EWELINA BASIAK

IMPACT OF STARCH-BASED FILMS ON THE QUALITY OF PLUMS

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Śliwki (Prunus domestica cv. Jojo) zostały podzielone na 5 grup. Po 28 dniach testów twardość owijanych filmami owoców była największa, zaś owoców powlekanych roztworami nieznacząco różniła się od grupy kontrolnej. Oznacza to, że czas sprzedaży śliwek może być o 1/3 dłuższy.

Słowa kluczowe: filmy do żywności, powłoki, materiały skrobiowe

Plums (*Prunus domestica* cv. Jojo) were divided onto 5 groups. After 28 days of conducted tests, firmness was greatest with starch and starch-whey protein films, and with coated materials was not significantly less than with the control group. This means that customers can consume plums for even 1/3 longer than their shelf-life.

Keywords: edible films, coatings, starch materials

1. INTRODUCTION

Plums are a seasonal fruit with a short postharvest storage life due to the acceleration of quality parameters loss such as firmness, balance, colour, titratable acidity (TA) and total soluble solids (TSS). Edible starch-based coatings have a positive effect on quality parameters. The main aim of this work was to measure the firmness and the total acidity.

2. MATERIALS AND METHODS

2.1. MATERIALS

Wheat starch was supplied by Hortimex (Konin, Poland). The whey protein isolate (WPI, ~90% protein) BiPRO was obtained from Davisco Foods International Inc. (Le Sueur, MN., USA). Anhydrous glycerol (99.9% purity) was purchased from Sigma-

Aldrich (Germany). 600 plums of the *Prunus domestica* variety Jojo were harvested in ripening time from 4 trees. Plums were picked from a garden and they were directly transported to the laboratory. Fruits were put in a storage chamber (3.5°C, 35% related humidity (RH)) and were kept there for one day. After that, the fruits were divided into five parts: fresh, coated in starch solution, coated in starch-whey protein solution (80/20%), wrapped in starch films and wrapped in starch-whey protein films (80/20%). There were 120 plums in each of groups. Next these plums were put onto plastic trays. There were 6 plums on each of these trays. This means that 20 trays with the same treated fruit were prepared for 10 days of measurements. Every week, 4 trays of each sort were taken from the cooling room. One part was used for measurements on the same day and the second part was kept for a few days at room temperature (to achieve the same conditions as in a grocery). The tests were then executed and experiments were conducted for 28 days.

2.2. PREPARATION OF STARCH AND STARCH/WHEY PROTEIN EDIBLE FILMS AND COATINGS

Film-forming aqueous solutions were prepared by casting wheat starch and whey protein isolate in the following proportions: 100-0% and 20-80%. Glycerol was used as a plasticiser at 50% w/w of the biopolymer dry weight (i.e. 50% of its total dry weight). Wheat starch film-forming solutions were prepared by dissolving 5 g of whey starch powder in 100 ml distilled water. Whey protein film-forming solutions were also prepared by dissolving 5 g of whey protein isolate in 100 ml distilled water. The solutions were heated in separate beakers in a water bath under a 700 rpm stirring at 85°C for 30 minutes to denature the whey protein and to obtain a complete gelatinisation of starch. Then, film-forming solutions were cooled down to 40°C. Glycerol was added. Solutions were cooled down to equal room temperature (25°C). Then, part of the solutions was used for films, and the second part as coatings. In order to prepare the films, 30 ml of film-forming solutions (starch and starch-whey protein) were poured onto a Petri plate to obtain a constant film thickness of about 80 µm. Films were dried at 25°C and 30% RH for 48 hours. Dry films were peeled off and stored at 53±1% RH and 25±1°C in desiccators containing saturated magnesium nitrate for 7 days prior to testing. With the second part of solutions (starch and starch-whey protein), fruits were immersed for 60 seconds, directly before the experiment. The coating solution and fruit had the same temperature.

2.3. FIRMNESS

The firmness of the fruit was measured using a TA.XT plus texturometer (Stable Microsystems, United Kingdom) equipped with a special 4 mm tip for this study. The plum peel was removed as thin as it was possible (with a new sharp razor) and the flesh was located on the texturometer table. Measurements were made in 15 repetitions.

2.4. TITRATABLE ACIDITY AND TOTAL SOLUBLE SOLID

Using garlic press equipment, the juice was squeezed from plums. Juice samples were centrifuged and divided into two parts. One part was used for the TSS determination. Using a digital refractometer, the TSS was measured and expressed as a percentage (%) of dry content. The second part of the juice was used for TA measurements taken by an automatic titrator (compact titrosampler rondo tower, Metter Toledo, Switzerland) with 0.1 mol L^{-1} NaOH to an end-point of pH 8.2. The TA was expressed as a gram of citric acid per litre of plum juice (g L^{-1}). The TSS: TA ratio was calculated and expressed as %. 3 replications of each sample were made.

2.5. STATISTICAL ANALYSIS

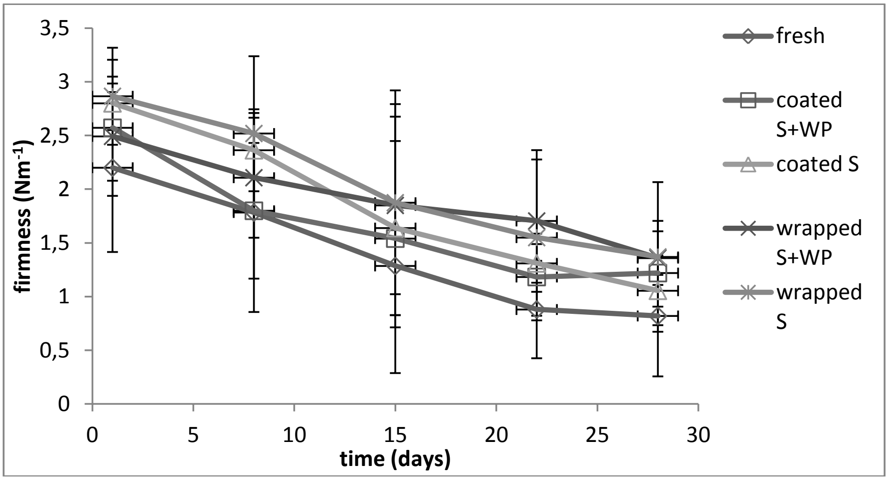
Statistical analysis was performed with Statgraphics Plus, version 5.0 (Manugistics Corp., Rockville, Md, U.S.A.). The analysis of variance (ANOVA) and Fisher's LSD multiple comparisons were performed to detect significant differences in the film properties. The significance level used was 0.005.

3. RESULTS

3.1. FIRMNESS

One of the crucial factors affecting fruits and vegetables shelf life is flesh firmness, which is directly related to postharvest product ripeness [1]. The firmness of plums stored in 3.5°C and 22°C was presented on the figures 1a and 1b respectively. In the first two weeks of storage, the highest firmness is noticed for fruits wrapped by starch material and for plums coated by starch-based solution at both temperatures. After the next two weeks, firmness is highest for fruits wrapped in starch-whey protein (80/20%) films. During the whole storage process, the lowest firmness is observed for fresh plums. Independent of their storage temperature, fresh fruits firmness loss was the fastest.

a)



b)

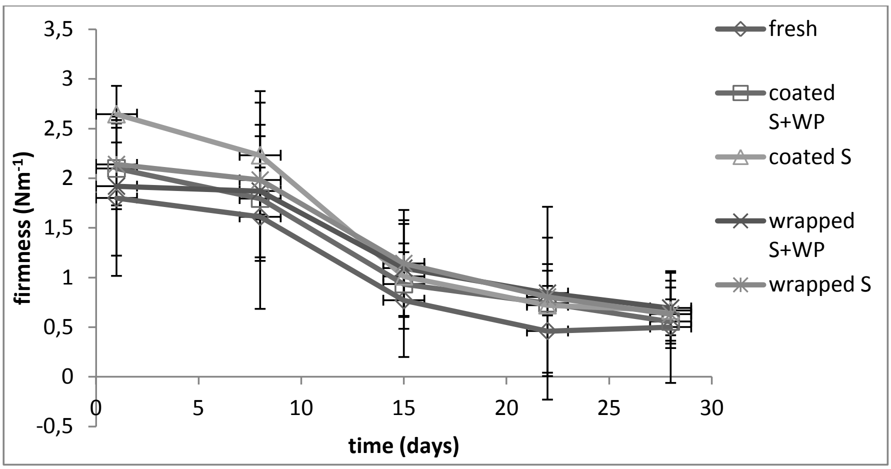


Figure 1a,b Firmness of fresh, coated in starch solution, coated in starch/whey protein solution (80/20), wrapped in starch film and wrapped in starch/whey protein (80/20) film plums in 3.5°C and 22°C, respectively.

Rysunek 1a,b. Twardość świeżych, powlekanych roztworem skrobi i skrobi z białkiem (80-20%), pakowanych w folie skrobiowe i skrobiowo-białkowe (80-20%) śliwek w 3,5°C i 22°C.

Firmness depends on factors as fruit maturity, harvesting time and variety of fruit, so values in literature for different kinds of plums at different maturity stages are not comparable with those ones presented in this study, but the trend is the same [2].

Results presented by Hussain et al. [3] show that the coating process significantly prolongs the firmness of agriculture products. *Prunus domestica* L. cv. Santa Rosa covered by carboxymethyl cellulose coatings after 12 days of storage had firmness even 3 times higher than fresh fruit. Liu et al. (2014) worked with *Prunus salicina* L. cv. Sanhuali plums. Some of the fruits were kept in plastic baskets for 20 days wrapped by chitosan films, and somewhere coated by chitosan solution. After 3 weeks of storage at 5°C and 90% of RH, the firmness of fresh fruit decreased by more than 5 times, and the firmness of coated and wrapped Japanese plums was 2 and 2.5 times lower for treated plums. Choi et al. [4] also showed that the *Prunus salicina* L. plum cv. Formosa coated by hydroxypropyl methylcellulose with essential oils have higher firmness in storage and in room conditions. After 14 days of storage at 23°C, the firmness of fresh plums was at approximately 5.33 $Nm^{-1}$and 9.58 Nm^{-1} for HPMC coating with essential oil addition. Results obtained after 14 days of storage at 5°C showed a higher value of firmness than in room conditions. At 5°C, the respiration is lower so mass and water losses are lower as well. Firmness for control plums in 5°C was 11.68 Nm^{-1} and 15.45 Nm^{-1} for HPMC coating.

3.2. TITRATABLE ACIDITY AND TOTAL SOLUBLE SOLID

The effect of coating and wrapping on TA and TSS of plums kept at 3.5°C and 22° C is shown in table 1.

Table 1. The effect of coating and wrapping on titratable acidity (TA) and total soluble solid (TSS) of plums kept at 3.5°C and 22° C. Data are expressed as mean ± SD.

Tabela 1. Wpływ powlekania i pakowania na kwasowość miareczkową i zawartość substancji stałych śliwek przechowywanych w 3,5°C i 22°C.

time (days)		1	8	15	22	28
TA (g/100mL) in 3.5°C	control	0.75 ± 0.03^{c}	0.69 ± 0.01^{c}	0.68 ± 0.02^{c}	0.62 ± 0.01^{b}	0.64 ± 0.01^{b}
	coated S+WP	0.74 ± 0.02^{c}	0.70 ± 0.03^{c}	0.69 ± 0.02^{c}	0.68 ± 0.03^{c}	0.63 ± 0.01^{b}
	coated S	0.69 ± 0.03^{c}	$0.66 \pm 0.03^{b.c}$	0.64 ± 0.03^{b}	0.61 ± 0.02^{b}	0.60 ± 0.01^{b}
	wrapped S+WP	0.71 ± 0.03^{c}	0.68 ± 0.02^{c}	0.63 ± 0.04^{b}	0.62 ± 0.02^{b}	0.58 ± 0.01^{a}
	wrapped S	0.69 ± 0.02^{c}	0.67 ± 0.03^{c}	$0.65 \pm 0.03^{b.c}$	0.61 ± 0.02^{b}	$0.59 \pm 0.02^{a.b}$
TA (g/100mL) in 22°C	control	0.76 ± 0.04^{c}	0.72 ± 0.03^{c}	0.69 ± 0.01^{c}	0.67 ± 0.02^{b}	$0.62 \pm 0.01^{a.b}$
	coated S+WP	0.76 ± 0.04^{c}	0.73 ± 0.02^{c}	0.71 ± 0.03^{c}	0.65 ± 0.02^{b}	0.59 ± 0.01^{a}
	coated S	0.72 ± 0.02^{c}	$0.68 \pm 0.03^{b.c}$	0.66 ± 0.03^{b}	$0.62 \pm 0.03^{a.b}$	0.58 ± 0.01^{a}
	wrapped S+WP	0.73 ± 0.03^{c}	$0.70 \pm 0.03^{b.c}$	0.67 ± 0.03^{b}	0.64 ± 0.02^{b}	$0.61 \pm 0.02^{a.b}$
	wrapped S	0.75 ± 0.03^{c}	$0.69 \pm 0.04^{b.c}$	0.66 ± 0.02^{b}	0.64 ± 0.03^{b}	$0.60 \pm 0.03^{a.b}$
TSS (°Bx) in 3.5°C	control	15.82 ± 0.34^{c}	18.15 ± 0.27^{e}	20.16 ± 0.21^{f}	20.70 ± 0.20^{f}	20.40 ± 0.15^{f}
	coated S+WP	12.50 ± 0.25^{a}	15.01 ± 0.15^{c}	18.55 ± 0.27^{e}	17.92 ± 0.29^{e}	18.23 ± 0.19^{e}
	coated S	15.70 ± 0.26^{c}	15.02 ± 0.12^{c}	15.64 ± 0.14^{d}	14.88 ± 0.22^{c}	15.84 ± 0.23^{d}
	wrapped S+WP	12.81 ± 0.21^{a}	14.10 ± 0.19^{b}	18.29 ± 0.32^{e}	13.07 ± 0.22^{a}	16.03 ± 0.17^{d}
	wrapped S	12.81 ± 0.32^{a}	14.00 ± 0.17^{b}	$15.13 \pm 0.26^{c.d}$	14.54 ± 0.26^{b}	15.00 ± 0.12^{c}
TSS (°Bx) in 22°C	control	15.07 ± 0.36^{b}	19.20 ± 0.41^{e}	21.91 ± 0.50^{g}	20.81 ± 0.32^{f}	21.15 ± 0.28^{g}
	coated S+WP	12.50 ± 0.24^{a}	18.18 ± 0.31^{d}	19.42 ± 0.19^{e}	20.70 ± 0.21^{f}	20.34 ± 0.29^{f}
	coated S	13.05 ± 0.35^{a}	19.05 ± 0.35^{e}	18.92 ± 0.24^{e}	19.01 ± 032^{e}	20.10 ± 0.27^{f}
	wrapped S+WP	15.19 ± 0.22^{b}	16.16 ± 0.31^{c}	16.57 ± 0.18^{c}	15.28 ± 0.23^{b}	16.30 ± 0.26^{c}
	wrapped S	18.09 ± 0.40^{d}	16.25 ± 0.28^{c}	18.34 ± 0.19^{d}	18.22 ± 0.16^{d}	18.20 ± 0.21^{d}

*)Values denoted by the same letter for a given parameter of the ambient air were not significantly different ($p < 0.05$)

Titratable acidity decreased according to the storage time. Values obtained in the same week of measurements do not affect significant differences at 3.5°C, nor at 22°C. Valero et al. [1] coated 4 varieties of European plums in alginate solution. The presented results showed the titratable acidity depending on plum cultivar. Anyway, edible coatings based on alginate delayed titratable acidity decrease in Blacamber, Lary Ann, Golden Globe and Songold varieties. Díaz-Mula et al. [5] presented a similar trend for yellow and purple European plum cultivars wrapped in MAP packages.

At both temperatures, the total soluble solid increases faster in fresh fruit. This means that untreated plums ripened quicker than coated and wrapped fruits. Changes of wrapped fruits are lower than those of coated, but the trend during the storage time is increasing. However, comparing to fresh fruit starch and starch-whey protein (80/20%) coatings and films significantly delayed the rising in total soluble solid. It means that using biodegradable films for packaging fresh material can keep the total soluble solid longer, which is better received by consumers. The same wrapping and coating processes also prolongate the shelf-life of storage postharvest crops. This data agrees with results reached by Liu et al. [6] for *Prunus salicina* L. cv. Sanhuali obtained plums coated and packaged in chitosan solution and films respectively, and with data published by Choi et al. [4] for *Prunus salicina* L. cv. Formosa plums covered in hydroxypropyl methylcellulose. The authors obtained the same rising trend with values from around 14 to 16 °Bx in the first two weeks of storage at 23°C.

CONCLUSIONS

European *Prunus domestica* cv. *Jojo* plums were covered and wrapped in coatings and films made from starch and starch-whey protein (80/20%) suspensions. The total soluble solid increased lower as well in treated fruits. Thus, titratable acidity increased according to storage time for all conducted samples. Fruits packaged in starch-based biomaterials can be stored for even 1/3 of their shelf-life longer.

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REFERENCES

[1] Valero, D., Díaz-Mula, H.M., Zapata, P.J., Guillén, F., Martínez-Romero, D., Castillo, S., Serrano, M., 2013. Effects of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage. Postharvest Biol. Technol. 77, 1-6.

[2] Mukhtar, A., Damerow, L., Blanke, M., 2014. Non-invasive assessment of glossiness and polishing of the wax bloom of European plum. Postharvest Biol. Technol. 87, 144–151.

[3] Hussain, P.R., Suradkar, P.P., Wani, A.M., Dar, M.A., 2015. Retention of storage quality and post-refrigeration shelf-life extension of plum (Prunusdomestica L.) cv. Santa Rosa using combination of carboxymethyl cellulose (CMC) coating and gamma irradiation. Radiation Phys. Chem. 107, 136–148.

[4] Choi, W.S., Singh, S., Lee, Y.S., 2016. Characterization of edible film containing essential oils in hydroxypropyl methylcellulose and its effect on quality attributes of 'Formosa' plum (Prunus salicina L.). LWT - Food Sci. Technol. 70, 213-222.

[5] Díaz-Mula, H.M., Martínez-Romero, D., Castillo, S., Serrano, M., 2011. Modified atmosphere packaging of yellow and purple plum cultivars. 1. Effect on organoleptic quality. Postharvest Biol. Technol. 61, 103–109.

[6] Liu, K., Yuan, Ch., Chen, Y., Liu H., 2014. Combined effects of ascorbic acid and chitosan on the quality maintenance and shelf life of plums. Sci. Hort. 176, 45–53.

EWELINA BASIAK

WPŁYW POWLEKANIA ŚLIWEK FILMEM NA BAZIE SKROBI NA JAKOŚĆ ŚLIWEK

Śliwki są owocami sezonowymi, dostępnymi w Polsce (z europejskich sadów) przez około 4-6 tygodni w ciągu roku. Śliwki odmiany *Prunus domestica* cv. Jojo zostały zebrane w ogrodzie Instytutu Leibniz w Poczdamie i bezpośrednio po zebraniu przewiezione do laboratorium i umieszczone w chłodni, w temperaturach $3{,}5^0$C i 22^0C, 35% wilgotności powietrza. Owoce podzielono na 5 grup: kontrolna, śliwki umieszczone na plastikowych tackach i pokryte filmem skorobiowym, pokryte filmem skrobiowo-białkowym (80-20%), śliwki powlekane skrobią i powlekane skrobią z białkiem (80-20%). 1, 8, 15, 22 i 28 dni po zebraniu owoców z sadu zostały przeprowadzane testy na twardość, kwasowość miareczkową i na zawartość całkowitej rozpuszczalnej substancji stałej. Każdego dnia, w którym były przeprowadzane testy, próbki z owocami przeniesiono z chłodni do temperatury pokojowej 22^0C. Po kilku godzinach zmierzono temperaturę i przy pomocy ostrego noża z owoców usunięto skórkę i przeprowadzono test twardości w 15 powtórzeniach. Test został wykonany na teksturometrze TA.XT plus (Stable Microsystems, Wielka Brytania), przy użyciu specjalnej 4 mm końcówki dedykowanej do tego rodzaju testów. Za pomocą wyciskarki do czosnku wyciskano sok ze śliwek. Próbki soku odwirowano i podzielono na dwie części. Jedną część wykorzystano do oznaczenia całkowitej zawartości rozpuszczalnych substancji stałych (TSS). Za pomocą cyfrowego refraktometru zmierzono TSS i wyrażono jako procent (%) suchej masy. Drugą część soku wykorzystano do pomiarów kwasowości dającej się miareczkować (TA) wykonanych za pomocą automatycznego titratora (Metter Toledo, Szwajcaria) z 0,1 mol L-1 NaOH do wartości końcowej pH 8,2. Miareczkowalna kwasowość została wyrażona jako gram kwasu cytrynowego na litr soku śliwkowego (g L-1). Obliczono stosunek TSS: TA i wyrażono w %. Wykonano 3 powtórzenia dla każdej próbki. Jednym z kluczowych czynników wpływających na trwałość owoców i warzyw jest jędrność miąższu, która jest bezpośrednio związana z dojrzałością produktów po zbiorze [1]. W pierwszych dwóch tygodniach przechowywania najwyższą jędrność mają owoce zawijane w skrobię oraz śliwki powlekane roztworem na bazie skrobi w obu temperaturach. Po kolejnych dwóch tygodniach jędrność jest największa w przypadku owoców zawiniętych w folię skrobiowo-białkową (80/20%). W całym okresie przechowywania najmniejszą jędrność mają świeże śliwki. Świeże owoce, niezależnie od temperatury przechowywania, najszybciej tracą jędrność. Jędrność zależy od takich czynników jak dojrzałość owoców, termin zbioru i różnorodność owoców, dlatego wartości literaturowe dla różnych rodzajów śliwek w różnych etapach dojrzałości nie są porównywalne z prezentowanymi w niniejszym opracowaniu, ale trend jest ten sam [2]. Kwasowość podlegająca miareczkowaniu zmniejszała się wraz z czasem przechowywania. Wartości uzyskane w tym samym tygodniu pomiarów nie wpływają na istotne różnice przy $3{,}5^o$C, ani przy 22^oC.W obu temperaturach wzrost całkowitej rozpuszczalnej substancji stałej następuje szybciej w świeżych owocach. Oznacza to, że nietraktowane śliwki dojrzewają szybciej niż owoce powlekane i opakowane. Zmiany w owocach opakowanych są mniejsze niż w owocach powlekanych, ale tendencja w czasie przechowywania jest rosnąca. Jednak w porównaniu do powłok z filmami ze skrobi i skrobi z białkiem (80/20%) można wywnioskować, że zmiany postępują wolniej w filmach. Oznacza to, że użycie biodegradowalnych folii do pakowania świeżego materiału może dłużej zachować całkowitą rozpuszczalną substancję stałą, co jest lepiej odbierane przez konsumentów. Procesy owijania i powlekania wydłużają również okres przydatności do spożycia upraw pożniwnych.

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