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Physical Characteristics of Cookies Enriched with Microencapsulated Cherry Pomace Extract

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Abstract**—**Pomace, a by-product from fruit processing industry is the potential source of valuable bioactive. Cookies are popular, ready to eat and low price foods; therefore, enrichment of these products is of great importance. In this work, bioactive compounds extracted from cherry pomace, encapsulated in soy and whey proteins, have been incorporated in cookies, replacing 10 (SP10 and WP10) and 15% of wheat flour (SP15 and WP15). Cookie geometry (diameter (D), thickness (T) and spread ratio (D/T)), cookie weight, cookie hardness and cookie surface colour were measured. Sensory characteristics are also examined. The results show that encapsulated cherry pomace bioactives have positively influenced the cookie mass. Diameter, redness (a* value) and cookie hardness increased. Sensory evaluation of cookies, revealed that up to 15% substitution of wheat flour with WP encapsulate produced acceptable cookies similar to the control (100% wheat flour) cookies.

Keywords**—**Cherry pomace, polyphenols, microencapsulation, cookies, physical characteristics.

I. Introduction

THAT sweet cherries contain anthocyanins has been known since the beginning of the 20th century. The major anthocyanins in sweet cherries include the 3-O-glucoside and 3-O-rutinoside (-rhamnosyl-d-glucopyranose) of cyanidin, with peonidin-3-O-rutinoside and -glucoside, as well as pelargonidin-3-O-rutinoside occurring in much lower amounts [1]. During production of sour cherry juice, a large amount of by-products remains as a rich source of polyphenols, especially anthocyanins.

A significant property of anthocyanins is their antioxidant activity, which plays an important role in the prevention of neuronal and cardiovascular illnesses, cancer and diabetes, among others [2]. Anthocyanin pigments readily degrade during the thermal processing and storage which can have a dramatic impact on color quality and may also affect nutritional properties. By encapsulation, the active compound can be protected from environmental destructive factors as water, oxygen, light, and other conditions [3]. Freeze drying is the best technique for the retention of polyphenolic compounds and the antioxidant activity and it is successfully used for encapsulation thermosensitive substances [4]. Proteins have many functional properties. Nutritionally, soybean protein resembles animal protein more closely than other vegetable protein. Besides, studies confirmed that proteins are good carriers of polyphenols, due to polyphenols interaction with proteins (non-covalent hydrophobic interactions which may be stabilized by hydrogen bonds) [5].

Encapsulation of bioactive compounds, techniques and wall materials were studied, but there are not many studies about their incorporation in real food systems.

The aim of this paper was to investigate the effect of substituting 10% and 15% of wheat flour with bioactive compounds extracted from cherry pomace, encapsulated with soy and whey proteins, on physical characteristics of cookies. Cookies are ready-to-eat, non-expensive, very popular flour confections, especially among children. The low nutritional quality of wheat flour, which is the most important ingredient used for the production of cookies, has been of major concern in its utilization. Therefore, the use of bioactive compounds that will nutritionally enriched cookies is of great importance.

II. Materials and Methods

A. Preparation and Extraction of Sour Cherry Pomace

Ripe sour cherries, variety ‘Feketićka’, were purchased from local producer “Horkai“, Feketić, Serbia. Sour cherry pomace was obtained by pressing the unfrozen seedless sour cherries through a cheesecloth. The yield of pomace compared to the unfrozen fruits was 22.40%. The obtained pomace was dried in a freeze drier (Christ Alpha 2-4 LSC, Martin Christ, Osterode am Harz, Germany) at -40° C for 120 h. Moisture content in pomace was 74.90%. The extraction of (poly) phenolic substances from dry pomace was performed using 50% ethanol aqueous solution. Sample of pomace (100 g) was extracted in three steps: with 500 ml for 3 min on a high performance homogenizer (Silent Crusher M, Heidolph Instruments GmbH, Kelheim, Germany) and for 60 min on a laboratory shaker (Unimax 1010, Heidolph Instruments GmbH, Kelheim, Germany) and twice with additional 250 ml for 30 min. Each time liquid extract was collected after separating the pomace solids by vacuum filtration using Whatman filter paper Ø 47 mm. The three obtained three extracts were combined and organic solvent in the collected hydro-alcohol extract was evaporated by rotary evaporation set at 40 °C.

B. Encapsulation of Sour Cherry Pomace Extract

Concentrated water pomace extract (100 ml) was mixed with wall material (50 g of soy protein isolate (“Macrobiotic prom”, Belgrade, Serbia) or whey (“Lučar”, Novi Sad, Serbia), core:coating ratio of 2:1) with additional 200 ml of water for 30 min on laboratory shaker (200 rpm). The

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homogenized mixtures were iced and then freeze dried at -40 °C for 24 h, yielding a purple-blue and red free-flowing powders - soy protein (SP) and whey protein (WP) encapsulates, respectively. The microcapsulated powders were packed in airtight containers and stored at 4 °C.

C. Biscuit Preparation

Blends of wheat flour (T-500 "Ratar", Pančevo) and SP and WP encapsulates, containing 10% and 15% of encapsulated powder were prepared on a replacement basis. Each blend was mixed thoroughly using the F-6-RVC agitator (Forberg International AS, Norway).

Biscuit dough was prepared according to the following formula: flour blend (wheat flour without encapsulate was used for the preparation of control biscuit sample) 200 g, vegetable fat 42 g, sugar 70 g, $NaHCO_3$ 0.6 g, NH_4HCO_3 0.4 g and NaCl 1.1 g. The measured amount of flour was mixed in a mixer (ZD2245, Stephan - Werke GmbH and Co., Hamelin, Germany) for 0.5 min, and after the addition of the total amount of fat and powdered sugar, the mixing was continued for 5.5 min at low speed (60 rpm/min). All other components dissolved in distilled water were added into the mixer and dough was mixed for 15 min. The amount of water was calculated in relation to the water content of the flour blends in order to obtain dough samples with 24% moisture content. After mixing, the dough samples were allowed to rest for 30 min in covered bowls. The dough was processed by sheeting it between two cylinders of laminator (Marchand LA4-500, Materiel modern marchand, Rueil – Malmaison, France). The gap settings between the cylinders were: 14 mm, 10 mm, 7 mm and 5 mm, with 15 s resting period between each passage. Consequently, the dough was cut by using a stainless mould, and prepared cookie dough was baked for 15 min at 230 °C in a laboratory oven followed by cooling (2h) and packaging (in high-density polyethylene). Biscuit samples with blends of wheat flour and SP/WP encapsulates, containing 10% of encapsulate powder were marked as SP10/WP10, and with 15% of encapsulate powder as SP15/WP15.

D. Cookie Dimensions

Cookie dimensions, including diameter, height and weight, were measured on three replicates and mean values recorded. Cookie diameters (D - the longest and the shortest cookie diameters were measured and consequently the values of mean cookie diameters were calculated) and thickness (T - length between the top and the bottom of the cookie) were measured with a vernier caliper. Spread ratio parameter (D/T) was calculated as the ratio between the mean cookie diameter and the mean thickness. Weights were determined by using a Mettler digital top loading balance (EL204-IC; Mettler, Buchi Switzerland).

E. Cookie Hardness

Cookie hardness was measured by a Texture analyzer HD Plus (Stable Micro systems, UK). The cookies were analysed by using a Knife Edge with Sloted Insert (HDP/BS) and 250 kg load cell at a 1.5 mm/s pre-test speed, test speed of 2 mm/s and 10mm/s post-test speed. The resulting force-deformation curve was analysed for hardness. The analysis was carried out in triplicates.

F. Cookie Color

Cookies upper surface color was measured in triplicates 24 h after baking. The CIE*Lab* colour coordinates (L* - lightness, a* - redness to greenness and b* - yellowness to blueness) [6], were determined by using MINOLTA Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan) together with D-65 lighting, a 2° standard observer angle and an 8-mm apperture in the measuring head. The Chroma Meter was calibrated by using a Minolta calibration plate.

G. Sensory Analysis

Cookie samples were evaluated by a panel of 25 consumers, 24 h after baking. Panelist scored the cookie characteristics (color, appearance, flavor, texture and overall acceptability) using 7 - point hedonic scale (1 - dislike extremely, 2 - dislike very much, 3 - dislike moderately 4 - neither like nor dislike, 5 - like moderately, 6 - like very much, 7 - like extremely) [7]. Cookie samples were served to panelists on white plastic plates labeled with three-digit codes from a random number table. Panelists were asked to swallow samples and to rinse their mouths with water between samples.

H. Statistical Analysis

All data are presented as average and standard deviation. Statistical analysis was carried out using STATISTICA 12.0 (StatSoft, Inc., Tulsa, OK, USA). All data were presented as mean value with their standard deviation indicated (mean ± SD). Variance analysis (ANOVA) was performed, with a confidence interval of 95% ($P < 0.05$). Means were compared by Duncan's multiple range test.

III. Results and Discussion

A. Cookie Dimensions

Based on ANOVA (Table I) the addition of WP and SP encapsulates resulted in cookies with weight that were significantly different ($p<0.05$) from that of the control. SP encapsulate increased weight more than WP encapsulate. It is possible that increased water retention in flours with SP encapsulate accounted for this difference.

TABLE I
Geometric Properties of Cookie Samples

Sample	Weight (g)	D (mm)	T (mm)	DD/T ratio
Control	12.03 ± 0.7^{a}	6.68 ± 0.23^{d}	0.71 ± 0.02^{a}	9.41
WP10	13.79 ± 0.28^{b}	6.54 ± 0.05^{c}	0.91 ± 0.04^{c}	7.19
WP15	14.33 ± 0.44^{b}	6.08 ± 0.07^{a}	0.93 ± 0.04^{c}	6.54
SP10	14.11 ± 0.79^{b}	6.28 ± 0.15^{b}	0.83 ± 0.02^{b}	7.56
SP15	15.51 ± 0.25^{c}	6.21 ± 0.08^{b}	0.85 ± 0.01^{b}	7.31

$^{a–d}$ means ± SD with different superscript letters in the same column differ significantly ($p<0.05$)

According to the results in Table I, diameter of cookies decreased with the substitution of wheat flour with WP and SP encapsulates, consequently, these cookies were characterized with higher cookie thickness. Ability of WP and SP encapsulates to absorb available water (because of high content of proteins) in cookie dough provoked elastic shrinkage after baking. There is less water available for gluten component which suppressed cookie spreading. Also, WP encapsulate has a higher content of sugar and higher sugar concentrations in the water phase led to higher internal dough viscosity, resulting in limited cookie spread [8]. Therefore, cookies with WP encapsulate had lower values for diameter than cookies with SP encapsulate. Spread ratio (D/T) of cookie samples decreased with increasing share of cherry pomace extracts. Reference [9] reported that the spread factor of control sample also evidenced significantly higher values than samples with cherry powder.

B. Cookie Hardness

Hardness is a very important property of cookies that contributed cookie quality. Cookies from flour with SP encapsulate were significantly harder than the control (Fig. 1), but hardness value for the control and cookie with 15% of WP encapsulate were not significantly different (p>0.05).

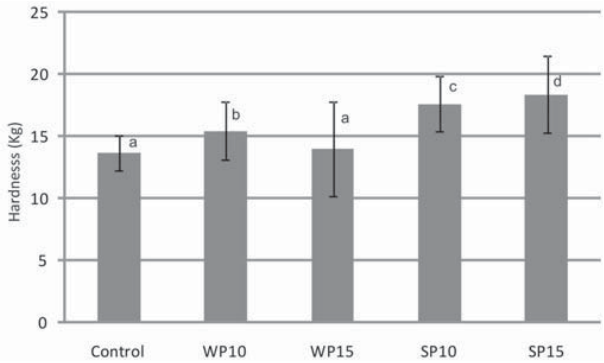

Fig. 1 Hardness changes of evaluated cookie samples

Protein rich flour necessitates more water to obtain a machinable cookie dough, and cookie prepared from a high-absorption dough tend to be hard handle during dough preparation and handling [10]. Soy proteins can bind significant amount of water and therefore samples with SP encapsulate were hardest. Whey protein isolate contains high content of sugar. Sugar makes the product fragile, since it tends to disperse the protein and starch molecules, thereby preventing the formation of a continuous mass [11].

TABLE II
COLOR PARAMETERS OF COOKIES CONTAINING WP AND SP CHERRY POMACE EXTRACT ENCAPSULATES

Cookie sample	L*	a*	b*
Control	80.66 ± 0.22^{d}	1.91 ± 1.09^{a}	23.72 ± 0.17^{b}
WP10	64.59 ± 0.42^{c}	10.52 ± 0.13^{c}	25.79 ± 0.69^{c}
WP15	55.90 ± 0.75^{a}	12.42 ± 0.19^{e}	26.07 ± 1.01^{c}
SP10	58.03 ± 0.29^{b}	9.52 ± 0.46^{b}	19.28 ± 0.49^{a}
SP15	55.52 ± 1.29^{a}	11.94 ± 0.41^{d}	19.77 ± 0.12^{a}

$^{a–e}$ means ± SD with different superscript letters in the same column differ significantly (p<0.05).

A. Cookie Color

The effect of replacing wheat flour with anthocyanins from cherry pomace encapsulated on whey and soy proteins are shown in Table II.

The addition of WP and SP encapsulates favor the development of cookies color because of high content of sugar and proteins in whey protein isolate and high content of proteins (90%) in soy protein isolate which contributed to Maillard reactions, so the lightness (L* value) decreased with increasing the level of encapsulates. At the same time, a positive a* values (redness) in samples with encapsulates, increased (higher in WP15 and SP15 then in WP10 and SP10) because of characteristic anthocyanins structure [12]. Reference [9] shows that redness (a*) of cookies color increased, whereas the lightness (L*) and yellowness (b*) decreased as the concentration of cherry powder increased. Samples with antocyanins encapsulated in whey proteins had significantly higher a* values (p<0.05) then samples with soy proteins. WP cookies had significantly higher b* values (p<0.05), while the addition of SP encapsulates decreased this values compared with control sample. Increasing the amount of encapsulates from 10 to 15% showed no difference in b* values (p>0.05).

B. Sensory Analysis

The effects of encapsulated cherry pomace extracts on the sensory quality of cookies are summarized in Table III.

The WP encapsulate containing cookies had higher scores for color in comparison to the control sample. Cookie color become darker with higher level of encapsulates, because of higher level of anthocyanins, but SP encapsulates caused dark color of cookies sample, what panelists did not like. Concerning cookie appearance, the control sample was characterized with the highest scores. Addition of SP encapsulate did not affect these attribute, while the WP encapsulate addition caused a decrease in the scores for appearance from 6.21 to 2.89 (cookie shape was deformed and surface was cracked).

TABLE III
SENSORY SCORES OF EVALUATED COOKIE SAMPLES

Sample	Color	Appearance	Flavor	Texture	OA^{A}
Control	3.31 ± 0.74^{a}	6.21 ± 0.83^{c}	5.62 ± 0.52^{c}	5.36 ± 0.74^{b}	4.95 ± 0.95^{d}
WP10	6.22 ± 0.65^{c}	3.66 ± 0.71^{b}	6.54 ± 0.74^{d}	6.23 ± 0.44^{c}	6.26±0.71^{b,c}
WP15	5.41 ± 0.44^{c}	2.89 ± 0.92^{a}	6.86 ± 0.44^{d}	5.57 ± 0.82^{c}	6.45 ± 0.63^{c}
SP10	4.43 ± 0.79^{c}	6.00 ± 0.89^{c}	3.42 ± 0.82^{a}	4.95 ± 061^{b}	5.63 ± 0.89^{b}
SP15	3.85 ± 0.84^{b}	5.78 ± 0.93^{c}	4.35 ± 0.61^{b}	3.54 ± 0.52^{a}	4.07 ± 0.66^{a}

$^{a–e}$ Means ± SD with different superscript letters in the same column differ significantly (p<0.05).
^{A} Overall acceptability

The addition of encapsulates significantly affected flavor of cookies sample (p<0.05). Higher percentage of WP encapsulate in cookies increased intensity of flavor associated with fresh cherries which elicited positive reactions among evaluators. Sample WP15 had the highest score for flavor (6.86), but the addition of the SP encapsulates decreased these scores (3.42 for sample SP10). The evaluators also reported mild residual taste in SP samples, described as "milky", probably because of high protein content in soy protein encapsulate.

The results of sensory analysis showed that scores assigned by the judges for texture were in good agreement with the measurements derived from the physical (hardness) test. Soy protein isolate had a high content of proteins which absorb water during cookies preparation which results in a cookies hardness [13]. On the other hand, whey protein isolate contains high content of sugar which makes the product fragile.

Concerning the overall acceptance, it can be observed that all cookies were sensory acceptable. The WP cookies acquired the highest scores (6.26 for WP10 and 6.45 for WP15), while the addition of SP encapsulates induced the decrease in overall acceptance of cookies. The low overall acceptability of the cookies containing SP encapsulates was attributed, by the panellists, to a high hardness, a mild residual flavour and darkening.

IV. Conclusion

Obtained results for physical characteristics of cookies showed that application of bioactive compounds extracted from cherry pomace, encapsulated in soy and whey proteins in amount of 15% in cookies is possible. Diameter of cookies decreased with the substitution of wheat flour with WP and SP encapsulates, while these cookies were characterized with higher cookie thickness. The addition of WP and SP encapsulates resulted in a higher cookies weight. SP cookies were significantly harder than the control. The lightness (L* value) and yellowness (b*) of cookies decreased with increasing the level of encapsulates, while the redness (a*) of cookies color increased. SP and WP encapsulate caused changes of sensory characteristics of cookies. The WP encapsulate containing cookies had higher scores for color, flavor, texture and overall acceptability in comparison to control sample.

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