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ASSESSMENT OF THE POSSIBILITY OF USING EDIBLE ALGINATE FILMS AS COLORIMETRIC PH INDICATORS IN INTELLIGENT FOOD PACKAGING®

Ocena możliwości zastosowania jadalnych folii alginianowych jako kolorymetrycznych wskaźników pH w opakowaniach inteligentnych do żywności®

Key words: edible films, sodium alginate, pH indicator, intelligent packaging.

The aim of the work presented in the article was to evaluate the possibility of using edible alginate films based on the infusions of hibiscus flowers, chokeberry and blackcurrant fruit pomace as colorimetric pH indicators in intelligent food packaging. The films were made from aqueous infusions by casting method. The color and its change under different pH from 2 to 12 were examined. The films showed a color change from purple to red in an acidic environment and to dark gray in an alkaline environment. The color change of the films prepared with the addition of infusions from chockeberry and blackcurrant pomace indicated the possibility of using them as colorimetric pH indicators, which needs more research.

Słowa kluczowe: folie jadalne, alginian sodu, wskaźnik pH, opakowanie inteligentne.

Celem pracy przedstawionej w artykule była ocena możliwości zastosowania jadalnych folii alginianowych wytworzonych na bazie naparów z wytłoków z kwiatów hibiskusa, owoców aronii i czarnej porzeczki jako kalorymetrycznych wskaźników pH w opakowaniach inteligentnych do żywności. Folie wytworzono z wodnych naparów barwnych metodą wylewania. Zbadano barwę i jej zmianę pod wpływem pH od 2 do 12. Folie wykazywały zmianę barwy z fioletowej do czerwonej w środowisku kwaśnym oraz do ciemnoszarej w środowisku zasadowym. Zmiana barwy folii przygotowanych z dodatkiem naparów z wytłoków z aronii i czarnej porzeczki wskazała na możliwość zastosowania ich jako kolorymetrycznych wskaźników pH i celowość prowadzenia dalszych badań.

INTRODUCTION

Food packaging meets a few basic functions, which include: protective and informative, marketing, logistics, utility, sales and ecological. These functions affect on the quality of packaged products and reduce the risk of product adulteration and misleading consumers at the stage of distribution in the supply chain [3]. Proper selection of packaging for food products enables standardization of production and maintaining the quality of products at a constant level. Nowadays, there is an increasing need to control and monitor the conditions outside and inside the packed products. This control is possible using intelligent packaging, enriched with colorimetric indicators of freshness [8].

Intelligent or smart packaging act as an indicator informing about the characteristics of the product, including changes in the composition of the product or in the environment around the product, such as an increase in the amount of carbon dioxide, biogenic amines and other compounds that are products of microbial metabolism, formed in the food packaging during storage. Smart packaging also provides information about changes in environmental parameters of the packed product, such as temperature and humidity. There are technologies for the production of intelligent packaging with indicators placed outside the packaging and those in which indicators are placed inside the packed product. When the indicator is located inside the packaged product, it is necessary to separate the indicator from the food in order to limit the potential migration of ingredients from the indicator to the food as much as possible. Intelligent packaging provides consumers with information about quality changes of food [2]. Through the color reactions between the components of the indicator and the product and/ or its environment, the indicator's color changes, which is a colorful message about the deterioration of the properties of the packed food [13]. Based on the Commission Regulation (EC) No 450/2009 [4] on active and intelligent materials and

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articles intended to come into contact with food, intelligent packaging ensures control of the packed product and its environment by monitoring the environmental conditions and the stability of the packaged produc. Intelligent packaging communicates to consumers about changes in food product.

The mechanism of action of colorimetric indicators in smart packaging is based on chemical and enzymatic changes, reactions to the produced metabolites of microorganisms, changing the pH of the environment and mechanical damage to the packaging. Smart packaging, through an element placed inside or outside packaging reacts with the environment, providing information about changing environmental conditions of the product or changes related to the product itself [2]. The production of pH color sensitive edible films is possible by adding a natural dye to the film-forming solution, which is safe in contact with food. The interaction of the dye with the film-forming agent is crusial to form the color change of the indicator as a result of environmental changes [1]. Biopolymers can be used for the production of indicators in intelligent packaging. Polysaccharides are an example of a biopolymer used to obtain edible films [10], they can be extracted from by-products resulting from the processing of fruit and vegetables, e.g. fruit pomace, bran, fruit and vegetable peels. Compounds from by-products of the agro-industrial industry may be a valuable source of bioactive compounds such as anthocyanins or carotenoids [9]. These pigments, characterized by low permeability to oxygen and light radiation, have good antioxidant properties. The recovery of bioactive compounds from waste is used for the production of intelligent packaging, using the reactivity of these compounds to some environmental factors [11]. The combination of the functions of biopolymers with bioactive dyes obtained from waste enables the production of biodegradable smart packaging. Natural dyes are used for the production of indicators of freshness, temperature-time indicators or detectors of the presence of oxygen and carbon dioxide, which react to changes in the pH of the environment, light and changes in the temperature of the product. These dyes can be extracted from fruit waste such as blackberry and blueberry pomace, black rice bran, grape skin and turmeric residues. Such packaging, due to the natural ingredients, does not contribute the negative effects on environmental and the consumer health [14].

The aim of the research was to assess the possibility of using edible alginate films based on infusions of hibiscus flowers, chokeberry and blackcurrant pomace as colorimetric pH indicators in intelligent food packaging.

MATERIALS AND METHODS

The research materials were edible films based on aqueous infusions of chokeberry and blackcurrant pomace and hibiscus flowers (Greenfield Sp. Z o. o. Sp. K., Warsaw). The film-forming material was sodium alginate (Agnex, Białystok). Glycerol (Avantor Perfomance Materials Poland, Gliwice) was used as a plasticizer. Model buffers with a pH from 2 to 12 were purchased from Alfachem Sp. z o.o. (Lublin). The aqueous infusions from grounded fruit pomace or hibiscus flowers were prepared at the concentrations of 2.5 g and 5 g using the water at 95° C and 25 minutes of extraction. Then, the solutions were filtered through a filter paper (Warchem Sp. z o.o., Marki), separating the pomace solids from the infusions. The pH of the infusions were measured using the pH-meter model CPO-505 (Elektron Sp.j., Warsaw). The color of the infusions were evaluated using the CR-5 colorimeter (MINOLTA, Tokyo, Japan) in the CIE L*a*b* color system. The infusions were used as solvents in the preparation of a film-forming solutions based on sodium alginate at 1.5 and 2%. The control sample was a film made with the addition of distilled water. The mixtures were heated to the temperature of 60°C and mixed for 20 minutes with the use of a magnetic stirrer RT10 (IKA, Poland Sp. Z o.o.). After the solutions were cooled down to ambient temperature, glycerol was added at the concentration of 50% relative to biopolymer. The mixtures were poured in constant amount on a series of Petri dishes and dried in a SUP 65 W/G laboratory dryer (WA-MED Bożena and Jan Warchoł Sp. J., Płock) at the temperature of 35°C for 24 hours. After drying, films were conditioned in a KBF 240 climatic chamber (Binder GmbH, Tuttlingen, Germany) for 48 hours at 25°C and 50% of relative humidity prior to testing. The measured properties of the obtained alginate films included the measurement of the film thickness, color, opacity and sensitivity to the changes in pH. The film thickness was measured with an accuracy of 1 μm in a minimum of three repetitions using a ProGage thickness gauge (Thwing-Albert Instrument Company, West Berlin, USA). To determine the color of the films, measurements were made using a CR-300 colorimeter (MINOLTA, Tokyo, Japan) in the CIE L*a*b* color system. The samples were placed on a white standard with constant values at (L*=97.04, a*=(-0.08), b*=2.15) and the color was measured in 6 repetitions. The total color difference (ΔE) was calculated according to the equation presented by Sobral et al. [15]:

$$\Delta E = \sqrt{(L^* - L)^2 + (a^* - a)^2 + (b^* - b)^2} \quad (1)$$

where: L*, a*, b* – values for the white standard;
L, a, b – values for the films.

The film opacity was measured in 6 repetitions using a Helios γ spectrophotometer (Thermo Electron Corporation, Waltham, USA) at a wavelength of 600 nm. The film opacity was calculated according to the equation presented by Han and Floros [6]:

$$O = \frac{A_{600}}{l} \quad (2)$$

where: O – film opacity [A/mm];
A600 – absorbance at the wavelength of 600 nm;
l – film thickness [mm].

The determination of the pH sensitivity of the films were evaluated visually by placing films in model buffers with a pH in the range of 2-12. The statistical analysis was performed using the anaysis of variance (ANOVA) with the Tukey test at the significance level of p = 0.05 using the Statistica 13.0 program (StatSoft Polska Sp.z o.o., Kraków).

RESULTS AND DISCUSSION

The pictures of infusions made from chokeberry and blackcurrant pomace and hibiscus flowers were presented in Figure 1. The fruit pomace infusions had a red-purple color,

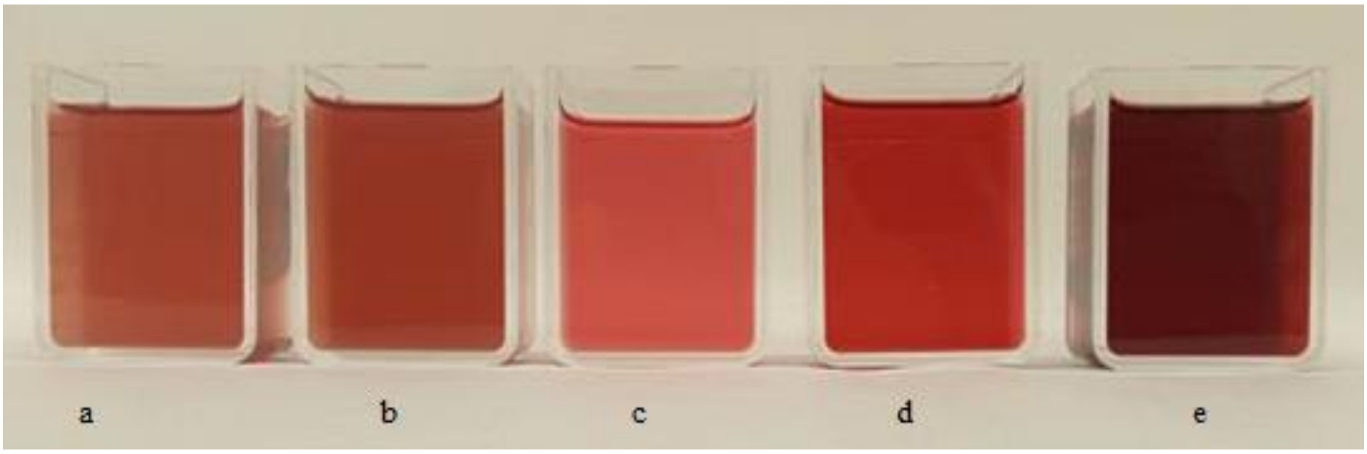

Fig. 1. Infusions of chokeberry at a concentration of 2,5% (a) and 5% (b), blackcurrant at a concentration of 2,5% (c) and 5% (d) and hibiscus flowers at a concentration of 2,5% (e).
Rys. 1. Napary z wytłoków z aronii o stężeniu 2,5% (a) i 5% (b), czarnej porzeczki o stężeniu 2,5% (c) i 5% (d) oraz kwiatów hibiskusa o stężeniu 2,5% (e).

Source: Own study

Źródło: Opracowanie własne

whereas the hibiscus flower infusion had significantly darker purple color, which can be used as a source of color pigments in the preparation of edible films. The infusions were made from grounded pomace due to the greater bioavailability of the pigments. Preliminary studies have shown that the infusions of ungrounded pomace were brighter, indicating that the dyes were located in the dried fruit, the release of which was limited. In general, the fruit pomace is characterized by a high content of polyphenols, antioxidants, fiber, pectins and antioxidants being a good source of natural dyes, including anthocyanins [17].

The produced infusions differed in the type and amount of pomace used in their preparation. Therefore, it can be visually observed that the infusions differ in color intensity, from light red to dark red. The color of the infusions is darker with the increase in the concentration of the pomace used. Table 2 presents the results of the L*, a* and b* color parameters of analyzed infusions. The L* parameter determines the lightness, which is define as black for values closed to 0 and white for values closed to 100. The highest L* value was observed for the infusion from the blackcurrant pomace at the concentration of 2,5%, while the lowest for infusion from the hibiscus flowers. The higher the concentration of pomace used, the redder the color of the infusions. The tested fruit infusions had an intense red color, which is related to the presence of anthocyanins in the fruit pomace [12,16]. The differences in the color parameters between the samples were statistically significant (p <0.05). The saturation of infusions is influenced by the content of pigments, as well as the amount of solid particles (stones, stalks, twigs) present in the pomace used. The darkest hibiscus infusion was characterized by an intense red color, which was related to the fact that only hibiscus petals were used in the infusion, without the remaining parts of the plant. In addition, the color of the infusion from the hibiscus flowers is also connected with its chemical composition, including a relatively high content of organic acids (15-30%), which are citric, malic, tartaric, oxalic and hibiscus acids. Moreover, this flower is a source of anthocyanins, influencing its intense red color, as well as phenols [18]. Parameters a* and b* were both positive, indicating the color towards to red and yellow, respecively.

Table 1. L*, a*, b* color parameters and pH of tested infusions
Tabela 1. Parametry barwy L*, a*, b* i pH badanych naparów

Infusion	L*	a*	b*	pH
A2,5%	42,53 ± 0,01^{b}	43,21 ± 0,03^{b}	34,43 ± 0,03^{c}	4,23
A5%	47,23 ± 0,01^{d}	41,48 ± 0,01^{a}	32,47 ± 0,02^{c}	3,98
CP2,5%	60,42 ± 0,00^{e}	57,07 ± 0,02^{d}	21,18 ± 0,01^{a}	3,08
CP5%	44,32 ± 0,00^{c}	67,16 ± 0,02^{e}	46,23 ± 0,04^{e}	2,92
H2,5%	21,83 ± 0,02^{a}	53,52 ± 0,06^{c}	37,22 ± 0,11^{d}	2,58

Abbreviations: A2,5 and A5 – infusions from chokeberry pomace at 2,5% and 5%, CP2,5 and CP5 – infusions from blackcurrant pomace at 2,5% and 5%, H2,5 – infusions from hibiscus flower at 2,5%. Different superscripts letters ($^{a-e}$) within the same column indicate significant differences ($p < 0.05$).

Oznaczenia: A2,5 i A5 – napary z wytłoków z aronii o stężeniu 2,5% i 5%, CP2,5 i CP5 – napary z wytłoków z czarnej porzeczki o stężeniu 2,5% i 5%, H2,5 – napar z kwiatów hibiskusa o stężeniu 2,5%. Różne litery przy wartościach ($^{a-e}$) w tej samej kolumnie wskazują na istotne różnice ($p < 0,05$).

Source: Own study

Źródło: Opracowanie własne

The analyzed infusions differed in the pH values ranging from 2,58 to 4,23, which correspond to the acidic reaction (Table 1). Differences in the acidity of analyzed infusions may result in the different chemical composition of used materials. Hibiscus infusion had the lowest pH value (2,58).

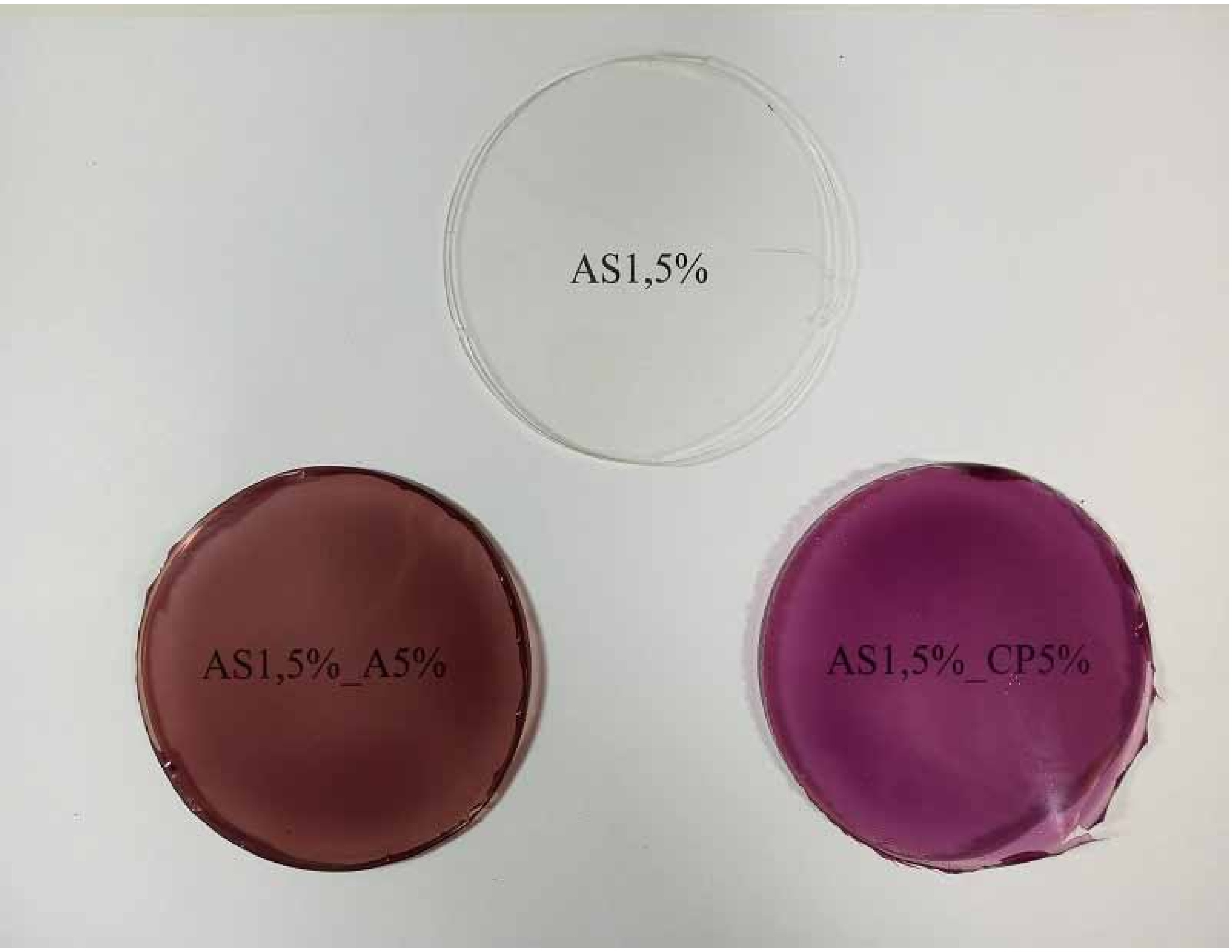

Fig. 2. Edible films prepared without (AS1,5%) and with the infusions of chokeberry (AS1,5%_A5%) and blackcurrant (AS1,5%_CP5%) pomace.
Rys. 2. Folie jadalne wytworzone bez (AS1,5%) i z dodatkiem naparów z wytłoków z aronii (AS1,5%_A5%) i czarnej porzeczki (AS1,5%_CP5%).
Source: Own study
Źródło: Opracowanie własne

According to Znajdek-Awiżek and Matłowska [18], hibiscus is a plant with a high content of organic acids, which may have an influence on the low pH of the infusion obtained from hibiscus flowers, which resulted in very dense film-forming solutions. The blackcurrant pomace infusion also had a low pH (2,92), however no negative effects were observed in contact with sodium alginate. In general, blackcurrant pomace is also a source of organic acids such as: citric, malic, maleic and tartaric acids [7], which contributed to the low pH of the infusions. The highest values of pH, 4,23 and 3,98, were noted for infusions with 2,5% and 5% of chokeberry pomace. Comparing the pH values of the obtained infusions, it can be concluded that the highest amount of organic acids in hibiscus flower infusions and chokeberry pomace infusions affected the lower pH values. At the low pH of the solution, the color of the infusions is the most intense, which results from the dominance of the flavylic cation responsible for the red color of anthocyanins [16].

Different type of edible films were prepared with the use of sodium alginate as gelling agent at the concentration of 1,5 and 2% and the infusions from fruit pomace and hibiscus flowers as solvents. In the case of the control films, the solvent was distilled water. All films were prepared using glycerol as a plasticizer. It was observed an instant gelling for hibiscus flowers infusions in contact with sodium alginate, resulting in high density, which is probably due to the low pH value (2,58). The gel structure of the hibiscus mixture resulted in a gelatinous consistency of the solutions. There was no possibility to pour out the exact amount of the film-forming solutions and obtain thin films. Therefore, for the next step of studies, only infusions from the chockberry and blackcurrant pomace were taken into account. However, the concentration of fruit pomace used in the study was significant. Film-forming solutions prepared from the infusions at the concentration of 2,5% were less intense in red color. Fig. 2 shows pictures of obtained films with the use of sodium alginate at 1,5%. The control films were transparent and slightly shiny, while the films prepared with the use of infusions were characterized by a semi-transparent structure with a red-violet color. All the films were uniform, smooth, without any cracks and pores, and they differed in color.

The film thickness varied depending on the fruit pomace infusion used. As shown in Table 3, the thickness of the films ranged from 58,4 µm for control films at lower concentration of biopolymer (AS1,5%) to 76,9 µm for films prepared with the infusion of blackcurrant and biopolymer at the concentration of 2% (AS2%_CP2,5%). The control films were the thinnest, however the higher concentration of sodium alginate resulted in higher thickness (from 58,4 to 78,6 µm), which is often observed for films prepared at different concentrations of biopolymers affecting the functional properties of films [5]. An increase in the sodium alginate content resulted in higher thickness values. The differences in thickness values between films at the same biopolymer concentration (2%) and the fruit infusions at the same content (5%) can be explain by the presense of blackcurrant residues, which could resulted in higher thickness.

Table 2. Thickness of analyzed edible films

Tabela 2. Grubość badanych folii jadalnych

Film	Thickness [µm]
AS1,5%	58,4 ± 6,5[a]
AS2%	78,6 ± 7,9[b]
AS1,5%_A5%	60,0 ± 1,4[a]
AS2%_A2,5%	76,6 ± 1,4[b]
AS1,5%_CP5%	72,9 ± 10,5[b]
AS2%_CP2,5%	76,9 ± 4,3[b]

Abbreviations: AS1,5% and AS2% – control films prepared at the concentration of sodium alginate of 1,5 and 2%, AS1,5%_A5% and AS2%_A2,5% – films prepared with the infusions of chokeberry pomace, AS1,5% _CP5% and AS2%_CP2,5% – films prepared with the infusions of blackcurranr pomace. Different superscripts letters ([a-b]) within the same column indicate significant differences ($p < 0.05$).
Oznaczenia: AS1,5% i AS2% – folie kontrolne przygotowane przy stężeniu alginianu sodu 1,5 i 2%, AS1,5%_A5% i AS2%_A2,5% – folie przygotowane z naparów z wytłoków z aronii, AS1,5 %_CP5% i AS2%_CP2,5% – folie sporządzony z naparów z wytłoków z czarnej porzeczki. Różne litery przy wartościach ([a-b]) w tej samej kolumnie wskazują na istotne różnice ($p < 0,05$).

Source: Own study

Źródło: Opracowanie własne

The L*, a* and b * color parameters as well as the total color difference (ΔE) of the analyzed films are presented in Table 3. The L* value indicates the lightness, which was the highest for control films (96,01-96,16) and lowest for films prepared with the infusions of chockeberry and blackcurrant at the concentration of 5%. It means that these films were the most dark compared to others. The a* color parameter showed negative valued for control films and positive for films prepared with the fruit infusions showing the color toward red. The b* parameter was positive for control films and those prepared with the infusions of chockeberry pomace indicating the yellow colow, and negative values, color toward to blue, were observed for films contaning infusions from blackcurrant pomace. As the concentration of the fruit pomace in infusions increased, the color of the films became more red or blue, respectively. The results of the total color difference (ΔE) can be interpreted using the following guidelines [12]: ΔE <1 – the difference in color is not perceived; ΔE [1-2] – the difference in color is noticeable by a qualified observer; ΔE [2-3,5] – the difference in color is noticeable by an unqualified observer and ΔE> 5 – the color difference is significant. The total color difference (ΔE) of the analyzed films were significant and were 5,66 and 5,71 for control films and from 40,09 to 61,39 for films with fruit infusions. When the biopolymer was used at lower concentration, the higher values of total color difference were observed as a result of the higher effect of pigments in film-forming solutions.

Table 3. L*, a*, b* color parameters and total color difference (ΔE) of edible films

Tabela 3. Parametry barwy L*, a*, b* i bezwzględna różnica barwy (ΔE) folii jadalnych

Film	L*	a*	b*	ΔE	Opacity [A/mm]
AS1,5%	96,01 ± 0,26[e]	-0,13 ± 0,04[a]	3,41 ± 0,20[b]	5,66 ± 0,23[a]	0,35 ± 0,03[a]
AS2%	96,16 ± 0,23[e]	-0,17 ± 0,03[a]	3,49 ± 0,22[b]	5,71 ± 0,25[a]	0,52 ± 0,02[a]
AS1,5%_A5%	49,68 ± 1,44[b]	22,61 ± 0,25[d]	6,18 ± 0,20[c]	53,17 ± 1,29[d]	7,01 ± 0,14[e]
AS2%_A2,5%	56,38 ± 0,89[c]	13,00 ± 0,33[b]	8,74 ± 0,19[e]	44,08 ± 0,90[c]	5,74 ± 0,13[d]
AS1,5%_CP5%	47,14 ± 1,68[a]	31,79 ± 0,51[e]	-6,09 ± 0,47[a]	59,36 ± 1,15[e]	3,49 ± 0,59[c]
AS2%_CP2,5%	61,28 ± 0,88[d]	17,56 ± 0,14[c]	-6,16 ± 0,86[a]	40,09 ± 0,77[b]	1,53 ± 0,09[b]

Abbreviations: AS1,5% and AS2% – control films prepared at the concentration of sodium alginate of 1,5 and 2%, AS1,5_A5% and AS2%_A2,5% – films prepared with the infusions of chokeberry pomace, AS1,5% _CP5% and AS2%_CP2,5% – films prepared with the infusions of blackcurranr pomace. Different superscripts letters ([a-e]) within the same column indicate significant differences ($p < 0.05$).
Oznaczenia: AS1,5% i AS2% – folie kontrolne przygotowane przy stężeniu alginianu sodu 1,5 i 2%, AS1,5%_A5% i AS2%_A2,5% – folie przygotowane z naparów z wytłoków z aronii, AS1,5% _CP5% i AS2%_CP2,5% - folie sporządzony z naparów z wytłoków z czarnej porzeczki. Różne litery przy wartościach ([a-e]) w tej samej kolumnie wskazują na istotne różnice ($p < 0,05$).

Source: Own study

Źródło: Opracowanie własne

Film opacity is presented in Table 3. The values ranged from 0,35 for control film at the concentration of sodium alginate of 1,5% to 7,01 A/mm for films prepared with the infusion of chockeberry at the concentration of 5%. It can be observed that an increase in the opacity values is connected with lower concentration of biopolymer and higher concentration of fruit pomace used, which is attributted to the higher content of pigments. Comparing two fruit pomace used, higher values of film opacity were observed for those prepared with the chockeberry pomace, indicating that these films are less transparent to light. Taking into account the higher values of total color difference and opacity, as the most relevant, films prepared at the concentration of sodium alginate at 1,5% and the fruit pomace at 5% were used for evaluating the color changes in different pH buffers from 2 to 12. The results were presented in Figure 2 for films prepared with the infusions based on chockeberry pomace and on Figure 3 for films prepared with the infusions based on blackcurrant pomace. The color changes from violet to intense dark red at pH 2 and to dark gray at pH 8 and 12 were observed for films contaning chockeberry pomace infusions. The films with the infusions of blackcurrant pomace showed a more pronounced color changes of the film due to the increase in pH of the buffers. The color changed from purple to intense red at pH 2 and to dark blue at pH 8. Immersion of the film in acidic pH did not significantly affect the color of the film made of chokeberry and blackcurrant pomace. The films in an acidic environment remains red in color, which results from the presence of the flavylic cation, responsible for the red color of anthocyanins. Strengthening of the film structure in an acidic environment was also observed, as well as higher hydration in an alkaline environment, which was related to the solubility of the film in buffers. The neutral environment visibly changed the color of the films. Increasing the pH in the alkaline direction caused discoloration of the film. The films became lighter with a blue tinge appearing in both cases, which is attributted to the fact that the flavylic cation has probably disappeared. The change in the color can be observed due to the decomposition of anthocyanins from the films, caused by the instability of these compounds in buffer solutions [16].

SUMMARY

The article assessed the possibilities of using edible alginate films based on infusions from chokeberry and blackcurrant pomace and hibiscus flowers as colorimetric pH indicators that can be used in intelligent food packaging. Chokeberry and blackcurrant pomace infusions were characterized by an intense red color, which can be used as a solvent in the production of biopolymer films with the desired red color. The infusions of hibiscus flowers were characterized by an intense red color, and the low pH, which resulted in the gelation of film-forming solutions and there was no possibility to obtain thin films. The use of sodium alginate at a concentration of 1,5% with the addition of glycerol at 50% allowed for the

Fig. 3. Reaction to the changing pH from 2 to 12 for films prepared with the infusions of chokeberry pomace (AS1,5%_A5%).

Rys. 3. Reakcja na zmianę pH z zakresu 2–12 przez folie przygotowane z naparów z aronii (AS1,5%_A5%).

Source: Own study

Źródło: Opracowanie własne

Fig. 4. Reaction to the changing pH from 2 to 12 for films prepared with the infusions of blackcurrant pomace (AS1,5%_CP5%).

Rys. 4. Reakcja na zmianę pH z zakresu 2–12 przez folie przygotowane z naparów z czarnej porzeczki (AS1,5%_CP5%).

Source: Own study

Źródło: Opracowanie własne

production of films with the desired functional properties, such as: flexibility and lack of cracks and pores, surface smoothness and homogeneity, uniform distribution of pigments from the fruit pomace infusions. The control films were characterized by high brightness and low opacity, while the color films were dark and less transparent to light. Films prepared at the concentration of sodium alginate at 1,5% and the chockeberry and blckacurrant pomace at 5% were the most relevant in color to be used as colorimetric pH indicators. After immersing those films in various pH buffers from the range of 2-12, a clear change in the color of the film was observed, which probably resulted in the decomposition of anthocyanins under the influence of the changing pH of the environment. Color of the films in an acidic environment increased the intensity to red, and in an alkaline environment changed to dark blue or dark gray. The color change of the films prepared with the addition of infusions from the chockeberry and blackcurrant pomace indicated the possibility of using them as colorimetric pH indicators, which needs more research.

PODSUMOWANIE

W artykule oceniono możliwości zastosowania jadalnych folii alginianowych wytworzonych z naparów z wytłoków z aronii i czarnej porzeczki oraz kwiatów hibiskusa jako kolorymetrycznych wskaźników pH, które mogą znaleźć zastosowanie w opakowaniach inteligentnych do żywności. Napary z wytłoków z aronii i czarnej porzeczki charakteryzowały się intensywną barwą czerwoną. Mogą być one stosowane jako rozpuszczalnik przy wytwarzaniu folii biopolimerowych o pożądanej barwie czerwonej. Napary z kwiatów hibiskusa charakteryzowała intensywnie czerwona barwa, zaś niskie pH, wpłynęło na szybkie żelowanie roztworów powłokotwórczych i uniemożliwienie wytworzenia cienkich folii. Zastosowanie alginianu sodu o stężeniu 1,5% z dodatkiem 50% glicerolu umożliwiło wytworzenie folii o pożądanych właściwościach użytkowych, takich jak: elastyczność i brak pęknięć oraz porów, gładkość i jednorodność powierzchni, równomierność rozprowadzenia substancji barwnych z naparów. Folie kontrolne charakteryzowały się wysoką jasnością i niską nieprzezroczystością, zaś folie barwne były ciemne i mniej przepuszczalne dla światła. Folie wytworzone z zastosowaniem alginianu sodu o stężęniu 1,5% i naparów z aronii i czarnej porzeczki w stężeniu 5% wykazywały najbardziej pożądaną barwę. Po zanurzeniu tych folii w różnych buforach pH z zakresu 2-12, można zauważyć wyraźną zmianę barwy folii, która wynika z rozpadu antocyjanów, pod wpływem zmiennego pH środowiska. Folie barwne w środowisku kwaśnym zwiększyły intensywność barwy czerwonej zaś w środowisku zasadowym zmieniły barwę na ciemnoniebieską lub ciemnoszarą. Zmiana barwy folii przygotowanych z zastosowaniem naparów z wytłoków z aronii i czarnej porzeczki wskazuje na możliwości zastosowania badanych folii jako kolorymetrycznych wskaźników pH oraz celowość dalszych badań.

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