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# COMPARATIVE ANALYSIS OF MILLING TECHNOLOGIES IN DARK AND MILK COCOA TOPPING PRODUCTION FOR ICE CREAM

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**ABSTRACT**

Chocolate and cocoa toppings are widely used for confectionery products. Toppings used for ice creams contain higher fat content (about 40-60%) to ensure a greater flow to cover the whole product. The dark cocoa topping consists of cocoa and sugar powder distributed in vegetable fat, while cocoa topping with the added 7% non-fat milk fraction is regarded as a milk cocoa topping. This research aimed to determine and compare the impact of the ball mill, and five-roll mill and conching used for the production of dark and milk cocoa toppings regarding the particle size distribution, rheology properties and content of moisture, sucrose, fat and lactose. The obtained results showed that the volume-weighted mean parameter D (4,3) was lower in the samples produced in a ball mill. Additionally, the viscosity, linear and Casson, slightly increased in samples produced in a ball mill except for the milk cocoa topping which had 0.55 fold higher value of linear viscosity compared to the sample produced using a five-roll mill and conching. Regarding the results of NIR spectroscopy, it was found that the samples produced in a ball mill showed higher values of moisture, but lower values of sucrose, lactose and fat.

Keywords: cocoa topping, ball mill, five-roll mill, rheology, particle size distribution

## 1. INTRODUCTION

Ice cream is a frozen dessert consumed and loved all over the world. It is a frozen mixture of ingredients such as milk, sweeteners, stabilizers, aromas and emulsifiers [1]. In its generic sense, the term "ice cream" includes all whipped dairy products manufactured by the process of freezing and consummated in that particular state, including ice milk, sherbet and frozen yogurt [2]. To answer the consumer's requests, the manufacturing industries are trying to formulate products that have the richest flavor and texture, and at the same time are accepted by the consumers. In addition to that, the current Rulebook of the Republic of Serbia on quality and other requirements for milk, dairy products, composite dairy products, and starter culture is allowing the manufacturing companies to produce and enrich frozen dairy products with confectionery products like chocolate or cocoa toppings [3]. Confectionery toppings for ice cream contain higher amounts of fat (40 – 60 %) in comparison to their ambient counterparts to ensure the completion of the coating process. The difference between chocolate and cocoa toppings is in the fat phase, where the chocolate topping is comprised of cocoa butter and the cocoa topping contains cheaper vegetable fat [4, 1]. Since cocoa butter is very expensive, toppings for ice cream are mainly produced using cheaper versions of vegetable fat. The properties of cocoa toppings can be altered by changing the type of vegetable fat or the level of fat contained in the topping to answer to customer demands. In many countries, cocoa toppings usually include coconut oil as a fat phase, at levels of 45 – 60 %. During the consumption, ice cream gives away the cooling effect in the mouth, and because of that, the cocoa coating used for covering this frozen dairy dessert should have a lower melting point (around 23 °C) than their ambient counterparts [4]. Since customer acceptance is the most important, during the production of confectionery products it is crucial to pay attention to particle size

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distribution and rheology of the produced coatings. Values of the particles that are considered optimal are between 15 – 30 μm. If the particles are bigger than that, it can leave a sandy feeling in the mouth that is unacceptable for the customers [5]. Cocoa topping can be produced using a three or five-roll mill for refining the mass and conching for the development of the flavor or using a ball mill where the refining and flavor development occur at the same time. In terms of refining using a five-roll mill, the refining is carried out with roll refiners. For the topping produced in a ball mill, often used for small production, ingredients like cocoa and sugar powder, with vegetable fat i.e. coconut oil, are placed in a jacketed tank filled with the grinding media – stainless steel balls. The refining mass, together with stainless balls, is stirred by a rotating shaft with arms [6, 7]. Alampresse et al. [6] examined and optimized the process of ball milling for the production of chocolate in terms of refining time and energy consumption. To date, no work has been done to determine the difference between cocoa toppings produced using different kinds of milling. This study aimed to determine and compare the particle size distribution, rheological properties, and content of moisture, fat, sucrose and lactose in the cocoa toppings for ice cream produced using a five-roll mill and conching and also using a ball mill.

## 2. MATERIALS AND METHODS

### 2.1. Material

Dark cocoa topping (DCT) consisted of sugar (37.95 %), coconut oil (48.5 %), cocoa powder (13%), aroma (0,01%), lecithin and polyglycerol polyricinoleate (0.54%). On the other hand, milk cocoa topping (MCT) consisted of sugar (36.09%), coconut oil (32.47%), milk material (12%) from which milk fat (2.13%), cocoa mass (11.8%), cocoa butter (5%) and lecithin (0.51%). Ingredients were kindly provided by the Barry Callebaut industry.

### 2.2. Preparation of dark and milk cocoa topping

Laboratory samples, dark and milk cocoa toppings for ice cream were produced under industrial conditions at the Barry Callebaut industry (Novi Sad, Serbia) using the five-roll mill and conching. At first, dry conching lasted for about 1 hour at the temperature of 65 °C, and afterward, the wet conching lasted for another 30 minutes at 55 °C. The complete process lasted for 2.5 hours. Additionally, the samples of dark and milk cocoa toppings for ice cream were produced using a laboratory ball mill at a temperature of 60°C for 1.5 hours with the maximum speed of the mixer. Ingredients were the same for both batches.

### 2.3. Particle size distribution of dark and milk cocoa toppings for ice cream

Particle size distribution of produced toppings for ice cream were determined using a Mastersizer 2000, laser diffraction particle size analyzer (Malvern Instruments, England). Toppings were dispersed in sunflower oil, and the analysis was conducted using a Hydro 2000 μP unit. The results were processed via Mastersizer 2000 software and shown 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.

### 2.4. Rheological properties of dark and milk cocoa toppings for ice cream

Rheological properties of cocoa toppings were analysed by the Rheo Stress 600 (Haake, Germany), equipped with coaxial cylinders Z20DIN at the temperature of 40 ± 1 ° [8]. First, the shear rate was increased from 0

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$s^{-1}$ to 60 $s^{-1}$ in three minutes and kept constant for one minute at 60 $s^{-1}$. Then, the shear rate decreased from 60 $s^{-1}$ to 0 $s^{-1}$ in three minutes.

### 2.5. Determination of content of fat, moisture, sucrose and lactose using NIR spectroscopy

The content of fat, moisture, sucrose and lactose were determined with MPA II multi-purpose analyser (Bruker, USA). The results were shown as a percentage values.

## 3. RESULTS AND DISCUSSION

### 3.1. Particle size distribution in dark and milk cocoa toppings for ice cream

The results of particle size distribution analysis of milk cocoa topping produced using five-roll mill and conching are shown in Fig. 1 (upper image) and ball mill (bottom image). As shown, the results indicated that the mean weighted parameter D (4,3) was slightly lower for the milk topping produced using ball mill (13.65 µm) compared to the topping produced with five-roll mill and conching (13.81 µm). Additionally, the parameter d (0,9) was higher for the milk topping produced in ball mill (29.92 µm). This parameter indicates that the 90% of the total particle volume include particles that are smaller than 29.92 µm. The value of this parameter in topping produced using five-roll mill and conching was 29.62 µm.

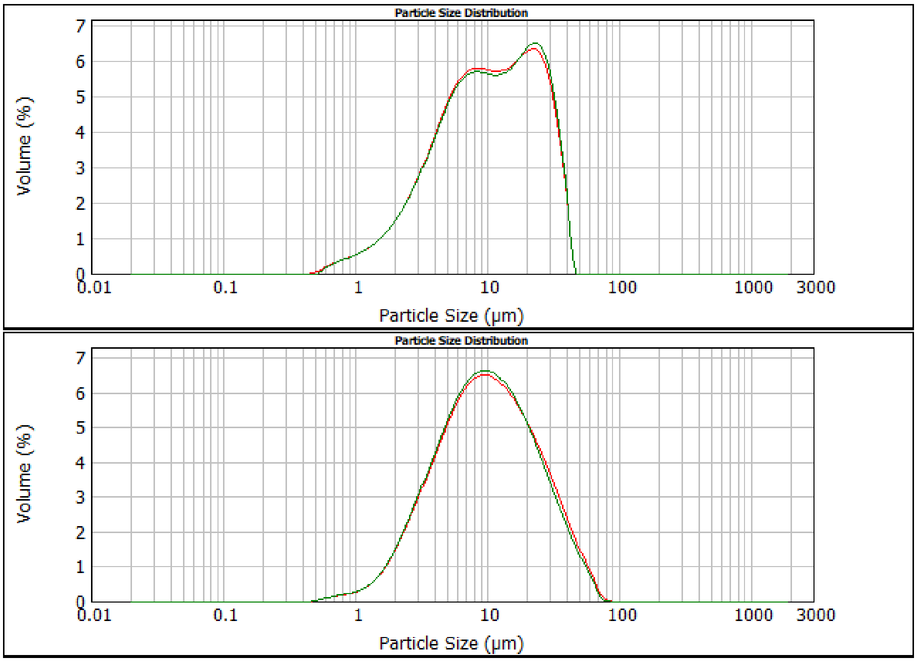


***Figure 1. Particle size distribution in milk cocoa topping produced by five-roll mill and conching (upper) and ball mill (bottom)***

On the other hand, the difference for the dark cocoa topping regarding particle size distribution and mainly mean volume-weighted parameter D (4,3) is more noticeable. The value of D (4,3) in the sample produced in the ball mill was 14.611 µm and in the sample produced using a five-roll mill and conching 15.749 µm. The particles in the range of 15-30 µm are optimal, but if the particles are bigger than that, a gritty feeling in the mouth can occur. Also, smaller particles have a larger surface area, and more of fat phase is needed for

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the complete covering of these particles [5, 9]. The results are shown in Fig. 2 where the upper image represents particle size distribution in the dark cocoa sample produced using a five-roll mill and conching and the bottom image represents distribution in the sample produced using the ball mill.

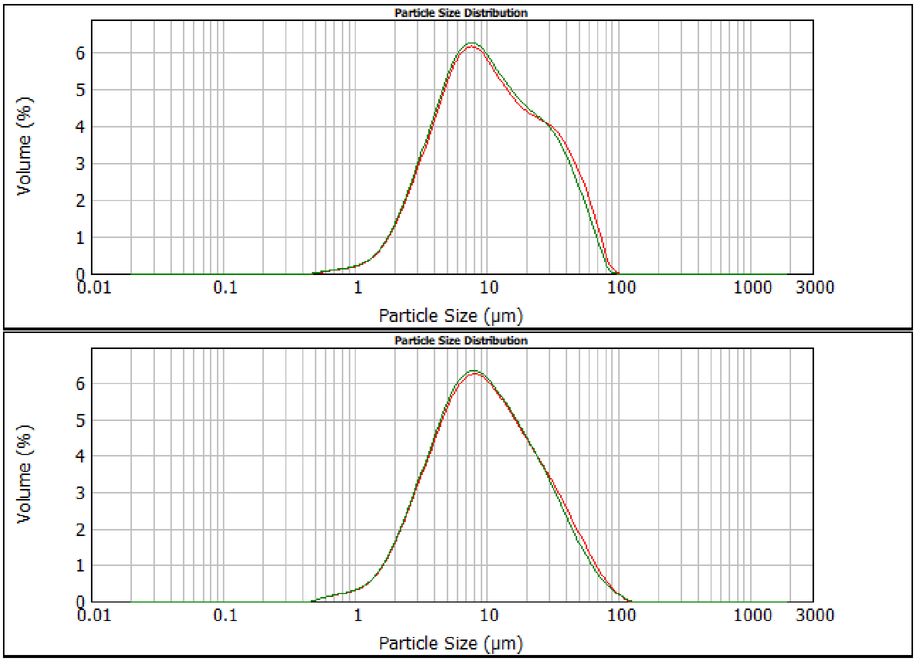


*Figure 2. Particle size distribution in dark cocoa topping produced by five-roll mill and conching (upper) and ball mill (bottom)*

### 3.2. Rheological properties of dark and milk cocoa topping for ice cream

Rheological properties of confectionery products can predict the behavior during processing as well as sensory properties, structural organization and interactions within the system [10]. Analyzed parameters are Casson and linear viscosity (Pa·s), including the yield stress (Pa) of the samples and shown in Tab. 1.

*Table 1. Rhelogical properties of DCT and MCT produced using five-roll mill and conching and a ball mill*

| Sample | Yield stress (Pa) | Casson viscosity (Pa·s) | Linear viscosity (Pa·s) |
|---|---|---|---|
| DCT – ball mill | $0.24\pm0.001^{a}$ | $0.152\pm0.05^{a}$ | $0.194\pm0.02^{a}$ |
| DCT – five-roll mill and conching | $0.25\pm0.002^{b}$ | $0.151\pm0.06^{b}$ | $0.192\pm0.07^{b}$ |
| MCT – ball mill | $1.0\pm0.002^{c}$ | $0.252\pm0.01^{c}$ | $0.376\pm0.07^{c}$ |
| MCT – five roll mill and conching | $0.09\pm0.003^{d}$ | $0.213\pm0.04^{d}$ | $0.242\pm0.02^{d}$ |

The results show significant difference ($p < 0.05$) between the samples. As expected, values of Casson and linear viscosity in the samples produced in the ball mill were higher (0.152 and 0.194 Pa·s for dark, and 0.252 and 0.376 Pa·s for milk cocoa topping) and are in agreement with the results of particle size distribution analysis. In DCT samples, there is a slightly increase in viscosity values in the samples produced with a ball mill. Additionally, the increase of linear viscosity in MCT produced in a ball mill was 0.55 fold higher compared to the sample produced using the other mill. This occurrence can be explained with the presence of smaller particles in the samples produced in a ball mill that led to increase in values of rheological

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parameters. Also, the value of Casson viscosity in MCT sample produced in a ball mill was 1.18 fold increased, compared to the MCT sample, produced using a two-part equipment, five-roll and conching. Jovanović et al. [11] incorporated blueberry juice encapsulated on whey in white chocolate. The results of their study showed that the samples with higher concentrations of encapsulate lowered the fat content available for the covering of the particles. Because of that, an increase in the value of viscosity occurred. In our study, an increase in viscosity was present because particles are smaller and have larger surfaces that need a higher amount of fat for the covering. According to that, we observed the agreement in the result of rheology and particle size distribution analysis.

### 3.3. Content of moisture, fat, sucrose and lactose in dark and milk cocoa toppings for ice cream

NIR spectroscopy is a method based on the measuring absorption of electromagnetic radiation in the wavelength range of 780–2500 nm in wide range of types of food. When applied to confectionery products, NIR spectroscopy provides a rapid analysis of sucrose, lactose, fat and moisture in mentioned products [12]. According to results shown in Fig. 3., there is no significant difference ($p < 0.05$) amongst the samples. However, a slightly lower values for the content of fat was detected in DCT sample produced in a ball mill (50.82%) compared to the sample produced using different mill (50.87%). Additionally, the same trend was observed in DCT sample where the content of sucrose and lactose was 38.16% and 1.17% respectively. The same trend was observed for the MCT sample produced in a ball mill. However, it was noticed that the content of moisture was slightly higher ($p > 0.05$) for the samples produced a ball mill and the values were 0.38% for DTC and 0.46% for MTC sample.

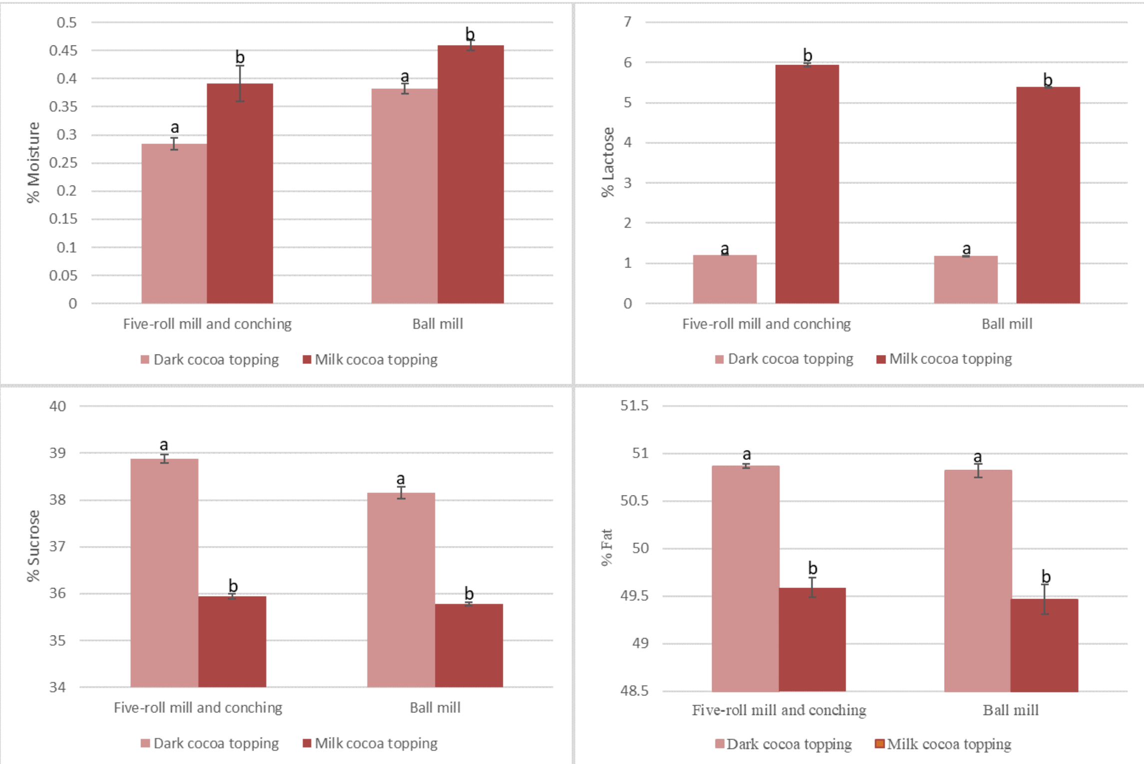


***Figure 3. Content of moisture, fat, sucrose and lactose in DCT and MCT produced by five-roll mill and conching and ball mill***

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## 4. CONCLUSIONS

This research aimed to investigate and compare the differences in cocoa toppings made for ice cream using different milling technologies. The results showed that the samples produced in a ball mill had lower values of mean volume-weighted diameter D [4,3] and slightly higher values of Casson viscosity. However, the MCT sample produced in a ball mill had 0.55 fold higher value of linear viscosity, but this increase will not have a negative effect during the covering of the ice cream. According to the results, it can be concluded that cocoa toppings produced in a ball mill, equipment that requires less storage space, shorter production time, and thus less energy, have almost identical quality as cocoa topping produced using the five-roll mill and conching. Additionally, by using a ball mill, instead of two-part equipment, a five-roll mill and conching, companies can save time and energy, and still produce high-quality cocoa topping for ice cream.

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