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SHELF-LIFE EXTENSION OF FRESH-CUT APPLE CUBES WITH CHITOSAN COATING

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Abstract

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The possible use of chitosan coating on fresh-cut apples was investigated in this research. Manually sliced apples were treated with solutions of 1, 2.5, 5 and 10 g.kg^{-1} chitosan in acetic acid and then stored at 4°C for 17 days. Physical, physico-chemical, microbiological and sensory properties of the samples were monitored during the storage period. It was found that chitosan coatings inhibited the growth of microorganisms and affected significantly and positively the storage time of the products. Changes in the sensory qualities of taste were evaluated. A chitosan coating retarded water loss and the drop in sensory quality, increasing the soluble solid content and titratable acidity. The data revealed that applying a chitosan coating preserved effectively the quality and extended the shelf-life of fresh-cut apples.

Key words: Edible coatings, physical parameters, shelf-life extension

Abbreviations: GlcN -β-1,4-linked glucosamine; M_w - Average molecular weight; CFU.g^{-1} - total number of microorganisms; R_m - Impedance real part; X_m - Impedance imaginary part

Introduction

Edible films and coatings from chitosan make considerable sense and interest in the food industry in the recent years as a new generation of food packaging material. There are several advantages of this technology in comparison with the traditional plastic packaging. They are: ecologically friendly; produces from renewable sources; nontoxic, biodegradable; made from by-products valuable materials; able to incorporate preservatives and other functional ingredients, like antioxidants, antimicrobial agents, vitamins, etc.

One of the preferred biopolymer used for edible coatings is chitosan. It is a cationic polysaccharide with a high molecular weight and a linear polymer that is composed of β-1,4-linked glucosamine (GlcN) with various quantities of N-acetylated GlcN residues, is normally obtained by the alkaline deacetylation of chitin extracted from an abundant source of shellfish exoskeletons or the cell walls of some microorganisms and fungi. The chitosan films are used as coating of fresh and fresh cut fruits and vegetables (apples, oranges, tomatoes, peppers, berries etc.) because they are flexible, offer valuable properties such as elasticity, selective permeability and act as microbial barrier against pathogens (*Candida, Escherichia Coli, Staphylococcus aureus, Bacillus cereus, Proteus vulgaris*, *Botrytis cinerea*). As a result chitosan coatings are able to extend effectively the shelf-life (H. Qi et al., 2011; Chien et al., 2007; Vargas et al., 2008).

Material and Methods

Materials: Apples (var. Florina) were bought from local market. High molecular weight chitosan (M_w=600 kDa) with 95% N-deacetylation was obtained from Sigma. All other chemicals were obtained from commercial sources and were of analytical grade.

Sample preparation: The apples were rinsed gently with tap water by hand and dried naturally. Then they were peeled, cored and chopped for cubes (10*10*20 mm). The cubes were dipped into chitosan-acetic acid solutions with different chitosan concentrations (0, 1, 2.5, 5, 10 g.kg^{-1}) for 1 minute and air-dried for 20 minutes. After that they were packed by aluminium folio and stored refrigerated (4°C) for 17 days (Qi et al., 2011).

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Methods

1. Physical methods:
   a. Texture (rupture test): The rupture force was measured on the fresh-cut apple cubes by Stable Micro Systems XT2Aplus texture analyzer, with Ø 25 mm cylindrical measure probe and slowly deformation speed. Rupture stress were calculated based on the area of the ruptured cube-side.
   b. Dielectric parameters: impedance of the fresh-cut apple cubes was investigated by GW INSTEK 8110G precision LCR meter in frequency range between 20Hz–10MHz with pin electrodes (gap 10 mm). Similar method and calculations were used earlier for monitoring the changing of the impedance during drying by Zsivanovits and Vozáry (2011)
   c. Visual parameters: For further analysis the fresh-cut apple cubes were captured by computer supported image analyzing system. The browning of the fresh-cut apple cubes were monitored based on the pictures.
2. Sensory parameters were evaluated by hedonic ratings of sensory attributes. 7 consumers joined to the panel every times.
3. Chemical parameters were analyzed by standard methods for total soluble solids, total sugar content, titratable acidity, pectin content, ascorbic acid content and antioxidant activity.
4. Microbiological parameters were analyzed by standard traditional methods based on ISO 4833:2003 standard for horizontal method for the enumeration of microorganisms–colony-count technique at 30°C for the Total Plate Count microorganisms (CFU.g^{-1}) and ISO 21527-1 for the Total number of moulds (CFU.g^{-1}) was used. Pathogens were analyzed based on ISO 4832-2006 (coliforms) and ISO 16649-2:2001 (*E. coli*).

Results and Discussion

An undesirable consequence of cutting is softening; tissue stress results in a loss of firmness, principally owing to enzymatic hydrolysis of cell wall pectic substances and the action of pectinolytic enzymes, the decrease in cellulose crystallinity and the thinning of cell walls.

The firmness in our experiments was characterized by the rupture stress in compression mode static experiments. The rupture stress of the control (apple cubes without chitosan coating) decreased significantly (about 60%) during the 17 days of storage (Figure 1).

Coating with chitosan effectively retarded the tissue softening in the samples. The hardest samples at the end of the storage period were these coated with 5 g.kg^{-1} and 10 g.kg^{-1} chitosan solutions. Coating with 1 g.kg^{-1} chitosan solution did not show significant effect. The results are in agreement with many previous reported research papers (Qi et al., 2011).

It was found that the impedance of the apple cubes decreased during the storage (Figure 2). This result could be explained with weakening the strength of the cell-wall and mixing of cytoplasm with intercellular liquid. (Vozary et al., 1999; Vozary et al., 2002). The impedance decay was slower for coated samples. Chitosan coating prevents the diffusion of liquids. It could also interact with the pectin acid in the cell wall and in that way stabilizes the cells.

The aging reduce the turgor of the cells and the health of the cellular system. That process decreases the impedance of the apple cubes (control). The dipping of apple cubes into the chitosan solution causes diffusion of water and low molecular weight ions. That diffusion also reduces the impedance. The low chitosan concentration can not save the membrane system (up to 2.5 g.kg^{-1} chitosan concentration). The film formed from solutions with high chitosan concentration, acts like barrier for low molecular weight ions and for water and in this way decreases the speed of the impedance redaction.

Based on our experimental results the impedance of apple cubes coated with higher concentrated chitosan solutions possess higher impedance. Therefore an assumption could be done that chitosan film could preserve the healthy stage of cellular membrane system. Above the critical chitosan concentration the impedance did not change already.

The colour changing of the samples was investigated based on the comparison of captured pictures. Browning was more slowly for coated apple cubes in comparison with the results reported in the literature (Qi et al., 2011; Chien et al., 2007). Coatings deposited from 2.5 g.kg^{-1} chitosan solution could preserve the colour of the samples for 2 weeks during the storage. The colour preserving was not better if higher concentrations of chitosan had been used. The browning is the fastest on the probes with acetic acid. The higher chitosan concentration could save the light yellow colour of the cubes

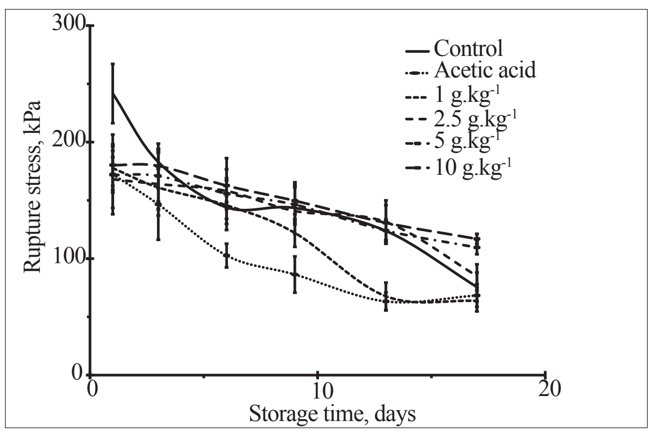

Fig. 1. Softening of the apple cubes during the shelf-life period

for longer time. The experimentally end of shelf-life time based on the colour changes was 17 days (Figure 3).

The sensory parameters were evaluated by consumer tests with 7 participants attending. The assessors were first asked to rank three coded samples (apple cubes) by colour from the most preferred (=6) to least preferred (=1) and then for each one to evaluate the appearance, colour, texture, flavour and acidity on a 9-points hedonic scale (1=dislike extremely; 5=neither like nor dislike; 9=like extremely). The tests were repeated later during the storage as well.

At the beginning of the experimental series the only cut cubes hade the highest rating, but their quality worsening was very fast. The samples with 2.5 g.kg^{-1} concentration coating received the highest ranking in all parameters. Unfortunately the after-taste of acetic acid solvent was not acceptable for some of the rankers and they later do not taste the samples. (Table 1 and Figure 4).

Throughout the storage period, the all analyzed chemical parameters showed a decreasing trend (Table 2). In the control apple cubes the total soluble solids, the total sugar, titratable acids and ascorbic acid content, pectin substances and antioxidant

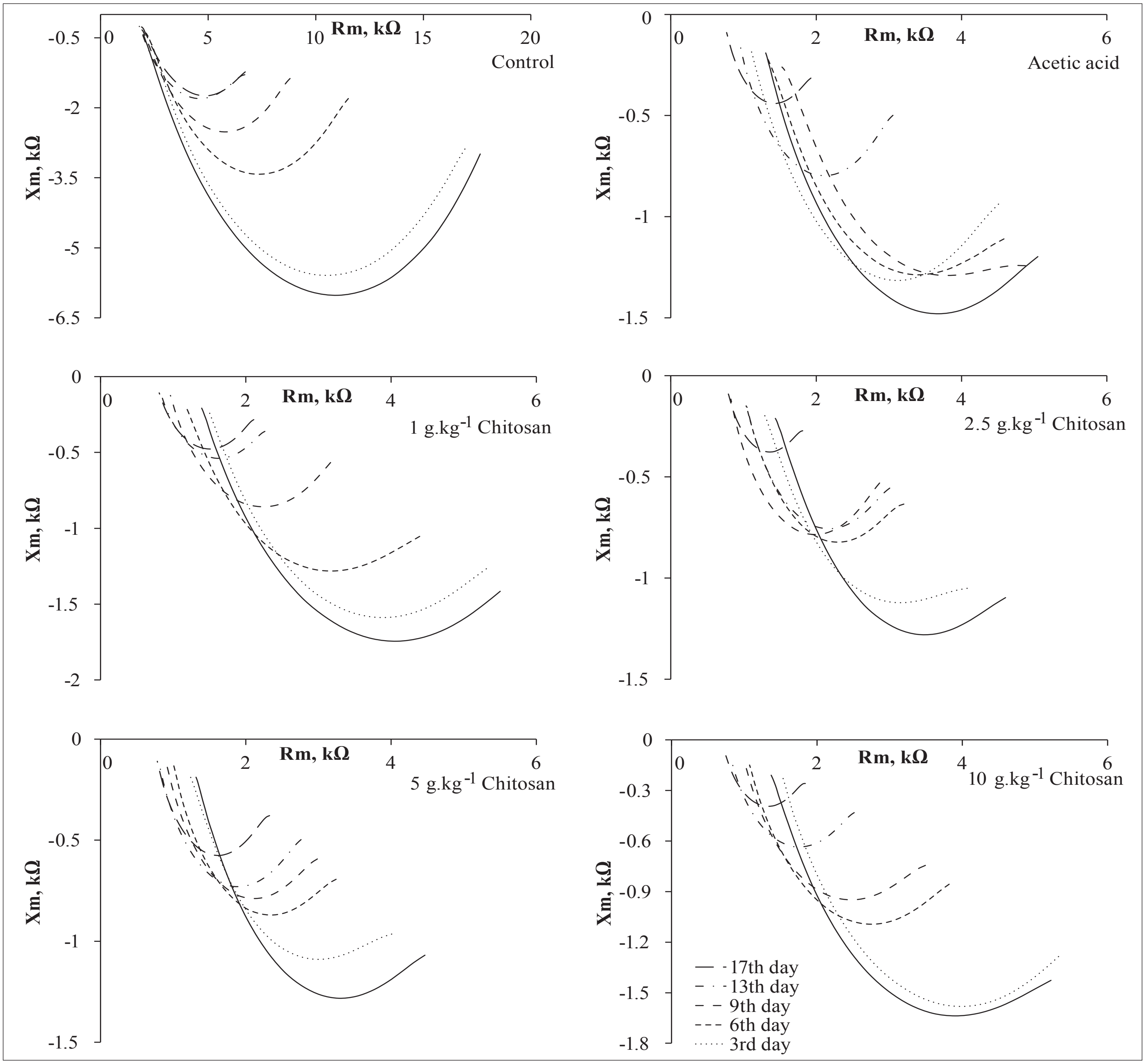

Fig. 2. Impedance changing of the coated apple cubes during the shelf-life time

activity was found to decrease faster than in coated cubes. After 17 days of storage, the losses of total soluble solids (7%), the total sugar (16%), titratable acids (9%), ascorbic acid (36%) and pectin substances content (5%) for coated apple cubes were lower than those for control cubes – 15%, 20%, 11%, 40% and 8% respectively (Ghaouth, et al., 1992). The coated apple cubes retained almost double higher antioxidant activity compared to control cubes. The reduced decrease in chemical parameters is probably due to the fact that the thin layer of chitosan on the surface of apple cubes delays the metabolic process. The changes in the apple cubes that had been treated with different percent of chitosan did not considerably.

Based on the microbiological tests significant antimicrobial effect of the chitosan coatings was observed. The total number of pathogens for samples coated with 2.5 $g.kg^{-1}$ or higher chitosan solutions maintain during the storage period the same values as at the beginning of the experiments.

Table 3 presents the results of the microbiological analysis of chitosan-coated and uncoated fresh-cut apple cubes. Based on our results the optimal coating concentrations were 2.5 $g.kg^{-1}$ and 5 $g.kg^{-1}$, because with this the total plate count of microorganisms was not changed. The total number of fungus and moulds also increased on the uncoated samples, from 110 to $150x10^3$, but was not changed for the treated samples. The results are similar to Du et al. (1997).

Conclusions

Edible coatings from chitosan extended the shelf-life time of fresh-cut apples. They possessed microbiological barrier effect, preserved the texture and the visual parameters of the samples.

Future works: In the future the team would like to extend the use of edible coatings for other fruits, like berries or cherry. Maybe it is possible to find chitosan modifications with optimal taste and without causing stomach problems (water soluble modifications with lower molecular-weight). We would like to investigate more physico-chemical, microbial and barrier parameter on coated fruits.

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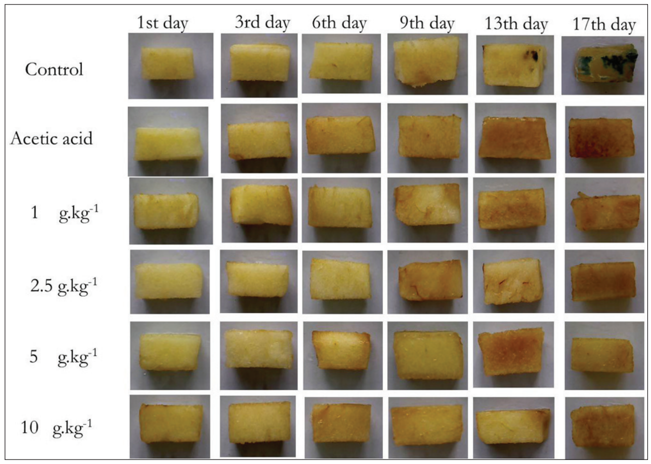

Fig. 3. Browning of the apple cubes during the storage period

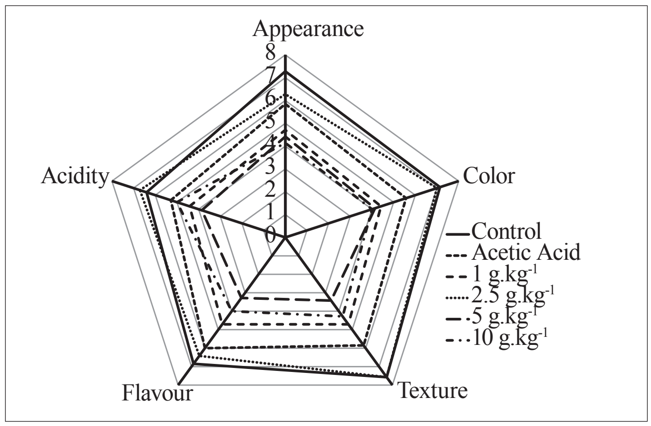

Fig. 4. Organoleptic profile of the apple cubes

Table 1
Hedonic ratings of the samples treated with acetic acid

Samples	Appearance	Color	Texture	Flavour	Acidity
Control	7.28	7.14	7.57	6.85	6.40
Acetic Acid	5.85	5.57	5.85	6.00	5.28
1 $g.kg^{-1}$ chit.	4.71	4.42	4.71	4.71	4.42
2.5 $g.kg^{-1}$	6.28	7.00	7.57	6.42	6.71
5 $g.kg^{-1}$	4.42	4.14	3.42	3.28	3.85
10 $g.kg^{-1}$	4.14	4.00	4.28	4.00	5.00

1=dislike extremely; 5=neither like nor dislike; 9=like extremely

Table 2
Chemical parameters during the shelf-life time

Treatment of the probe	Total soluble solids	Total sugar content	Titratable acidity	Pectin substances	Ascorbic acid	Antioxidant activity,
	$g.kg^{-1}$	$g.kg^{-1}$	$g.kg^{-1}$	$g.kg^{-1}$	$\mu g.g^{-1}$	$\mu mol.g^{-1}$
1st day						
Control	132.4	100.9	4.4	6.1	15.0	18.4
Acetic acid	125.9	88.2	6.4	4.2	14.6	15.8
1 $g.kg^{-1}$ chit.	125.1	84.5	5.0	6.0	14.5	12.3
2.5 $g.kg^{-1}$	128.3	96.4	4.9	4.6	14.8	12.7
5 $g.kg^{-1}$	127.4	90.0	4.8	5.4	15.0	11.7
10 $g.kg^{-1}$	141.3	110.1	4.5	5.8	14.5	14.8
8th day						
Control	125.8	84.00	4.1	5.9	9.8	15.0
Acetic acid	118.0	75.6	5.7	4.0	10.1	14.2
1 $g.kg^{-1}$ chit.	121.6	76.4	4.5	5.7	9.6	9.1
2.5 $g.kg^{-1}$	117.3	79.8	4.1	4.2	9.7	9.2
5 $g.kg^{-1}$	119.7	82.5	3.8	5.4	9.8	10.3
10 $g.kg^{-1}$	127.3	86.7	4.0	5.8	10.0	12.9
17th day						
Control	122.6	80.5	3.9	5.6	9.0	12.5
Acetic acid	112.0	69.0	5.1	3.8	9.2	10.8
1 $g.kg^{-1}$ chit.	109.1	70.0	4.8	5.5	8.8	8.2
2.5 $g.kg^{-1}$	111.5	73.8	3.7	4.1	9.1	7.5
5 $g.kg^{-1}$	116.4	80.0	3.6	5.2	8.9	9.5
10 $g.kg^{-1}$	120.0	92.5	4.1	5.5	9.2	12.1

Table 3
Total plate count of microorganisms and the total number of moulds and pathogens during the shelf-life time

Treatment of the probe	Total plate count of microorganisms		Total number of moulds		Total number of coliforms		Total number of Escherichia coli	
	CFU/g							
	1st day	8th day	1st day	8th day	1st day	8th day	1st day	8th day
Control	$7.6x10^3$	$280x10^3$	110	$150x10^3$	< 10	< 10	< 10	< 10
Acetic acid	30	1.6x103	30	30	< 10	< 10	< 10	< 10
1 $g.kg^{-1}$ chit.	< 10	$4x10^3$	< 10	< 10	< 10	< 10	< 10	< 10
2.5 $g.kg^{-1}$	< 10	10	< 10	< 10	< 10	< 10	< 10	< 10
5 $g.kg^{-1}$	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
10 $g.kg^{-1}$	< 10	50	< 10	< 10	< 10	< 10	< 10	< 10

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