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THE COMPARISON OF THE EFFECTIVENESS OF COCOA BUTTER (CB) AND COCOA BUTTER ALTERNATIVES (CBA) IN CHOCOLATE MANUFACTURE

BUDIANTO[1] DIAH KUSMARDINI[1]

Abstract: *This study aimed at (a) comparing the effectiveness of the use of Cocoa Butter (CB) and Cocoa Butter Alternatives (CBA) on food products and (b) measuring the effectiveness of the sub-groups of the Cocoa Butter Alternatives. In this study, the researchers used Structural Equation Modelling (SEM) with the Partial Least Square (PLS) approach. The analysis showed that (a) CB was more effective in the utilization than CBA and (b) after comparing sub-groups of the CBA examined in this study, Cocoa Butter Substitute (CBS) was more effective than Cocoa Butter Replacer (CBR) and Cocoa Butter Equivalent (CBE). This study is a practical recommendation for the use of CBA so that it can be widely applied in the chocolate industry.*

Key words: *Cocoa Butter (CB), Cocoa Butter Alternatives (CBA), Cocoa Butter Substitute (CBS), Cocoa Butter Replacer (CBR), Cocoa Butter Equivalent (CBE).*

1. Introduction

Cocoa Butter (CB) is a formula in chocolate production. The unique characteristics of CB make solid chocolate products melt at 20°C [22], thereby causing a feeling of pleasure [6] because of having a composition of 21% 1,3 dipalmitoyl-2-oleoyl-glycerol (POP), 40% 1,3-stearoyl-2-oleoyl-3,1-palmitoyl-glycerol (POS), and 27% 1,3-distearoyl-2-oleoyl-glycerol (SOS). Due to having these unique characteristics, it makes CB sought after as a raw material in chocolate products. The availability of raw materials and the high cost of CB force the chocolate industry to switch to Cocoa Butter Alternatives [2], [14], [22, 23]. Cocoa Butter Alternatives (CBA) are a solution in reducing production costs and

[1] Chemical Engineering, Al-Kamal Institute of Science and Technology, Jakarta, Indonesia;
Correspondence: Budianto; email: budianto_delta@yahoo.com.

maintaining the availability of raw materials in the form of CB. Over time, CBA has dominated the topic of studies concerning chocolate production. CBA is a CB engineering which includes Cocoa Butter Replacer (CBR), Cocoa Butter Substitute (CBS), and Cocoa Butter Equivalent (CBE). With the number of studies related to CBA, a big question arises: *How effective can CBA be adopted into chocolate products?* Although many studies have been done on this topic, the results of those studies may not necessarily be optimized in terms of their application.

Therefore, this study encourages optimizing the findings of previous studies so that those studies are not limited to theory and can be applied in the real world of industry. Referring to the previous studies, no one has measured the effectiveness of CBA which serves as CB on the chocolate-based food production process. For that reason, this study focuses more on the effect of CB and CBA on chocolate products. The objectives of this study were (a) to determine to what extent the influence of CB and CBA on food products and (b) to examine the CBA which has the greatest influence on food products in Indonesia. These objectives help the researchers to find out the impact of the use of CBA in the chocolate-based food industry.

a. *Cocoa Butter* (CB)

CB has a melting point ranging from 27°C – 35°C. The character of CB depends on its fatty acid composition [9], [17], [27]. CB contains palmitic, stearate, and oleic fatty acids, giving it a cool and melting character in the mouth [9], [17]. The types of free fatty acids in CB can be seen in Table 1. Furthermore, the physicochemical composition of CB can be seen in Table 2.

The composition of fatty acids in Cocoa Butter (CB) [10] Table 1

Types of Fatty Acids	% Fatty acids
Saturated Fatty acids	**54-64**
Palmitic acid (C16:0)	24.5-33.7
Stearic acid (C18:0)	33.7-40.2
Myristic acid (C14:0)	0-4
Arachidic acid (C20:0)	1
Lauric acid (C12:0)	0-1
Unsaturated fatty acids	**36-43**
Oleic acid (18:1)	26.3-35
Palmitoleic acid (C16:1)	0-4
Linoleic acid (18:2)	1.7-3
α – Linoleic acid	0-1
others	1.6
Triacylglycerol	**≥70**
1 (3) palmitoyl-3 (1) stearoyl-2-oleoyl glycerol (POS)	42.2
1 (3) -distearoyl-2-oleoylglycerol.dll (SOS)	24.2

Types of Fatty Acids	% Fatty acids
1,3-dipalmitoyl-2-oleoylglycerol.dll (POP)	21.8

Table 2

Physicochemical properties of Cocoa Butter (CB) [14]

Iodine value [g 12/100g]	32-35
Saponification value [mg KOH/g]	192-199
Acid value [mg NaOH/g]	1.04-1.68
Peroxide value [meq O_2/kg]	1.00-1.10
Melting point [°C]	29-40

b. *Cocoa Butter Alternatives* (CBA)

Cocoa Butter Alternatives (CBA) is butter that replaces the function of CB vegetable fat in whole or in part (Figure 1). CBA has experienced rapid development. Previous studies have divided CBA into three, namely Cocoa Butter Replacer (CBR), Cocoa Butter Substitute (CBS), and Cocoa Butter Equivalent (CBE). CBR comes from natural plant fats or is produced specifically by chemical or enzymatic fractionation of vegetable fats [7], [18], [23-25], [30, 31]. The fatty acid composition of CBR is similar to that of CB with a triglyceride structure that is more or less similar. CBR can be divided into two groups, namely CBE and CBS.

CBE has vegetable fats that are similar to the physical and chemical characteristics of CB [3], [20]. In terms of processing, it is sometimes mixed with CB to get a similar character to CB (Tables 3 and 4). The fatty acids contained in CBE are palmitic acid, stearic acid, and oleic acid. CBE comes from a mixture of palm oil, fractionated palm oil, illipe, sal nut palm oil, and mango kernel oil. CBE is divided into 2 sub-groups, namely Cocoa Butter Extender (CBEX) and Cocoa Butter Improver (CBI). CBS has chemical and physical properties similar to Cocoa Butter. The oil source that is often used in CBS is hydrogenated and fractionated palm kernel oil which contains a stear in fraction that is solid at room temperature and contains more saturated fatty acids [4], [21]. The use of large amounts of CBS will increase the melting point of chocolate because CBS has semi-solid characteristics at room temperature [26].

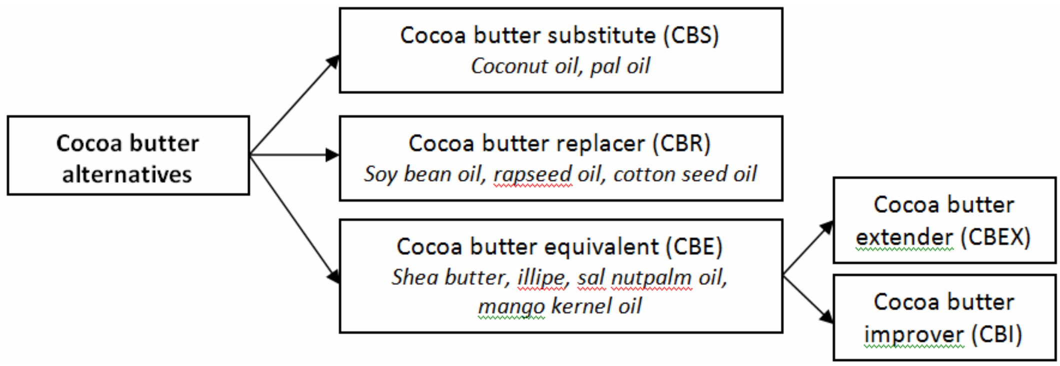

Fig. 1. *Subgroups of Cocoa Butter Alternatives (CBA)* [19]

Properties of Cocoa Butter Alternatives (CBA) [19] Table 3

Properties	CBE	CBR	CBS
Types of fatty acids	Non-lauric acid plant fats	Non-lauric acid fats	Lauric acid-containing fat
Physical and chemical properties	Similar in physical and chemical properties like melting profile and polymorphisms to cocoa butter	The distribution of fatty acid is similar to cocoa butter but the structure of triglycerides is completely different	Chemically different to cocoa butter, with some physical similarities
Mixing properties	Mixable in every amount without altering the properties of cocoa butter	Only in small ratios can mix to cocoa butter	Suitable only to substitute cocoa butter to 100%
Main fatty acid	Palmitic (P), stearic (S), oleic acid(O), linoleic (L), andarachidicacid(A)	Elaidic acid (E), stearic acid(S), palmitic (P), and linoleic(L)	Lauricacid (L) andmyristic acid (M)
Main triglycerides	POP, POS, SOS	PEE, SEE	LLL, LLM, LMM
Examples	Palm oil, illipe butter, shea butter, kokum butter, and sal fat	Hydrogenated oil, soya oil, rapeseed oil, cottonseed oil, groundnut oil, and palm olein	Coconut oil, palm kernel oil, and MCT

2. Materials and Methods
2.1. Mapping and Sampling

Mapping research variables was conducted to get an overview of the variables and indicators and to find out the concentration of studies related to CB using the VOS viewer software.

Samples in this study were 141 chocolate-based food companies in Indonesia. The data were collected using a questionnaire compiled based on the result of the preliminary study on the documents concerning the CB and CBA used by those companies.

Table 4

Physicochemical properties of different fats commonly used as replacers of Cocoa Butter (CB) [10]

Fatty acids [%]	**Mango seed kernel fat**	**Shea butter**	**Sal fat**	**Illipe butter**	**Tea seed oil**	**Kokum kernel fat**	**CB**
Palmitic acid	3-18	3.4-8.0	4.6-8.3	18-21	17.40	-	25.2-33.7
Stearic acid	24-57	37.0-58	34.7-43.2	39-46	4.30	50-60	33.3-40.2
Oleic acid	34-56	33.0-50.0	40.4-42.4	34-37	55.96	36-40	26.3-35.2
Linoleic acid	1-13	3.0-6.65	1.5-2.8	-	21.15	-	1.7-3.6
Arachidic acid							
Triglycerides							
POP	1	3		7	-	trace	18.9-23.4
SOS	40-59	42	42	45	-	72	27.5-33.0
POS	11-16	6	11	34	-	6	42.8
SOO	23	-	16	26	-	-	-
SOL	-	-	-	5	-	-	-
SLS	-	-	-	5	-	-	-
OOO	5	-	3	6	-	-	-
AOO	-	-	4	-	-	-	-
SOA	4	-	13	-	-	-	-
POO	5	-	-	-	-	-	-
Other physicochemical properties							
Iodine value	39-48	52-56	31 - 45	29-38	83.73	-	34.74-37.33
Saponification value	-	-	-	-	192.37	-	193.62-196.71
Melting point [°C]	34-43	32-45	30-36	37-39	-	-	27-40

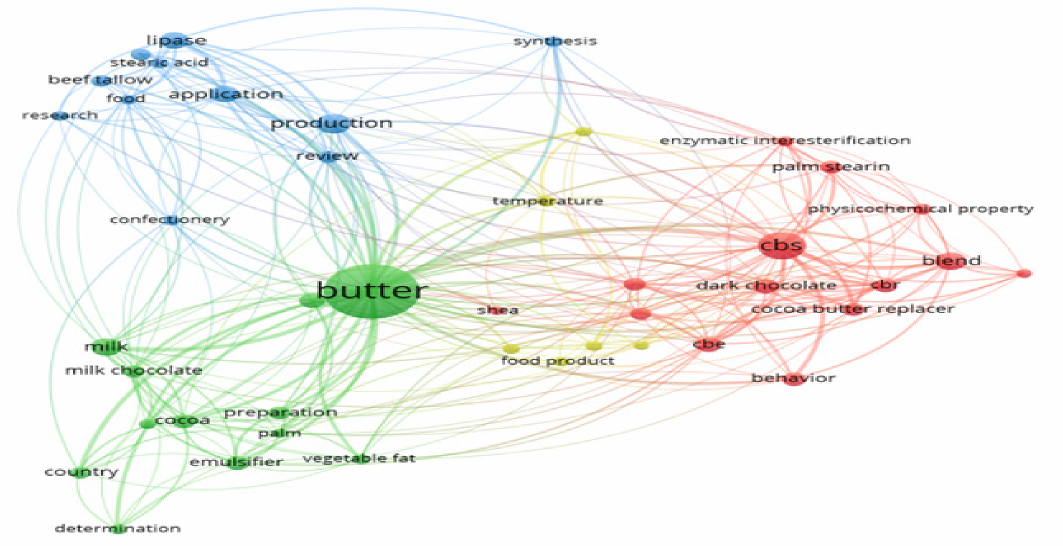

Fig. 2. *Research map*

2.2. Selection of Variable Indicators

The indicators were selected using the Principal Component Analysis (PCA) with SPSS software. This was carried out to determine indicators of various activity items to be evaluated. The function of PCA was basically to reduce several variables into new variables or new dimensions which were the result of indicator extraction [1], [13], [16], [20]. The PCA was used in this study because the applied indicators were relatively new. Therefore, there was no reference to the indicators used for the variables [15]. Furthermore, the indicators applied in this study can be seen in Table 5.

2.3. Statistical Testing

Statistical testing was conducted to find out to what extent the relationship between variables. In this study, the employed statistical test was the Structural Equation Modelling (SEM) with the Partial Least Square (PLS) using Smart PLS software v. 6.0. The applied validity test was the cross-loading with a value of > 0.7 [5] and the Square Root of Average Variance Extracted (AVE) with a value of > 0.50 [8]. Meanwhile, the applied reliability test was the Cronbach's Alpha with a value of > 0.6 and the Composite Reliability with a value of > 0.7 [11, 12]. The structural model test was employed by accommodating all construct variables which were formulated in hypothesis testing. All employed standard parameters were referred to in Hair et al. [11].

Extraction method of principal component analysis Table 5

INDICATORS	PARAMETER	CODE	Rotation Method: Varimax with Kaiser Normalization VARIABEL (* significant *p*= 0.05)					
			CB	**CBR**	**CBS**	**CBE**	**PROD.**	**Food Product**
Melting point [°C]	35±4	A1	**.661***	.231	.343	.122	.199	.320
Peroxide value [meq O_2/kg]	1.05±0.05	A2	**.832***	.322	.236	.161	.386	.11
Acid value [mg NaOH/g]	1.35±0.3	A3	.309	.313	.129	-.901	.130	-.902
Saponification value [mg KOH/g]	196±3	A4	.322	.204	.22	-.741	.23	-.742
Iodine value [g 12/100g]	34±1	A5	.335	.295	.185	.284	.383	.482
Rape seed oil	-	B1	.521	.486	.192	-.581	.193	-.582
Soya oil	-	B2	.431	.577	.299	-.421	.300	-.422
Hydrogenated oil	-	B3	.414	**.646***	.414	.285	.156	.27
Ground nut oil	-	B4	-.443	**.851***	.308	-.261	.309	-.262
Cottonseed oil	-	B5	.415	.500	.140	-.101	.141	-.102
Palm olein + Rape seed oil	-	B6	-442	.321	-.054	.214	-.055	.215
Palm olein	-	B7	.415	**.874***	.272	-.59	.273	-.60
Coconut oil	-	C1	-442	0.432	**.855***	-.219	.156	.28
Palm kernel oil	-	C2	.416	0.467	**.835***	.215	.309	-.58
MCT	-	C3	-441	.299	.270	.232	.141	-.218
Illipe butter	-	D1	.417	.414	.283	**.894***	-.056	.216
Shea butter	-	D2	-.196	.308	.296	**.719***	.274	-.61
Kokum butter	-	D3	.217	.140	.309	**.765***	.156	.29
Sal fat	-	D4	.240	-.054	.322	**.601***	.309	-.378
Precise composition dosage	-	M1	.218	.418	.335	.283	.141	.538
Expiration status of CB& CBA	-	M2	-.197	.497	.348	.191	-.057	.217
CB and CBA conditions according to the Certificate of Analysis (COA)	-	M3	.218	.418	.361	-.219	.275	.462
CB and CBR storage [°C/% RH]	25/60	M4	-.345	.339	.374	.366	.156	.30
Chocolate Mixing Temperature [°C]	35±4	M5	.083	.160	.387	-.220	.309	.498
Fineness [micron]	35±2	M6	-.310	.178	.400	.367	**.765***	.453
Homogeneity of mixing	homogeneous	M7	.084	.196	.413	-.221	**.685***	.487
R&D	-	M8	-.311	.214	.388	-.180	**.635***	.531
Melt chocolate in the mouth	-	Y1	.085	.232	0.457	-.139	.295	**.673***
Maximum moisture content [%]	1	Y2	.085	.232	.562	.417	.486	**.742***
Typical chocolate flavor	-	Y3	-.312	-.317	.367	-.181	.577	**.639***
Typical Chocolate Smell	-	Y4	.086	.293	.450	.418	.217	**.834***
Product life time [months]	12	Y5	-.313	-.318	.414	-.182	.240	.489

2.4. Research Framework

The research framework used in this study can be seen in Figure 3. The variable of production becomes a mediating variable between CBR, CBS, CBE, and CB on the variable of food products. The variable of CB also has a direct relationship (without mediation) with the variable of food products.

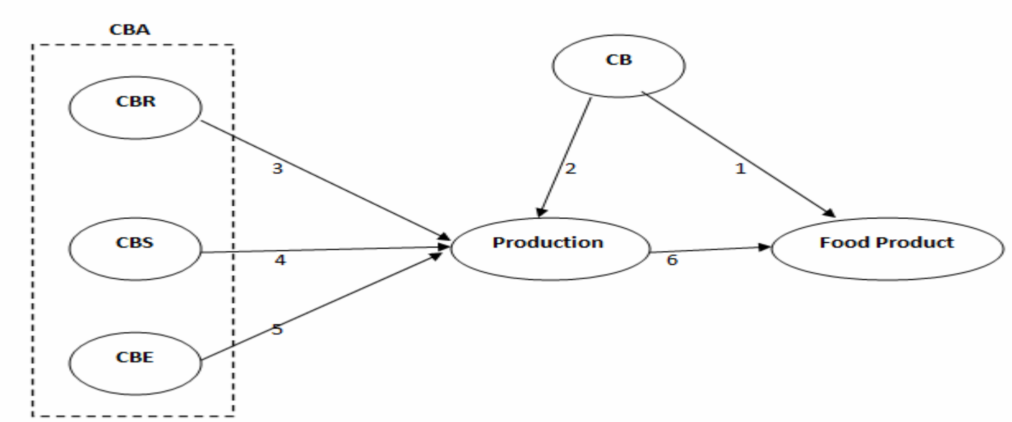

Fig. 3. *Research framework*

3. Results

The results of the outer model test, covering convergent validity, discriminate validity, and reliability, in Table 6, showed that all check items met the requirements for further processing. Table 6 referred to Figure 4 as the result of SEM-PLS analysis.

Table 7 contributed to mapping the path between variables (direct or mediated). Furthermore, the value of f^2 served to find out the extent of the relationship between variables. Meanwhile, the value of R^2 was used to measures to what extent the model's ability to explain endogenous variations.

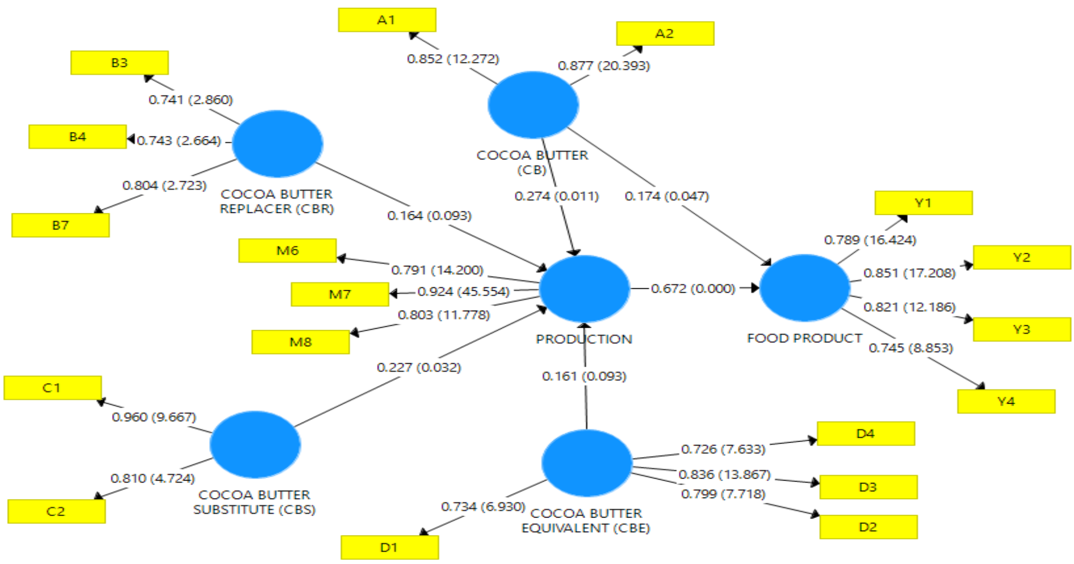

Fig. 4. *SEM-PLS analysis*

Validity and reliability tests Table 6

Tests	Parameter	Standard	Results
Convergent Validity	Loading factor (outer loading)	>0.7	0.726–0.960
	AVE	>0.5	0.583 – 0.788
	Communality	>0.5	0.583 – 0.788
Discriminant Validity	Root Square AVE and correlation of latent variables	Root Square AVE > Discriminant validity	Root Square AVE > Discriminant Validity
	Cross Loading	>0.7	0.726 – 0.906
Reliability	Cronbach's Alpha	>0.6	0.663 – 0.718
	Composite Reliability	>0.7	0.807 – 0.881

The Effect of variable paths Table 7

No	Paths	Coefficient (β)	T-statistics >1.65	*p*-Value < 0.05	f^2	Note
1	CB—FP	0.174	1.594	0.056	0.059	(+) not significant
2	CB—PROD.	0.274	2.383	0.009	0.071	(+) significant
3	CBR—PROD.	0.164	1.468	0.071	0.036	(+) not significant
4	CBS—PROD.	0.227	1.680	0.047	0.068	(+) significant
5	CBE—PROD.	0.161	1.329	0.092	0.025	(+) not significant
6	PROD.—FP	0.672	7.975	0.000	0.883	(+) significant
7	CB—PROD.--FP	0.184	2.038	0.021		(+) significant
8	CBR—PROD.--FP	0.110	1.509	0.066		(+) not significant
9	CBS—PROD.--FP	0.155	1.656	0.049		(+) significant
10	CBE—PROD.--FP	0.108	1.330	0.092		(+) not significant

f^2= 0.02- 0.15 indicating Weak Effect; f^2= 0.15-0.35 indicating Sufficient Effect;
$f^2 \geq 0.35$ indicating Strong Effect.
R^2:PROD. 0.291……FP: 0.584

4. Discussions

As aforementioned in the beginning, one of the objectives of this study was to find out to what extent the influence of CB and CBA on food products. The results of statistical testing showed that CB had a positive (not significant) effect (5.9%) on food products (FP) and CB had a positive (significant) effect on FP mediated by production (PROD). Furthermore, CB also had a positive effect (7.1%) on PROD. Meanwhile, CBA (CBR and CBE) did not give a positive effect on FP mediated by PROD. CBA activities represented by CBS were able to give a positive effect on FP mediated by PROD. CBS had a positive effect (6.8%) on PROD. Based on these results, CB was more influential than CBA in terms of utilization in the chocolate industry.

The next objective was to compare CBA activities to find out which one had the greatest influence on FP. CBS represented CBA as a variable that had a positive effect on FP mediated by PROD. CBR only contributed 3.6% to PROD and 2.5% to CBE. Therefore, the order based on the greater influence was CBS, CBR, and CBE sequentially.

The variable of PROD had the greatest influence (88.3%) on FP and succeeded in mediating CB and CBS on FP. However, PROD failed to mediate CBR and CBE on FP. Furthermore, exogenous latent variables (CB, CBS, CBR, and CBE) were able to explain the PROD activity by 29.1% (R^2), while FP was able to be explained 58.4% by the exogenous variables. PROD activities which included R&D (M8) were able to convert the needs of CB and CBA through continuous innovation and analysis. Quality control activities to obtain homogeneity of mixing (M7) by maintaining product fineness (M6) ranging from 35 microns may create a uniform texture (shape, color, smell, and taste).

The variable of FP focused more on product quality standards on CB, such as the melting property at body temperature (Y1), the max water content of 1% (Y2), organoleptic tests in the form of taste (Y3) odor (Y4), and product stability tests for 1 year. Indicators on the variable of FP were able to understand the desirability of the exogenous variables (CB, CBS, CBR, CBE, PROD) by 58.4%.

The failure of the CBA (CBE and CBR) is interesting to explore. Therefore, this becomes a practical recommendation for the implementation of innovations in the form of CBE and CBR to be accepted in the market. Furthermore, the failure factors for PROD in mediating CBR and CBE in this study are presented in Table 8 below.

By referring to Table 8, the role of R&D must be maximized, especially the use of abundant raw materials in the form of hydrogenated oil and groundnut oil as raw materials for CBR. Constraints in the form of melting points and mixing can be anticipated by trial innovation to get the ideal formula (closer to CB). This is contrary to the findings of Smith [28] which state that the mixing process can be carried out at all ratios. In another hand, this also rejects the findings of Lipp and Anklam [20] that CBE can completely replace CB.

Consistency of taste and flavor can be evaluated by making tolerance standards (taste and flavor) to a maximum limit close to CB. This finding is in line with a study conducted by Buchgraber and Anklam [3] while rejects the findings of Gunstone [10] which state that there is no significant change in taste and smell.

Continuous efforts can be conducted by involving PROD (M8) activities in product innovation with strict control in the analysis (M6, M7).Studies related to CBA must be strongly encouraged so that it can be applied in the industrial sector and previous studies can be evaluated by direct application extensively for its use in the chocolate industry, in which this is the concentration of previous studies [7], [18], [20], [29].

This study indicated that, among the CBA sub-groups, CBS is more acceptable than CBR and CBE. This cannot be separated from the availability of raw materials and consumer tolerance on changes in the character of chocolate products by using CBA as a substitute for CB. These results support the findings of Jahurul et al. [14] and Calliauw et al. [4].

The dominant influence of PROD on FP (88.3%) showed that any activity on CBA must be able to synergize with PROD to produce products that are widely accepted by consumers and can be applied in all areas of chocolate manufacturing. The evolution of CBA activities must be flexible and simple in its application in the manufacturing industry.

Constraints in the use of CBR and CBE Table 8

No.	Factors	CBR	CBE
1	Melting point (CB = 35°C)	Its average melting point is ≥ 38°C. This condition makes the character of the chocolate bar solid (difficult to melt in the mouth).	Its interval melting point is 18.5 ± 21.78 [31]. It has a high-temperature interval so that its stability is easy to change.
2	Mixing	Only in small ratios can be mixed with cocoa butter.	CBEX cannot be mixed in every ratio.
4	Impurity compound	Elaidic acid (E)	Diglycerides, Diacyl-Glycerol (DAG)
5	The availability of raw materials	Hydrogenated oil and groundnut oil. The availability of them is abundant. However, they have not been optimized for use.	Illipe butter, shea butter, kokum butter, and sal fat. They are very limited (not widely available in Indonesia).
6	Taste	The taste of cocoa is unstable. Furthermore, other tastes sometimes appear (influenced by the origin of fatty acids).	
7	Flavor	The flavor in chocolate products is unstable. In addition, other flavors still appear.	

5. Conclusions

After comparing the effectiveness of CB and CBA in chocolate manufacturing, the position of CB is superior in a wide range of applications. It can be concluded that CB can have a direct (almost significant) and positive effect on FP mediated by PROD.

The CBA sub-group that has an indirect positive effect on FP is CBS, while CBR and CBE have not been able to be fully applied in the chocolate industry in Indonesia. This is a challenge for further studies so that the use of CBA can be more varied in the chocolate industry.

6. Conflict of Interest

Neither of the authors has a conflict of interest associated with this study.

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