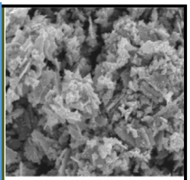
JOBIMB, 2024, Vol 12, No 1 SP1, 35-38
https://doi.org/10.54987/jobimb.v12iSP1.936

HIBISCUS PUBLISHER

JOURNAL OF BIOCHEMISTRY, MICROBIOLOGY AND BIOTECHNOLOGY

Website: http://journal.hibiscuspublisher.com/index.php/JOBIMB/index



JOBIMB VOL 12 NO 1 SP1 2024
COCONUT ZnO NP FESEM

Effects of Polyglycerol Polyriconoleate (PGPR) as Partial Substitute of Cocoa Butter and Lecithin on Rheology and Shelf Life of Chocolate Glaze

Norhayati Hussain[1, 2]*, Wong Pei Er[2] and Komati Rajentran[2]

[1]Halal Products Research Institute, Universiti Putra, Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[2]Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra, Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

*Corresponding author:
Assoc. Prof. Dr. Norhayati Hussain,
Department of Food Technology,
Faculty of Food Science and Technology,
Universiti Putra, Malaysia,
43400 UPM Serdang,
Selangor,
Malaysia.
Email: aryatihussain@upm.edu.my

HISTORY

Received: 7th April 2024
Received in revised form: 5th July 2024
Accepted: 29th July 2024

KEYWORDS

Bloom formation
Cocoa butter replace
Emulsifier
Thickness
Casson yield

ABSTRACT

Despite the prevalence of chocolate-based inclusions, the impact of polyglycerol polyricinoleate (PGPR) on chocolate glaze properties is limited. The objectives of this study are to determine the effects of cocoa butter (CB) concentrations and lecithin to PGPR (L:PGPR) blend ratios on the rheological properties of chocolate glaze and to identify the impact of the thickness and stability of the selected chocolate glaze by different storage conditions. Rheological analysis, volume take-up, surface area and density were measured to calculate the glaze thickness for three consecutive layers. Chocolate glaze is made of either 35% or 40% CB, with 0.7% emulsifier of three different L:PGPR ratios (10:0, 7:3, and 3:7). Sample D (35% CB, 0.49% L, 0.21% PGPR) showed similar ($p > 0.05$) Casson yield stress (1.230 ± 0.297 Pa) and Casson viscosity (0.910 ± 0.127 Pa s) as control (1.578 ± 0.195 Pa, 0.769 ± 0.010 Pa s) made of 40% CB with 0.7% lecithin. Water activity and total plate count were within satisfactory limits. Rheological behaviours and shelf stability for both samples were similar ($p < 0.05$) up until 14 days of storage. This study may serve as a reference for industry to use PGPR to replace CB and lecithin in chocolate glaze applications of bakery products.

INTRODUCTION

Chocolate is classified into milk, dark and other types, based on cocoa content standards set by regulatory bodies. The global chocolate market, valued at USD 133.38 million in 2022, is projected to reach USD 181.78 billion by 2031 [1]. Chocolate glazes traditionally rely on cocoa butter and emulsifiers for texture, stability, and flow properties. The rising popularity of chocolate alternatives, like polyglycerol polyricinoleate (PGPR), is driven by affordability and availability. PGPR, derived from castor oil, is a potential substitute for emulsifiers in chocolate glazing, exhibiting good emulsifying properties and contributing to the desired texture [2-5]. Previous research [6] highlights the correlation between sensory perception and rheological attributes in food, emphasizing the importance of viscosity in impacting sensory experiences. Despite the prevalence of chocolate-based inclusions, research on chocolate glazing applications and the impact of PGPR on chocolate glaze properties is limited.

The objectives of this study are (1) to evaluate the rheological effects of cocoa butter (CB) concentrations and L:PGPR blend ratios on chocolate glaze, (2) to investigate the effect of layers of the formulated chocolate glaze formulation on the thickness and (3) to examine the impact of different storage conditions on thickness and stability of the selected chocolate glaze. This study may serve as a reference for PGPR to replace CB and lecithin in chocolate glaze applications on bakery products

MATERIALS AND METHODS

Materials

Cocoa powder from “The HomeBaker” (Malaysia), raw cocoa butter from “Future Food” (Ghana), soy lecithin paste from “EvaChem” (Malaysia) and donuts from “Juara Maju Jaya” (Malaysia), were sourced from Shopee. Additional components comprised PGPR from Beryl's Cookies Factory (Seri Kembangan, Selangor), icing sugar from "Bake With Yen"

https://doi.org/10.54987/jobimb.v12iSP1.936

(Malaysia), and corn oil by "Seri Murni" from Whole Foods Express Sri Serdang.

Preparation of chocolate glazes

The optimal formulation of 40% CB and 0.7% lecithin which served as the control in this study is based on previous research [7]. The L:PGPR ratios (10:0, 7:3, and 3:7) followed previous research [4] that highlighted L:PGPR ratios of 3:7 which significantly reduced yield stress among ratios of 2:1, 2.5:1 and 3:1. Six formulations were tabulated in **Table 1**.

Table 1. Chocolate glaze formulations containing different CB and L: PGPR ratios.

Formulation code	CB (%)	Sugar (%)	L:PGPR ratios	L (%)	PGPR (%)
Control	40	29.3	-	0.7% w/w	-
A	40	29.3	7:3	0.49% w/w	0.21% w/w
B	40	29.3	3:7	0.21% w/w	0.49% w/w
C	35	34.3	-	0.7% w/w	-
D	35	34.3	7:3	0.49% w/w	0.21% w/w
E	35	34.3	3:7	0.21% w/w	0.49% w/w

Manual tempering process was employed following previous research [8, 9] due to limited access to an industrial tempering machine. Cocoa butter was melted in a jacketed kettle then cocoa powder, icing sugar, and emulsifiers were added with continuous stirring then heated and maintained at around 50°C to ensure complete melting. The jacketed kettle was then transferred to a cold-water bath (10°C) until reached 32°C. Later, it was removed from the cold water and cooled to 27°C to form stable CB crystals, then reheated to 31°C.

Rheological behaviour

Rheological analyses were done using Haake RheoStress RS600 (Thermo Scientific, United States) following the method [10] which employed a parallel-plate geometry with a diameter of 35 mm and a 1 mm gap, operating at 40 °C. Shear stress and viscosity were measured while the shear rate increased logarithmically from 2 s^{-1} to 50 s^{-1} and held for 2 min. The experimental data were fitted into the Casson model following the equation [11]:

$$\sqrt{\tau} = \sqrt{\tau 0} + \sqrt{\mu_c} \cdot \sqrt{\gamma} \qquad \text{(Eqn. 1)}$$

where
τ = Shear stress
$\tau 0$ = Casson yield stress
μ_c = Casson viscosity
γ = Shear strain rate

Chocolate glaze stability

Chocolate glazes were kept at room temperature (approximately 25°C - 30°C in Malaysia) and chill storage (4°C). Sampling occurred at 7 day intervals for glazing thickness measurements, followed by total plate count (TPC) and colour measurement until blooming appeared. For TPC, the chocolate glaze samples were spread-plated and incubated aerobically at 37 °C for 48 h. The CR-410 Chroma Meter (Konica Minolta, Japan) was used to measure the L* (luminance), a* (green to red), and b* (blue to yellow) for whiteness index (WI) using the formula (Eqn. 2):

$$WI = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}} \qquad \text{(Eqn. 2)}$$

Statistical analysis

All experiments were conducted in triplicate, and statistical analysis was performed using Minitab 21.1 and one-way ANOVA. Tukey's test determined significant differences between means at a 95% significance level.

RESULTS AND DISCUSSION

Rheological behaviour

Table 2 shows Sample C (35% CB, 0.7% w/w L) displayed the highest Casson yield stress ($p < 0.05$) among all samples, while Sample B (0.172 Pa) and Sample E (0.582 Pa) with higher PGPR concentration (0.49%) showed significantly lower yield stress, aligning with prior research [12].

Table 2. Mean values of Casson yield stress (Pa) and Casson plastic viscosity (Pa.s) of different chocolate glaze formulations (Control, A, B, C, D, E).

Sample code	Casson yield stress (Pa)	Casson viscosity (Pa s)
Control	1.58 ± 0.195^{b}	$0.77 \pm 0.010^{b,c}$
A	$0.99 \pm 0.137^{b,c}$	0.35 ± 0.074^{d}
B	0.17 ± 0.007^{d}	$0.58 \pm 0.037^{c,d}$
C	2.45 ± 0.155^{a}	$0.70 \pm 0.038^{b,c}$
D	$1.23 \pm 0.297^{b,c}$	0.91 ± 0.127^{b}
E	$0.58 \pm 0.036^{c,d}$	1.44 ± 0.000^{a}

Note: Means followed by same letters (a, b, c, d) in the same column are not significantly different ($p > 0.05$).
Control: 40% CB + 29.3% sugar + 0.7% w/w L
A: 40% CB + 29.3% sugar + 0.49% w/w L + 0.21% w/w PGPR
B: 40% CB + 29.3% sugar + 0.21% w/w L + 0.49% w/w PGPR
C: 35% CB + 34.3% sugar + 0.7% w/w L
D: 35% CB + 34.3% sugar + 0.49% w/w L + 0.21% w/w PGPR
E: 35% CB + 34.3% sugar + 0.21% w/w L + 0.49% w/w PGPR

Reduced CB content in samples C, D and E has increased the Casson yield stress, aligning with research [11]. The control (0.77 Pa s) and Sample C (0.70 Pa s) reveal similar Casson viscosity ($p > 0.05$) in the absence of PGPR. The Casson viscosity value (0.35 Pa s) of Sample A (40% CB, 7:3 L:PGPR ratio) is lower than Sample B (0.58 Pa s) at 3:7 L:PGPR ratio, and also lower than 35% CB which recorded 0.910 Pa s (Sample D: 7:3 L:PGPR ratio) and 1.44 Pa s (Sample E: 3:7 L:PGPR ratio). Previous study [4] reported that up to 50% PGPR of emulsifier can be added to reduce viscosity in dark chocolate which contains 34% w/w fat. Surpassing 50% PGPR of emulsifier may lead to an unfavourable rebound and result in higher viscosity than before. In this study, a low limit of PGPR (between 0% to 30%) is applicable to replace 35% CB as reflected by sample D (35% w/w CB, 7:3 L:PGPR ratio) which shows an increase in viscosity compared to the prior study [4]. Sample D (35% CB, 0.49% w/w L, 0.21% w/w PGPR) exhibited similar Casson yield stress and viscosity ($p > 0.05$) to the control (40% CB, 0.7% L).

Chocolate glaze stability

Table 3 shows color and Whiteness Index of chocolate glazes stored at room temperature (RT) and chiller (CL). WI of all samples ranged from 22.12 to 23.85 ($p < 0.05$) at the initial 7 days with no visible bloom. WI of control and sample D increased significantly ($p < 0.05$) to a range of 25.05 to 26.77 on the 14th day, accompanied by fat bloom in samples stored at RT (**Fig. 1**). The chocolate glaze stored at non fluctuating temperature is expected to have a longer shelf life compared to the finding [10], where the WI of chocolate made of coconut oil increased from week 3 onwards when stored at fluctuating temperatures between 18°C and 30°C.

Manual tempering may lead to less stable crystal structure thus more rapid quality deterioration [9]. Lower WI values for control (25.51) and sample D (25.05) were observed at day 14 when stored at CL compared to RT (control-26.48, D- 26.77). Both the control and sample D exhibited similar shelf-life stability over 14 days of storage in RT and CL respectively, with CL preferred over RT. **Table 4** shows the total plate counts (TPC) of chocolate glazes stored at RT and CL. Despite bloom formation on the 14th day, TPC for all samples were TFTC throughout the 2 weeks storage period, indicating microbiological safety for consumption within two weeks as the acceptable TPC limit for chocolate confectionery stands at less than 100 CFU/g [13].

Table 4. Total plate count of chocolate glazes stored at RT and CL.

Samples types	Total plate count (CFU/g) Storage Conditions RT 7th day	14th day	CL 7th day	14th day
Control	TFTC	TFTC	TFTC	TFTC
Sample D	TFTC	TFTC	TFTC	TFTC

Note:
RT: Room temperature
CL: Chill temperature
Control: 40% CB + 0.7% w/w L
D: 35% CB + 0.49% w/w L + 0.21% w/w PGP

Table 3. Color and Whiteness Index (WI) of chocolate glazes stored at RT and CL.

Sample types	Colour	Storage Conditions RT 0 day (fresh)	7th day	14th day	CL 7th day	14th day
Control	L*	22.85 ± 0.08[f]	22.81 ± 0.20[f]	26.55 ± 0.18[b]	22.18 ± 0.06[g]	25.58 ± 0.04[c]
	a*	2.67 ± 0.08[e]	3.23 ± 0.11[b,c]	3.11 ± 0.04[c,d]	2.97 ± 0.06[d]	3.10 ± 0.04[c,d]
	b*	0.10 ± 0.02[d,e]	1.00 ± 0.06[c,d]	1.02 ± 0.02[c,d]	0.89 ± 0.03[e]	1.04 ± 0.01[c,d]
	WI	22.81 ± 0.074[f]	22.74 ± 0.197[f]	26.48 ± 0.183[b]	22.12 ± 0.053[h]	25.51 ± 0.040[c]
D	L*	22.42 ± 0.05[g]	23.94 ± 0.06[e]	26.85 ± 0.03[a]	22.29 ± 0.08[g]	25.13 ± 0.04[d]
	a*	1.92 ± 0.04[f]	3.54 ± 0.10[a]	3.25 ± 0.01[b,c]	3.22 ± 0.03[b,c]	3.35 ± 0.06[b]
	b*	0.63 ± 0.04[f]	1.23 ± 0.03[a]	1.16 ± 0.05[a,b]	1.07 ± 0.03[b,c]	1.17 ± 0.02[a]
	WI	22.41 ± 0.050[g]	23.85 ± 0.058[e]	26.77 ± 0.026[a]	22.22 ± 0.075[g,h]	25.05 ± 0.039[d]

Note:
Means followed by same letters (a, b, c, d) in the same column (L*, a*, b*, WI) are not significantly different ($p > 0.05$).
RT: Room temperature
CL: Chill temperature
Control: 40% CB + 0.7% w/w L
D: 35% CB + 0.49% w/w L + 0.21% w/w PGPR


(A)


(B)

Fig. 1. (A) Bloom formation on the surface of Control stored at RT (left) and CL (right) on day 14th. **(B)** Bloom formation on the surface of sample D stored at RT (left) and CL (right) on day 14th.

CONCLUSION

The rheological analysis shows that sample D (35% CB, 0.49% L, 0.21% PGPR) demonstrated similar ($p > 0.05$) Casson viscosity and Casson yield stress with the control. Whiteness index of samples stored at chill storage is lower than samples stored at room temperature, indicating storage at chill storage is preferred over room temperature to maintain the quality of chocolate glazes. Despite the subtle variation ($p < 0.05$) in glaze thickness between the formulations due to various interactions in the chocolate matrix, similarity of sample D with the control suggests a viable cost-saving alternative for manufacturers by replacing 5% of CB with only 0.2% PGPR without altering the final product quality.

ACKNOWLEDGMENT

Authors wish to thank Universiti Putra Malaysia for supporting the research under the grant GP-IPS/2023/9747400.

REFERENCES

1. Straits Research. Chocolate Market Growth Size, Demand and Forecasts, 2023-2031 [Internet]. straitsresearch.com. 2022 [cited 2024 Mar 13]. Available from: https://straitsresearch.com/report/chocolate-market
2. Bastida-Rodríguez J. The Food Additive Polyglycerol Polyricinoleate (E-476): Structure, Applications, and Production Methods. ISRN Chem Eng. 2013;2013:1-21.
3. Mortensen A, Aguilar F, Crebelli R, Di Domenico A, Dusemund B, Frutos MJ, et al. Re-evaluation of polyglycerol polyricinoleate (E 476) as a food additive. EFSA J. 2017;15(3).
4. Schantz B, Rohm H. Influence of lecithin–PGPR blends on the rheological properties of chocolate. LWT Food Sci Technol. 2005;38(1):41-5.
5. Sözeri Atik D, Bölük E, Toker OS, Palabiyik I, Konar N. Investigating the effects of Lecithin-PGPR mixture on physical properties of milk chocolate. LWT. 2020;129:109548.
6. Tadros TF. Food rheology and mouth feel. De Gruyter eBooks. 2017;329-42.
7. Yeganehzad S, Kiumarsi M, Nadali N, Rabie Ashkezary M. Formulation, development and characterization of a novel functional fruit snack based on fig (Ficus carica L.) coated with sugar-free chocolate. Heliyon. 2020;6(7).
8. Valrhona EGC, McLachlan C, Hermé P. Encyclopedia of Chocolate: Essential Recipes and Techniques. Bau F, editor. Paris: Flammarion; 2018. 416 p.
9. Talbot G. Chocolate temper. In: Industrial Chocolate Manufacture and Use. 1994;156-66.
10. Abdul Halim HS, Selamat J, Mirhosseini SH, Hussain N. Sensory preference and bloom stability of chocolate containing cocoa butter

substitute from coconut oil. J Saudi Soc Agric Sci. 2019;18(4):443-8.
11. Kouřilová V, Dufková R, Hřivna L, Kumbár V. Use of rheological plastic models to describe the flow behaviour of unconventional chocolate masses. Czech J Food Sci. 2022;40(4):305-12.
12. Garti N, Aserin A. Effect of emulsifiers on cocoa butter and chocolate rheology, polymorphism, and bloom. In: Cocoa Butter and Related Compounds. AOCS Press; 2012. p. 275-305.
13. Amevor PM, Laryea D, Barimah J. Sensory evaluation, nutrient composition and microbial load of cashew nut–chocolate spread. Cogent Food Agric. 2018;4(1):1502224.