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ORIGINAL RESEARCH PAPER

THE INFLUENCE OF DIFFERENT VACUUM IMPREGNATION SOLUTIONS ON THE COLOUR OF FRESH-CUT APPLE SLICES

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Abstract: The present paper focuses on the colour changes of freshly peeled/sliced fruits by using vacuum-impregnation of the apple slices with freshly prepared fruit juice and their mixture with two types of honey with the role of inhibition of the enzymatic browning of the apples. These syrups have the advantage of inhibiting the enzymatic browning of the fruits due to their high content of organic acids. The change in the colour of the fruits was monitored by using a colorimetric system, CIELAB.
The obtained results were used to identify the best vacuum-impregnation solution for the preservation of the apple slices that can be marketed.

Keywords: *acacia and polyfloral honey, colour measurements, fruit juices, vacuum impregnation*

INTRODUCTION

The necessity to assure all the vitamins, micronutrients, phenols and antioxidants that sustain a healthy life has increased in the recent years, and therefore the consumption of fresh-cut fruits and vegetables registered a continuous growth [1, 2]. Moreover, the consumers are demanding food products rich in healthy compounds that are of high quality and are not losing their content in bioactive compounds after processing.

In general, the food processing systems are continuously developed so that the storage stability is increased while the consumers' acceptance is satisfied.

The latest trends in food consumption are focusing on portioned fresh-cut fruits and vegetables. To satisfy the consumers' demands, these portioned products should also present acceptable appearance, which in the cases of sliced fruits and vegetables suffers from exposure to the atmospheric oxygen and different microorganisms. It is considered that a nice sliced fruit or vegetable colour is a decisive quality factor for the consumers [3].

Unfortunately, the appearance of the fresh-cut fruits and vegetables is strongly affected by the browning process, because of the alteration of the cell structure and involvement of the peroxidase and polyphenol-oxidase in reactions that negatively contribute to the colour change as well as to the change of the flavour of the products [4].

In the case of fresh-cut apples, the colour change is mainly due to the enzymatic browning as mentioned above and is facilitated by the diffusion of the oxygen into the cut slices.

The variation of yellowness and brightness is correlated with reduced content and high diversity of polyhydroxyphenols pattern. Higher redness values are determined by large quantities of chlorogenic acid or catechin [5]. The formation of the brown pigment could be a result of the Maillard reaction between catechin and lysine or fructose [6]. These results underline the importance of the apple cultivars used to obtain chips or snacks and of the treatments applied before packaging.

The most common used browning inhibitor is sulphite, which later was connected to allergic-like reactions or respiratory diseases [7].

The latest published results have shown that the interest in finding natural anti-browning agents can also be coupled with the possibility to produce different functional food products [8 – 10]. For example, probiotic fruits have been obtained as a result of apple impregnation with lactobacilli. The reported bacterial concentration in the final product was similar to the one present in milk products [11].

It is well-known that the structure of the apple tissue is characterised by porosity, property that can allow the outward compounds to be introduced and to obtain products with higher nutritional properties. One aspect which is less explored is that of maintaining the quantity of the native nutrient after processing. If we consider, for example, apple slices, good results have been obtained after applying vacuum drying [12].

In the case of apples, the internal cell deformation due to pressure modification and resistance to liquid flux is lower compared with other fruits [13, 14]. Therefore, based on the literature review, the vacuum impregnation can be considered a promising technique that contributes to the limitation of the pigments' formation [15]. The samples matrix characteristics influence the results of further treatments applied. These imply

that tissue cells dimensions have a determinant contribution to internal and external liquid transportation [16].
The use vacuum impregnation of different natural antioxidants on apple slices, followed by vacuum drying and packaging in a gentle vacuum atmosphere [17], represents a way to obtain healthy aperitifs.
In the present study, we focused on the identification of the optimum combinations of different kinds of honey types and fruit juices to limit the enzymatic browning process and prolong the preservation period of vacuum impregnated apple slices.

MATERIALS AND METHODS

Materials

The *Idared* apple variety, lemons, and pineapples were bought from a local retailer, and immediately stored at 4 °C. All fruits were of uniform size and defect-free. The apples were hand-peeled, cored and uniformly sliced prior the vacuum impregnation.
Two types of honey, polyfloral and acacia, were purchased from local producers from the western part of Romania.

Apparatus

The lemon fruits and the pineapple were passed through a home extractor to obtain the juices necessary for the preparation of different syrups.
The vacuum impregnation was made using a system consisting of a vacuum pump and vacuum meter RL2 REFCO Model, Ltd. Switzerland, connected to glass desiccators as a vacuum chamber.
For the determination of the apple colour changes, a Datacolor 500 spectrophotometer was used. The measurements were made in three different points. The K/S parameter, that is indicating the depth of the colour, was automatically calculated at the wavelength of maximum absorbance by the Datacolor Tools 2.0 software.

Methods

Apple slices were impregnated with different juices or syrups as presented in Table 1.

Table 1. *Solutions used for the impregnation of apple slices.*

Solution denomination	Fresh Lemon juice, [%]	Fresh Pineapple juice, [%]	Acacia honey, [%]	Polyfloral honey, [%]	Water
L	100	-	-	-	-
LA10	100	-	10	-	-
LP10	100	-	-	10	-
P	-	100	-	-	-
PA10	-	100	10	-	-
PP10	-	100	-	10	-
LP	50	50	-	-	-
LPA10	50	50	10	-	-
LPP10	50	50	-	10	-
W	-	-	-	-	100
WA10	-	-	10	-	100
WA20	-	-	20	-	100
WP10	-	-	-	10	100

The transversal cut apple slices were of an appropriate thickness (approximately 5 mm) to ensure the opacity of each sample. The treatment of the apple slices was made immediately, limiting as much as possible the exposure to the atmospheric oxygen. Each sample was weighed before and after vacuum impregnation procedure. The impregnation of the apple slices was performed at 400 mbar constant vacuum, for 10 min, followed by a relaxation time at atmospheric pressure for another 10 min. [18]. After treatment, the excess of syrup/juice on the fruits' surface was gently removed using filter paper. The vacuum impregnation procedure was performed in an excess of solution (syrup/juice: apple ratios was 20 : 1) to avoid eventual changes in the solution characteristics during the procedure.

Mass measurements

The mass change of apple samples was determined using an analytical balance. The mass gain (m_g) of the vacuum impregnated apple slices was calculated according to (Equation 1):

$$m_g\% = \frac{(m - m_1)}{m_1} * 100 \quad (1)$$

where: m - mass of the impregnated apple slice;

m_1 - initial mass of the fresh fruit.

The measurement was repeated 3 times for each apple slice sample.

RESULTS AND DISCUSIONS

The apple slices were treated in the same conditions during the vacuum impregnation process, and as it can be observed from Table 2, the highest mass gain (%) was observed in the case of pure lemon juice, while the lowest value was registered for the 20 % acacia honey in water syrup. The differences can be attributed to the differences in the viscosity of the samples, if the values for the different concentrations of acacia honey in water syrups, or even to the viscosity of the type of used honey. Another factor is the composition of the pure juices if the values obtained with pure lemon juice and pineapple juice are compared.

The variation of the colour of the vacuum impregnated apple slices was monitored for 15 days, and the obtained results are shown in Figures 1, 2, 3, and 4.

The CIE L^* parameter reflects the brightness of the samples. This value can be used as an indicator of colour change during the preservation of fruits and vegetable colour. The observed colour changes in case of studied apple slices can be attributed to the oxidation reactions or an increase in the amount of coloured compounds in the samples [5].

Table 2. *Effect of vacuum impregnation on weight gain*

	Temperature [°C]		
Sample	**m_1, [g]**	**m, [g]**	**m_g, [%]**
W	14.69	16.58	12.87
WP10	9.76	10.75	10.14
WA10	12.35	13.74	11.25
WA20	14.08	15.45	**9.73**
L	11.27	12.84	**13.93**
P	12.70	14.32	12.74
LA10	13.51	15.23	12.73
LP10	11.39	12.86	12.96
PA10	13.85	15.63	12.85
PP10	13.69	15.34	12.05
LP	12.53	14.27	13.89
LPA10	15.22	17.01	11.76
LPP10	14.67	16.39	11.72

The less affected by the colour change are the sample treated with pure lemon juice (**L** and the one treated with the mixture of 50 % lemon and 50 % pineapple juices (**LP**). It has to be pointed out that in these two cases, the CIE L^* values are the highest compared to the other examples (84.77, respectively 83.73) and the registered values are nearly constant until the end of the 15th day.

For the untreated sample (**A**) the CIE L^* value decreases in the first 48 h from 87.37 to 80.26 at the end of the monitoring period, day15th, the registered values being with 11.07 % lower.

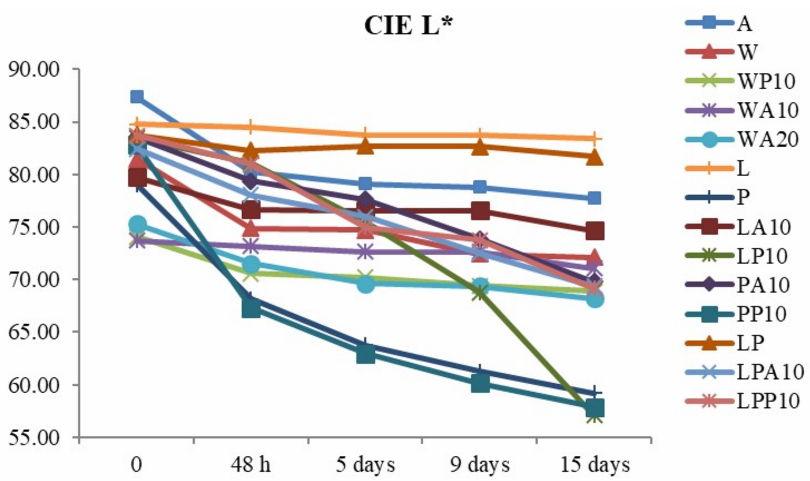

Figure 1. *CIE L^* values registered for apple slices after vacuum impregnation*

The highest decrease is observed in the case of pineapple juice (**P**), 10 % polyfloral honey in lemon juice (LP10) and 10 % polyfloral honey in pineapple juice (PP10). For the above-mentioned samples, in the first 48 h, the L^* value is with 13.45 %, 2.77 % and respectively 18.75 % lower, the final values being 59.22 (**P**), 57.10 (**LP10**) and 57.85 (**PP10**).

For acacia syrups impregnation solutions, the brightness value presents a smaller and more constant decrease compared with the other ones.

During the observation period, the browning process was not uniform and could be determined by the polyhydroxyphenols that are not evenly dispersed on the surface of the slices. Our results are in good agreement to other previously presented in the literature [13]. It can be considered that the colour modification in the first 48 hours is determined by the enzymatic oxidation.

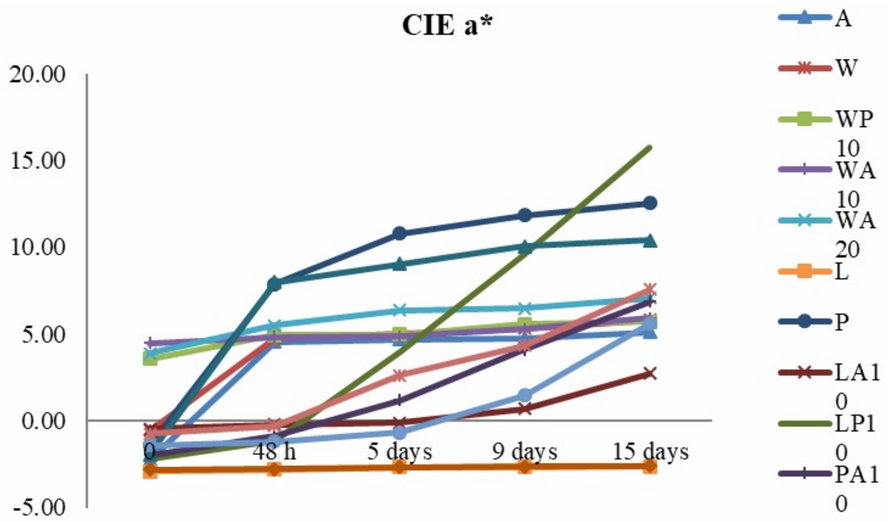

Figure 2. *CIE* a^* *values registered for apple slices after vacuum impregnation*

The registered CIE a^* values (Figure 2) vary among the considered apple samples, but the variation of this parameter is similar to the observation for the parameter L^*. For the apple slices treated with pure lemon juice **L**, and lemon juice and polyfloral honey, **LP**, the results show the absence of browning phenomena. For these samples, a protective role is determined by the organic acids present in the impregnation solution.
Compared with the control sample (**A**), the lower browning rates have the acacia honey base syrups impregnated slices.

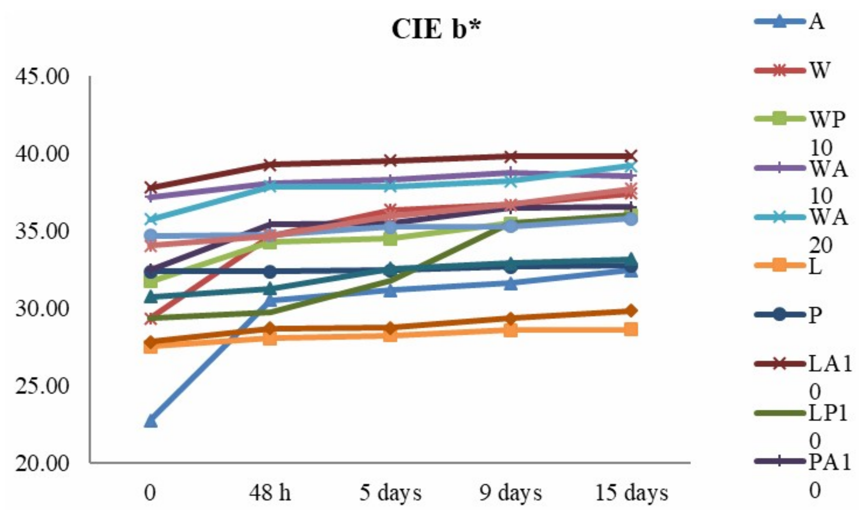

Figure 3. *CIE* b^* *values registered for apple slices after vacuum impregnation*

The b* value is the chromatic indicator on the blue to the yellow axis. It has almost a constant value for all of the considered samples. The behaviour differences appear in the first 48h for the control sample and aqueous solutions. After the first two days of observation, the values obtained remain almost constant until the 15th day.

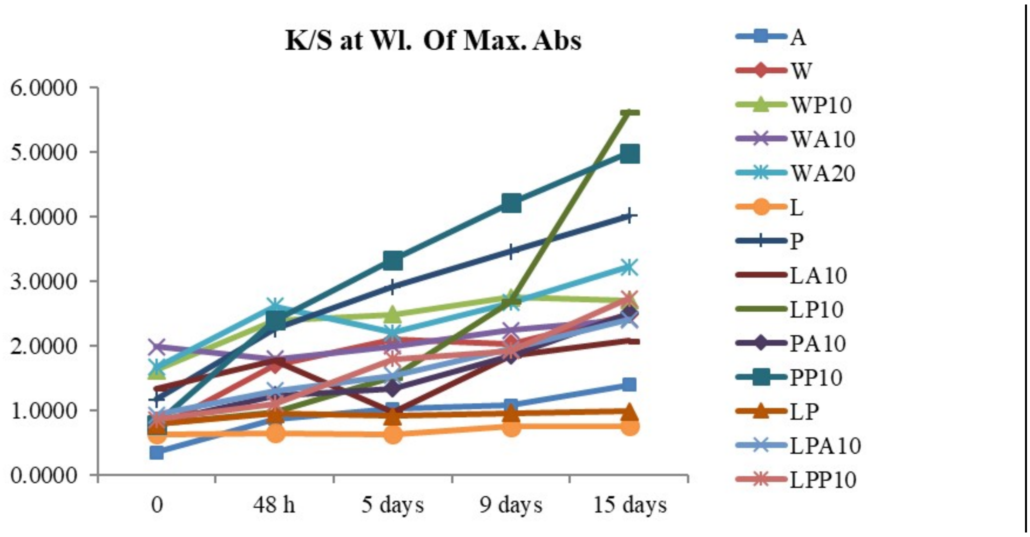

Figure 4. *K/S values at the wavelength of maximum absorbance registered for apple slices after vacuum impregnation*

K/S value indicates the samples colour strength. The values obtained for the different vacuum impregnated apple slices with the prepared syrups indicate that the sample impregnated with pineapple juice (**PP10**-4.9876, **P**-4.0151) and polyfloral honey (**LP10**-5.6179) have the highest registered values. These results might be considered unacceptable from the consumers' point of view.

The best results in terms of consumers' acceptability were registered for the samples treated with pure lemon juice, the mixture of lemon and pineapple juice, or the syrup obtained from fresh lemon juice and 10 % polyfloral honey.

CONCLUSIONS

The vacuum impregnation of the fresh-cut apple slices with different syrups obtained with two types of honey and fresh juices of lemon and pineapple shows that the acacia honey has the potential to inhibit the enzymatic browning of the considered samples, and in the same time to increase their nutritional value.

Another important observation is that the lemon juice is positively contributing to the preservation of the vacuum impregnated apple samples with syrups based on this. The fresh-cut apple slices vacuum impregnated with these syrups will be accepted by the consumers that are usually avoiding the products that were suffering from enzymatic browning.

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AUTHOR CONTRIBUTION

All authors have equal contribution.

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