EFFECT OF COCONUT AND PALM OIL ON CHOCOLATE PRODUCED IN BALL MILL

UTJECAJ KOKOSOVE I PALMINE MASTI NA ČOKOLADE PROIZVEDENE U KUGLIČNOM MLINU

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Abstract: *Chocolate is one of the most consumed confectionery products in the world. Cocoa butter is, along to cocoa mass and sugar, the main and the most expensive ingredient in chocolate. Many producers are replacing part of cocoa butter with other fats, which have lesser price. This research gives insight in effect of coconut and palm oil addition on chocolate produced in ball mill. The aim of this study was to determine rheology properties, colour and hardness of chocolates containing cocoa butter equivalents.*

Key words: *chocolate, ball mill, coconut oil, palm oil*

Sažetak: *Čokolada je jedan od najpopularnijih konditorskih proizvoda na svijetu. Kakao maslac je, uz kakaovu masu i šećer, glavni i najskuplji sastojak čokolade. Mnogi proizvođači dio kakao maslaca zamjenjuju drugim mastima koje imaju manju cijenu. Ovo istraživanje daje uvid u učinak dodavanja kokosove i palmine masti na čokoladu proizvedenu u kugličnom mlinu. Cilj ovog rada bio je utvrditi reološka svojstva, boju i tvrdoću čokolada koje sadrže kakao maslac ekvivalente.*

***Ključne riječi**: čokolada, kuglični mlin, kokosova mast, palmina mast*

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1. Introduction

Cocoa butter is one of the main and most expensive ingredients in chocolate. Fatty acid composition is relatively simple and mainly contains palmitic, stearic, oleic and linoleic acid. There are no naturally occurring fats that have the same physical properties as cocoa butter but because of its price, it is often replaced by cocoa butter alternatives, which are subdivided into cocoa butter equivalents (CBEs), replacers (CBRs) and substitutes (CBSs) [1, 2].

Palm and coconut oil are fats rich in lauric acid [3]. They have similar physical properties as cocoa butter but differ in form of triglycerides. Because of that chemical dissimilarity, legislation limited its use up to 5% in chocolate [4].

Coconut oil has very low iodine value and high oxidative stability. Because of high content of lauric acid it melts at 24-29 °C [4]. Palm oil is rich in carotenes which have high bioavailability and it is often used in chocolate production because it forms stable crystal network [5, 6].

Good quality chocolate has a good snap, it is solid at room temperature and melts easily at human body temperature [7]. Ingredients used in the production are responsible for this characteristics, mainly cocoa butter. The aim of this research was to study partial replacement of cocoa butter with coconut and palm oil and its influence on chocolate rheology, hardness and colour (fat bloom).

2. Materials and methods

2.1 Chocolate production

Chocolates were produced in ball mill according to recipes shown in Table 1. Temperature was controlled by a water bath (55 °C) and speed of mixing was 60 rpm. On 500 g of mixture, 3 kg of balls for milk and 2.5 kg for dark chocolates were used. All ingredients were added at the beginning except for cocoa butter (added after 2 h) and vanillin (added after 2.5 h). Total mixing time was 3 h. Tempering was carried out by hand and temper index (Sollich Tempermeter E3) was in the range 4 – 7. After molding, the chocolates were cooled for half an hour at 8 °C.

Materials used for production were: cocoa mass (DGF, France), cocoa butter (DGF, France), sugar (Gourmandise, Croatia), powdered milk (Dukat, Croatia), coconut oil (Priroda i društvo, Croatia), palm oil (Rapunzel, Germany), liquid lecithin (Azelis Croatia, Croatia) and vanillin (Acros organics, Belgium).

Sample	Cocoa mass (%)	Cocoa butter (%)	Sugar (%)	Powdered milk (%)	Palm oil (%)	Coconut oil (%)
D0	36.00	21.47	42.00	-	-	-
DP	36.00	16.47	42.00	-	5.00	-
DC	36.00	16.47	42.00	-	-	5.00
M0	12.00	22.00	45.00	20.47	-	-
MP	12.00	17.00	45.00	20.47	5.00	-
MC	12.00	17.00	45.00	20.47	-	5.00

*in all chocolates 0.50% lecithin and 0.03% vanillin was added;
D0 (dark chocolate without palm or coconut oil), DP (dark chocolate with palm oil), DC (dark chocolate with coconut oil), M0 (milk chocolate without palm and coconut oil), MP (milk chocolate with palm oil), MC (milk chocolate with coconut oil)

Table 1. Composition of chocolate samples

2.2 Hardness

Texture Analyser TA.XT (Stable Micro systems, Great Britain) with maximal force 50 kg was used to measure hardness of chocolate samples. "Three point bending rig" extension was used for analysis and results are expressed as a gram of force needed to break the chocolate. Samples were compressed under the following conditions: extension speed 3.0 mm/s and extension travel 5.0 mm. Five repetitions were performed and the results were processed with Texture Exponent 32 software.

2.3 Rheological properties

Rheological properties of molten chocolate at 40 °C were measured with rotational rheometer Rheo Stress 600 (Haake, Germany). Measurements were made according to IOCCC [8] applying the hysteresis loop using concentric cylinder system. Flow curves were determined by increasing share rate from 1 to 60 s^{-1} (during 180 s), keeping at 60 s^{-1} (during 60 s) and decreasing from 60 to 1 s^{-1} (during 180 s). Casson viscosity and yield stress were determined. Casson model is widely used for expressing viscosity of liquid chocolate.

2.4 Colour

Colour of samples was measured with chromameter Konica Minolta CR-400. The measurement was carried out in the LCh and CIEL*a*b* system. Colour was measured after cooling of samples (0 h) and 7 days after cooling. L* shows lightness, a* red or green colour and b* yellow or blue. Total colour change (ΔE) (1) and whiteness index (WI) (2) were calculated according to:

$$\Delta E = \sqrt{(L^* - L_0^*)^2 - (b^* - b_0^*)^2 - (a^* - a_0^*)^2} \quad (1)$$

$$WI = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}] \quad (2)$$

2.5 Statistical analysis

Main analysis of variance was determined at $p<0.05$. This analysis shows effect of independent variables (type of chocolate and fat) on dependent variable (hardness, rheological properties and colour). Analysis was conducted using Statistica software.

3. Results and discussion

3.1 Hardness

Chocolate hardness is defined as amount of force needed to break a bar of chocolate [9]. Hardness of dark and milk chocolates with and without coconut and palm oil can be seen in Fig. 1. It is visible that dark chocolates are harder than milk chocolates. This decrease of hardness of milk chocolates was due to presence of milk fat, which has a softening effect on chocolate [10]. This is confirmed by statistical analysis in Table 3., where statistically significant difference is shown for type of chocolate.

To produce chocolate with a good snap tempering process needs to be properly conducted. The goal is to obtain a desirable β(V) form of crystals [3]. As can be seen at Fig. 1., milk and dark chocolates produced with coconut and palm oil had statistically lower hardness than chocolates with only cocoa butter. Biswas et al. [11] reported same decrease of hardness for chocolates produced with cocoa butter substitute based on palm oil. It is known that coconut oil exhibits only β' crystals and this may be the reason for lower hardness in these chocolates [4]. Also, presence of lauric acid in these two oils results in sharp melting profile at lower temperatures than cocoa butter [12] which means that they may alter compact crystal network of cocoa butter which is responsible for characteristic snap of chocolate.

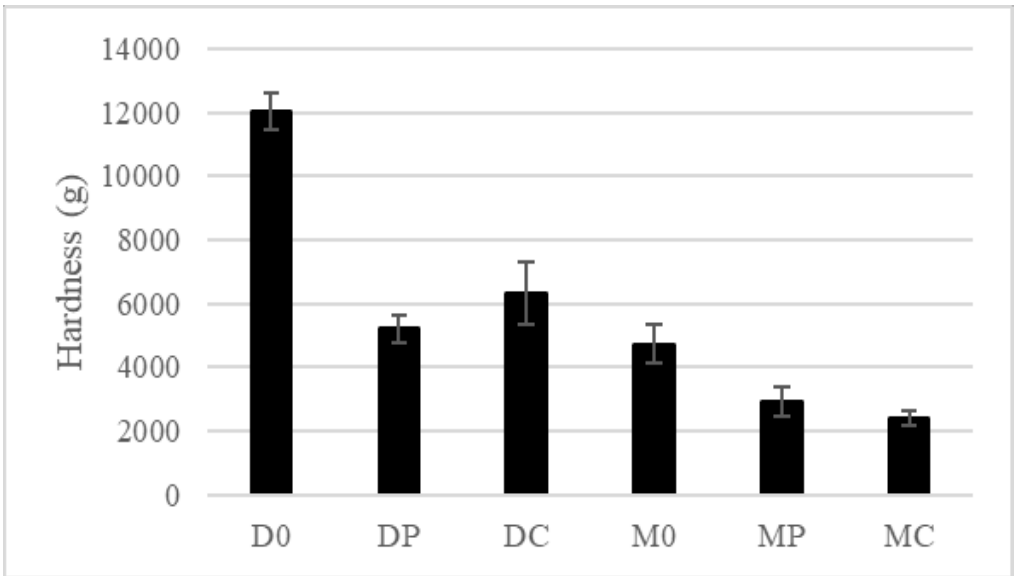

Figure 1. Hardness of chocolate samples

3.2 Rheological properties

For defining chocolate rheology Casson mathematical model is commonly used. Casson yield stress presents energy required to start the flow of molten chocolate and Casson plastic viscosity is energy needed to keep a flow in motion [9]. High viscosity of chocolates presents a problem for production process and it is not desired by consumers [11]. From Fig.2. it can be seen that milk and dark chocolate without addition of coconut and palm oil had slightly higher Casson viscosity and yield stress. An exception is yield stress of milk chocolate with palm oil which needs to be further studied to determine does combination of milk fat and palm oil has negative effect on chocolate yield stress. Statistical analysis (Table 3) shows that type of chocolate has a significant effect on Casson yield stress.

Abdul Halim et al. [4] determined that chocolate with addition of coconut oil also had lower viscosity. Biswas et al. [11] determined the same for dark chocolate with palm oil but added amounts were much higher than in our research.

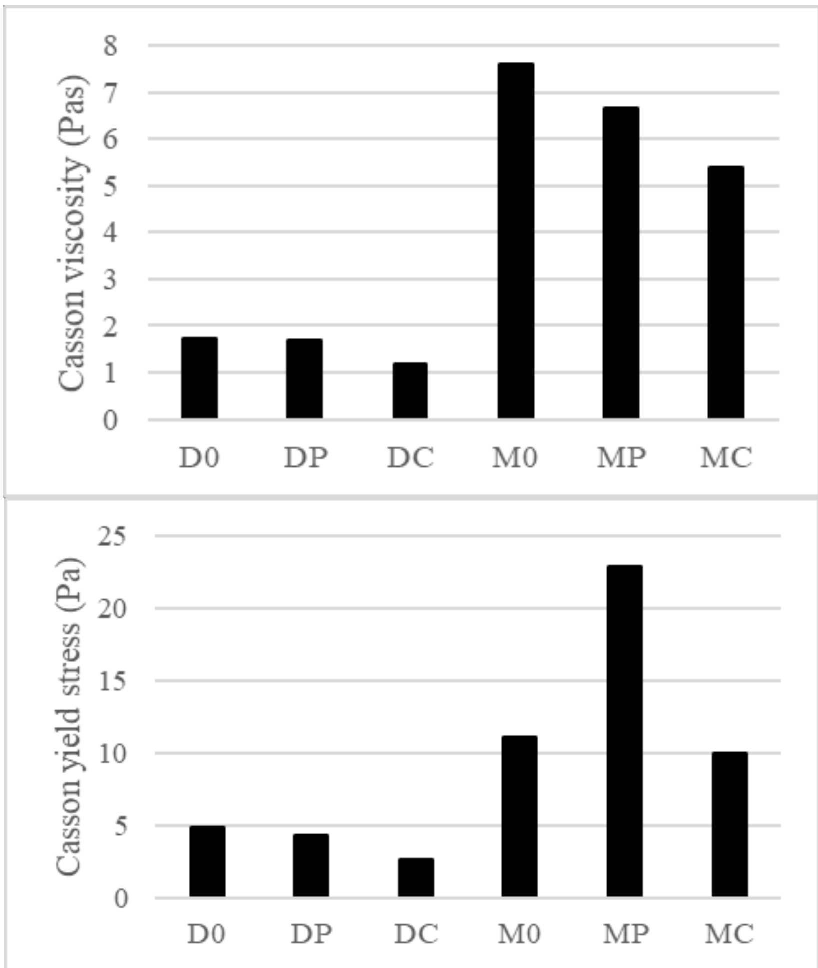

Figure 2. Casson viscosity and yield stress of chocolate samples

3.3 Colour

Chocolate colour is very important for consumers acceptance and from Table 2. it can be seen that all chocolates have positive values for parameters a* (colour red) and b* (colour yellow). Also, parameter h shows that they are closer to red colour since 0° presents red and 90° yellow colour.

Fat bloom of chocolates presents as whitish stains on surface and can be developed upon poor tempering or large temperature variations [13]. Chocolates with fat bloom also show loss of gloss, smoothness and undesirable discoloration [11].

From Table 2. it can be seen that chocolates without palm and coconut oil have greatest total colour change. However, whiteness index did not change significantly after 7 days in any of chocolate samples. Researches already reported that chocolates with coconut and palm oil have better resistance to fat bloom formation [4, 6, 11, 14] but also that addition of coconut oil contributes to shiner surface of chocolate [15]. In Table 3 it can be seen that type of chocolate and fat used in production have significant effect on total colour change and whiteness index.

High melting triglycerides from palm and coconut oil help inhibit fat bloom during temperature fluctuations [16] but good oxidative stability of palm and coconut oil could also contribute to lesser colour change of chocolate [4].

All these results show that these samples are well tempered and that coconut and palm oil added in amount of 5% can contribute to smaller total colour change.

Sample	L*	a*	b*	C	h	ΔE	WI
D0 – 0 h	30.53 ± 0.76	9.30 ± 0.05	8.78 ± 0.27	12.79 ± 0.21	43.32 ± 0.82		29.36 ± 0.65
D0 – 7 days	28.92 ± 0.67	8.34 ± 0.13	7.30 ± 0.04	11.09 ± 0.11	41.19 ± 0.35	2.44 ± 0.35	28.06 ± 0.60
DP – 0 h	29.96 ± 0.65	8.51 ± 0.17	8.06 ± 0.26	11.72 ± 0.27	43.43 ± 0.80		28.98 ± 0.55
DP – 7 days	29.60 ± 0.52	8.30 ± 0.08	7.75 ± 0.39	11.36 ± 0.29	42.99 ± 1.41	0.71 ± 0.34	28.69 ± 0.44
DC – 0 h	30.66 ± 0.44	8.89 ± 0.19	8.12 ± 0.40	12.05 ± 0.39	42.38 ± 0.96		29.62 ± 0.34
DC – 7 days	30.36 ± 0.38	8.76 ± 0.07	7.97 ± 0.16	11.84 ± 0.15	42.29 ± 0.36	0.50 ± 0.16	29.36 ± 0.32
M0 – 0 h	40.29 ± 0.46	10.69 ± 0.19	14.85 ± 0.26	18.29 ± 0.32	54.25 ± 0.16		37.55 ± 0.31
M0 – 7 days	39.43 ± 0.46	10.51 ± 0.11	14.36 ± 0.20	17.80 ± 0.19	53.79 ± 0.39	1.01 ± 0.43	36.87 ± 0.36
MP – 0 h	40.83 ± 0.85	10.40 ± 0.22	18.20 ± 0.27	20.95 ± 0.31	60.25 ± 0.48		37.22 ± 0.68
MP – 7 days	40.39 ± 0.33	10.43 ± 0.14	17.99 ± 0.14	20.80 ± 0.16	59.89 ± 0.30	0.56 ± 0.20	36.86 ± 0.24
MC – 0 h	40.49 ± 0.41	10.58 ± 0.12	14.90 ± 0.26	18.28 ± 0.23	54.61 ± 0.53		37.74 ± 0.32
MC – 7 days	40.80 ± 0.53	10.61 ± 0.12	15.03 ± 0.25	18.39 ± 0.27	54.77 ± 0.27	0.57 ± 0.29	38.00 ± 0.41

Table 2. Colour parameters, total colour change and whiteness index of chocolate samples

	Effect	**Sum of squares**	**DF**	**Mean square**	**F-Value**	**P-Value**
Hardness	Intercept	950242573	1	950242573	584.5745	**<0.001**
	Type of chocolate	155274083	1	155274083	95.5222	**<0.001**
	Type of fat	114968259	2	57484130	35.3633	**<0.001**
	Error	42263746	26	1625529		
Casson yield stress	Intercept	98.18024	1	98.18024	278.6356	**0.003570**
	Type of chocolate	37.76547	1	37.76547	107.1784	**0.009202**
	Type of fat	1.95458	2	0.97729	2.7736	0.265002
	Error	0.70472	2	0.35236		
Casson viscosity	Intercept	523.5444	1	523.5444	22.45122	**0.041770**
	Type of chocolate	171.6601	1	171.6601	7.36132	0.113233
	Type of fat	57.3200	2	28.6600	1.22903	0.448625
	Error	46.6384	2	23.3192		
ΔE	Intercept	27.83693	1	27.83693	118.6111	**<0.001**
	Type of chocolate	1.87682	1	1.87682	7.9970	**0.008900**
	Type of fat	8.74381	2	4.37191	18.6284	**<0.001**
	Error	6.10196	26	0.23469		
WI	Intercept	32617.09	1	32617.09	151603.2	**<0.001**
	Type of chocolate	547.69	1	547.69	2545.7	**<0.001**
	Type of fat	7.99	2	4.00	18.6	**<0.001**
	Error	5.59	26	0.22		

Bold values were considered significant at $p<0.05$

Table 3. Main effects analysis of variance

4. Conclusions

Milk and dark chocolates were produced in ball mill with addition of 5% of coconut and palm oil. Hardness, Casson yield stress and viscosity showed lower values for all chocolates produced with palm and coconut oil. In addition, hardness was lower but rheology values were higher for milk chocolates. Total colour change showed smaller change for chocolate with added oils after 7 days. Also, whiteness index did not change significantly.

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