www.foodandfeed.fins.uns.ac.rs
FOOD AND FEED RESEARCH
Journal of the Institute of Food Technology – FINS
University of Novi Sad
ISSN
2217-5369
(print version ceased in 2023)
2217-5660 (online)

UDK 663.918.4:634.73+663.81]:66.022.392

Original research paper

DOI: 10.5937/ffr0-46552

BLUEBERRY JUICE ENCAPSULATED ON MALTODEXTRIN: THE IMPACT ON THE PROPERTIES OF WHITE CHOCOLATE

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Abstract: The lower content of phenolic compounds in white chocolate makes this confectionery product unhealthier and, thus, adequate for enrichment compared to other types of chocolates like dark or milk. Less phenolics in white chocolate is due to absence of dark cocoa solids, abundant in these compounds. This study aimed to develop a new product with a higher nutritional value than regular white chocolate by enriching white chocolate with blueberry juice as a natural source of polyphenols. Since phenolic compounds are highly sensitive to heat, light, oxygen, and pH, encapsulated form of blueberry juice was used to increase their stability in the product. Blueberry juice was encapsulated on maltodextrin (B/M) and added to white chocolate at 80 g/kg and 100 g/kg concentrations. Enrichment significantly ($p<0.05$) increased the content of total dietary fibres and carbohydrates in the white chocolate and decreased proteins and total fats. The addition of the encapsulates significantly ($p<0.05$) impacted all particle size parameters, especially volume-weighted mean D[3,4] which increased (14.38 μm for B/M80 and 16.00 μm for B/M100) compared to the control (13.06 μm). Rheological properties are of great importance for products like chocolate and the incorporation of the encapsulates significantly ($p<0.05$) increased the values of rheology parameters like Casson viscosity (1.04 Pa·s for B/M80 and 1.21 Pa·s for B/M100). Likewise, enrichment significantly ($p<0.05$) decreased the hardness of the sample (B/M80) compared to the control. Furthermore, the content of total polyphenols and antioxidant capacity significantly ($p<0.05$) increased following the added concentration of the encapsulates. The highest content of total polyphenols and antioxidant capacity was observed in the chocolate sample enriched with 100 g/kg of encapsulate. The colour of the enriched samples significantly ($p<0.05$) differed from the control sample. The impact of the added encapsulate on sensory properties was not significant ($p>0.05$) except for the sweetness. The enriched chocolate samples were less sweet. The results of this study indicate the potential of maltodextrin as a carrier of sensitive bioactive compounds for the enrichment of products like white chocolate.

Key words: *rheological behaviour, chemical composition, sensory analysis, texture, colour, antioxidant capacity*

INTRODUCTION

Chocolate is a delicious confectionery product loved by many people around the world. This product is rich in carbohydrates, fat, and proteins and also contains appreciable amounts

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of polyphenols and other bioactive components such as minerals like magnesium and iron (Cinquanta et al., 2016; Arunkumar & Jegadeeswari, 2019). It consists of several solid ingredients like cocoa, sugar and/or milk powder that are dispersed in a continuous phase of cacao butter and/or milk fat, depending on the type of chocolate (Fernandez, Müller & Sandoval, 2013). There are three types of chocolates: dark, milk and white chocolate. According to the directives 2000/36/EC of the European Parliament and the Council relating to cocoa and chocolate products intended for human consumption, ''dark chocolate'' is a product produced from cocoa products and sugar, which contains a minimum of 35% of total dry solids. ''Milk chocolate'' is a product formulated from cocoa solids, sugar and milk or milk products. It must contain a minimum of 25% total dry cocoa solids; a minimum of 14% dry milk solids, a minimum of 3,5% milk fat and at least 25% total fat (cocoa butter and milk fat). On the other hand, ''white chocolate'' is defined as a product obtained from cocoa butter, milk or milk products and sugar that contains at least 20% cocoa butter and 14% dry milk solids from which is at least 3,5% milk fat (European Council, 2013). As aforementioned, white chocolates have a lower biological functionality compared to other chocolate types due to the absence of dark cocoa solids that are rich in phenolic compounds (Toker et al., 2018).

Polyphenols are a group of compounds found in many plant-based foods like fruits, vegetables and cereals. They are known for their biologically active properties as antioxidants, which have been associated with a variety of health benefits e.g. their consumption reduces the risk of cardiovascular disease, osteoporosis, diabetes mellitus and cancer (Scalbert, Johnson & Saltmarsh, 2005; D'Archivio et al., 2007; Dragovic-Uzelac, Levaj, Mrkic, Bursac & Boras, 2007; Abbas et al., 2017).

Blueberry is considered a healthy fruit because of its high content of polyphenols, particularly anthocyanins (Wu et al., 2023). In fruits, anthocyanins are commonly present in the epidermal and hypodermal layers of the skin, but they can be found in every part of the fruit as in many berries (Wallace & Giusti, 2013). These compounds are responsible for colours such as pink, red, violet to dark blue present in fruits, vegetables and flowers (Andersen & Jordheim, 2013). They are sensitive to environmental factors including pH value, temperature, presence of light, oxygen and ascorbic acid. Because of that, the encapsulation technique has been used to preserve the stability of bioactive compounds by entrapping them in other substances by forming a protective wall. This process produces particles that are from a few nanometers to a few micrometres in size (Khazaei, Jafari, Ghorbani & Kakhki, 2014; Khoo, Azlan, Tang & Lim, 2017; Qi et al., 2022). Araujo-Díaz et al. (2017) encapsulated blueberry juice on maltodextrin as a carrier using a spray-drying process because of maltodextrin properties such as low hygroscopicity. Maltodextrin is produced through acid and/or enzymatic hydrolysis of starch and it consists of 2–3 % glucose and 5–7 % maltose. Maltodextrin can be found in the form of tasteless white hygroscopic spray dry powder (Parikh, Agarwal & Raut, 2014; Xiao, Xia, Zhao, Niu & Zhao, 2022) which can be successfully used as a carrier to protect bioactive compounds such as anthocyanins. In addition, several studies have examined the effectiveness of maltodextrin as a carrier in encapsulating various products e.g. raspberry juice (Anekella & Orsat, 2013), lactobacilli and raspberry juice (Anekella & Orsat, 2014), and citrus aqueous extracts (Can Karaca, Low & Nickerson, 2013). These studies suggest that maltodextrin can be useful for preserving and providing a longer shelf life for these products.

In the past years, there has been a rise in purchaser interest regarding the consumption of food that has a high nutritional value or enriched traditional food also known as functional foods. Therefore, the demand for the functional food has been spread all over the market, including the confectionery products.

As mentioned before, white chocolate does not contain dark cocoa solid particles, which are carriers of high amounts of phenolic compounds, making this product suitable for the enrichment and production of white chocolate with higher nutritional value. At this moment, there are some functional chocolates on the market that are enriched with cinnamon particles (Muhammad, Saputro, Rottiers, Van de Walle & Dewettinck, 2018), whey protein (Jovanović et al., 2022), probiotics (Hossain, Ranadheera, Fang & Ajlouni, 2020), green tea

extract (Lončarević et al., 2019), etc. In our previous research (Lončarević et al., 2018; Lončarević et al., 2019), green tea extract and blackberry juice were encapsulated using maltodextrin as a carrier and added to white chocolate. With this addition, the results of our research showed an increase in the content of preserved polyphenols. Furthermore, the enriched samples embraced the colour of the encapsulates, and therefore enriched samples had an attractive colour on the surface and unusual flavour coming from the encapsulates. Also, Dean et al. (2016) investigated the impact of the addition of encapsulated peanut skin extracts in milk chocolate on phenolic content and antioxidant properties. Extracts were encapsulated on maltodextrin as a carrier because of the bitterness of the extracts. The results have revealed that the addition has increased the phenolic content. Enriched chocolates had a higher content of phenolic compounds and were rated as acceptable in comparison to the control sample. The use of the encapsulation technique has protected bioactive compounds through the process of the production of chocolates, which is performed at high temperatures. Regarding that, the encapsulation of the blueberry juice on maltodextrin and the addition of those extracts in white chocolate, which is low in phenolic compounds can have the potential as a functional food.

In opposition to our previous study (Jovanović et al., 2022), which regarded to encapsulation of blueberry juice on whey as a carrier and its possible use as a functional ingredient in chocolates, this study deals with the encapsulation of blueberry juice on maltodextrin as a carrier and its impact on physical, chemical and sensory properties of white chocolate including its potential use as a functional ingredient.

MATERIALS AND METHODS

Chocolate ingredients

Laboratory experiments included the use of white chocolate with 34.8% cocoa butter, which was provided by Eugen Chocolate Ltd., Gložan, Serbia and blueberry juice encapsulated in tasteless maltodextrin (labelled as B/M) using the spray-drying technique, purchased from Frutarom Etol Ltd., Škofja Vas, Slovenia.

Tempering chocolate

A modified Brabender farinograph was used for the tempering of the chocolates. The kneader was connected to two thermostats (Lauda Ecoline Staredtition E 215 T, Germany) using two-way taps. This allowed immediate change in the temperature of the kneader and fast temperature changes within 30 s in the treated chocolate mass (Pajin et al., 2012). First, the 120 g white chocolate (control sample-C) was placed in a farinograph kneader at a temperature of 42˚C for 30 minutes to melt the chocolate without any danger of protein denaturation. After that, enriched chocolates were prepared the same as the control, only after melting, the encapsulates were added to the mixture at concentrations of 80 g/kg (B/M80) and 100 g/kg (B/M100). Then, the samples were gently stirred at constant temperature for 60 minutes. Afterwards, the samples were stirred for 60 minutes at 29.5 ˚C. The stirred chocolate mass was then poured into plastic moulds that weighed 50 g and cooled in the refrigerator for 90 min at the temperature of 5˚C. The chocolate samples enriched with 80 and 100 g/kg of blueberry juice encapsulated in maltodextrin (marked as B/M80 and B/M100, respectively) were tempered under the same conditions as previously described.

Chemical composition of chocolates

The chemical composition of the control and enriched chocolates was described by the determination of the content of proteins, total fat, moisture, ash and total dietary fiber using standard methods (AOAC, 2000). The formula used to estimate carbohydrate content was:

Carbohydrate content (%) = 100% - (% moisture + % protein +% total fat + % ash + % total fiber).

Particle size distribution in encapsulates and chocolates

Particle size distribution analysis has been conducted using a Mastersizer 2000 laser diffraction particle size analyzer (Malvern Instruments, Malvern, England). This device was used for analyzing particle size in encapsulate (B/M), control sample and enriched chocolates. The Hydro 2000 μP unit was used for the dispersion of chocolate in the sunflower oil, while the Scirocco unit was used for dispersing blueberry juice encapsulates in

the air. The results were processed via Mastersizer 2000 software and presented as the volume-based PSD and described by PSD parameters: volume mean diameter D[4,3] and parameters d(0,1), d(0,5), d(0,9) that represent the particle sizes where 10, 50 or 90% of the total particle volume include particles that are smaller than that size.

Rheological properties of chocolate mass

Rheological properties of chocolate mass were determined at the temperature of 40 ± 1 ˚C using a Rheo Stress 600 (Haake, Karlsruhe, Germany), equipped with coaxial cylinders Z20DIN (IOCCC, 2000). The shear rate was increased from 0 s^{-1} to 60 s^{-1} in three minutes and kept constant for one minute at 60 s^{-1}. After that, the shear rate was reduced from 60 s^{-1} to 0 s^{-1} in three minutes.

Chocolate hardness

The texture analyzer TA.HDplus (Stable Micro System, Godalming, England) was used to define the chocolate hardness. The method used in this analysis was compression with the 3-Point Bending Rig HDP/3PB (Baycar, Konar, Poyrazoglu, Goktas & Sagdic, 2021).

Colour of encapsulates and chocolate samples

MINOLTA Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan) was used to measure the colour on the surface of the encapsulates and chocolate samples. The colour was measured on five spots and the average value was used. For this measurement D 65 lightning, a 2˚ standard observer angled and an 8-mm aperture in the measuring head were used. MINOLTA Chroma Meter was calibrated with a Minolta calibration plate (No. 11333090; Y=92,9, x=0.3159; y=0.3322). The results were given using the obtained values of CIELab colour coordinates: L*-lightness, a*-redness to greenness and b*- yellowness to blueness (CIE, 1976).

Total polyphenol content (TPC) and antioxidant capacity (AC) assay

Extraction of the chocolate samples was conducted using methods by Belščak-Cvitanović et al. (2012) and Belščak-Cvitanović et al. (2015). First, it was necessary to defat the samples. The defatting of the 2 g chocolate sample was completed by adding 10 ml of n-hexane, three times and then left to air dry for 24 hours. Afterwards, the extraction was done with 2x10 mL of 70% methanol in an ultrasound bath in two consecutive extractions. The sample was centrifugated for 10 min at 3000 rpm after every extraction. Supertnatans, previously filtered, were then used for polyphenols and antioxidant activity measurements.

For the determination of polyphenol content in white chocolate samples, the Folin-Ciocalteau method was used and adjusted to a microtiter plate (González-Molina, Moreno & Garcia-Viguera, 2008). Before applying it to microtiter plate wells, the reaction mixture was prepared from 15 μL of extracts, 170 μL of distilled water, 12 μL of Folin-Ciocalteau's reagent (2M) and 30 μL of 20% Na_2CO_3. After applying, microtiter plate wells were shaken and left in the dark for 1 hour. Water was used for the blank. The absorbances were read at 750 nm, and the results were demonstrated as g GAE/kg, because of the use of gallic acid for calibration.

Furthermore, the determination of the antioxidant capacity in the chocolate samples was conducted with the adjusted microtiter plate, and DDPH assay (Girones-Vilaplana, Mena, Moreno & Garcia-Viguera, 2013). Chocolate extract (10 μL) was mixed with $DPPH^{\cdot}$ solution (250 μL) in methanol (0.89 mmol/L) in the mi-croplate well and left at room temperature in the dark for 50 min. After that, the absorbances were read at 515 nm. Methanol was used as a blank. The antioxidant capacity of the samples was calculated using the next formula:

$AC\ (\%) = 100 - (As/Ao)$.

where: As – absorbance of the reaction mixture with the sample;

Ao – absorbance of the initial $DPPH^{\cdot}$ solution.

For the calibration, Trolox was used.

Sensory evaluation

Sensory analysis was conducted in the sensory laboratory with partitioned booths, by a panel of 8 trained panelists, 24 hours after the preparation of the samples. White plastic plates marked with three-digit codes were used for sample serving. Trained panellists established a 7-point scale where 1 means the least intensity and 7 means the most intensity. Panellists evaluated the following sensory attributes: colour intensity (light to dark); glow

(mat to shiny); surface appearance (unacceptable to distinctive); hardness (soft to hard); sweetness (lightly sweet to very sweet); smoothness (very even to very granular); melting (slowly to quickly); blueberry odour (light to distinct); blueberry taste (light blueberry notes to distinct blueberry notes).

Statistical analysis

All experiments were rerun three times except for the sensory analysis which was conducted eight times. The gathered results were processed using a one-factor ANOVA and the means were compared by Duncan's test at a significance level of 0.05 using the Statistica 13.0 software (TIBCO, Palo Alto, CA).

RESULTS AND DISCUSSION

Chemical composition of control and enriched chocolate samples

Table 1 presents the proximate composition of the chocolate samples. Enrichment of white chocolates with blueberry juice encapsulated in maltodextrin significantly ($p<0.05$) affected the content of proteins and fat in the samples.

The greater the addition of the blueberry juice encapsulates (80 g/kg and 100 g/kg), the lower the content of proteins in the samples (3.61 and 3.54 g/100 g, respectively). Furthermore, total fat decreased in the enriched samples, with the lowest amount noticed in the sample B/M100 (34.98 g/100 g). This result was significantly ($p<0.05$) different from the control sample, which had the highest amount of total fats (37.58 g/100g). On the other hand, the content of the total dietary fibres and carbohydrates significantly ($p<0.05$) increased with the addition of the blueberry encapsulates in white chocolate. Additionally, the energy values of chocolate samples decreased with increasing concentration of encapsulates. These findings indicate that the enrichment with blueberry juice encapsulates significantly positively influenced the nutritional profile of white chocolate.

Table 1.
Chemical composition of control (C), chocolate samples with 80 g/kg (B/M80) and 100 g/kg (B/M100) of blueberry encapsulates

Sample	Proteins	Total fats	Total dietary fiber	Carbohydrates	Energy
	(g/100 g as is basis)				(kJ/100 g as is basis)
C	3.94 ± 0.04^{a}	37.58 ± 0.22^{c}	1.02 ± 0.05^{a}	56.67 ± 0.29^{a}	2428.99
B/M80	3.61 ± 0.11^{b}	35.98 ± 0.08^{b}	1.46 ± 0.11^{b}	58.15 ± 0.18^{b}	2392.86
B/M100	3.54 ± 0.06^{b}	34.98 ± 0.09^{a}	1.55 ± 0.21^{b}	59.15 ± 0.06^{c}	2372.39

[a-c] Values followed by the same letter within the same column are not significantly different ($p>0.05$) according to Duncan's test

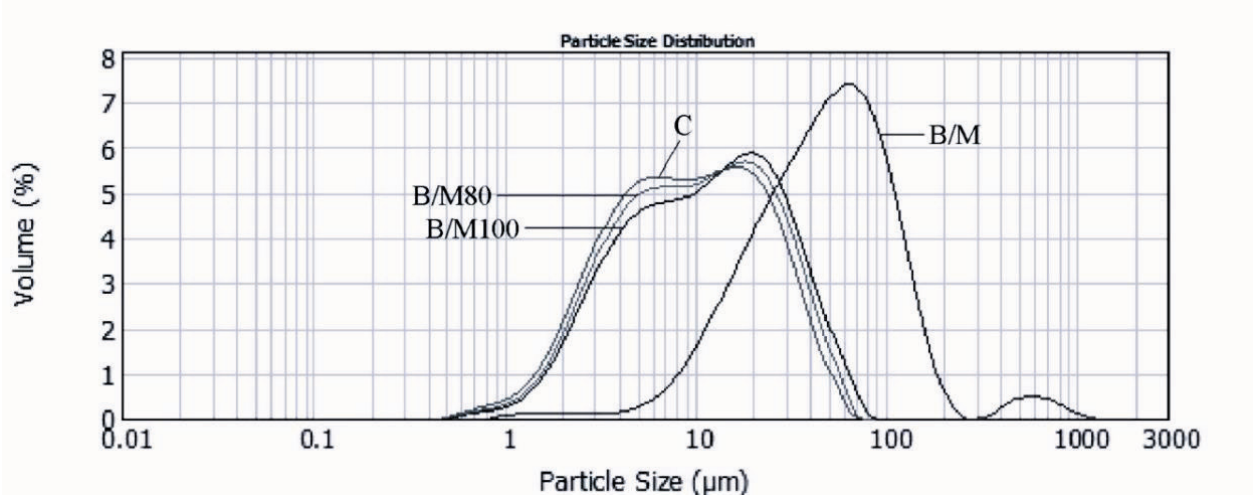


Figure 1. Particle size distributions of the white chocolate (C), blueberry juice encapsulated in maltodextrin (B/M) and chocolates with 80 and 100 g/kg encapsulates (B/M80 and B/M100) respectively

Table 2.
Particle size parameters of blueberry juice encapsulates (B/M), control (C) and enriched chocolate samples (B/M80 and B/M100)

Samples	Particle size parameters (μm)			
	d(0.1)	d(0.5)	d(0.9)	D[4,3]
Encapsulate				
B/M	14.53 ± 0.09	48.73 ± 0.21	123.69 ± 0.17	71.65 ± 0.26
Chocolate samples				
C	2.59 ± 0.04[a]	9.18 ± 0.06[a]	29.35 ± 0.20[a]	13.06 ± 0.02[a]
B/M80	2.79 ± 0.03[b]	10.24 ± 0.10[b]	32.28 ± 0.34[b]	14.38 ± 0.16[b]
B/M100	2.96 ± 0.06[c]	11.53 ± 0.26[c]	35.77 ± 0.86[c]	16.00 ± 0.37[c]

[a-c] Values represent the average of triplicates ± SD. Means with different letters in superscript in columns are significantly different between chocolate samples ($p<0.05$)

Influence of the addition of blueberry juice encapsulates on particle size distribution in chocolate

The distribution of particle size in the control and enriched chocolate samples is presented in Fig. 1. With the addition of the blueberry juice encapsulated in maltodextrin (B/M), the obtained results showed that all particle size parameters in the samples B/M80 and B/M100 significantly ($p<0.05$) increased in comparison to the control sample. The values for the parameter D [4,3] for B/M80 and B/M100 were 14.38 and 16.00 μm respectively, and for the control sample 13.06 μm. The observed change in the distribution of the particle size in the enriched chocolates was expected and could be related to the greater particle size in B/M (D[4,3] was 71.65 μm). Comparing the obtained results with the results from our previous studies (Lončarević et al., 2019; Jovanović et al., 2022), it can be concluded that the size of encapsulates exerted a minor change in the particle size distribution.

Particle distribution and particle size play a significant role in rheological behaviour. Particle size, besides the flow properties, is a very important factor in determining the viscosity and texture of the produced chocolates (Minifie, 1970). The smaller particles in samples are more important regarding the flow properties and the largest have an impact on the mouthfeel during consummation (Shah, Jones & Vasiljevic, 2010). The particle size parameters are displayed in Table 2. As can be seen in Table 2, the addition of the encapsulates in chocolate samples significantly ($p<0.05$) affected all parameters of the particle size distribution. The values of the parameters in the enriched samples were higher compared to the control. The parameter d (0.5) in samples B/M80 and B/M100 was 10.24 μm and 11.53 μm respectively, indicating that the size of 50% of particles increased 1.11-fold for B/M80 and 1.26-fold for B/M80 compared to the control sample. Likewise, the d (0.9) values showed that the size of 90% of the particles for B/M80 and B/M100 increased (32.28 μm and 35.77 μm, respectively) in comparison to the control (29.35 μm). According to Rakin et al. (2023), particle size above 30 μm in chocolate leaves a gritty feeling unacceptable to consumers. Even though the particle size in enriched chocolates increased, the chocolate samples did not reach particle size values above 30 μm. According to that, B/M can be used in the production of chocolates as a supplementary ingredient.

Influence of the addition of encapsulates on rheological and textural properties of chocolate

The influence of the added encapsulates on the rheological properties of chocolate is presented in Fig. 2. The results of the analysis showed the thixotropic flow of the samples. The Casson model was used for fitting the flow curves and obtaining the next parameters: Casson yield stress (Pa) and Casson viscosity (Pa·s). The value of these parameters was significantly ($p<0.05$) increased in enhanced chocolates and sample B/M100 showed the significantly highest value of Casson viscosity (1.21 Pa·s) in comparison to other samples: 1.04 Pa·s for B/M80 and 0.63 Pa·s for the control sample (results not shown). Looking back at the results in Table 1, this phenomenon can be explained by the reduction of fat

content in these samples. Do et al. (2007) reported in their study that the reduction of the fat content (to a value of 22%) of the chocolate samples resulted in higher viscosity. Our previous research (Petrović et al., 2022), in which blueberry juice was encapsulated on whey protein and added to white chocolate, also showed a significant ($p<0.05$) increase in Casson yield stress and Casson viscosity values.

The impact of the addition of the B/M encapsulates on the hardness of the chocolate samples at 25˚C is shown in Fig. 3. The addition of the blueberry encapsulates lowered the hardness of the enriched samples. The hardness of the samples B/M80 (3.46 kg) and B/M100 (3.35 kg) significantly ($p<0.05$) differred from the control sample (4.04 kg).

This might be partially attributable to the reduced fat content i.e. the increase in the concentration of the nonfat solid particles in the enriched chocolate samples. Do, Hargraves, Wolf, Hort and Mitchell (2007) reported that the reduction of the fat content in chocolate significantly ($p<0.05$) decresed the hardness of the samples. On the other hand, Belščak-Cvitanović et al. (2012) examined the impact of raspberry leaf extracts on the hardness of milk, dark and semi-sweet chocolate.

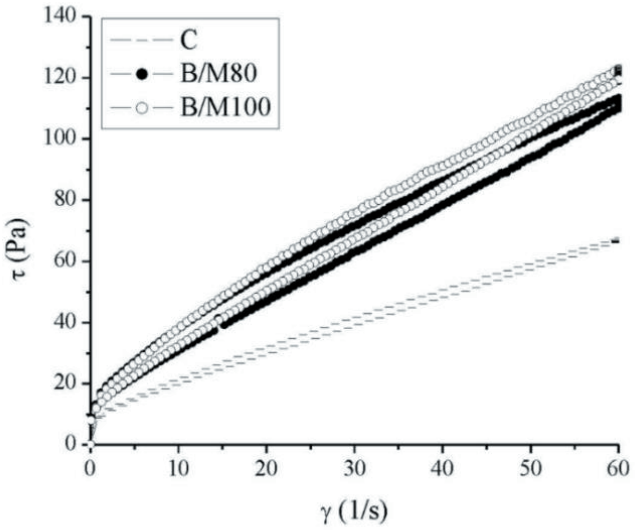
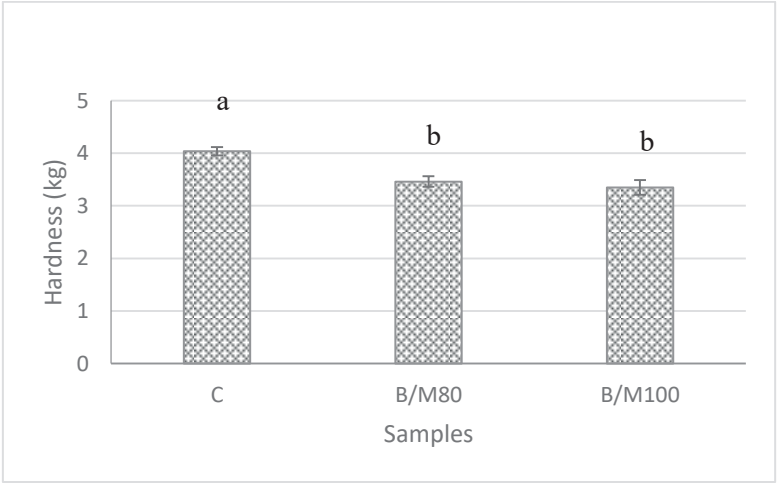


Figure 2. Flow curves of white chocolate (C) and chocolates enriched with 80 g/kg (B/M80) and 100 g/kg (B/M100) of B/M



[a,b] *Values represent the average of triplicates ± SD. Means with different letters on bars are significantly different between the chocolate samples ($p<0.05$)*

Figure 3. The hardness of white chocolate (C) and chocolates enriched with 80 g/kg (B/M80) and 100 g/kg (B/M100) of B/M

Their study showed that adding raspberry leaf extracts at 1% and 3% supplementation levels significantly ($p<0.05$) impacted the texture of the chocolate samples by decreasing their hardness. Only the dark chocolate sample with 3% of the raspberry leaf extract did not significantly ($p<0.05$) differ from the control dark chocolate sample.

The effects of enrichment of white chocolate on polyphenol content and antioxidant activity

As mentioned before, blueberries are considered healthy because of their high content of polyphenolic compounds (Wu et al., 2023). According to the results shown in Table 3, the content of total polyphenols increased with the addition of the encapsulates. The content of total polyphenols elevated with the increase of the added amount of the encapsulate. The same trend was observed for the antioxidant capacity of the samples. Similar phenomena occurred in our previous study about blueberry juice encapsulated in whey protein as a carrier (Jovanović et al., 2022). Comparing the results from the two studies, it can be seen that the phenolics content and antioxidant capacity were doubled in the chocolate samples enriched with encapsulates containing maltodextrin as a carrier. This can be explained by the greater ability of maltodextrin to bind these compounds and protect them by encapsulation. Maltodextrin appears to have a greater binding ability since it conserved higher amounts of phenolic compounds. Additionally, this is in in agreement with the results of our earlier study (Tumbas Šaponjac et al., 2016) on encapsulation of sour cherry pomace using whey and soy protein as carriers and their incorporation into cookies. The loss of antioxidant activity in the samples with whey-based encapsulate after 4 months was higher than in the samples with soy protein-based encapsulate. Likewise, Bakowska-Barczak and Kolodziejczyk (2011) conducted research aimed at encapsulating black currant pomace, rich in anthocyanins, with maltodextrin as a carrier for the extract.

The authors reported good antioxidant activity, with a vague change after storage at 25 °C. Aroyeun and Jayeola (2016) examined the impact of green tea extract in form of the powder on the content of the polyphenols in milk chocolate. The results of their investigation showed a significant ($p<0.05$) increase in the content of examined bioactive compounds in comparison to the control, thus improving the nutritional and health value of the chocolate. This increase followed the amount of the added concentration of the green tea powder, rich in polyphenolic compounds. The maximum increase was noticed in the sample with the highest enrichment of the green tea powder (50%) and it was 28.4% higher than the control sample (162.39 mg/100 g gallic acid).

Table 3.
The content of total polyphenol compounds and antioxidant capacity of white chocolate (C) and chocolates enriched with 80 g/kg (B/M80) and 100 g/kg (B/M100) of B/M encapsulate

Sample	Total polyphenols (g GAE kg^{-1})	Antioxidant capacity (mmol TE kg^{-1})
C	0.30 ± 0.02^{a}	1.22 ± 0.06^{a}
B/M80	2.15 ± 0.01^{b}	11.67 ± 0.38^{b}
B/M100	2.41 ± 0.016^{c}	14.49 ± 0.42^{c}

Values represent mean values .$^{a-c}$ Values followed by the same letter within the same column are not significantly different ($p>0.05$) according to Duncan's test

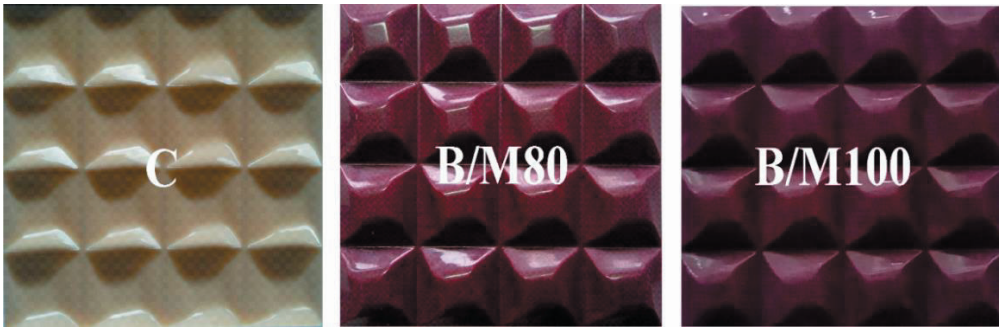


Figure 4. Photographs of white chocolate (C) and chocolates enriched with 80 g/kg (B/M80) and 100 g/kg (B/M100) of B/M

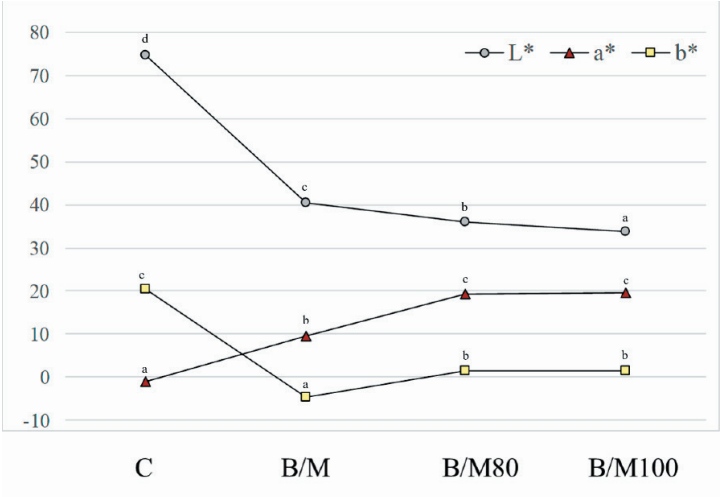


Figure 5. Surface colour in white chocolate (C) and chocolates enriched with 80 g/kg (B/M80) and 100 g/kg (B/M100) of B/M

Effects of the addition of encapsulates on the color of the chocolates

Natural additives, such as natural colourants and bioactive compounds, have become increasingly popular in the food industry. This is because they offer a range of benefits, including improved food safety, enhanced nutritional value, and better sensory properties (Zin, Márki, & Bánvölgyi, 2020). Adding blueberry juice encapsulates to the white chocolate affected the colour of the samples captured in the photograph shown in Fig. 4. The enrichment of chocolates induced a change in the colour of the samples. The colour on the surface of the enriched chocolates has taken the burgundy colour, which intensity increased as the concentration of encapsulates incresed in the chocolate formulation.

Colour atributes L* (lightness), a* (red tone), and b* (yellow tone) were measured on the surface of the chocolate samples (Fig. 5). Regarding lightness and yellow tone, the values for the control sample were significantly ($p<0.05$) higher than other samples. The surface of the control sample appeared to be quite bright and had a noticeable yellow tone. Adding B/M, with the lowest value for L*, resulted in statistically different ($p<0.05$) colour properties for the enriched chocolates compared with the control chocolate. The enriched samples B/M80 and B/M100 did not significantly differ ($p<0.05$) from each other. On the other hand, the control sample had the lowest value for the parameter a*, which is statistically different ($p<0.05$) compared to the enriched samples. A negative value of this parameter points out the presence of the green tones.

Sensory evaluation of the chocolate samples

Figure 6 displays scores received by the panellist during sensory evaluation of the chocolate samples. The enriched samples acquired a reddish colour, which intensity increased ($p<0.05$) with higher concentration of added encapsulate. Chocolate enrichment with the studied encapsulate affected chocolate appearance dominated by a prominent colour change, but the samples were free from bubbles or any visible damage on the surface.

The increase in the amount of the added encapsulate elevated the chocolate hardness, but the hardening did not reach statistical significance ($p>0.05$) compared to the control. Regarding smoothness, the panellists observed that even though the particle size in the enriched chocolate increased, it did not leave a sandy mouthfeel while consumed. However, the panellists noticed the intensification in the blueberry scent and flavour with the increase in the enrichment, though it was not significant ($p<0.05$). On the other hand, the sweetness in the enriched chocolates significantly ($p<0.05$) decreased. Sweetness lowering was also observed in our previous study (Jovanović et al., 2022), in which the carrier for the blueberry encapsulates was whey protein. Decreased sweetness in the enriched chocolates was considered as an improvement in the taste compared to the control sample.

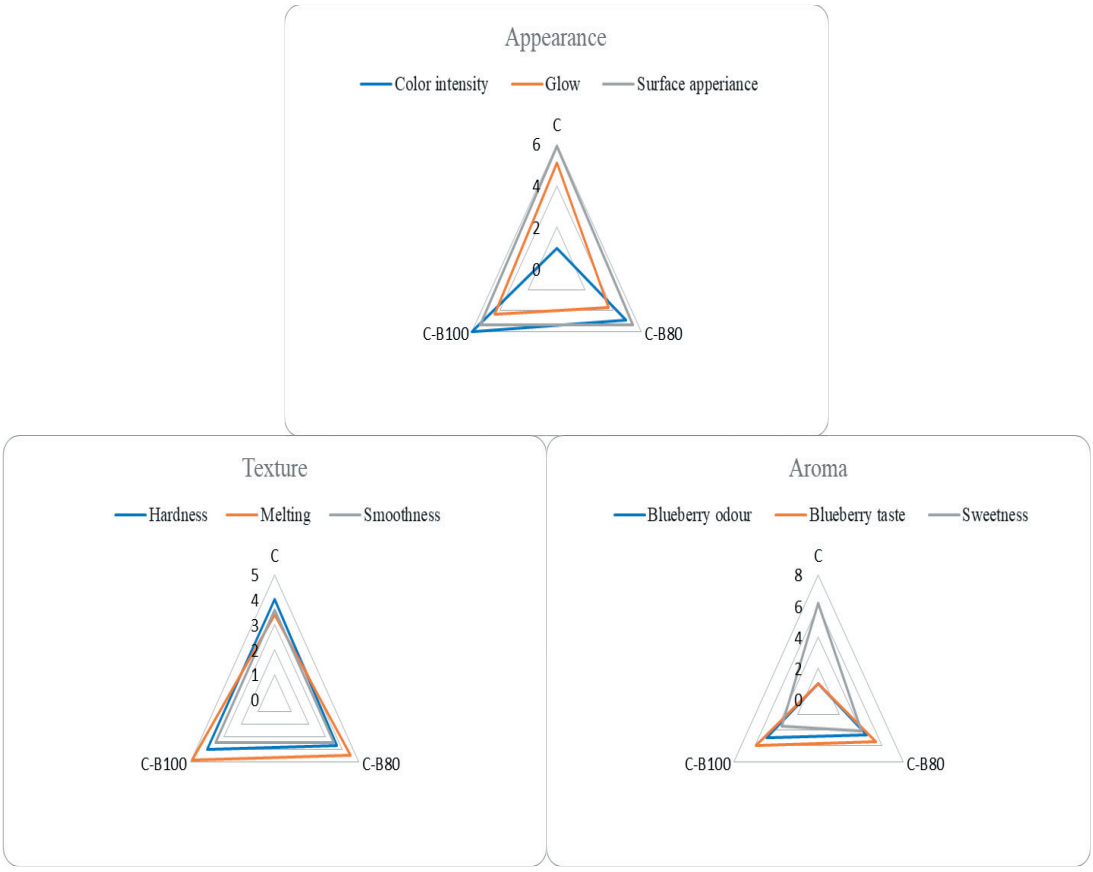


Figure 6. Sensory evaluation of the control (C) and the enriched chocolate samples with 80g/kg (B/M80) and 100 g/kg (B/M100)

CONCLUSIONS

This study dealt with white chocolate enrichment to obtain a product with higher nutritional value.The addition of 80 g/kg and 100 g/kg of blueberry juice encapsulates significantly ($p<0.05$) contributed to the decrease in the content of proteins and total fats, but at the same time, the content of total dietary fibres and carbohydrates significantly ($p<0.05$) increased compared to the control sample. White chocolate enrichment went alongside with a significant ($p<0.05$) increase in the volume-weight mean D [4,3] in both samples following the added amount. Relating to rheological properties, the enrichment significantly ($p<0.05$) affected parameters like Casson yield stress and Casson viscosity by increasing them in comparison to the control. Concerning the content of total polyphenols and antioxidant activity, the inclusion of the blueberry encapsulates in the white chocolate significantly ($p<0.05$) impacted these parameters. Polyphenolic compounds and antioxidant activity were elevated by supplementation following the concentration of added encapsulates. The colour of the enhanced chocolates significantly differred ($p<0.05$) in contrast to the control. As for the sensory properties, improved chocolates were accepted by consumers, they did not significantly ($p>0.05$) differ, aside from sweetness. Enriched chocolates had lower sweetness which was graded as a positive property. In our previous study, where we encapsulated blueberry juice in whey as a carrier, the sensory evaluation showed that adding blueberry encapsulates in white chocolates reduced the sweetness of the chocolates. In summary of the obtained findings, enrichment of the chocolates lowered the energy values of the chocolate samples and improved their nutritional profile in terms of higher content of total dietary fibres and polyphenolic compounds content and higher antioxidant capacity.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Science, Technological Development and Innovations, Serbia, program (451-03-47/2023-01/200134).

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SOK OD BOROVNICE INKAPSULIRAN NA MALTODEKSTRINU: UTICAJ NA OSOBINE BELE ČOKOLADE

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Sažetak: Niži sadržaj fenolnih jedinjenja u beloj čokoladi čini ovaj konditorski proizvod manje zdravim i time adekvatnim za obogaćivanje u odnosu na druge vrste čokolade, crnu ili mlečnu. To se dešava zbog odsustva tamnih čvrstih delova kakaoa u beloj čokoladi, bogatih ovim jedinjenjima. Naše istraživanje je imalo za cilj da razvije novi proizvod sa većom nutritivnom vrednošću od obične bele čokolade. Poznato je da su fenolna jedinjenja veoma osetljiva na toplotu, svetlost, kiseonik i pH, i zbog toga je bilo potrebno njihovo inkapsuliranje na maltodekstrinu. Sok od borovnice, kao izvor polifenola, inkapsuliran je na maltodekstrinu (B/M) i dodat u belu čokoladu u količini od 80 g/kg, odnosno 100 g/kg. Obogaćivanje bele čokolade značajno je ($p<0.05$) povećalo sadržaj ukupnih dijetetskih vlakana i ugljenih hidrata uz smanjenje sadržaja proteina i ukupne masti. Dodavanje inkapsulata značajno je ($p<0.05$) uticalo na sve parametre veličine čestica, posebno na vrednost zapreminsko srednjeg prečnika D[3,4] koja je povećana (14.38 mm za B/M80 i 16.00 mm za B/M100) u poređenju sa kontrolom (13.06 mm). Reološka svojstva su od velikog značaja za proizvode kao što je čokolada, a inkorporacija inkapsulata značajno ($p<0.05$) povećava vrednosti reoloških parametara kao što je Cassonov viskozitet (1.04 Pa·s za B/M80 i 1.21 Pa·s za B/M100). Isto tako, obogaćivanje je značajno ($p<0.05$) smanjilo tvrdoću uzorka (B/M80) u poređenju sa kontrolom. Štaviše, sadržaj ukupnih polifenola i antioksidativni kapacitet značajno su porasli ($p<0.05$) nakon dodavanja određene koncentracije inkapsulata. Najveći sadržaj ukupnih polifenola i antioksidativni kapacitet uočen je u uzorku čokolade sa 100 g/kg inkapsulata. Boja obogaćenih uzoraka značajno se ($p<0.05$) razlikovala od kontrolnog uzorka. Uticaj dodatog inkapsulata na senzorna svojstva nije bio značajan ($p>0.05$) osim slatkoće. Uzorci čokolade koji su obogaćeni bili su manje slatki. Rezultati ove studije ukazuju na potencijal maltodekstrina kao nosioca osetljivih bioaktivnih jedinjenja za obogaćivanje proizvoda poput bele čokolade.
Ključne reči: *reološka svojstva, hemijski sastav, senzorna analiza, tekstura, boja, antioksidacioni kapacitet*

Received: *15 September 2023/* ***Received in revised form:*** *05 December 2023/* ***Accepted:*** *06 December2023*

Available online: *December 2023*