoes maintained under refrigeration for 12 days.

2. Materials and methods

Potatoes (*Solanum tuberosum* L. *cv.* Asterix*)* were acquired from Mercabarna (Mercado de Abastecimientos de Barcelona SA.). Tubers were selected, washed in tap water to remove surface dirt, dried and stored in the dark at a cool temperature (12±2 ºC). Potato tubers that were free of defects were hand-peeled, cut into rectangular strips with a cross-section of 10x10 mm with a manual slicer and rinsed in distilled water. Any post-harvest chemical washing was applied. Then, strips were randomly assigned into four groups.

2.1 Treatments

Four treatments were applied to the raw material: i) for the control treatment, strips were rinsed in distilled water 1:4 (w/v) and ii) the strips were blanched in hot water, 1:4 (w/v) at 85ºC for 3.5 minutes (Pedreschi, Moyano, Kaack, & Granby, 2005); iii) for the ultrasound treatment, the potato strips were dipped in an ultrasound bath (40 kHz frequency and 200 W of generation power, P-SELECTA 3000617, Barcelona, Spain) filled with citric acid solution 2% (w/v) at 1:4 (w/v) for 5 minutes. The samples were stored for 10 minutes at room temperature for these treatments and then dried with paper towels. In the alginate treatment (iv), the strips were dipped in a coating solution with sodium alginate 2% (w/v), glycerol 1% (w/v) and calcium lactate 2% (w/v) for 3 minutes (Chiumarelli et al., 2011). Coated strips were drained at 16±2ºC for 1 hour to dry the coating material.

After the treatments, portions of 100±5 g were vacuum-packed (-98 kPa, in a vacuum sealer VM-18 ORVED S.p.A., Italy) in coextruded polyamide/high density polystyrene bags (Coex. PA/PEHD-70/150; thickness: 22 μm; O_2 transmission rate: 8 cm^3/m^2 dbar at 25ºC) and stored at 3±1ºC for up to 12 days. Two replicates of 100±5 g of vacuum-packaged potatoes were assessed for each treatment and sampling date.

The frying process was conducted in sunflower oil at 180±5ºC for 6 min (this time was fixed according to the palatability of the fried strips) in an electrical fryer (Taurus Professional Compact, Oliana, Spain) at a proportion of 4:1 (w:w) (Gökmen & Palazoğlu, 2009). After frying, the strips drained for 1 min and were then placed at room temperature on absorbent paper for 10 min to remove excess oil.

2.2. Ultrasound equipment

The ultrasound bath was made of a welded aluminium sheet, with a capacity of 9 L, and the dimensions were 12 cm x 46 cm x 12 cm (height x width x depth). The equipment had four steel cone-shape transductors (45 mm/38 mm in diameter; 47 mm length). The experiments were conducted in batch mode in a non-refrigerated system. The operating conditions had previously been optimized, and the distribution of the ultrasound in the bath was uniform (Amaral et al., 2015). The increase of the temperature in the water was less than 2ºC after 5 min of treatment.

2.3 Analytical determinations

All of the analyses were carried out on days 1, 4, 8 and 12 for vacuum-packaged and fried potatoes. Vacuum-packaged potato samples (control, blanched, ultrasound and alginate treatments) were characterized in triplicate. For PPO activity, total sugar and acrylamide samples were collected, immediately frozen at -20 ˚C and subsequently freeze-dried at -54 ˚C and 0.07 mbar vacuum for 40 h by Telstar Cryodos -50 freeze dryer (1 KVA of potency, model 2G-6, Telstar, Barcelona, Spain).

The dry matter content was determined by drying 5 g of potato at 65ºC for 24 h. (AOAC 931.04). The pH was measured with a potentiometer according to AOAC (981.12). Polyphenol oxidase (PPO) activity was determined in 3 g of lyophilized potato samples by determining the absorbance increase at 410 nm over a period of 3 minutes. The results were expressed as units of enzymatic activity. One unit of PPO activity was defined as a change in absorbance at 400 nm per min and mL of enzymatic extract. The initial reaction rate was estimated from the linear portion of the plotted curve.

Sugars were extracted and measured by the procedure used in vegetables with slight modifications (Hernandez, Gonzalez-Castro, Alba, & de la Cruz Garcia, 1998). Samples consisting of 2 g of potato were extracted by refluxing for 30 min with 20 mL of 70% ethanol. The extract was vacuum-filtered, and the filtrate was filled to 25 mL with 70 % ethanol. A 5-mL aliquot of the solution was passed

through a Waters Sep-Pak C column, filtered (0.45 μm pore size membrane), and then injected onto the HPLC (Hewlett Packard series 1100). The instrument was equipped with a Beckman 110B injector and a Beckman Refraction Index Detector (RID). Fructose, glucose and sucrose separation were performed using a Phenomenex Luna column (250 x 4.6 mm i.d.) at a constant temperature of 28°C using isocratic elution of acetonitrile-water (78:22 v/v). The flow rate was 1.2 $mL \cdot min^{-1}$. The average of the results of three replications was expressed as $g \cdot kg^{-1}$ of lyophilized weigh (LW).

In fried potatoes, oil uptake determination consisted of a Sohlext extraction of the dried potato sample and gravimetric quantification of the oil content (AOAC 934.05), and dry matter was also determined under the same conditions for vacuum-packaged potatoes.

Acrylamide was assessed in fried potato strips following the extraction procedure used by Yang, Achaerandio & Pujolà (2016). GC analysis of the extract samples was performed on an AutoSystem gas chromatograph equipped with a flame ionization detector (FID) (Hewlett Packard 5890 series II). The column used was an Agilent HP-FFAP capillary (length = 25 m, i.d.= 0.2 mm, and film thickness = 0.3 μm), and the analysis conditions were as follows: the initial column temperature was set at 100 ºC for 0.5 min and then raised at a gradient of 10ºC/min to 200 ºC. The temperatures of the injector and detector were set to 250 and 260 ºC, respectively; helium was used as the carrier gas at a flow rate of 1 mL/min, splitless for 1 min, and the injection volume was 1 μL. The results were expressed as $\mu g \cdot kg^{-1}$ of lyophilized weight (LW).

2.3 Physical properties

The instrumental texture of the potato strips (vacuum-packaged and fried) was measured using a TA.TXplus texture analyser (Stable Microsystems Ltd., Godalming, UK) equipped with a 30-kg load cell and connected to a Warner Bratzler blade set at a speed of 1 $mm \cdot s^{-1}$. Twenty measurements of each treatment for each day were made. Shear force was measured as the maximum shear strength value and expressed as the maximum force (N).

2.4 Colour evaluation

The colour of the vacuum-packaged and fried potato strips was measured using a Minolta CR-400 colourimeter (Osaka, Japan) in the CIE laboratory space. The L* (lightness), a* (greenness [-] to redness [+]), and b* (blueness [-] to yellowness [+]) were recorded and evaluated. Five readings were

taken at two sites on the surface of the potato strips for each treatment and replicated. The parameters of hue angle (H*) and chroma (C*) were calculated as $H^* = \tan^{-1}(b^*/a^*)$ and $C^* = (a^{*2}+b^{*2})^{1/2}$. Colour differences (dL* and dH*) were calculated by subtracting the L*H* values for the sample from the control samples on the first day of analysis. The results were expressed as the mean value.

2.5 Microbiological analyses

Analysis of Coliforms, Enterobacteriaceae, mesophilic aerobic microorganisms, yeast and moulds were carried out according to ISO 4832:2006, ISO 21528-2:2004, ISO 4833:2003 and ISO 21527:2008, respectively. Two bags were evaluated for each treatment and each day of analysis.

2.6 Statistical analysis

The data reported are the mean of duplicate experiments. A statistical study of variations after application of treatments and during storage was carried via two-way ANOVA using Minitab (v.17, MINITAB Inc., State College, PA) at a 95% confidence level. The differences between samples were determined using Tukey´s least significant difference test. Pearson's correlation analysis was carried out to study the relationships between variables.

3. Results and discussion

3.1 Vacuum packaged potato strips

Colour changes were evaluated by the lightness (L*) and Hue angle (H*) parameters, and colour differences were compared to the control on the first day of storage. The L* values were between 55.33 for alginate 2% treated samples at 12 days of storage and 66.02 for blanched samples after 4 days of storage. The immersion of strips in sodium alginate solution promoted reduction of the lightness of the potatoes and, according to (Calder, Kash, Davis-Dentici, & Bushway, 2011), this is a signal of browning. The higher the negative difference, the higher the degree of browning obtained. Moreover, significant differences were observed for alginate 2 % after 8 days of storage ($p<0.05$, data not shown). Table 1 shows the lightness difference (dL*) between samples. There was an increase for blanching with storage, while alginate 2% had the opposite behaviour. Blanched potato samples showed higher values of the Hue angle (124.72º) immediately after processing and during the storage ($p<0.05$, data not shown). The Hue angle of the other samples of vacuum-packaged potatoes was

approximately 100º, as observed by (Fernandes, Soratto, Evangelista, & Nardin, 2010). The authors also stated that this value indicates a yellow pulp of the potato, which is desirable for frying. The Hue angle difference (dH*) is especially notorious for blanching (Table 1), whereas in the alginate 2 % and US + citric acid treatments, there were no significant differences during the time of storage. This difference indicated the effect of blanching, resulting in a brownish yellow colour. Adams & Brown (2007) stated that the after-cooking darkening of potatoes may be due to a reaction in which a coloured chlorogenic acid-ferric iron complex is formed.

The dry matter (DM) content is very important for fried potato texture, and the use of this parameter has been found to be appropriate for predicting various texture attributes and for giving information about potatoes after the application of treatments (Arvanitoyannis, Vaitsi, & Mavromatis, 2008). In agreement with our results, Tajner-Czopek, Figiel, & Carbonell-Barrachina (2008) observed that the initial dry matter content of potato tubers suitable for frying was 208.1 $g \cdot kg^{-1}$, and the DM content of potato strips after blanching was 203 $g \cdot kg^{-1}$. In this study, the initial DM content varied from 175.2 to 202.9 $g \cdot kg^{-1}$. No statistically significant differences were found ($p < 0.05$), either between treatments or storage times, in the content of DM in vacuum-packaged potatoes (Table 1).

Initial values of the shear force of control vacuum-packaged potatoes were approximately 7 N (Table 1). This value is slightly lower than the value found by Feltran, Lemos, & Vieites (2004) for the Asterix potato cultivar (8.15 N). As expected, the blanching treatment had the greatest effect on the texture of the vacuum-packaged potatoes. According to Alvarez, Canet & Tortosa (2001) and García-Segovia, Andrés-Bello, & Martínez-Monzó (2008), the blanching temperature had an influence on the softening and texture of potato tissue by starch gelatinization as well as on changes in pectic substances. The statistically significant decrease ($p<0.05$) of the shear force in the blanching treatment was maintained throughout the 12 days of storage at 3±1ºC.

As expected in a cultivar suitable for French fries, the Asterix cultivar had a low reducing sugar content, less than 3 $g \cdot kg^{-1}$ (FoodDrinkEurope, 2011). However, Rodriguez-Saona & Wrolstad (1997) and Fernandes et al. (2010) noted that the content of sugars is not enough to explain or predict the quality of fried potatoes. Fernandes et al. (2010) concluded that despite Markies and Mondial potato cultivars showing higher and lower sugar contents, respectively, these varieties presented an

197 acceptable colour after being fried. In our results, sucrose was the major sugar (0.40 -0.24 $g \cdot kg^{-1}$),
198 and the content of reducing sugars, in general, was slightly lower (0.11- 0.22 $g \cdot kg^{-1}$) on the first day of
199 storage (Table 1). In the case of sucrose, statistically significant differences ($p < 0.05$) were found at
200 four days of storage, with the sucrose content in the alginate treated samples significantly lower than
201 in the blanching and control samples. In general, the storage time involved a reduction of the sucrose
202 content in all of the treatments tested. This decrease can possibly be attributed to the hydrolytic
203 processes of the disaccharides.
204 The initial pH of the vacuum-packaged potatoes was between 4.99 and 5.96 (US + citric 2 % and
205 blanching, respectively). The use of citric acid at 2% in the ultrasonic bath involved lowering the pH
206 of the potato samples to 0.72 ($p < 0.05$), which was maintained during storage until the eighth day
207 (Figure 1). This behaviour was in accordance with the results reported by Calder et al. (2011), who
208 also observed a reduction of the pH of fresh-cut potato slices after 1 minute of immersion in solutions
209 of sodium acid sulphate at 3% and citric acid at 3 %.
210 Blanching was the most effective treatment to inhibit polyphenol oxidase (PPO) activity. The
211 application of US + citric acid 2% and alginate 2% treatments to potato strips involved non-significant
212 differences in PPO activity. During storage, the PPO activity of coated samples was similar to that of
213 the control samples, but there were statistical differences in the sonicated samples (Figure 1). The
214 enzymatic activity of PPO can be limited by pH adjustment and/or the use of chelators or reducing
215 agents (Girelli, Mattei, Messina, & Tarola, 2004). Contrary to this statement, in our results, there was
216 no effect of US-citric acid 2% on the PPO activity of the treated samples. Wang et al. (2015) observed
217 that a higher PPO activity does not always correlate with more browning. The same results were
218 obtained by Cantos, Tudela, Gil, & Espn (2002) in potato strips (8 x 8 mm) stored at 4ºC for 6 days.
219 Jiang et al. (2013) used sodium alginate in mushrooms, and they observed similar patterns of PPO
220 activity in the coated and control samples. Additionally, the authors obtained a positive synergetic
221 effect of the alginate coating (2% and 3%) and 100% of O_2 in the inhibition of PPO activity ($p<0.05$).
222 Sodium alginate 2 % was not an effective treatment for reducing the microbial load in vacuum-
223 packaged potatoes (Figure 2). Nevertheless, the combination of US-citric acid 2 % was useful in the
224 reduction of total coliforms, Enterobacteriaceae and aerobic bacteria. However, the reduction of yeasts

and moulds was lower. The inactivation of microorganisms could result from a combination of physical and chemical mechanisms, which occur during cavitation and cause the formation of free radicals and H_2O_2 (Oyane et al., 2009). In a recent review, Cebrián, Mañas, & Condón, (2016) noted that the treatment medium pH had little or no influence on microbial resistance to manosonication and non-thermal UV treatment. From our results, the reduction of microbial counts may be due to the effect of cavitation in bacteria cells.

3.2 Fried potato strips

The frying process entailed an increase of dry matter content in the potato samples on the first day of storage (430.1-452.4 $g \cdot kg^{-1}$, Table 2). This increase was similar for all treatments and throughout the storage time; no statistically significant differences were found ($p > 0.05$). The opposite behaviour was observed in the shear force of the fried potato. The shear force decreased with the frying process, but no significant differences between treatments and storage time were found. This finding is consistent with previous reports by Calder et al. (2011), who also did not find significant differences in the shear force of fried potatoes, although the control and the citric acid treated fried potato slices had a dried and case-hardened appearance on the surface of the raw fries over storage time.

The colour of the fried potatoes (evaluated with the L* and H* parameters) decreased after frying. The lightness on the first day of storage ranged between 60.35 to 54.68 and 90.54 to 83.15 for hue angle according to the treatment carried out. Non-significant differences were found between treatments ($p<0.05$). A positive difference of lightness for US + citric acid 2 % and negative differences of L* for blanching, alginate treatment and the control were found (Table 2). The same behaviour was observed in the H* parameters.

The frying process involved oil absorption in the potato strips and entailed, as previously discussed, an increase of DM. Moreno, Brown, & Bouchon (2010) noted that fried products reached the state of equilibrium after 10 min of cooling, when the competition between the drainage of oil from the surface and suction of oil from the crust had ceased. Our results are in agreement with their results. In our work, after frying, the potato strips were drained for 1 min and were then placed at room temperature for 10 min.

Controlling the frying time and oil temperature may reduce acrylamide formation because it could reduce Maillard reactions and minimize the hydrolysis of sucrose during frying (Medeiros Vinci, Mestdagh, & De Meulenaer, 2012). The content of acrylamide in fried potatoes was between 3.00 to 4.42 $mg \cdot kg^{-1}$ at the initial time and 2.89 to 3.81 $mg \cdot kg^{-1}$ at 12 days of storage at 3±1ºC. Non-significant differences were found in the acrylamide content in the treated fried potatoes and throughout storage time at 3ºC for 12 days ($p<0.05$). These values are in agreement with the results obtained by Yang, Achaerandio, & Pujolà (2016) for French fries of the Kennebec and Agria cultivars, but were higher than those of the Red Pontiac cultivar.

3.3 Correlation between parameters

Significant Pearson correlations between parameters analysed in vacuum-packaged potato and fried potato strips are shown in Table 3. The study of Pearson correlations noted that the PPO activity was positively correlated ($p <0.01$) with some of the physical and chemical parameters, such as pH, shear force, DM and hue angle (vacuum-packaged and fried potato strips), and negatively correlated with the sucrose content ($p<0.05$). However, the major presence of microorganisms in vacuum-packaged potatoes may promote the PPO enzymatic activity ($p < 0.001$; $r = 0.858$ and 0.804 for coliforms and Enterobacteriaceae, respectively).

Acrylamide formation was highly correlated with pH, dH* and dL*. The higher the content of acrylamide, the lower the lightness (L*) and higher the hue angle (H*) in fried potato strips. Related to pH, an increase in pH implied a decrease of the acrylamide content, as other works noted (FoodDrinkEurope, 2011).

A higher pH and DM content were observed in vacuum-packaged potatoes, and the absorption of oil in fried potatoes increased, while the shear force decreased ($p<0.05$).

The sucrose content in vacuum-packaged potato strips had opposite effects on the PPO activity and oil absorption ($p< 0.05$, $r = -0.593$, PPO activity and $p<0.01$, $r = 0.932$, oil absorption): a higher content of sucrose tended to increase oil absorption, but the PPO activity decreased. Similar effects on oil absorption were observed with the total sugar content ($p<0.05$ $r = 0.838$).

4. Conclusions

A non-thermal treatment (5 min, ultrasound bath 42 kHz) with citric acid 2% was an efficient treatment for maintaining the quality attributes of vacuum-packaged potato strips. Sonication coupled with an acid medium inhibited microbial growth (Enterobacteriaceae, coliforms and mesophilic bacteria) and maintained the visual appearance and texture of the samples up to 12 days of storage at 3±1ºC. The use of an edible coating (sodium alginate 2%) did not favour the maintenance of the microbial quality and promoted the reduction of the lightness and increased the browning of the strips. The blanching treatment (3.5 min at 85ºC) was the treatment that had the higher inhibitory effect on PPO activity. However, blanching had significant and negative effects on the colour and shear force in vacuum-packaged potato strips. In general, none of the treatments assessed in this research involved significant differences in oil absorption, colour, shear force or acrylamide content in the fried potato strips.

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Table

T**able1**

Color differences, Dry matter content, Shear force, Reducing sugar and Sucrose content of vacuum packaged potato strips stored at 3±1ºC for 12 days

Parameters	Treatments	Storage time			
		Day 1	Day 4	Day 8	Day 12
dL*	Control	-	-0.25	0.76	-0.28
	Blanching	-1.05	4.10	1.34	1.83
	US-citric 2%	0.88	-0.04	0.43	-0.65
	Alginate 2%	-5.82	-7.32	-5.65	-6.59
dH*	Control	-	1.27	0.89	0.47
	Blanching	24.33	24.33	27.34	26.29
	US-citric 2%	1.62	2.20	1.69	1.74
	Alginate 2%	0.94	1.21	0.52	0.69
DM $g.kg^{-1}$	Control	192.0±11.3 Aa	175.8±1.5 Aa	172.5±2.1 Aa	190.3±4.0 Aa
	Blanching	202.9±1.6Aa	196.0±9.2 Aa	203.7±12.8 Aa	199.5±2.9 Aa
	US-citric 2%	185.6±6.0 Aa	185.7±17.5 Aa	182.2±22.7Aa	178.8±4.0 Aa
	Alginate 2%	175.2±11.6 Aa	156.7±16.3 Aa	155.4±23.6 Aa	171.5±20.8Aa
Shear force (N)	Control	7.00±0.05Aa	7.43±0.12Aa	7.07±0.17Aa	7.11±0.13Aa
	Blanching	5.19±0.36Ba	5.34±0.35Ba	5.90±0.66Aa	6.11±0.06Ba
	US-citric 2%	6.53±0.17Aa	6.68±0.15Aa	7.14±0.11Aa	6.81±0.26ABa
	Alginate 2%	6.87±0.02Aa	7.10±0.12Aa	6.87±0.01Aa	6.83±0.01ABa
Reducing sugars $g.kg^{-1}$ FW	Control	0.20±0.02Aa	0.18±0.06Aa	0.17±0.01ABa	0.10±0.04Ba
	Blanching	0.17±0.01Aa	0.11±0.03Aa	0.18±0.00ABa	0.19±0.01ABa
	US-citric 2%	0.23±0.05Aa	0.15±0.03Aa	0.14±0.02Ba	0.27±0.01Aa
	Alginate 2%	0.11±0.05Aa	0.13±0.03Aa	0.22±0.02Aa	0.13±0.01Ba
Sucrose $g.kg^{-1}$FW	Control	0.40±0.01Aa	0.27±0.02Bb	0.27±0.02Ab	0.18±0.03Ac
	Blanching	0.39±0.02Aa	0.38±0.03Aa	0.31±0.08Ab	0.22±0.00Ac
	US-citric 2%	0.25±0.03Aa	0.25±0.01BCa	0.24±0.01Aa	0.17±0.02Ab
	Alginate 2%	0.24±0.07Aab	0.15±0.02Cc	0.16±0.01Ab	0.21±0.01Aab

US-citric 2% = Ultrasound bath with citric acid solution 2%, Alginate 2% = Sodium alginate 2% with glycerol 1% and calcium lactate 2%. Color parameters: dL* =difference of Luminosity dH*= difference of Hue angle. Data represents the mean ±standard error. Different capital letters in the same column indicates statistical differences ($p<0.05$). Different small letters in the same file indicates statistical differences ($p<0.05$).

Table 2

Physical parameters (dL*,dH* and Shear force), dry matter content, oil absorption and acrylamide content in fried potato strips stored at 3±1ºC for 12 days

Storage time	Treatments	dL*	dH*	DM $g.kg^{-1}$	Shear force (N)	Oil Absorption $g.kg^{-1}FW$	Acrylamide $mg.kg^{-1}FW$
Day 1	Control	-	-	444.5±18.0Aa	1.27±0.19Aa	177.9±18.5Aa	3.93±0.82Aa
	Blanching	-1.99	-5.03	452.0±11.5Aa	1.14±0.22Aa	172.8±21.0Aa	3.80±0.69Aa
	US-citric 2%	1.46	1.51	452.4±29.8Aa	1.64±0.25Aa	155.9±2.2Aa	3.00±0.32Aa
	Alginate2%	-4.21	-5.88	430.1±17.9Aa	1.40±0.14Aa	155.1±1.9Aa	4.42±0.11Aa
Day 12	Control	-1.14	-2.08	449.1±2.7Aa	1.55±0.31Aa	146.2±1.1Aa	3.45±1.14Aa
	Blanching	-3.55	-9.03	489.2±31.8Aa	1.23±0.01Aa	159.3±12.5Aa	3.62±1.50Aa
	US-citric 2%	0.23	0.55	469.4±0.3Aa	1.91±0.20Aa	143.0±3.0Aa	2.89±0.25Aa
	Alginate2%	-2.49	-7.92	431.7±14.1Aa	1.76±0.04Aa	139.1±11.5Aa	3.81±1.10Aa

US-citric 2% = Ultrasound bath with citric acid solution 2%, Alginate 2% = Sodium alginate 2% with glycerol 1% and calcium lactate 2%. Color parameters: dL* =difference of luminosity dH*= difference of Hue angle. Data represents the mean ±standard error. Different capital letters in the same column indicates statistical differences ($p<0.05$). Different small letters in the same file indicates statistical differences ($p<0.05$).

Table 3

Significant Pearson correlations between the studied factors in vacuum-packaged potato and fried potatoes strips

Vacuum-packaged potato		Fried potato		
	PPO		Acrylamide	Oil absorption
dH*fried	0.703**	dH*fried	0.742*	-
H*	0.901**	dL*fried	-0.895*	-
pH	0.783**	pH	0.779*	0.703*
DM	0.692*	DM	-	0.932*
Shear force	0.842**	Shear force fried	-	-0.838*
Shear force fried	0.787**			
Sucrose	-0.593*	Sucrose	-	0,932**
		Total sugars	-	0.838*
Enterobacteriaceae	0.858**			
Coliforms	0.804**			

*p< 0.05, **p<0.01.

Figure caption

Figure1. PPO activity (%) (bars) and pH (points) of vacuum-packaged potato strips stored at 3±1ºC along time.

Control (white bar), ultrasound + citric acid 2% (ponted bar), alginate 2% (grey bar) and blanching (black bar).

Values are the average of two experiments and triplicate samples ± error deviation. Different lower-case letters indicate statically different groups by Tukey's test ($p < 0.05$) between treatments the same day of analysis.

Figure2. Reduction of Mesophilic bacteria (A), Coliforms (B), Enterobacteriaceae (C) and yeast and moulds (D) counts (log10UFC·g-1) of vacuum-packaged potato strips stored at 3±1ºC along time.

Control count at day 1 was used as reference value ( ). Control (white bar), ultrasound + citric acid 2% (ponted bar), alginate 2% (grey bar) and blanching (black bar).

Values are the average of two experiments and duplicate samples ± error deviation. Different lower-case letters indicate statically different groups by Tukey's test ($p < 0.05$) between treatments and day of analysis.

Figure 1

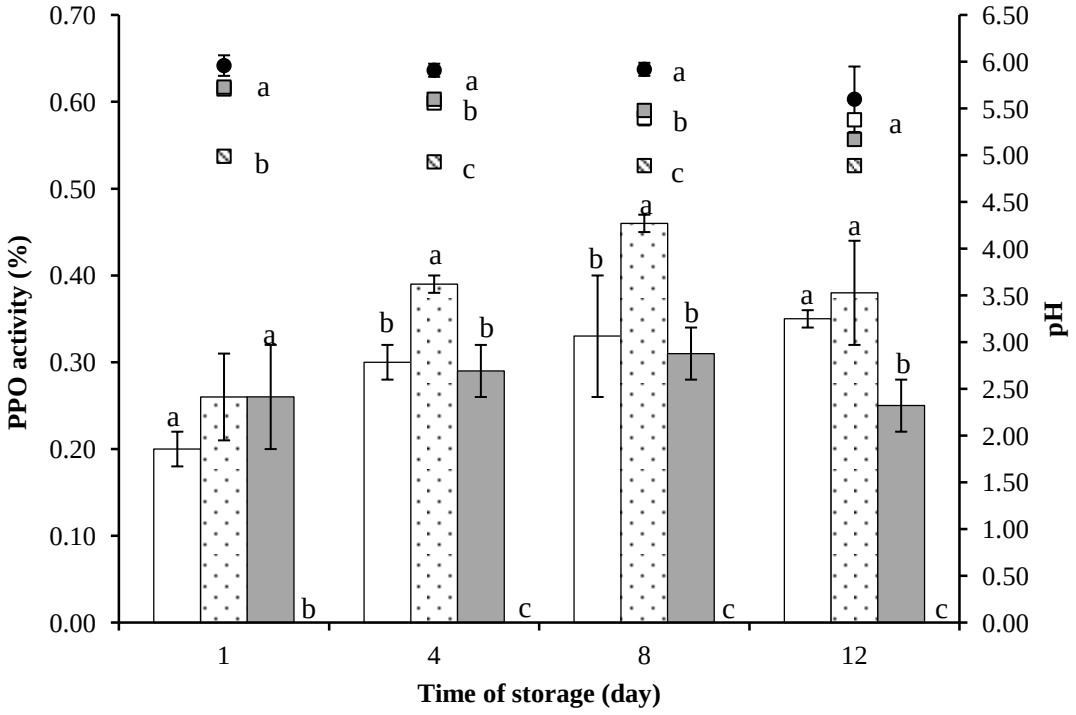
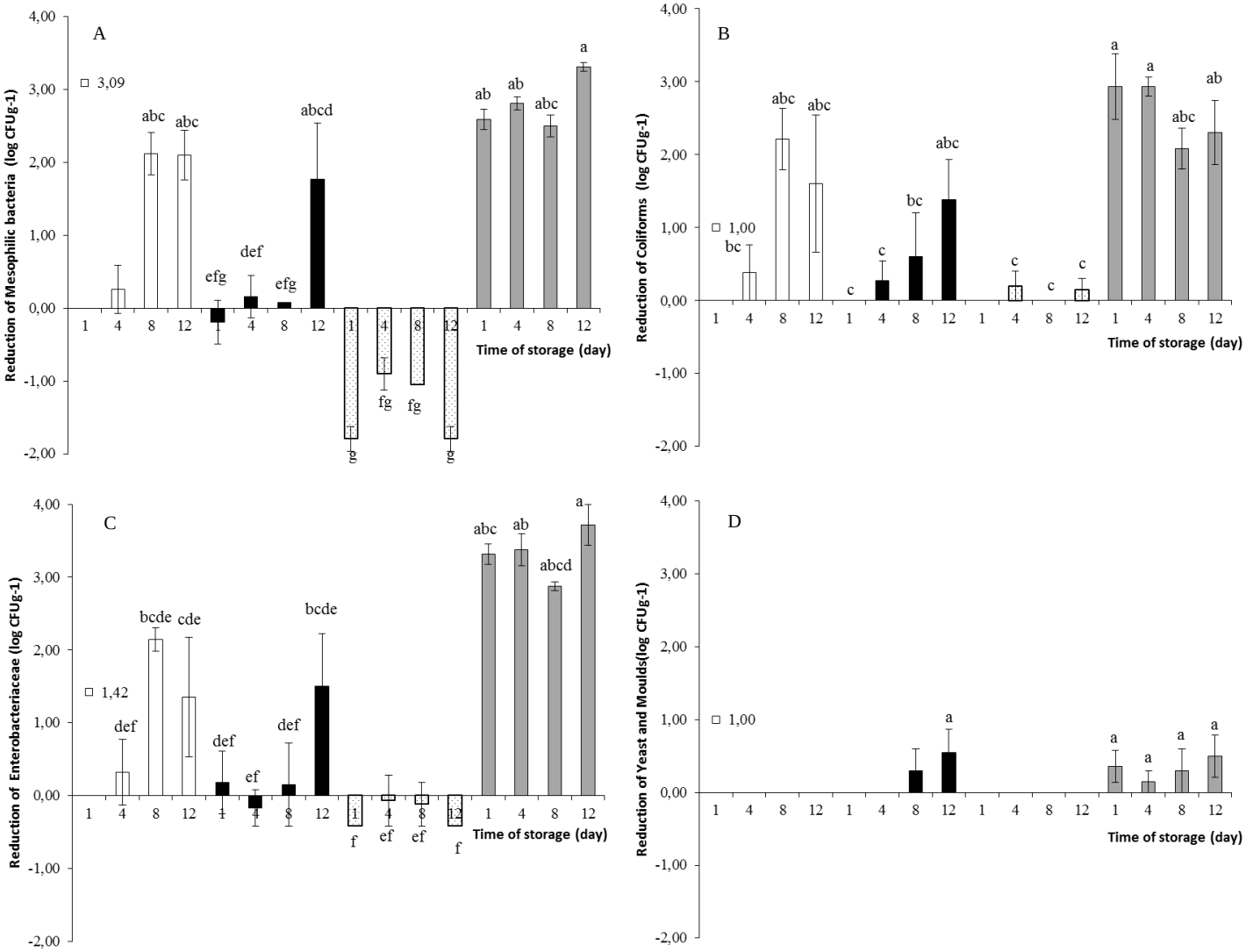

PPO activity (%)
pH
Time of storage (day)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1
4
8
12
a
b
c

Figure 2


A
3,09
Reduction of Mesophilic bacteria (log CFUg-1)
Time of storage (day)
B
1,00
Reduction of Coliforms (log CFUg-1)
Time of storage (day)
C
1,42
Reduction of Enterobacteriaceae (log CFUg-1)
Time of storage (day)
D
1,00
Reduction of Yeast and Moulds(log CFUg-1)
Time of storage (day)