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The developing of reduced-sugar ready-to-drink cocoa beverages: optimization of stabilizers and sugar replacers concentration

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Abstract

Sugar has a role in the intrinsic properties of the product and gives a satiety effect after consumption. Nevertheless, its adverse effect on the human body becomes an essential reason to reduce the sugar content including in ready-to-drink (RTD) cocoa beverages. Besides the sugar, the properties of the beverages are also affected by the stabilizers. The development of reduced-sugar RTD cocoa beverages was studied in two steps. Initially, the stabilizers comprising kappa-carrageenan (κ-carrageenan) and carboxymethyl cellulose (CMC) were optimized in the full-sugar RTD cocoa beverage by which the concentrations of the stabilizers could stabilize cocoa particles and the beverage met its prominent characteristics regarding the sensorial properties also physical properties (sedimentation, rheology, and color). The CMC and κ-carrageenan respectively varied into formulas, which were F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%), F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), and F9(0.075%;0.03%). The chosen formula given by this first optimization, F5, was used as a basic formula for reducing the sugar of the beverage in which isomalt together with one of the high-intensity sweeteners (HISs), sucralose, was used as sugar replacer. The research revealed that the F5 within its sugar content was reduced until a portion of 37.04%, could still be tolerable based on sensorial properties.

Keywords: cocoa; beverages; sugar; κ-carrageenan; carboxymethyl cellulose; isomalt; sucralose.

Practical Application: The optimization of stabilizers and sugar replacers concentration was needed in developing reduced-sugar ready-to-drink cocoa beverages. The study revealed that the calorie of the optimized formula was close to the leading trademark low-calorie drink. The result can facilitate reducing sugar both in the reformulation of an existing product and in the development of a new product.

1 Introduction

Sugar is applied not only for sweetening the food product but also for giving bulking effect and enhancing the flavor. The important aspect of sugar is the capability in giving satiety and pleasure by integrating oral, gastrointestinal, and brain responses (Hutchings et al., 2019). Moreover, the sugar's sweetness has a unique characteristic that is difficult to be replicated with other sweeteners (Palazzo & Bolini, 2014). Nevertheless, sugar has recently become a concern regarding its adverse effects on human health. The obvious effects of sugar consumption in excess portions are obesity, dental caries, and non-communicable diseases, including diabetes mellitus and hypertension (Malik et al., 2010). Therefore, World Health Organization (WHO) has released a guideline that free sugar consumption should be no more than 10% of total energy, moreover, consumption beneath 5% is favorable to the human body. However, the sugar consumption by global per-capita remains over the recommendation (Newens & Walton, 2016). At the same time, several countries had done some efforts to reduce sugar consumption. The strong approach is applying a tax on sugar, especially on sugar-sweetened beverages (Hutchings et al., 2019). The others have adopted policies and regulations, including labeling, reformulation of products, and restriction of portion size (Coyle et al., 2019).

The sugar reduction must meet consumer acceptance moreover in the reformulation of an existing product. A combination of sweetness substitutes is used in the efforts, including polyols, fibers, and high-intensity sweeteners (HISs). Polyols and fibers providing bulk can be applied volume for volume. However, their less sweetness level makes they must be combined with HISs. The one of polyols is isomalt which has a similar sweetness profile as sugar without any accompanying aftertaste (O'Donnell & Kearsley, 2012). Compared with other polyols, the sweetness level of isomalt is resistant to the heating process, moreover, there is no cooling sensation if it is ingested in the mouth. However, the sweetness power of the isomalt is about 45-65% of sugar, so it needs to synergy with other polyols or HISs to get desired sweetness level. The other consideration is the consumption of isomalt in excessive portions causes a laxative effect so that some regulations began to regulate the use of isomalt and adjust the acceptable daily intake of isomalt (Tennant, 2014).

Sucralose, HIS with a sweetness level is about 450-650 times of sugar, can be combined with isomalt for reducing sugar in marketable beverages or in developing new reduced-sugar beverages. This is applicable in a wide range of types of products

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water-based or fat-based, even sucralose is readily soluble in alcoholic drinks. It is different from other HISs that are less or not soluble in alcohol-type products (Schiffman & Rother, 2013). Sucralose is also stable in a wide range of pH and high temperatures (Chattopadhyay et al., 2014).

Even though the sugar replacers contribute essentially to the sugar reduction, the reduction still becomes a challenge for food research or industry. Some world's food companies have reduced the sugar by 10-25% in the product. Theoretically, the reduction of sugar in beverages is easy to be conducted by replacing part of sugar-by-sugar substitutes including isomalt and sucralose. However, it is uncertain yet to meet the acceptance of consumer associated with sweetness level, texture, and aroma, besides the potential effect of the substitute, such as laxative effect and aftertaste which must be considered.

Meanwhile, hydrocolloids need to be added to cocoa beverages for stabilizing cocoa powder. Some types of polysaccharides, CMC and κ-carrageenan can be utilized as stabilizers through the increase of viscosity and the formation of a network. Nevertheless, it has been studied that higher viscosity will decrease the sweetness of sugar-contained liquid (Kistler et al., 2021). Therefore, both stabilizer and sweetener must be synergized to achieve desired cocoa beverages. Then, this study was focused on developing reduced-sugar RTD cocoa beverages through optimization of stabilizer at the first step with the core objective was to stabilize cocoa particles represented by sedimentation parameter. In addition, the accompanying parameters, including rheology, color, and sensory characteristic, had to be evaluated. The formula which met the physical and sensorial preference was resumed to be the basic formula for optimization of sugar replacer concentration in which the evaluation of the optimization was based on sensory properties too.

2 Materials and methods

The main material was local cocoa powder obtained from Griya Cokelat Nglanggeran, Gunungkidul District, Indonesia which was 200-mesh sieved. K-carrageenan was obtained from CV Karagen Indonesia. CMC was obtained at Intisari, Yogyakarta, Indonesia. Sucralose was purchased from Kanbo®. Isomalt was purchased from Boneo, Orafti®. Skim milk was purchased from Indo Prima®. Other ingredients including sugar, lecithin, and salt were obtained from local market of Intisari, Yogyakarta, Indonesia.

2.1 Methods

Preparation of chocolate ready-to-drink beverages

The development of reduced-sugar RTD cocoa beverages was completed in two steps. The first one was the optimization of the concentration of κ-carrageenan and CMC as stabilizers of full-sugar RTD cocoa beverages. The formula with optimized stabilizer concentration was resumed as a basic formula for reducing the sugar of the beverages. The steps of formulation were depicted in Figure 1.

At the first step, CMC and κ-carrageenan respectively varied into various concentration, which were F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%),

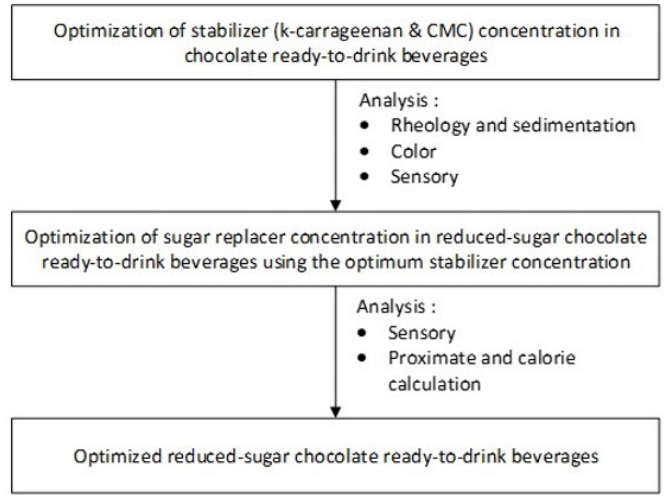

Figure 1. The two steps of optimization in reduced-sugar RTD cocoa beverages formulation.

F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), and F9(0.075%;0.03%). The other ingredients included cocoa powder (1.5%), soy lecithin (0.015%), skimmed milk (3%), sugar (9%), table salt (0.02%), and water (86.4%). The process was initiated by dissolving CMC in water at 90°C for 10 minutes in a portion of one-fourth of the total water. The solution then was added with skimmed milk, sugar, and salt. On the other hand, the hydration of cocoa powder was carried out with half of the total water by adding soy lecithin as a surfactant. The hydration was conducted for 15 minutes. Those two mixtures were mixed with stirring. Meanwhile, the κ-carrageenan previously dissolved with the rest of the water at 90 °C was mixed into a cocoa-milk-sugar mixture, while stirring was maintained during mixing. Thus, the mixture was pasteurized by the Low-Temperature Long Time (LTLT) method at 65 °C for 30 min and then was immediately cooled to 20 °C. The sample was packed in a PET bottle and then it was stored at 4 °C before being analyzed for sedimentation, rheology, color, and sensory characteristic.

The preparation of the sugar-reduced beverages was almost like the preparation of beverages with full sugar. The difference was a part of sugar was replaced by a certain amount of sucralose and isomalt based on Table 1. The estimation of the range of sucralose and isomalt concentration as sugar replacers was considered by the Acceptance Daily Intake (ADI) of sucralose which is 0-15 mg/kg of body weight and the laxative threshold of isomalt which is 0.25 g/meal per kg (Berry et al., 2016; Mäkinen, 2016; Livesey, 2001). The laxative effect of isomalt became a constraint in determining isomalt concentration. The assumption was the beverages could be consumed by an adult who weighs 50 kg. Based on the calculation, the maximum consumption of isomalt is 12.5 g isomalt/serving of 244 g beverage with a three-time maximum daily serving. Meanwhile, sucralose concentration was determined by the trial error with a limited number of trained panelists so that the beverages were accepted with 5 mg of sucralose per beverage serving. The weight of sucralose was ignored in the calculation because the weight of sucralose was very little compared with isomalt.

Table 1. Formulas containing isomalt and sucralose as sugar replacers in 244 g cocoa beverages per serving.

Formula	Sucrosa (g)	Isomalt (g)	Sucralosa (mg)	% Replacing of Sucrose
S1	27	-	-	0
S2	20.25	6.75	5	25
S3	18.9	8.1	5	30
S4	18	9	5	33.33
S5	17	10	5	37.04

Analysis of rheology

The rheological property of beverages, namely viscosity, was analyzed by Brookfield Viscometer Model MLVT115 (Middleboro, USA). The measurement of apparent viscosity was conducted with spindle LV-1 (no.61) by applying a low shear rate (0,167-1,67 1/s). If the shear rate is more than the range, % torque was not appropriate which was 75%. The flow behavior depicted the relationship between shear rate and shear stress in a unit of 1/s and mPa.s respectively. Furthermore, the power-law model, also known as the Ostwald de Waele relationship, was used to fitting data of flow profile with the Formula 1 as follows:

$$\tau = K\gamma^{n} \quad (1)$$

which: τ= shear stress, ϒ= shear rate, K= flow consistency index, n=flow behavior

Determination of sedimentation

Sedimentation of a cocoa particle in cocoa beverages was analyzed following Mazo Rivas et al. (2018) with modification. Sedimentation was visually analyzed under gravity using 50 mL graduated falcon filled with 50 mL beverage. The filled falcon was stored in the refrigerator at 4 °C, then sedimentation was measured on the 4th day which was stated as sedimentation index (SI) according to the following Formula 2:

$$SI(\%) = \frac{V_s}{V_i} x100\% \quad (2)$$

where *Vs* was sediment volume (mL) and *Vi* was initial volume (mL).

Some samples had sediment which could not be volumetrically stated because it was only stuck at bottom of the falcon wall. Furthermore, gradually visual observation was also used to investigate the amount of sediment. The values of grades comprised no sediment (-), very thin sediment (+), thin sediment (++), moderately dense sediment (+++), strongly dense sediment (++++).

Analysis of color

The color of cocoa beverages was estimated using chromameter (Konica Minolta CR-80) with CIE L*a*b* as the color variable. L* describes brightness with values ranging from 0-100 (black to white). A positive (+) of a* represents red, the opposite represents green. Meanwhile, the b* value shows yellow for positive (+) and blue for negative (-).

Analysis of chemical properties

Chemical properties including protein, fat, moisture, and ash were determined using methods based on AOAC 2000. Protein and fat were determined by Kjeldahl and Mojonnier respectively. Moisture and ash were analyzed by the thermogravimetric method. Total carbohydrate was determined by different. Dietary fiber was also determined, using the enzymatic method. Those properties were used for energy calculation. The analysis was conducted for the chosen formula obtained from the optimization of the stabilizer (first optimization) because it was used as a basis for the optimization of sugar replacer. The energy of sugar-reduced beverages was calculated by considering the amount of sugar replaced by isomalt and sucralose. The energy value is determined according to the following Formulas 3, 4 and 5 (Food and Agriculture Organization, 2003).

$$\text{Total carbohydrate}\left(\frac{g}{100g}\right) = 100\left(\frac{g}{100g}\right) - \text{moisture}\left(\frac{g}{100g}\right) - \text{protein}\left(\frac{g}{100g}\right) - \text{fat}\left(\frac{g}{100g}\right) \quad (3)$$

$$\text{Net carbohydrate}\left(\frac{g}{100g}\right) = \text{Total carbohydrate}\left(\frac{g}{100g}\right) - \text{polyol}\left(\frac{g}{100g}\right) - \text{dietary fiber}\left(\frac{g}{100g}\right) \quad (4)$$

$$\text{Energy Value}\left(\frac{kcal}{100g}\right) = \text{protein}\left(\frac{g}{100g}\right)x4\left(\frac{kcal}{g}\right) + \text{fat}\left(\frac{g}{100g}\right)x9\left(\frac{kcal}{g}\right) + \text{net carbohydrate}\left(\frac{g}{100g}\right)x\, 4\left(\frac{kcal}{g}\right) + \text{polyol}\left(\frac{g}{100g}\right)x2\left(\frac{kcal}{g}\right) \quad (5)$$

Sensory evaluation

The sensory evaluation was conducted twice. The first one was used for optimizing stabilizer concentration. The beverages were evaluated by the hedonic test which is participated by 25 untrained panelists. The evaluated parameters were color, homogeneity, viscosity, flavor, taste, texture, consistency, and overall acceptance. The panelists were served fresh beverages which were stored at refrigerator 4 °C. The panelists had to score their preference ranging from 1 (dislike extremely) to 7 (like extremely). Meanwhile, the second sensory test in which the sugar replacer concentration was optimized was like the previous test, but the difference was the sensory parameters comprising color, homogeneity, viscosity, taste, sweetness, bitter after taste, texture, consistency, and overall acceptance.

3 Results and discussion

3.1 Sedimentation of cocoa powder in beverages

Naturally, in the suspension system, cocoa powder owning a certain weight and size undergo sedimentation was driven by gravity. Stabilizers can be utilized to avoid sedimentation by some mechanisms. CMC can increase the viscosity of suspension by which the gravity force can be against. Meanwhile, κ-carrageenan can entrap cocoa particles by its interaction with casein micelle forming the three-dimension network. The influence of both stabilizers in sedimentation can be seen in Table 2 with the visual appearance shown in Figure 2.

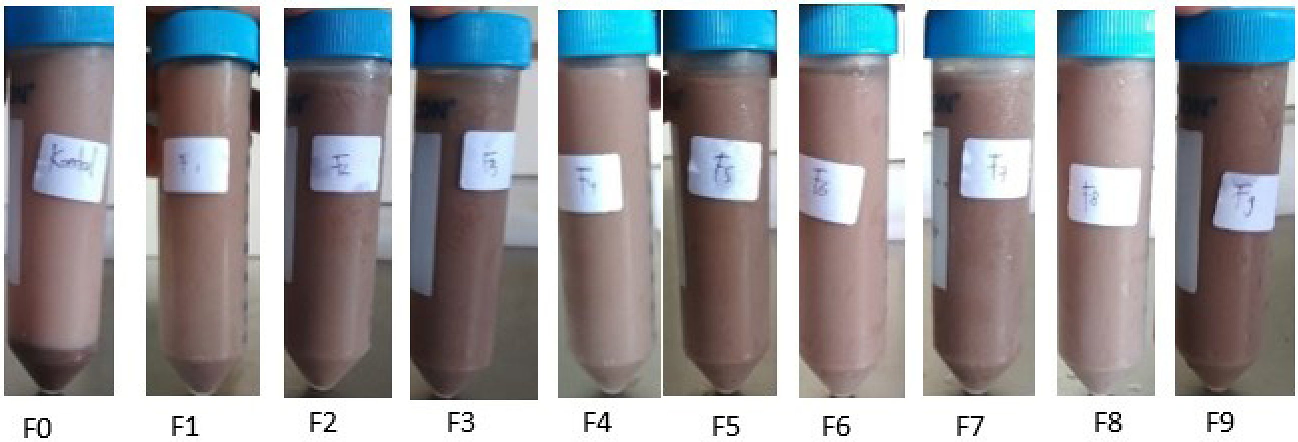

Figure 2. The visual appearance of cocoa beverages based on stabilizer concentration.

Table 2. Sedimentation index and sediment level of the cocoa particle in cocoa beverages based on stabilizer concentration.

Formula	SI (%)	The amount of sediment
F0	10	++++
F1	6.12	+++
F2	0	+
F3	0	-
F4	6.12	++
F5	0	-
F6	0	-
F7	6.12	++
F8	0	-
F9	0	-

Note: Formula based on stabilizer (% CMC; % κ-carrageenan): F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%), F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), F9(0.075%;0.03%). The values of sediment grades comprised no sediment (-), very thin sediment (+), thin sediment (++), moderately dense sediment (+++), strongly dense sediment (++++).

As we know, the beverage process is carried out under neutral pH (pH of the skim milk is 6.2-6.4). In this condition, casein will be negatively charged because it is induced by the c-terminus of κ-casein which forms 'hairy' polyelectrolyte brushes on the surface of the casein micelle. This negative charge makes micellar caseins repel each other and avoid flocculation and aggregation (McSweeney & Fox, 2013). Making chocolate drinks involves a heating process followed by a cooling process. When the temperature is lowered, the transformation of κ-carrageenan occurred from the coil into the helix (Cavallieri et al., 2011). The C-terminus of κ-casein will form an interaction with the helix of κ-carrageenan, thus forming a three-dimensional network that will stabilize the cocoa particle.

Like κ-carrageenan, CMC is an anionic polysaccharide that will be negatively charged at a neutral pH of 6.2-6.4. Therefore, CMC will not be adsorbed on the negative surface of casein (Wu et al., 2013). At this condition, non-adsorbed CMC will interact with casein micelles through hydrogen interactions so that it will increase serum viscosity (Abedi et al., 2014; Hao et al., 2012). By increasing the viscosity, casein will be stabilized, which in turn will also support the stabilization of cocoa particles in the system through the casein/κ-carrageenan interaction as previously described.

Visually observation also shows a similar result. Generally, the greater the concentration of stabilizer was used, the fewer cocoa particles to be settled. However, each stabilizer had a different effect. If F1, F4, and F7 are compared, in this case, the concentration of κ-carrageenan remained constant, the addition of CMC concentration was only able to reduce sediment by a small amount. It meant that the CMC concentration of 0.075% would not induce viscous-enough suspension for avoiding sedimentation if the concentration of κ-carrageenan were little (0.01% or under).

On the other hand, if F1, F2, and F3 were compared as well as F4, F5, and F6, in this case, the concentration of CMC remained constant, it was seen that the addition of κ-carrageenan concentration was able to reduce the amount of the sediment significantly. K-carrageenan concentration of 0.02% induced enough three-dimensional network to entrap cocoa particles with a minimum CMC requirement of 0.05%. By this research formula F3, F5, F6, F8, and F9 had been able to avoid the forming of sediment.

3.2 Rheology properties

The rheological properties of the beverages were depicted in Figure 3. As sedimentation profile, the stabilizer concentration also affected the flow behavior of the beverage. The absence of a stabilizer caused the beverage to lack viscosity and had a Newtonian flow pattern like water. It might be that the result caused the cocoa powder to undergo sedimentation, especially formula F0 as known in Table 2.

Based on rheological properties that was shown on Table 3, the cocoa beverage with the addition of a stabilizer had flow as a shear-thinning type. This type of flow will show a decrease in viscosity when the shear rate is raised. The flow index (n) can be used as a parameter in predicting the type of flow pattern. Fluids with $n < 1$ are included as the shear-thinning fluid (Rao, 2014). Cocoa drink without stabilizer F0 is included in Newtonian fluid because it has a value of n close to 1, whereas the others with

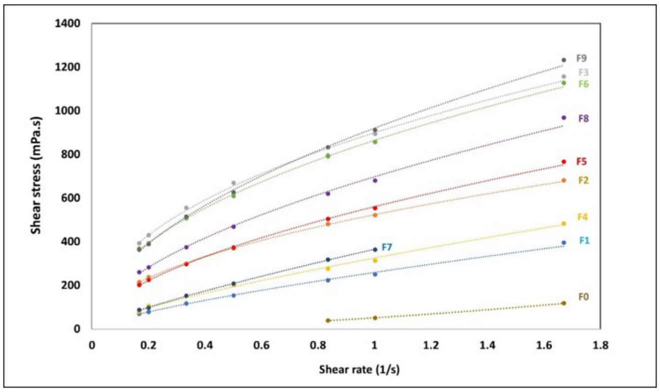

Figure 3. Rheological profile of reduced-sugar RTD cocoa beverages based on optimization of stabilizers.

Table 3. Rheology profile of cocoa beverage by power-law properties.

Formula	K (Flow consistency index, mPa s^{-n})	Flow behaviour (n)	Apparent Viscosity (mPa)
F0	50.9	1.62	42.91
F1	258.9	0.75	239.23
F2	523.3	0.50	496.45
F3	899.0	0.46	856.47
F4	325.0	0.75	300.31
F5	560.1	0.57	527.45
F6	864.2	0.49	820.72
F7	364.9	0.81	335.05
F8	697.2	0.56	657.25
F9	920.0	0.53	870.03

Note: Formula based on stabilizer (% CMC; % κ-carrageenan): F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%), F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), F9(0.075%;0.03%).

stabilizer belong to shear-thinning fluid because the n value was less than 1. This is due to the addition of a κ-carrageenan solution which has pseudoplastic flow properties. As the shear rate increases, the viscosity decreases, on the other hand, the viscosity increases when the shear rate is reduced (Azizi & Farahnaky, 2016).

K-carrageenan and CMC have contributed to increasing the viscosity of the system. The main factor is that both are hydrocolloid polysaccharides which are natural polysaccharides and water molecules forming the hydrocolloid system. In addition, the viscosity was affected by both κ-carrageenan/casein and CMC/casein interactions. As previously explained, the interaction of κ-carrageenan and casein micelles will induce a helical conformation and three-dimensional network which not only stabilizes the cocoa particles but also forms a denser system due to the formation of these macromolecules. CMC also has the same tendency that the hydrogen interaction of CMC/casein will increase the viscosity of the system. However, it should be noted that the addition of CMC in skim milk at neutral pH will cause an increase in micelle diameter which will trigger aggregation and further phase separation. The addition of more than 0.1% CMC will cause phase separation (Du et al., 2009). Therefore, in this study, a maximum CMC concentration of 0.075% was used.

The casein micelle has a high sensitivity to κ-carrageenan compared with CMC. It was proven by the increase of viscosity of the system by raising κ-carrageenan concentration (0.01-0.03%) was higher than that of CMC concentration (0.025-0.075%). Based on Table 3, when the concentration of κ-carrageenan was raised but the constant concentration of CMC was maintained (in this case F1, F2, and F3 were compared as well as F4, F5, and F6), the change of consistency index and flow behavior was significantly different. Meanwhile, if F1, F4, and F7 were compared as well as F2, F5, and F8 (CMC was raised but the concentration of κ-carrageenan was constant), the difference in consistency index and flow behavior were insignificant. From this study, it was found that κ-carrageenan has a greater effect on the rheological properties of beverages than CMC. The addition of κ-carrageenan gave a greater increase in plasticity when compared to the addition of CMC. The interaction of κ-carrageenan/casein micelle is thought to contribute to network formation in addition to increasing the overall viscosity (Tran et al., 2021).

Besides CMC and κ-carrageenan, the other hydrocolloids can also be utilized in improving the texture or rheological properties of milk-based beverages. Gellan gum was used as a texture modifier in an acerola-milk smoothie and resulted in the pseudoplastic behavior of the samples (Leal et al., 2022). Meanwhile, inulin can improve the texture dan rheological properties of yogurt drinks composed of water-soluble soy extract (WSSE) and goat milk (Ribeiro et al., 2023). The fermented dairy drink showed pseudoplastic behavior and good adjustment to the Power Law model. In the research, inulin acted as a thickener by forming hydrogen bound with casein and the three-dimensional network among insoluble sub-micron crystalline inulin particles. Therefore, in further research, either gellan gum or inulin has an opportunity to be applied as a stabilizer of cocoa particles in cocoa-milk-based beverages.

3.3 Color properties

Generally, the addition of hydrocolloids (CMC and κ-carrageenan) could shift the beverage into a different chromatic space as shown in Table 4. The darker brown color of cocoa beverages was identified by lower lightness (L*), redness (a*),

Table 4. Effect of different concentrations of stabilizers on CIE L* a* b* color properties of beverages.

Formula	L*	a*	b*
F0	42.90^{a}	6.17^{a}	8.03^{a}
F1	34.17^{bc}	5.80^{bc}	7.10^{bc}
F2	34.43^{b}	5.53^{de}	6.77^{d}
F3	33.93^{bc}	5.43^{ef}	6.77^{d}
F4	34.43^{cd}	5.70^{bcd}	6.87^{cd}
F5	32.07^{f}	5.90^{b}	7.23^{b}
F6	34.00^{bc}	5.63^{cde}	6.73^{d}
F7	32.97^{de}	5.47^{ef}	6.20^{e}
F8	34.53^{b}	5.27^{f}	6.20^{e}
F9	32.50^{ef}	5.43^{ef}	6.20^{e}

Note: Formula based on stabilizers (% CMC; % κ-carrageenan): F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%), F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), F9(0.075%;0.03%).

and yellowness (b*). Hydrocolloids as stabilizers had reduced lightness (L*), redness (a*), yellowness (b*) but and these changes was affected by the concentration and type of hydrocolloids. Increasing the dose of CMC caused a significant reduction in lightness, redness, and yellowness but κ-carrageenan had no similar effect. It is also possible at a given concentration; CMC gives the effect of increasing turbidity (Teleszko et al., 2019). Meanwhile, κ-carrageenan may not give a turbidity effect because it forms transparent gelation in the final process and product. It meant that CMC had the capability in enhancing the color intensity of cocoa beverages to be darker. The study by Leal et al. (2022) showed similar results that the increasing concentration of gellan gum increases the color intensity of acerola smoothie by lowering the luminosity variable (L *). Acerola was dominated by anthocyanin, so the darker and more intense color was signed by higher redness (a*) and higher yellowness (b*).

3.4 Sensory characteristics

According to Table 5, the un-presence of CMC and κ-carrageenan makes unpleasant properties in the F0. The color of the beverage without stabilizers is not liked by the panelists significantly. That's due to sedimentation and non-homogeneity. Separation of cocoa particles from the suspension induced discoloration of the top of the liquid, while the bottom contained the cake of sediment. Another consequence of the absence of a stabilizer is not only on the visual parameter but also on the aspect of the sense of taste. Sedimentation reduces taste preferences for the product. Moreover, the inhomogeneous beverages have a like-sandy texture and have consistency and viscosity that may be too light.

The dose of CMC and carrageenan must meet the preference because panelists did not like either too watery or too heavy a beverage. The high viscosity and consistency were significantly affected by the carrageenan instead of CMC concentration. Formulas F8 and F9 tend to have high viscosity, thus they have low sensorial preferences. Homogeneity and stability of cocoa particles in suspension tend to affect the flavor and taste which was got by the tongue of the panelist. Formulas F1 and F7 which tend to sedimentation, have low taste and aroma scores. This is because the unstable cocoa particle in the suspension causes the particle fraction that settles to be more than that which is suspended. The upper of the drink was swallowed first then the bottom (bottom). Thus, the first impression received by the ingestion of panelists was a bland taste with a less strong cocoa aroma.

There is an interaction between hydrocolloid and sweetener (in this case sugar). This interaction will affect the perception of taste and aroma in the product, including sweet taste. In the shear-thinning liquid system, the increase in shear rate will cause a smaller decrease in viscosity, so it tends to mask taste and flavor perception. As shown in Table 5, the formula F1which had the smallest decrease in viscosity when subjected to an increase in shear rate, F1 has the smallest flavor and taste preference values. Mixing that occurs in the mouth means an increase in the shear rate. If only a slight decrease in viscosity occurs due to the mixing, the transfer rate of the sweetener from bulk saliva to the taste bud of the tongue is also small.

From Table 5, most of the preferences for all sensory parameters of cocoa drinks are dominated by F3, F5, F2, and F9 respectively. Aprotosoaie et al. (2016) stated that flavor is the one most important parameter for consumer preference and an essential attribute of cocoa product quality. F5 was chosen as the basis for the formula in developing sugar-reduced RTD cocoa beverages with the consideration that F5 has a more flavor preference than other formulas, although the value is not significant compared to the F3 formula. In the further formulation, F5 acts as control (S1). The reduction of sugar by replacing it with isomalt and sucralose in various formulas was evaluated sensorial with the result as shown in Figure 4.

Sucralose is a HIS that can be degraded at high temperatures (above 120 °C) through a dechlorination process and decomposition into a harmful product. Meanwhile, the maximum temperature that was used in the process of making this RTD beverage only ranges from 60 °C related to mixing, dehydration, dissolving, and pasteurization. Thus, food deterioration that possibly happened was related to the denaturation and degradation of milk protein in the presence of heating above 60 °C for a long time. The production of cocoa beverages uses the low-temperature long-time (LTLT) pasteurization method for convincing the dispersion of casein micelles. However, overheating can destabilize the milk protein components, namely casein and whey protein. It is said that casein in the form of colloidal hydrate is stabilized

Table 5. Sensory properties of the different formulas of beverages based on the difference of stabilizers and sugar replacers concentrations.

Formula	Color	Homogeneity	Viscosity	Flavour	Taste	Texture	Consistency	Overall
F0	3.52ᵃ	3.08ᵃ	3.32ᵃ	4.08ᵃ	4.00ᵃ	3.28ᵃ	3.32ᵃ	3.32ᵃ
F1	5.36ᵇ	4.48ᵇᶜ	4.92ᵇᶜᵈ	4.68ᵃ	4.48ᵃᵇ	4.68ᵇ	4.52ᵇᶜ	4.68ᵇᶜ
F2	5.80ᵇ	5.08ᶜᵈ	5.40 ᶜᵈ	5.20ᵇ	5.28ᵇᶜ	4.80 ᵇ	5.12ᶜᵈ	5.36 ᶜᵈ
F3	5.44ᵇ	5.40ᵈ	5.24 ᶜᵈ	5.20 ᵇ	5.48ᶜ	5.28 ᵇ	5.36ᵈ	5.60 ᶜᵈ
F4	5.32ᵇ	5.40ᵈ	5.12ᶜᵈ	5.24 ᵇ	5.00 ᵇᶜ	4.96 ᵇ	4.92ᶜᵈ	4.92 ᶜᵈ
F5	5.44ᵇ	5.40ᵈ	5.16ᶜᵈ	5.40 ᵇ	5.12 ᵇᶜ	5.16 ᵇ	4.88 ᶜᵈ	5.12 ᶜᵈ
F6	5.52ᵇ	5.28ᶜᵈ	5.12ᶜᵈ	5.28 ᵇ	5.08 ᵇᶜ	4.76 ᵇ	4.76 ᶜᵈ	5.00ᶜᵈ
F7	5.28ᵇ	4.60ᶜᵈ	4.60ᵇᶜ	4.96 ᵇ	4.80 ᵇᶜ	4.68 ᵇ	4.64 ᶜᵈ	4.88ᶜ
F8	5.20ᵇ	3.80ᵃᵇ	4.20ᵇ	4.88 ᵇ	4.00ᵃ	3.80ᵃ	3.92ᵃᵇ	4.08ᵇ
F9	5.64ᵇ	5.16ᶜᵈ	4.48ᵇᶜ	5.24 ᵇ	5.00 ᵇᶜ	4.88 ᵇ	4.72 ᶜᵈ	5.16 ᶜᵈ

Note: Formula based on stabilizers (% CMC; % κ-carrageenan): F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%), F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), F9(0.075%;0.03%).

through polyelectrolyte brush of κ-casein. By the conformation, the core of micelle was grafted by the N-terminus of κ-casein. Meanwhile, the surface is governed by the C-terminus of κ-casein. The C terminus has a negative charge so that the micelle repels each other and is stabilized through electrostatic and steric stabilization mechanisms. Overheating induces casein dissociation in either the entire κ-casein or the C-terminus only. This makes casein susceptible to calcium activity in milk as well as forming casein coagulation. Meanwhile, the heating will also cause the denaturation of whey protein which will then interact with casein through an aggregation mechanism (McSweeney & Fox, 2013). From the explanation, the choice of sucralose as a sugar replacer is favorable considering the maintenance of temperature at 60 °C.

From Figure 4, the reduction of sugar by up to 37.04% can still be tolerated by the panelists. Replacement of sugar with isomalt and sucralose for all formulas did not change the values of all parameters significantly. However, decreased values for several parameters happened with sugar substitution, including homogeneity, taste, and sweetness, although it was not significant. The use of isomalt as a sugar substitute as well as a bulking agent seems to be able to maintain the physical characteristics of cocoa drinks such as viscosity, texture, and consistency.

As we know that the use of HIS without a bulking agent will have several effects, including mouthfeel. Commonly, consumers frequently describe diet or sugar-free beverages as 'thin' or 'watery' and many of these sensations are perceived as a negative. The use of isomalt as a bulking agent in beverages can restore mouthfeel. As shown in Figure 4 that S5 which maximum daily intake of isomalt can maintain mouthfeel as S1, the beverage with full sugar as a sweetener. It was proven that isomalt has other functions as bulking agent besides the function as a low-calorie sweetener. In addition, the combination of isomalt with a sucralose-based sweetener can reduce the weakness of sucralose in delivering sweet tastes that are slower in onset and longer in duration than the sweet taste from sucrose, and this characteristic introduces undesirable taste imbalances in products (Schiffman et al., 2007). From Figure 4, there was no significant difference in the sweetness parameter for all formulations. The combination of isomalt and sucralose provides a sweetness balance as well as sugar.

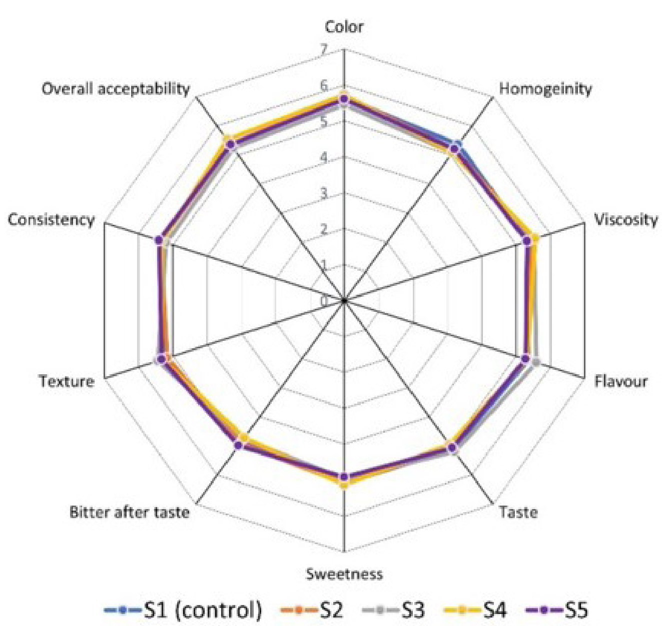

Figure 4. Sensorial properties of various formulas of reduced-sugar RTD cocoa beverages.

Table 6 showed that all reduced-sugar cocoa beverage formulas provided only a moderate reduction in calories. Even the formula S5 with maximum tolerable isomalt provides a calorie reduction of only 15.19%. This is because the basic formula S1 has a low-fat content, so the calorie reduction is only charged with reducing the sugar content without overriding the adverse effect of isomalt.

Although the use of isomalt is not able to reduce calories optimally because of its adverse effect, the calories contained in the beverage are close to other low-calorie drinks. As shown in Table 7, the calories in S5 are only 13.5% greater than the one leading trademark beverage A, and 45.2% different from the other leading trademark beverage B. Nevertheless, isomalt has properties as a bulking agent so it does not change the mouthfeel. Meanwhile, the use of HIS itself without the addition of bulking agent sweetener requires the use of excessive CMC as a stabilizer or the addition of other polysaccharides such as pectin or xanthan gum. Without the addition of hydrocolloids, the low-calorie beverage will seem watery. For industries whose products are already on the market but are still required by a calorie reduction policy, the use of a combination of low-calorie bulking agent sweetener and HIS can provide efficiency related to reformulation. In the future research, the additional sensory study based on consumer acceptance is essential to be conducted to evaluate how well the beverage is accepted by consumers.

Table 6. The percentage of reducing of calories of various reduced-sugar RTD cocoa beverages.

Formula	% Replacing of Sucrose	Calorie (kcal)/100 mL	% Reducing of Calorie
S1 (control)	0	57.78	-
S2	25	52.13	9.77
S3	30	50.87	11.96
S4	33.33	50.00	13.46
S5	37.04	49.01	15.19

Note: S1 (sucrose 100%), S2 (sucrose 75%, isomalt+sucralose 25%), S3 (sucrose 70%, isomalt+sucralose 30%), S4 (sucrose 66.67%, isomalt+sucralose 33.33%), S5 (sucrose 62.96%, isomalt+sucralose 37.04%).

Table 7. Comparison of sugar replacers and calories of reduced-sugar RTD cocoa beverage S5 and the leading trademark low-calorie cocoa beverages.

Product	% Reducing of Calorie	Sweeteners	Calorie (kcal/ 100 mL)
S5 (this research)	15.19	Sucrose, isomalt, sucralose	49.01
A (the leading trademark)	40	Acesulfame potassium, sucralose	42.37
B (the leading trademark)	60	Acesulfame potassium, sucralose	33.76

Approximately 100-200 untrained volunteers can be asked about their judgment of sensory preference and desire in purchasing (Lima et al., 2021; Galvão et al., 2022).

4 Conclusions

The development of the reduced-sugar RTD cocoa beverage was successfully conducted in two steps which were initiated by optimization of stabilizers concentration using κ-carrageenan and CMC. In the first step, the beverage which was fully sweetened by sugar was varied its CMC and κ-carrageenan concentration into some formulas, including F0(0%;0%), F1(0.025%;0.01%), F2(0.025%;0.02%), F3(0.025%;0.03%), F4(0.05%;0.01%), F5(0.05%;0.02%), F6(0.05%;0.03%), F7(0.075%;0.01%), F8(0.075%;0.02%), F9(0.075%;0.03%). By considering some parameters, such as sedimentation, rheology, color, and sensorial properties, the formula F5 was chosen as the preferred formula, then it was used as a basic formula in a later step in which reducing sugar using sugar replacers, i.e., isomalt and sucralose was optimized. The laxative threshold of isomalt, accompanied by Acceptance of Daily Intake (ADI) of sucralose became a consideration in determining sugar replacer concentration. Based on the organoleptic test, it can be concluded that the formula F5 that sugar content was reduced until the portion of 37.04% could still be tolerable. Its calorie content which was approximately 49.01 kcal/100 mL implies that the formula can be aligned with the leading trademark low-calorie cocoa beverage because the calories were insignificantly different.

Abbreviations

RTD: ready-to-drink.

CMC: carboxymethyl cellulose. κ-carrageenan: kappa-carrageenan.

HIS: high-intensity sweetener.

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