EFFECT OF HYDROCOLLOIDS AT DIFFERENT CONCENTRATIONS ON THE PHYSICOCHEMICAL PROPERTIES AND PARTICLE SIZE DISTRIBUTION OF WHITE CHOCOLATE GANACHE

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ABSTRACT - *The effect of the addition of hydrocolloids (carrageenan, pectin, and xanthan gum) at different concentrations (0.1%, 0.3%, and 0.5%) on the chemical properties (pH, moisture content, water activity, and total soluble solid), emulsion stability, viscosity (consistency and flow behavior index) and the particle size distribution of white chocolate ganache was investigated. The white chocolate ganache without adding any hydrocolloids was used as a control. The addition of hydrocolloids does not affect on the pH and total soluble solid of white chocolate ganache compared to control. However, depending on the concentrations used, hydrocolloids lower the moisture content and water activity of white chocolate ganache and effectively enhance their emulsion stability (98%-99%). White chocolate ganache added with hydrocolloids became significantly thicker and less Newtonian than the control. A low concentration of carrageenan and pectin had a desirable majority particle size (below 30 µm) of white chocolate ganache. Apart from that, a large particle size of white chocolate ganache (70 µm-115.0 µm) was obtained by adding xanthan gum from the lowest to the highest concentrations. The results suggested that the addition of carrageenan at a low concentration (0.1%) is the most effective to improve the chemical, emulsion stability, viscosity, and particle size distribution of white chocolate ganache*.

Key words: White chocolate ganache, hydrocolloids, chemical, emulsion stability, viscosity and particle size distribution.

INTRODUCTION

Ganache is commonly used as a filling for truffles and praline chocolates, glazes, or pastry (McGill and Hartel, 2018). Butter or sugar also can be incorporated into the ganache recipe to obtain different textures (Merachli *et al.,* 2021). Ganache is a mixture of chocolate and dairy milk, usually cream. Ganache is considered an emulsion due to the complex mix of at least two immiscible liquids (aqueous and fat phases formed between cream and chocolate) in which the droplets of one phase are dispersed in another phase (Saglio *et al.,* 2018). Once formed under mechanical shear, emulsions are stabilized by adding hydrocolloid to prevent instabilities such as Ostwald ripening (the growth of large oil droplets by the uptake of small oil molecules in the aqueous system), phase separation, aggregation, and coalescence (Costa *et al.,* 2019; McClements, 2007).

Generally, hydrocolloids can act as emulsifying agents and emulsion stabilizing agents in food products (Dickinson, 2009). Several hydrocolloids such as carrageenan, xanthan gum and, pectin were incorporated into the dairy products (acidified milk, cheese, ice cream, and yogurt) by interacting with proteins, particularly casein micelles from milk-based ingredients and polysaccharide chains (hydrocolloid) to improve their physical, rheology, stability, and sensory properties (Yousefi and Jafari, 2019). The addition of hydrocolloids at appropriate concentrations improved the rheological and textural characteristics of chocolates (Aidoo *et al.,* 2014; Syafiq *et al.,* 2014; Amir *et al.,* 2013) and chocolate-based confections (Bascuas *et al.,* 2021; Sikora *et al.,* 2003) and beverages (Godoi *et al,.* 2021; da Silva *et al.,* 2017). Although ganache is a popular confection produced for over 150 years, very little scientific research has been published about the roles of hydrocolloids in the chemical and physical properties of chocolate ganache systems. The existing literature touches on incorporating hydrocolloids in the rheological behaviors (flow and consistency index) of reduced-fat chocolate fillings using skimmed milk (Dias *et al.,* 2017; Dias *et al.,* 2015). However, none focuses on the water activity and physical characterization in terms of stability and particle size distribution of white chocolate ganache added with selected hydrocolloids. The aim of this study was to evaluate the influence of different food hydrocolloids (carrageenan, pectin, and xanthan gum) at different concentrations (0.1%, 0.3%, and 0.5%) on the physicochemical properties (pH, moisture, water activity, total soluble solid, emulsion stability, and viscosity) and particle size distribution of white chocolate ganache.

MATERIALS AND METHODS

Materials

White chocolate couverture pellets (Callebaut), unsalted cow butter and whipped cream (Anchor), inverted sugar (Trimoline) and hydrocolloids (carrageenan, pectin and xanthan gum) were purchased from Bake with Yen, Nilai, Negeri Sembilan, Malaysia.

Preparation of white chocolate ganache incorporated with different hydrocolloids

The formulation of white chocolate ganache incorporated with different hydrocolloids was developed according to Saglio *et al.* (2018) and Dias *et al.* (2018) with a few modifications. The formulations are presented in Table 1. The preparation of white chocolate ganache started with heating up the inverted sugar and whipped cream to 80°C by using a hot plate. After reaching 80°C, white chocolate was poured into the hot cream mixtures. Then, butter was added to the white chocolate-cream mixtures. Finally, each hydrocolloid was added into the white chocolate emulsion mixtures and mixed well (Sahin and Ozdemir, 2004). The emulsion system added with hydrocolloids (except control formulation) was homogenized with IKA T25 digital homogenizer (Ultra Turrax, Germany) at 11500 rpm for 30 s. Finally, white chocolate ganache was poured into the plastic container and stored in the chiller (4°C-5°C) for physicochemical and particle size distribution analysis.

Table 1: Formulations of white chocolate ganache incorporated with hydrocolloids at different concentrations

Ingredients (g)		**Carrageenan (%)**			**Pectin (%)**			**Xanthan gum (%)**		
	Control	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
White chocolate	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Whipped cream	35.0	34.9	34.7	34.5	34.9	34.7	34.5	34.9	34.7	34.5
Unsalted cow butter	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Inverted sugar	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Hydrocolloid	-	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5

Moisture content

Moisture content was analyzed according to the Finished Cocoa Products Analysis (Malaysian Cocoa Board, 2010) with modification by increasing the drying time. The moisture content of white chocolate ganache was calculated according to the equation:

$$\text{Moisture content (\%)} = (W_2 - W_3) / (W_2 - W_1) \times 100.$$

Where: W_1 represents the weight of moisture dish (g), W_2 represents the weight of white chocolate ganache and moisture dish (g) before drying, and W_3 represents the measured weight of dried white chocolate ganache and moisture dish (g) after drying.

pH

The pH of the ganache sample was measured according to the Manual of Finished Cocoa Products Analysis (Malaysian Cocoa Board, 2010). The pH of the sample was measured using calibrated pH meter (Eutech Instruments pH 2700).

Total soluble solid

Approximately 5 g of white chocolate ganache was mixed with 10 ml of water to determine the total soluble solid, measured as °Brix (Kim *et al.*, 2017). The diluted and filtered white chocolate ganache samples were measured six times using a refractometer (Aichose, China) at 20°C.

Water activity

Water activity (a_w) of white chocolate ganache was measured at 25°C using a water activity meter (Aqualab, USA). The measurement for each white chocolate sample was taken three times (Saglio *et al.*, 2018).

Emulsion stability

The emulsion stability of white chocolate ganache samples was observed based on the methods described by Hosseini *et al.* (2015). The sample was melted at 50°C for 20 min before observation. Ganache samples (approximately 30 g) were centrifuged at 2000 rpm for 10 min at 25°C using a refrigerated microcentrifuge (Eppendorf AG, Hamburg, Germany), and the supernatant (fat phase) was separated carefully. After the centrifugation, the samples were weighed. The following equation was used for the calculation of the emulsion stability:

$$ES(\%) = \frac{E1}{E0} \times 100,$$

where E0 and E1 are the weights before and after the centrifugation of the white chocolate ganache, respectively.

Viscosity

The viscosity properties (consistency index and flow behavior index) of white chocolate ganache added with different hydrocolloids were carried out by a HADV-II+Pro viscometer (Brookfield, USA) according to Dias *et al.* (2017; 2015). The equipment was operated at room temperature (20°C). The viscosity readings were measured in quintuplicate (n=5). The consistency index and flow behavior index of white chocolate ganache samples were evaluated according to the rheological model of Ostwald, also referred to as the Power-law model to obtain the flow curves (Dias *et al.*, 2017; Dias *et al.*, 2015).

Particle size distribution

The particle size distribution of white chocolate ganache incorporated with different hydrocolloids was analyzed using a Mastersizer 3000 laser particle size analyzer (Malvern Instruments Ltd., Malvern, England) equipped with a dispersion unit controller and sample dispersion unit according to the method described by Ramli and Ying (2011). Ganache sample (0.2 g) was dispersed in a beaker filled with 20 ml of distilled water. The sample was diluted 100-fold with distilled water before measurement. A diluted ganache sample was added slowly into the sample dispersion unit containing distilled water at ambient temperature until an obscuration of 15% was attained. The unit stirred at 3000 rpm to maintain the dispersion throughout the measurements. Software (Malvern MasterSizer Micro) was used to quantify the majority particle size diameter (D90), mean particle volume (D50), and the smallest particle size (D10) of white chocolate ganache (Malvern-Panalytical, 2013). The particle size diameter was reported in µm.

Statistical analysis

All experimental results were conducted in triplicate and expressed as mean ± standard deviation. The statistical analyses were carried out using SAS (Statistical Analytical System) software version 9.1. Data were analyzed by an analysis of variance (ANOVA) at a 95% confidence level to find any significant difference ($p < 0.05$) between the sample means.

RESULTS AND DISCUSSIONS

Chemical properties of white chocolate ganache added with different hydrocolloids

The chemical properties (pH, moisture, water activity, and total soluble solid) of white chocolate ganache added with different types and concentrations of hydrocolloids and control (white chocolate ganache without hydrocolloids) are shown in Table 2. One-way ANOVAs found insignificant differences ($p > 0.05$) between the means for pH and °Brix for all white chocolate ganache samples.

Table 2: Chemical properties of white chocolate ganache incorporated with different types and concentrations of hydrocolloids

Hydrocolloid	Concentration (%)	pH	Moisture (%)	Water activity (a_w)	Total soluble solid (°Brix)
Control	0	6.71 ± 0.01^a	20.13 ± 0.09^b	0.73 ± 0.00^a	69.00 ± 0.71^a
Carrageenan	0.1	6.70 ± 0.00^a	19.22 ± 0.14^d	0.71 ± 0.00^c	69.00 ± 0.71^{ab}
	0.3	6.71 ± 0.01^a	19.87 ± 0.07^c	0.72 ± 0.00^b	68.00 ± 0.00^a
	0.5	6.71 ± 0.00^a	20.92 ± 0.04^a	0.73 ± 0.00^a	68.00 ± 0.00^{ab}
Pectin	0.1	6.71 ± 0.00^a	18.96 ± 0.11^d	0.70 ± 0.00^d	68.50 ± 0.71^{ab}
	0.3	6.71 ± 0.00^a	18.35 ± 0.23^e	0.71 ± 0.00^c	68.50 ± 0.71^{ab}
	0.5	6.72 ± 0.02^a	17.94 ± 0.11^f	0.73 ± 0.00^a	68.50 ± 0.71^{ab}
Xanthan gum	0.1	6.71 ± 0.01^a	17.32 ± 0.29^g	0.70 ± 0.00^d	68.50 ± 0.71^{ab}
	0.3	6.71 ± 0.01^a	17.97 ± 0.11^f	0.71 ± 0.00^c	69.00 ± 1.41^{ab}
	0.5	6.70 ± 0.00^a	20.36 ± 0.14^b	0.74 ± 0.01^a	68.50 ± 0.71^{ab}

$^{a-c}$ Mean values with similar superscript letters within the column are not significantly different ($p > 0.05$)

Results showed that adding hydrocolloids at different types and concentrations did not affect the pH and total soluble solid of white chocolate ganache. The present study found that the pH values (6.7-6.72) of white chocolate ganache samples are higher than the previous works by Dias *et al.* (2015; 2017; 2018) in reduced-fat and cream-based white chocolate fillings (pH ranged between 5.83-6.4) added with various types and concentrations of hydrocolloids (carrageenan, CMC, pectin, alginate, and xanthan gum), might be influenced by different ingredients (dairy milk, sugar, and butter) used in the ganache formulation. Janhøj *et al.* (2008) reported that the steric repulsive forces were stabilized between the positively charged casein micelles (pH 6.7 close to neutral pH) in the acidified milk drinks with negatively charged hydrocolloids. Furthermore, pectin, carrageenan, and xanthan gum are stable in acidic food applications to enhance the physical properties by producing the gel-like textural of the products (Galanakis, 2021; Baines and Seal, 2012). Meanwhile, all white chocolate ganache samples had similar ($p > 0.05$) total soluble solid (ranged between 69-68 °Brix). Total soluble solid (TSS) is related to the total solids mainly consisting of sugar (sucrose, fructose, and glucose) as well as other soluble solids like hydrocolloids and minerals (Magwaza and Opara, 2015). Sugar content higher than 65 °Brix inhibits microbial growth with intermediate levels of water activity during storage at room temperature (Miquelim *et al.*, 2011). It indicated that all white chocolate samples (with or without hydrocolloids) might have good shelf-life stability when stored at ambient temperature.

The moisture content of white chocolate ganache without hydrocolloid is 20.13%. Table 2 shows the moisture content (ranged from 17.32% to 19.87%) of white chocolate ganache added with carrageenan and xanthan gum at the maximum level of 0.3% are significantly lower ($p < 0.05$) than the control. However, the concentration of both hydrocolloids at 0.5% increased significantly ($p < 0.05$) the moisture content of white chocolate ganache compared to control. Calle *et al.* (2020) reported that the addition of xanthan gum (0.21%) increased the moisture content of gluten-free bread significantly compared to bread samples without hydrocolloid due to the high-water binding ability by hydrocolloid to retain water molecules. Meanwhile, the moisture content (from 18.96% to 17.94%) of white chocolate ganache decreased with the addition of pectin (from 0.1% to 0.5%) due to the increased amount of solid fraction from pectin thus, dehydration of total moisture occurs (Javanmard *et al.*, 2012). Overall, the moisture content of all white chocolate ganache samples (with or without the addition of hydrocolloid) obtained are inside the optimal range of moisture content (approximately 16%-25%) for the emulsion-based fillings like ganache (Wybauw and Croes, 2010).

Meanwhile, the water activity (a_w) of white chocolate ganache added with hydrocolloids increased (from 0.7 to 0.74) at different concentrations (from 0.1% to 0.5%), as shown in Table 2. Results showed that white chocolate ganache added with 0.5% hydrocolloids (pectin, carrageenan, and xanthan gum) contained the highest a_w ($p < 0.05$) compared to lower concentrations (0.1% and 0.3%). However, the a_w of the control sample is similar ($p > 0.05$) with the values obtained by white chocolate ganache added with 0.5% hydrocolloids. A similar finding by Yeganehzad *et al.* (2020) reported that a_w of fruit snack-based chocolate core coated with pectin (a_w from 0.42 to 0.53) and Persian gum (a_w from 0.43 to 0.53) increased at different concentrations (pectin: from 0.25% to 0.39% & Persian gum: from 1.5% to 2.0%). However, in this study, all white chocolate ganache samples had lower water activity values than other previous works for similar ganache products (Saglio *et al.*, 2018 & Dias *et al.*, 2018) within the range between 0.85 and 0.93. Dias *et al.* (2018) reported that high a_w over 0.8 contributed to the crack on the chocolate fillings, which causes a moisture loss during storage due to the interaction between the soluble solids and water. However, our observed values (a_w ranged between 0.7-0.74) are below those reported by Dias *et al.* (2018), which indicated that white chocolate ganache added with different hydrocolloids might be stable from moisture loss during storage based on the results of emulsion stability. The incorporation of hydrocolloids into chocolate products can prevent water and fat migration as well as microbial contamination (Gounga *et al.*, 2008). It can be concluded that hydrocolloids had a significant effect on the moisture content and water activity of white chocolate ganache, but their effect depended on the concentration of hydrocolloids.

Physical properties of white chocolate ganache added with different hydrocolloids

The physical properties (emulsion stability and viscosity) of white chocolate ganache added with different types and concentrations of hydrocolloids and control (white chocolate ganache without hydrocolloids) are shown in Table 3.

Different types and concentrations of hydrocolloids significantly increased ($p < 0.05$) the emulsion stability (above 98%) of the white chocolate ganache compared to control (75.97%), as shown in Table 3. Pectin, xanthan gum, and carrageenan are commonly used hydrocolloids to improve the physical stability in the different types of emulsion systems (rice bran oil-in-water emulsion, walnut-protein/xanthan gum mixtures, and whey protein isolate-based emulsion) (Matsuyama *et al.*, 2021; Cai *et al.*, 2018; Piriyaprasarth *et al.*, 2016) and low-fat yogurt (Nguyen *et al.*, 2017). Results showed that white chocolate ganache added with carrageenan and pectin at the concentrations of 0.1% and 0.3% obtained the highest emulsion stability ($p < 0.5$) among all samples studied. However, the highest concentration (0.5%) of pectin and xanthan gum significantly lower ($p < 0.05$) the emulsion stability of the white chocolate ganache than smaller concentrations (0.1% and 0.3%). Meanwhile, higher concentrations of xanthan gum (from 0.1% to 0.5%) decreased the emulsion stability of white chocolate ganache.

Table 3: Emulsion stability and viscosity properties of white chocolate ganache incorporated with different types and concentrations of hydrocolloids

Hydrocolloid	Concentration (%)	Emulsion stability (%)	Consistency K ($Pa.s^n$)	Flow behaviour index (n)
Control	0	75.97 ± 0.36^e	51.34 ± 3.49^h	0.72 ± 0.06^a
Carrageenan	0.1	99.46 ± 0.4^a	65.35 ± 1.24^g	0.55 ± 0.05^b
	0.3	99.92 ± 0.06^a	74.60 ± 3.2^f	0.39 ± 0.04^c
	0.5	98.9 ± 0.00^b	82.64 ± 11.49^e	0.30 ± 0.00^d
Pectin	0.1	99.46 ± 0.18^a	82.09 ± 8.54^e	0.36 ± 0.05^d
	0.3	99.77 ± 0.08^a	106.88 ± 7.02^d	0.20 ± 0.02^e
	0.5	98.97 ± 0.14^c	151.21 ± 25.45^c	0.15 ± 0.03^f
Xanthan gum	0.1	98.95 ± 0.06^{bc}	159.37 ± 25.12^c	0.16 ± 0.04^f
	0.3	98.56 ± 0.49^{cd}	239.43 ± 14.42^b	0.01 ± 0.08^g
	0.5	98.10 ± 0.1^d	375.73 ± 15.5^a	0.02 ± 0.01^g

[a-c] Mean values with similar superscript letters within the column are not significantly different ($p > 0.05$)

It can be suggested that the addition of the appropriate amount of hydrocolloids could stabilize the oil-in-water emulsion system mainly contributed by the interactions between the positively charged protein (to absorb oil droplets) with the negatively charged polysaccharide (hydrocolloid) that can form a compact interfacial layer (Liu *et al.*, 2016; Piriyaprasarth *et al.*, 2016). Furthermore, excess hydrocolloid concentration might lead to the highly porous and shrinkage of the casein network that forms sedimentation (Sanchez *et al.*, 2000). Therefore, low concentrations at 0.1% and 0.3% of hydrocolloids improved the emulsion stability of white chocolate ganache.

According to the Power Law model, Table 3 represents the consistency (K) and flow behavior index (n) of white chocolate ganache added with different hydrocolloids and control. The control sample exhibited a rheological performance close to Newtonian fluid (n=0.72) and consistency (K=51.34 $Pa.s^n$). However, white chocolate ganache added with hydrocolloids became significantly thicker (ranged between K=65.35 $Pa.s^n$-375.73 $Pa.s^n$) and less Newtonian (ranged between n=0.55-0.02) than the control sample. Furthermore, white chocolate ganache added with hydrocolloids presented shear-thinning fluid behavior or pseudo-plasticity (Fagbenle *et al.*, 2020). Previous authors reported similar results on the chocolate products added with different hydrocolloids like low-fat chocolate fillings (Dias *et al.*, 2015 and 2017), cocoa syrup (Sikora *et al.*, 2003), and chocolate milk beverages (Godoi *et al.*, 2021; Zhu *et al.*, 2020; Kabirian *et al.*, 2015; Eduardo *et al.*, 2014). Based on the results, the consistency of white chocolate ganache increased significantly ($p < 0.05$) with higher concentrations of each hydrocolloid (from 0.1% to 0.5%). At a similar range of concentrations, the flow behavior index of white chocolate ganache decreased gradually ($p < 0.05$), thereby increasing the viscosity. The overall increase in the viscosity of white chocolate ganache added with hydrocolloids are due to the reaction with calcium ions from milk-based ingredients used in the formulation to form a stronger emulsion network with hydrocolloids (Phillips and Williams, 2009; Yanes *et al.*, 2002a). In addition, the bound water agglomerated with sugar particles to form a grainy texture, thus increasing the resistance to flow or thickening of the sample (Afoakwa *et al.*, 2007; Abbasi and Rahimi, 2006). Phillips and Williams (2000) stated that the emulsion system incorporated with hydrocolloids exhibits thickening properties above excess concentration, showing a non-Newtonian fluid behavior. The addition of xanthan gum at different concentrations showed the highest increase ($p < 0.05$) on the viscosity of white chocolate ganache, followed by pectin and carrageenan. However, xanthan gum enhanced the flocculation of oil droplets to form a three-dimensional network, fast creaming and entangled with itself (Galanakis, 2021; McClements, 2000). Based on the result, white chocolate ganache added with xanthan gum (0.3%-0.5%) observed an almost zero Newtonian fluid due to the depletion flocculation mechanism in the emulsion system. Bai *et al.* (2017) reported that a high concentration of pectin added in beverage emulsions is vulnerable to depletion flocculation. Therefore, carrageenan is the most suitable hydrocolloid to improve the viscosity of the white chocolate ganache.

Particle size distribution of white chocolate ganache added with different hydrocolloids

The particle size of the white chocolate ganache added with different hydrocolloids was characterized as shown in Table 4. The addition of hydrocolloids increased significantly ($p < 0.05$) the majority particle size diameter (D90), mean particle volume (D50), and the smallest particle size (D10) of white chocolate ganache compared to control.

Table 4: Particle size distribution of white chocolate ganache incorporated with different types and concentrations of hydrocolloids

Hydrocolloid	Concentration (%)	D10 (µm)	D50 (µm)	D90 (µm)
Control	0	1.13 ± 0.03^{i}	6.09 ± 0.06^{g}	15.07 ± 0.25^{i}
Carrageenan	0.1	1.28 ± 0.00^{h}	6.43 ± 0.12^{f}	16.13 ± 0.25^{h}
	0.3	3.84 ± 0.06^{a}	11.53 ± 0.06^{d}	25.87 ± 0.45^{f}
	0.5	3.18 ± 0.04^{c}	11.6 ± 0.1^{d}	29.27 ± 0.21^{e}
Pectin	0.1	2.95 ± 0.09^{d}	10.06 ± 0.12^{de}	22.27 ± 0.21^{g}
	0.3	1.94 ± 0.06^{g}	8.87 ± 0.17^{e}	30.33 ± 1.68^{e}
	0.5	2.34 ± 0.06^{f}	11.37 ± 0.12^{d}	38.63 ± 0.32^{d}
Xanthan gum	0.1	3.01 ± 0.21^{cd}	14.1 ± 1.4^{c}	73.6 ± 0.44^{c}
	0.3	3.61 ± 0.12^{b}	21.07 ± 2.17^{b}	78.47 ± 1.16^{b}
	0.5	2.65 ± 0.15^{e}	24.47 ± 2.29^{a}	115.00 ± 0.25^{a}

$^{a\text{-}c}$ Mean values with similar superscript letters within the column are not significantly different ($p > 0.05$)

A previous study by Godoi *et al.* (2021) also showed that protein-based hydrocolloids (gelatine, collagen hydrolysate, and microparticulated whey) increase the particle sizes (up to 40 µm) of low-fat chocolate-flavored milk compared to the control sample without the addition of hydrocolloids. The particle size distribution is one of chocolate's main physical and rheological properties (Barišić *et al.*, 2021; Yeganehzad et al., 2020). Results showed that the majority particle size (D90) of control, white chocolate ganache added with carrageenan (0.1%-0.5%) and pectin (0.1%) were lower than 30 µm. Bisig (2011) and Beckett (2009) stated that the desired particle size for chocolate products is approximately 17-30 µm which is toward the pleasant mouth feeling (Ziegler *et al.*, 2001). However, a larger particle size diameter than 30 µm has a gritty texture, indicating a low quality of chocolate (Bisig, 2011). In addition, the particle size of more than 35 µm contributed to a grainy or coarse in the mouth resulting in lower sensory acceptability (Puleo *et al.*, 2020). Based on those previous studies, the addition of pectin (0.3%-0.5%) and xanthan gum (0.1%-0.5%) increased the majority size of the particles (more than 30 µm) in the white chocolate ganache. The addition of xanthan gum at different concentrations increased sharply ($p < 0.05$) the majority particle size of white chocolate ganache (73.6 µm-115.0 µm), giving the undesirable effect on the physical properties of the white chocolate ganache. These results are in good agreement with previous work by Pang *et al.* (2020) found that acid soymilk gel added with 0.1% xanthan gum obtained a higher particle size (more than 59 µm) than sample containing 0.1% carrageenan (42 µm), indicating better compatibility of soy proteins with carrageenan compared to xanthan gum. Therefore, the addition of carrageenan at all concentrations (0.1%-0.5%) obtained the particle size distribution of white chocolate ganache under 30 µm compared to other hydrocolloids.

CONCLUSIONS

Effect of hydrocolloids (carrageenan, pectin, and xanthan gum) at different concentrations (0.1%, 0.3%, and 0.5%) on the chemical (pH, total soluble solid, water activity, and moisture content), emulsion stability, viscosity (consistency and flow behavior index) and particle size distribution of white chocolate ganache have been examined. Results showed that the total soluble solid and pH of white chocolate ganache are not influenced by adding different types and concentrations of hydrocolloids. Meanwhile, the addition of pectin, carrageenan, and xanthan gum at a certain concentration (0.1%-0.3%) decreased the moisture content significantly and water activity of white chocolate ganache compared to the control sample without hydrocolloids. In the meantime, interactions between the negatively charged hydrocolloids with positively charged milk protein stabilize the emulsion system of white chocolate ganache by forming a compact interfacial layer. Regarding physical properties, white chocolate ganache added with hydrocolloids became significantly thicker and less Newtonian than the control sample resulting from the reaction of calcium-ion with calcium-sensitive hydrocolloids to increase the resistance flow of the sample. On the other hand, carrageenan and pectin increased the majority particle size diameter of white chocolate ganache below 30 µm. Furthermore, an increase in the concentration of xanthan gum showed a negative effect on the particle size of white chocolate ganache in the range of 70 µm-115.0 µm. It can be concluded that the addition of hydrocolloids at less than the concentration of 0.3% had better emulsion stability, lower moisture content and water activity, thicker and larger particle size distribution of white chocolate ganache than the control sample without hydrocolloids.

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REFERENCES

Abbasi, S. and Rahimi, S. (2006). Influence of concentration, temperature, pH, and rotational speed on the flow behavior of Iranian gum tragacanth (*Katira*) solution. *Scientific Information Database*, **2:** 29-42.

Afoakwa, E.O., Paterson, A. and Fowler, M. (2007). Factors influencing rheological and textural qualities in chocolate – a review. *Trends Food Sci. Technol.* **18:** 290-298.

Aidoo, R.P., Afoakwa, E.O. and Dewettinck, K. (2014). Rheological properties, melting behaviours and physical quality characteristics of sugar-free chocolates processed using inulin/ polydextrose bulking mixtures sweetened with stevia and thaumatin extracts. *LWT - Food Sci. Technol*. **62:** 592-597.

Amir, I.Z., Sharon, W.X.R. and Syafiq, A. (2013). D-Optimal mixture design on melting and textural properties of dark chocolate as affected by cocoa butter substitution with Xanthan gum/Guar gum blends. *Int. Food Res. J.* **20:** 1991-1995.

Bai, L., Liu, F., Xu, X., Huan, S., Gu, J. and McClements, D.J. (2017). Impact of polysaccharide molecular characteristics on viscosity enhancement and depletion flocculation. *J. Food Eng.* **207:** 35–45.

Baines, D. and Seal, R. (2012). *Natural Food Additives, Ingredients and Flavourings*. 1st ed. Sawston. Woodhead Publishing Series.

Barišić, V., Petrović, J., Lončarević, I., Flanjak, I., Šubarić, D., Babić, J., Miličević, B., Doko, K., Blažić, M. and Ačkar, D. (2021). Physical properties of chocolates enriched with untreated cocoa bean shells and cocoa bean shells treated with high-voltage electrical discharge. Sustainability, **13:** 2620.

Bascuas, S., Espert, M., Llorca, E., Quiles, A., Salvador, A. and Hernando, I. (2021). Structural and sensory studies on chocolate spreads with hydrocolloid-based oleogels as a fat alternative. *LWT - Food Sci. Technol*. **135:** 110228.

Beckett, S.T., (2009). *Industrial Chocolate Manufacture and Use*. 4th ed. New Jersey. Blackwell Publishing Ltd.

Bisig, W. (2011). *Encyclopedia of Dairy Sciences.* 2nd ed. Massachusetts. Academic Press.

Cai, Y., Deng, X., Liu, T., Zhao, M., Zhao, Q. and Chen, S. (2018). Effect of xanthan gum on walnut protein/xanthan gum mixtures, interfacial adsorption, and emulsion properties. *Food Hydrocoll*. **79:** 391-398.

Calle, J., Benavent-Gil, Y. and Rosell, C.M. (2020). Influence of the use of hydrocolloids in the development of gluten-free breads from *Colocasia esculenta* flour. *Proc.* **53:** 6.

Costa, C., Medronho, B., Filipe, A., Mira, I., Lindman, B., Edlund, H. and Norgren, M. (2019). Emulsion formation and stabilization by biomolecules: The leading role of cellulose. *Polymers (Basel),* **11:** 1570.

Dias, J., Coelho, P., Alvarenga, N.B., Duarte, R.V. and Saraiva, J.A. (2018). Evaluation of the impact of high pressure on the storage of filled traditional chocolates. *Innov. Food Sci. Emerg. Technol.* **45:** 36-41.

Dias, J., Alvarenga, N. and Sousa, I. (2017). Shelf-life of reduced-fat white chocolate fillings using iota-carrageenan. *Emir. J. Food Agric*. **29:** 893-898.

Dias, J., Alvarenga, N. and Sousa, I. (2015). Effect of hydrocolloids on low-fat chocolate fillings. *J. Food Sci. Technol.* **52:** 7209-7217.

Dickinson, E. (2009). Hydrocolloids as emulsifiers and emulsion stabilizers. *Food Hydrocoll.* **23:** 1473–1482.

Eduardo, M.F., Correa De Mello, K.G.P., Polakiewicz, B. and Da Silva Lannes, S.C. (2014). Evaluation of chocolate milk beverage formulated with modified chitosan. *J. Agr. Sci. Tech.* **16:** 1301-1312.

Fagbenle, R.O., Amoo, O.M., Aliu, S. and Falana, A. (2020). *Applications of Heat, Mass and Fluid Boundary Layers*. Sawston. Woodhead Publishing.

Galanakis, C. (2021). *Food Structure and Functionality*. 1st ed. Massachusetts. Academic Press.

Godoi, F.C., Ningtyas, D.W., Geoffroy, Z. and Prakash, S. (2021). Protein-based hydrocolloids: Effect on the particle size distribution, tribo-rheological behaviour and mouthfeel characteristics of low-fat chocolate flavoured milk. *Food Hydrocoll*. **115:** 106628.

Gounga, M.E., Xu, S.-Y. And Wang, Z. (2008). Nutritional and microbiological evaluations of chocolate-coated Chinese chestnut (*Castanea mollissima*) fruit for commercial use. *J. Zhejiang Univ. Sci. B.* **9:** 675–683.

Hosseini, A., Jafari, S.M., Mirzaei, H., Asghari, A. and Akhavan, S., (2015). Application of image processing to assess emulsion stability and emulsification properties of Arabic gum. *Carbohydr. Polym*. **126**: 1–8.

Janhøj, T., Frøst, M.B. and Ipsen, R. (2008). Sensory and rheological characterization of acidified milk drinks. *Food Hydrocoll*. **22**: 798-806.

Javanmard, M., Chin, N. L., Mirhosseini, S. H. and Endan, J. (2012). Characteristics of gelling agent substituted fruit jam : studies on the textural, optical, physicochemical and sensory properties. *Int. J. Food Sci. Technol.* **47:** 1808–1818.

Kabirian, M., Salehi, E.A. and Noghabi, M.S. (2015). Investigation on the effect of carboxymethyl cellulose and carrageenan on the rheological, physicochemical and sensory characteristics of chocolate drink powder. *J. Appl. Environ. Biol. Sci*. **4:** 165-173.

Kim, S.M., Woo, J.H., Kim, H.W. and Park, H.J. (2022). Formulation and evaluation of cold-extruded chocolate ganache for three-dimensional food printing. *J. Food Eng*. **314:** 110785.

Kim, Y.J., Kang, S., Kim, D.H., Kim, Y.J., Kim, W.R., Kim, Y.M. and Park, S. (2017). Calorie reduction of chocolate through substitution of whipped cream. *J. Ethn. Foods,* **4:** 51-57.

Liu, K., Stieger, M., van der Linden, E. and van de Velde, F. (2016). Tribological properties of rice starch in liquid and semi-solid food model systems. *Food Hydrocoll*. **58:** 184-193.

Magwaza, L.S. and Opara, U.L. (2015). Analytical methods for determination of sugars and sweetness of horticultural products - A review. *Sci. Hortic*. **184:** 179–192.

Malvern-Panalytical (2013). Mastersizer 3000. https://www.malvernpanalytical.com/en /products/product-range/mastersizer-range/mastersizer-3000.

Matsuyama, S., Kazuhiro, M., Nakauma, M., Funami, T., Nambu, Y., Matsumiya, K. and Matsumura, Y. (2021). Stabilization of whey protein isolate-based emulsions via complexation with xanthan gum under acidic conditions. *Food Hydrocoll*. **111:** 106365.

McClements, D. (2000). Comments on viscosity enhancement and depletion flocculation by polysaccharides. *Food Hydrocoll*. **14:** 173-177.

McClements, D.J. (2007). Critical review of techniques and methodologies for characterization of emulsion stability. *Crit. Rev. Food Sci. Nutr.* **47**: 611–649.

McGill, J. and Hartel, R.W. (2018). Investigation into the microstructure, texture and rheological properties of chocolate ganache. *J. Food Sci*. **83:** 689-699.

Merachli, F., Devienne, J., Delmas, R., Plawinski, L., Leal-Calderon, F. and Delample, M. (2021). Impact of cocoa fibers on the stability and rheological properties of chocolate ganaches. *LWT - Food Sci. Technol*. **139:** 110505.

Miquelim, J.N., Alcântara, M.R. and Lannes, S.C.D.S. (2011). Stability of fruit bases and chocolate fillings. *Cienc. Tecnol. Aliment., Campinas,* **31:** 270-276.

Nguyen, P.T.M., Kravchuk, O., Bhandari, B. and Prakash, S. (2017). Effect of different hydrocolloids on texture, rheology, tribology and sensory perception of texture and mouthfeel of low-fat pot-set yoghurt. *Food Hydrocoll*. **72:** 90-104.

Pang, Z., Luo, Y., Li, B., Zhang, M. and Liu, X. (2020). Effect of different hydrocolloids on tribological and rheological behaviors of soymilk gels. *Food Hydrocoll*. **101:** 105558.

Phillips, G. O. and Williams, P. A. (2009*). Handbook of hydrocolloids*. 2nd ed. Chichester. Woodhead Publishing.

Phillips, G. O. and Williams, P. A. (2000). *Handbook of hydrocolloids*. 1st ed. Boca Raton. CRC Press.

Piriyaprasarth, S., Juttulapa, M. and Sriamornsak, P. (2016). Stability of rice bran oil-in-water emulsions stabilized by pectin-zein complexes: Effect of composition and order of mixing. *Food Hydrocoll*. **61:** 589-598.

Puleo, S., Miele, N. A., Cavella, S., Masi, P. and Di Monaco, R. (2020). How sensory sensitivity to graininess could be measured? *J. Texture Stud.* **51:** 242–251.

Ramli, N. and Ying, F.S. (2011). Effect of super olein and sunflower oil on the rheological properties of chocolate syrup. *Sains Malays*. **40:** 359-367.

da Salvia, B.P., da Silva, P.P., Augusto, M.M.M., de Garim, M.M. and Caetano, N.R. (2017). Analysis of the influence of hydrocolloids and whey in pasteurized chocolate dairy drink. *Rev. Eng. Tecnol*. **9:** 278-291.

Saglio, A., Bourgeay, J., Socrate, R., Canette, A. and Cuvelier, G. (2018). Understanding the structure of ganache: Link between composition and texture. *Int. J. Gastron. Food Sci.* **13:** 29-37.

Sahin, H. and Ozdemir, F. (2004). Effect of some hydrocolloids on the rheological properties of different formulated ketchups. *Food Hydrocoll*. **18**: 1015–1022.

Sanchez, C., Zuniga-Lopez, R., Schmitt, C., Despond, S. and Hardy, J. (2000). Microstructure of acid-induced skim milk-locust bean gum-xanthan gels. *Int. Dairy J.* **10:** 199-212.

Sikora, M., Juszczak, L. and Sady, M. (2003). Hydrocolloids in forming properties of cocoa syrups. *Int. J. Food Prop*. **6:** 215–228.

Syafiq, A., Amir, I.Z. and Sharon, W.X.R. (2014). Mixture experiment on rheological properties of dark chocolate as influenced by cocoa butter substitution with xanthan gum/corn starch/ glycerin blends. *Int. Food Res.* J. **21:** 1887-1892.

Wybauw, J.-P. and Croes, F. (2010). *Fine Chocolates Great Experience 3, Extending Shelf Life*. Ist ed. Germany. Lannoo Publishing.

Yanes, M., Durán L. and Costell, E. (2002). Effect of hydrocolloid type and concentration on flow behaviour and sensory properties of milk beverages model systems. *Food Hydrocoll*. **16:** 605-611.

Yeganehzad, S., Kiumarsi, M., Nadali, N. and Ashkezary, M.R. (2020). Formulation, development and characterization of a novel functional fruit snack based on fig (*Ficus carica* L.) coated with sugar-free chocolate. *Heliyon* **6:** e04350.

Yousefi, M. and Jafari, S.M. (2019). Recent advances in application of different hydrocolloids in dairy products to improve their techno-functional properties. *Trends Food Sci. Technol.* **88:** 468–483.

Zhu, Y., Bhandari, B. and Prakash, S. (2020). Relating the tribo-rheological properties of chocolate flavoured milk to temporal aspects of texture. *Int. Dairy J.* **110:** 104794.

Ziegler, G.R., Mongia, G. and Hollender, R. (2001). Role of particle size distribution of suspended solids in defining the sensory properties of milk chocolate. *Int. J. Food Prop*. **4:** 175–192.