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Optimising refined bleached deodorized palm stearin for its crude stearic acid iodine value to provide the stable specification of blended stearic acid distillate iodine value

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Abstract

On the commercial scale, the quality standard of Blended Stearic Acid Distilled (BSAD) couldn't be achieved by normal distillation. BSAD iodine value is mostly higher than maximum quality standard (0.2 mg/100 g), with the same iodine value (0.80 g/100 g) of feed Hydrogenated Splitted RBDPS Fatty Acid or HSRBDPSFA, feed capacity 5.5 ton/hour with bottom flash distiller temperature reaching 213°C. The separation and reduction of chemical impurities (so sensitive to oxidation/temperature/heat changing, and iodine value) were done. The effect of the reduction of feed iodine value (IV), increasing of feed capacity and bottom temperature of flash distiller column (BFD) were optimized to observe BSAD's iodine value trend by using a factorial design (3 x 2 x 3) method. The optimum condition was found on the feed IV of 0.60 g/100 g, at feed capacity 6.0 ton/hour, and BFD temperature 222°C. Iodine value of BSAD was stable and in specs on 0.175 g/100 g.

Keywords: Distillation, Iodine value, Bottom flash distiller temperature, Quality standard, Distillate, Feed capacity.

Introduction

Blended stearic acid distillate (BSAD) contains ~60 % w/w of palmitic acid ($C_{15}H_{31}COOH$ or C_{16}) and ~40 % w/w of stearic acid ($C_{17}H_{35}COOH$ or C_{18}). The weight ratio of C_{16} to C_{18} is 3:2, the specific ratio of BSAD can be achieved using RBDPS as raw material. The compositions of SRBDPSFA are shown in Table 1. RBDPS is highly suitable to obtain 60 % C_{16}; 40 % C_{18} of BSAD by cutting a part of the lower and higher boiler than $C_{16\text{-}18}$ in the suitable distillation process conditions of HSRBDPSFA.

The off specs of BSAD iodine value (BSAD IV) created lower competitive level in oleo chemical market. It couldn't be produced in the normal production cycle. Production will be inefficient and wasting energy. The overall items of quality specs couldn't be obtained. The off specs IV are the cause of the lower temperature of BFD column. It decreases down to 213°C. This affected BSAD compositions, from bigger loss of $C_{16\text{-}18}$ of BSAD to smaller weight ratio of C_{16} to C_{18} of BSAD and BSAD compositions tend to be off specs. It is a big effect to the lower production yield target and a big trouble also to the production schedule arrangement (Yusuf, 2010). There is a need to find way for getting the in specs of BSAD in the normal production cycle.

Table 1. The composition of SRBDPSFA of hydrolyzed RBDPS and HSRBDPSFA (Muhammad, 2009)

No	Fatty acid name	Symbols	double bond	SRBDPSFA, % w/w	HSRBDPSFA, % w/w
1	Lauric acid	C_{12}	0	0,1	0.1
2.	Myristic Acid	C_{14}	0	1.3	1.3
3	Palmitic Acid	C_{16}	0	57,4	57.4
4.	Stearic Acid	$C_{18\text{-}0}$	0	6.1	40.2
5.	Oleic Acid	$C_{18\text{-}1}$	1	27.9	-
6.	Linoleic Acid	$C_{18\text{-}2}$	2	6.2	-

Its IV was mostly over than 0.2 g /100 g (as the maximum of BSAD IV specs) which is produced commercially by using the same IV (0.80 g/100 g) of HSRBDPSFA (feed for distillation in this study), the process wasn't normal and the iodine value was unstable. Based on the practical data, the increasing of HSRBDPSFA's IV which is higher than 0.80 g/100 g produced the higher BSAD IV (Yusuf, 2010). Based on these facts, it's supposed that the lower HSRBDPSFA's IV (distillation process feed) can reach, the lower BSAD IV on the range of it quality standard will be. How much should the optimum feed IV be? It should be found out. Based on the experience, practically the lower HSRBDPSFA IV can be obtained through SRBDPSFA hydrogenation. This was also based on fatty acid hydrogenation theory (Robert, 1990). This wasn't the only way to solve the problem. Iodine value of BSAD was also higher when the feed capacity higher than 5.5 ton/hour (Yusuf, 2010). So the question "what will the optimum distillation conditions to get the in specs BSAD IV?" has to be studied.

Feed quality and distillation process conditions (temperature, pressure and mass balance) affect the quality of distillate which is produced (Muhammad, 2010; Muhammad, 2011). Regarding this, the optimum feed IV and distillation conditions of HSRBDPSFA have to be researched carefully and commercially in this study (Peter *et. al.,* 2004).

Iodine value was one of the quality parameters of the commercial premium BSAD, besides its color, heat stability and fatty acid compositions (PT. XXX, 2005). Getting the lower, the better and the more stable IV, Refined Bleached Deodorized Palm Stearin (RBDPS) was used as raw material; because the chemical impurities or impurities that's so sensitive to oxidation and heat had been decreased from RBDPS to a certain level.

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It is so suitable to produce BSAD through hydrolysis, hydrogenation and distillation. Impurities reduction (includes *unsaturated bond*) of the crude fatty acid (SRBDPSFA) can reduce fatty acid color and IV through fatty acid hydrogenation (Robert, 1990). The experience shows on the specific conditions, distillation process also separated the impurities to a certain level so that the amount of unsaturated bond (indicated by IV) will be lower and better. So hydrogenated SRBDPSFA feed could reduce BSAD' IV also through distillation and/or fractional distillation. By using of this HSRBDPSFA, reduction of HSRBDPSFAIV and optimization of distillation process conditions which is done in this research can reduce unsaturated bond or obtain lower and more stable amount of unsaturated bond or BSAD IV according to BSAD IV quality standard.

According to the practical experiences in oleo chemical industry, crude fatty acid of HSRBDPSFA contains impurities such as; a trace of caproic acid ($C_5H_{11}COOH$) or C_6, caprylic acid (C_7H_{15}, COOH) or C_8 and capric acid ($C_{10}H_{21}COOH$) or C_{10}. The light end composition of the first fractionation column of distillation showed this fact. These lower fractions are easier to oxidize and have bigger potential to form double bond or increase the iodine value of fatty acid which is being purified (Nur & Septin, 2006; Yusuf, 2010). The other impurities in crude fatty acid are hydrocarbons, aldehydes, ketones, sterols, phosphatides, glycerol and un-hydrolyzed RBDPS which also have big potential to increase the IV of fatty acid according to their chemical properties (Ketaren, 2008). The lower the impurities in fatty acid are, the better the fatty acid quality is or the bigger the impurities *can be separated,* the better the fatty acid quality is.

Impurities of crude fatty acid feed (CFAF) can be separated through distillation process to improve IV of fatty acid distillate. The impurities such as: fatty acid (< C_{12}) and C_{14}, hydrocarbons, aldehydes and ketones are separated as the light end fraction (low boilers) in the first fractionation column and the other impurities such as: sterols, phosphatides, glycerol and un-hydrolyzed triglyceride is separated as heavy fraction (high boilers) or residue (Brocmann *et al.*, 1987). It can be also applied to purify CFAF of HSRBDPSFA.

Providing the BSAD with the same quality standard as before had been done by increasing light fraction until 5 % of feed capacity, together with increasing precut column temperature under vacuum pressure to remove more the impurities, such as color bodies, fatty acids that are lower than lauric acid ($C_{11}H_{23}COOH$) or $C_{12,}$ myristic acid ($C_{13}H_{27}COOH$) or C_{14}, hydrocarbons, aldehydes and/or ketones of HSRBDPSFA (that are sensitive to color changing which cause it to be darker and increase the IV of fatty acid). It's followed by reducing BSAD *yield* until 85% (desired higher). The increasing of *precut column* temperature affected the increasing of BFD temperature and so it was potential to increase IV of BSAD relatively. The temperature had to be reduced so that IV will be relatively low. This was also based on the down grade acceleration of fatty acid that was affected by temperature (Brocmann *et al.*, 1987; Ketaren, 2008).

The providing was done by recycling the *rubber grade distillate* to the drier as the other big potential to increase BSAD IV, besides CFAF IV and distillation process conditions (the present distillation facility or Feld and Hanh style) (PT. XXX, 2005). In this research, it will be separated as a byproduct of rubber grade distillate to separate bigger the impurities of BSAD to obtain lower IV. See Fig. 1 (the modified Feld and Hanh style).

Based on this fact, it's supposed that feed IV wasn't suitable yet to produce BSAD as its quality standard of IV (0.2 g/100 g) and it was stable. It has to be studied. The distillation operating conditions weren't optimum also. For this, light end yield will be kept constant on the range 1.5 – 3% so that BSAD yield will be higher and closer to 93.0 % (as a normal specific yield of BSAD which could be obtained practically). To study, the feed capacity will be optimized above 5 ton/hour and BFD temperature will be set until finding new optimum point on the new optimum operating conditions of distillation.

Table 2. Steps of the research

Variables	$a_{1\ (F=5,50)}$		$a_{2\ (F=\ 5,75)}$		$a_{3\ (F=6,0)}$	
$c_{1\ (218^oC)}$	$b_{1(0,7)}$	$b_{2(0,6)}$	$b_{1(0,7)}$	$b_{2(0,6)}$	$b_{1(0,7)}$	$b_{2(0,6)}$
	X	X	X	X	X	X
$c_{2\ (220^oC)}$	X	X	X	X	X	X
	X	X	X	X	X	X
$c_{3\ (222^oC)}$	X	X	X	X	X	X
	X	X	X	X	X	X

Method

The raw material HSRBDPSFA was produced by hydrogenation of SRBDPS from Splitting Plant (SRBDPFA was produced by hydrolysis of RBDPS) in PT. XXX's facility. The raw material HSRBDPSFA was used as crude fatty acid feed. It was obtained and will be purified on the same plant site of the same manufacturer's facility. Medium pressure steam (11 bars) was used to perform vacuum pressure and oil thermal heater was used to heat up fatty acid in order to purify it and to produce BSAD.

The research was done by factorial method with 3 independent variables: feed rate (F) at level of 5.5; 5.75 and 6.0 ton/hour, feed Iodine Value (IV) at level of 0.7 and 0.6 g/100 g and bottom temperature of flash distiller (B FD) at 218, 220 and 222^{o}C (5 mbar). Factorial method was designed by constant model 3 x 2 x 3 and was repeated 2 times for each factor and BSAD IV was one of the quality parameter which was observed. Statistical analysis was performed by Minitab Release -14 software (Nur & Septin, 2006). Samples were analyzed every 4 hours which amounts were 100 ml of light fraction, 500 ml of BSAD and 100 ml of residue acid. Analysis procedure

Table 3. Means of the BSAD IV as effect of three optimized factors

No	F, ton/ hour	IV, g / 100 g	BFD, C^0	BSAD IV, g/100 g
1	5,5	0.7	218 220 222	0.150 0.160 0,170
		0.6	218 220 222	0.145 0.155 0.160
2	5,75	0.7	218 220 222	0.160 0,170 0,170
		0.6	218 220 222	0.155 0.165 0.165
3	6,00	0.7	218 220 222	0.165 0.175 0,180
		0.6	218 220 222	0,169 0,170 0.175

was done based on the procedure of AOCS official method Tg 1- 64 to analyse BSAD IV (David, 2006).

The correct results will be obtained by keeping top temperature of pre-cut column at 190°C and pressure at 21 mbar; Flash Distiller pressure at 5 mbar and temperature (B FD) as per the steps shown in Table 2; residue distiller pressure at 1 mbar and temperature at 250° C.

The research steps were based on the factorial method by 3 x 2 x 3 and were repeated 2 times. Table 2 shows steps of research. The symbols are used in the table such as: a_1, a_2, a_3 = variation of CFAF rate (ton/hour); b_1, b_2, b_3 = variation of feed IV (g/100 g) and c_1, c_2, c_3 = variation of BFD (°C).

Results and discussions

The results are provided in Table 3. The effect of process variables were analyzed with *Minitab Release* 14, where, F is feed rate, IV is feed iodine value and B FD is the bottom temperature of *flash distiller* column, and a symbol of * between two symbols of this process variable states the interaction between two or more variables. So F*IV is the interaction levels of F with IV and so on for the others, *dk* is degrees of freedom, Jk is sum of square, kt is central square, F_{Anova} and P_{Anova} are distribution test and significance test analysis of variance. Effect of process variables is significant, if $P_{Anova} < P\alpha = 0.05$.

The significance of the optimized process variables effect on the BSAD iodine value

The results of Factorial analysis and its significance (Table 4) describe the influence of optimized process variables on the BSAD IV. Statistical analysis shows that feed rate, F (P_{anova}= 0,000) and feed iodine value, IV (P_{anova}= 0,010), B FD (P_{anova}= 0,000) were lower than ($P\alpha$ = 0.05), the effects were so significant to the changing of BSAD IV. Interaction of F and IV (P_{anova} = 0,920), F and B FD (P_{anova} = 0,679), IV and B FD (P_{anova} = 0,175), F and IV also with B FD (P_{anova} = 0,920) didn't affected significant ($P_{anova} > P\alpha = 0.05$) changing of BSAD IV. The impact of each main factor to the BSAD IV is shown in the Fig. 2 and Fig. 3.

Effect of Optimization of the main variables and Its Interaction on BSAD IV

The increasing of BSAD IV was affected significantly by the optimization of the main variables (increasing of B FD, feed flow rate F and decreasing of feed iodine value), because significance test analysis of variance P_{anova} shows P_{anova} of B FD, P_{anova} of F and P_{anova} of IV were lower than 0.5 ($P\alpha$). See Table 4. The trends can be seen in Fig. 2.

The impact of the optimized main variables on BSAD IV is shown in Fig. 2 (by using Minitab 14 *software*). This picture shows the significant effect of the optimized main variables on BSAD IV. The same effect is also shown by the average values of the increment of BSAD IV within Table 5 and Table 6 (from Fig. 2).

The effect on increasing of F is significant to the increasing of BSAD IV. At F of 5.5 ton/hour BSAD IV is 0.156667 g/100 g, at F of 5.75 ton/hour BSAD IV is 0.164167 g/100 g and at F 6.0 ton/hour BSAD IV is 0.170833 g/100 g. The average of BSAD's IV increasing is 0.0075 g/100 g from F of 5.5 kg/hour to 5.75 kg/hour and 0.006666 g/100 g from F 5.75 kg/hour to 6.0 kg/hour. The average value of the overall BSAD IV increasing is 0.0070830 g/100 g.

This is easy to understand, because CFAF contains one of the impurities which were indicated by feed IV, and increasing of feed flow rate F

Table 4. BSAD IV Variance analysis and signification

Source		Dk	Jk	kt	F_{anova}	P_{anova}	Remark
Variation							
	F	2	0,0001256	0,0006028	18,08	0.000	Significant
	IV	1	0,000278	0,0002778	8,33	0.010	Significant
	B FD	2	0,0012722	0,0006361	19,08	0.000	Significant
	F * IV	2	0,0000056	0,0000028	0,08	0.920	Not significant
	F * B FD	4	0,0000778	0,0000194	0,58	0.679	Not significant
	IV * B FD	2	0,0000056	0,0000028	0,08	0.920	Not significant
	F * IV* B FD	4	0,0000111	0,0000028	0,08	0.986	Not significant
Error		18	0,0006000	0,0000333			
Total		35					

Table 5. The average values of BSAD IV as the effect of the main factors

No	The average value of BSAD IV, g/100 g		
	F = 5.5 t/h	F = 5.75 t/h	F = 6.0 t/h
1	0.156667	0.164167	0.170833
2	IV =0.6 g/100 g		IV =0.7 g/100 g
	0.161111		0.166667
3	B FD, 218°C	B FD, 220°C	B FD, 222°C
	0.155833	0.165833	0.170000

Note: t/h (ton/hour).

Table 6. The average increasing of BSAD IV as the effect of the main variables.

No	The average value of BSAD IV, g/100 g		The overall average increasing of BSAD IV, g/100 g
	F =5.5-5.75 t/h	F=5.75 -6.0 t/ hr	F = 5.5 - 6.0 t/ h
1	0.00750	0.006666	0.0070830
2	IV = 0.6-0.7 g/100 g		IV = 0.6-0.7 g/100 g
	0.0055560		0.0055560
3	BFD=218-220°C	BFD=220-222 °C	B FD = 218 °- 222 °C
	0.01000	0.004167	0.0070835

Notes: t/h (ton/hour)

will cause increasing of the amount of these impurities which were separated from CFAF at the same conditions. This increasing caused the produced BSAD had greater IV.

The effect of reducing feed IV on BSAD IV reduction and the effect of increasing B FD on increasing BSAD IV can be seen on the same tables, Table 5 and Tables 6. The effect of feed iodine value reduction is significant on BSAD IV reduction.

The average of BSAD IV reduction happened and caused the reduction of feed iodine value (IV). This reduction of iodine value (IV) caused more difficult separation of the iodine value together with BSAD at the same conditions. So the purifying that had been done on CFAF with lower IV produced lower BSAD IV at the same conditions. These data proved that the reduction of feed IV can improve quality of BSAD IV. So raw material with lower IV will produce BSAD with lower IV or on the contrary.

Table 7. The average BSAD production as the effect of the main variables.

No	The average value of BSAD production, kg/hour		
1	F = 5.5 t/h	F = 5.75 t/h	F = 6.0 t/h
	4.943.7	5,168.12	5,400.09
2	IV =0.6 g/100 g		IV =0.7 g/100 g
	5,171.92		5,169.13
3	B FD, 218 ° C	B FD, 220 ° C	B FD, 222 °C
	5,148.77	5,161.53	5,201.28

Note: t/h =ton/hour

The effect of the increasing BFD is significant on the increasing BSAD IV. This can be explained as follows: the increasing in B FD causes blended stearic acid with higher IV to evaporate and condense more at the same conditions. This was supported by the average BSAD IV (Table 3). At bigger B FD, BSAD with relatively higher IV was produced.

Based on the average of BSAD IV above, the effect of the optimized main variables were significant for increasing of BSAD IV, because of the increasing of feed flow rate F, bottom temperature of the flash distiller B FD and feed IV. All the optimized main variables affected BSAD IV quality. The average value of BSAD production as effect of the main variables can be seen within Table 7 which can be used to consider the optimum conditions in this optimization, distillation conditions to purify CFAF to get the in specs BSAD IV.

Based on the average value of BSAD IV in Table 5, the best BSAD IV is 0.161111 g/100 g. Based on Table 7 above the best BSAD production is obtained on the feed flow rate (F) is 6.0 ton/hour, feed IV is 0.6 g/100 g and B FD is 222°C.

The effect of feed flow rate and iodine value interaction on BSAD IV.

The results of one way ANOVA statistical analysis on the interaction of F with IV to the BSAD IV are shown within the Table 8. Based on the data, significance test analysis of variance P_{anova} = 0.048 for the interaction of increasing F at the same IV (0.7 g/100 g) and P_{anova} = 0.015 at the same IV (0.6 g/100 g). Both values of P_{anova} are lower than 0.05 (Pα). That's why the interaction of increasing F with the same IV, shows significant increasing on BSAD IV, also based on the factorial analysis within Table 4. See also Table 9 as supportive of such explanation. These values explained that the effect of the interaction of the increasing F factor with the same IV on the increasing of BSAD IV is significant on the same feed IV. The interaction trend of these 2 factors can be seen on the Fig. 3 and 3D surface plot on the Fig. 4.

It can be understood that the fact of this result is according to the mass and heat balance principles. The increasing of the CFAF mass, which was purified, needed more heat or proportional heat to maintain the same temperature. This was caused by more evaporation and condensation of the BSAD which was purified or separated, include the impurities of IV in BSAD. The increasing on F was caused by BSAD that was produced had more BSAD IV on the same feed IV.

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Table 8. The One way ANOVA for the interaction of F and IV to BSAD IV

No	IV = 0.7 (F_{anova} = 3.75 ; P_{anova} = 0.048)	IV = 0.6 (F_{anova} = 5.65 ; P_{anova} = 0.015)
1	F = 5.5 t/h (F_{anova} = 1.43 ; P_{anova} = 0.26)	
	IV of BSAD = 0.16000 StDev = 0.01095	IV of BSAD = 0.15333 StDev = 0.00816
2	F = 5.75 t/h (F_{anova} = 1,8 ; P_{anova} = 0.209)	
	IV of BSAD = 0.16667 StDev = 0.00516	IV of BSAD = 0.16167 StDev = 0.00753
3	F = 6.0 t/h (F_{anova} = 1.22 ; P_{anova} = 0.296)	
	IV of BSAD = 0.17333 StDev = 0.00816	IV of BSAD = 0.16833 StDev = 0.00753

Notes: St.Dev = Standard deviation; t/h =ton/hour

Table 9. The average of increasing of BSAD IV as effect of the interaction of increasing F at the same IV

No	The average values of increasing of BSAD IV, g/100 g		The *overall* of increasing BSAD IV, g/100 g
1	IV 0.7 g/100 g		
	F = 5.5 - 5.75 t/h	F = 5.75 - 6.0 t/h	F = 5.5 - 6.0 t/h
	0.00667	0.00666	0.006665
2	IV 0.6 g/100 g		
	F = 5.5 - 5.75 t/h	F = 5.75 - 6.0 t/h	F = 5.5 - 6.0 t/h
	0.00834	0.00666	0.00750

Note: t/h =ton/hour

Table 10. Means decreasing of BSAD IV as the interaction effect of the same F and decreasing feed IV

No	The average value of decreasing of BSAD IV, g/100 g			The overall average of decreasing of BSAD IV , g/100 g
	IV from 0,7 to 0,6 g/100g			
1	F = 5.5 t/h	F = 5.75 t/h	F = 6.0 t/h	F = 5.5 to 6.0 t/h
	0,00667	0,00500	0,00500	0,0055567

Note: t/h =ton/hour

Table 11. The One way ANOVA of the average BSAD IV as effect of the interaction of IV and B FD

No	IV = 0.70 g/ 100 g (F_{anova}= 5.83 ; P_{anova} = 0.013)		
	B FD 218 °C	B FD 220°C	B FD 222°C
	F_{anova} = 1.22 ; P_{anova} = 0.296	F_{anova} = 0.92; P_{anova} = 0.36	F_{anova} = 2.86 ; P_{anova} = 0.122
1	0.15833 StDev = 0.00753	0.16833 StDev = 0.00983	0.17333 StDev = 0.00516
	IV = 0.60 g/ 100 g (F_{anova} = 4.33 ; P_{anova} = 0.033)		
2	0.15333 StDev = 0.00816	0.16333 StDev = 0.00816	0.16667 StDev = 0.00816

Note: StDev = standard deviation.

So the increasing of feed flow rate F on the same feed IV is a variable which has a significant effect on increasing BSAD IV. It effect can't be neglected and very important to be controlled or manipulated exactly to obtain the in specs of BSAD IV.

The effect of the interaction of same feed flow rate F and decreasing feed IV: Based on the *one* way ANOVA analysis (Table 8) the interaction of the same F and decreasing feed IV isn't significant on decreasing of BSAD IV, because P_{anova} is greater than $P\alpha$ = 0,05 (for F = 5,5 ton/ hour, P_{anova} = 0,26 ; for F = 5,75 ton/hour ; P_{anova} = 0,209 and for F = 6,0 ton/ hour ; P_{anova} = 0.296). This means interaction of F and IV within the Table 4 did not significantly affect the decreasing of BSAD IV.

Table 10 supports the explanation of effect of the interaction of the same F and decreasing feed IV. Decreasing of feed IV has impact on the decreasing of BSAD IV. Feed IV greatly affected BSAD IV. This interaction is also very important to be controlled or manipulated exactly to get the in specs of BSAD IV. The optimum one was achieved at F = 6 ton/hour, IV = 0.6 g/ 100 g and BSAD IV of 0.16833 g/ 100 g (Table 8).

The effect of interaction of feed iodine value and temperature of the bottom flash distiller on BSAD IV.

The interaction of IV and B FD is shown in the Fig. 3 and Fig. 5. Based on the data in the Table 11, significance test analysis of variance P_{anova} = 0,013 for IV of 0.7 g/100 g; P_{anova} = 0,033 for IV of 0.6 g/100 g. Both P_{anova} are lower than 0.05 ($P\alpha$). Increasing of B FD affected the increasing of BSAD IV or vice versa.

Higher the B FD, more the Iodine value and the BSAD IV also increased. The optimum BSAD IV was found at the same feed IV 0.6 g/ 100 g and at a B FD 222°C with BSAD IV of 0.16667 g/ 100 g (This is lower than 0.2 g/100 g).

The effect of the interaction of IV decreasing and the same B FD: Based on the Table 11, the interaction of decreasing of IV and the same B FD did *not significantly affect* the decreasing of BSAD IV, because all P_{anova} values >0,05 (P_{anova} = 0,296 ; 0.36 and 0,122 for each of the B FD 218; 220and 220°C). This means IV*B FD interaction *did not significantly* affect the decreasing of BSAD IV as shown Table 2. See the *overall* average of the decreasing of BSAD IV in Table 13.

The decreasing of BSAD IV in this case (see Fig. 5) can happen, because the decreasing of IV impacted on lower IV impurities which was evaporated and condensed together with BSAD. This matches the principle of *garbage in garbage out.*

Although the effect of this interaction was not significant on the decreasing of BSAD IV, the data in the Table 12 show that BSAD IV was decreased. That's why the effect of this interaction are also so important to control, and manipulate in order to obtain the in specs according to BSAD IV quality standard, besides the interaction of the same IV and increasing of BFD. These two factors are so sufficient to be controlled or manipulated to obtain the quality of BSAD IV as its standard specs which were settled.

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Fig.1. The modified distillation process schema to provide BSAD with the better & stable BSAD IV

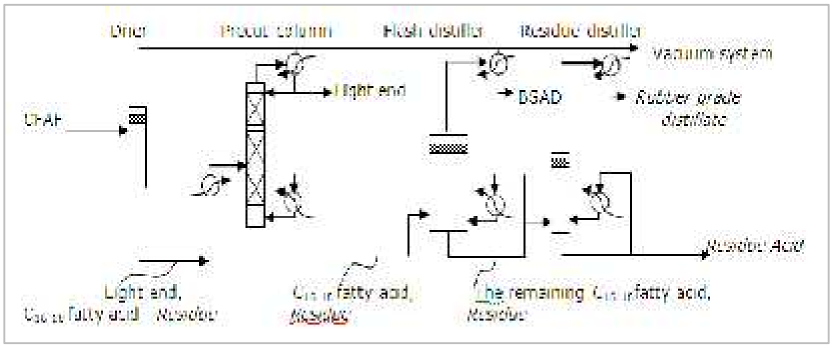


Fig.2. The average effect plot of the main variables on BSAD IV

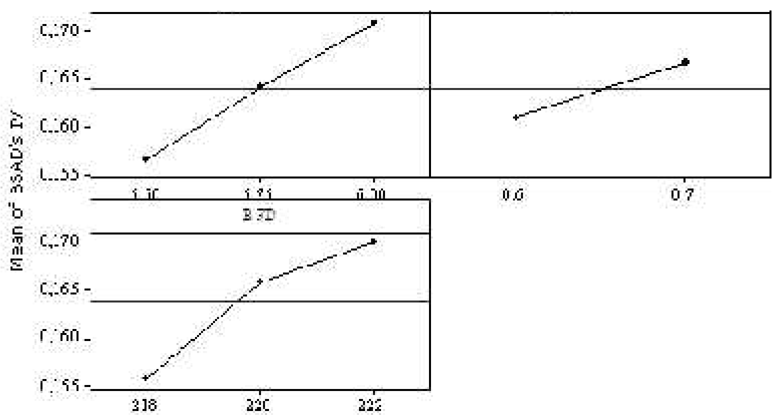


Fig. 3. Mean effect plot of interaction of main variables

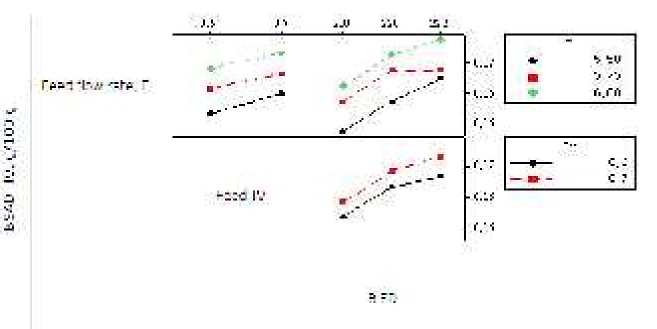
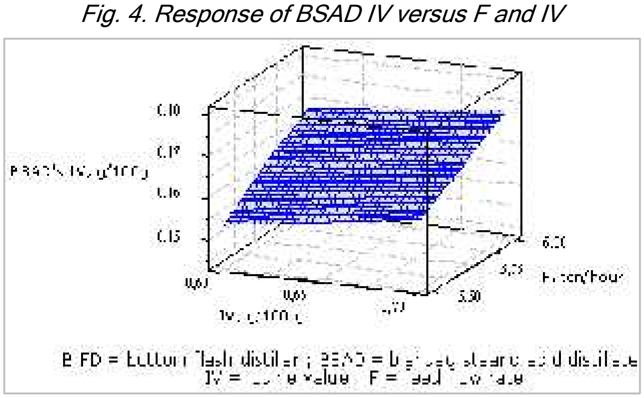


Fig. 4. Response of BSAD IV versus F and IV



The optimization of the distillation process conditions will be better to conclude (to find out feed flow rate F) by looking at Fig. 6. The production yield of BSAD is relatively better on the IV of 0.6 g/ 100 g than IV of 0.7 g/ 100 g on the increasing of B FD.

Based on the data above, optimum conditions were obtained for distillation on the interaction of IV 0.6 g/100 g and B FD222°C on F 6.0 ton/hour (from Table 11, on the third column), with the average of BSAD IV of 0.16667 g/100 g.

It was lower than the maximum quality standard of BSAD IV (It's lower than 0.2 g/100 g) and the most BSAD production was 5203.5 kg/hour.

Generally the optimum conditions were found at 6.0 ton/hour of Feed rate F, 0.6 g/ 100 g of feed IV and 222°C of B FD. These conditions produced BSDA with IV 0.175 g/ 100 g (Table 1, on the 5th column with bolt alphabet).

An idea to modify present distillation technology for better B SAD purification

The present distillation facility could be improved to produce and purify better BSAD IV quality including color, compositions of lauric and myristic acid (See Fig. 7).

The present main or flash distiller (Fig. 1) had no tray, just the demister that couldn't separate well the iodine of the feed to provide

Fig. 5. Response of BSAD IV Versus feed IV and B FD

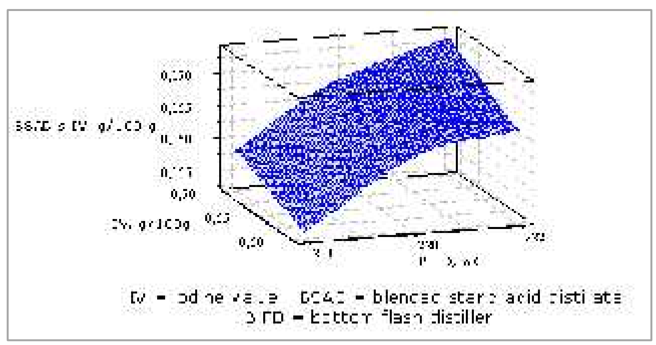


Fig. 6. Yield of BSAD as effect of the interaction of the

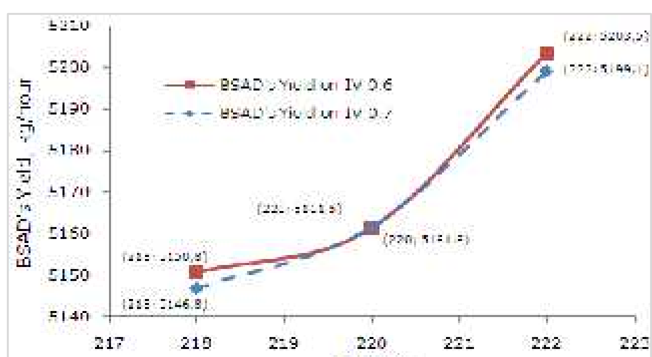


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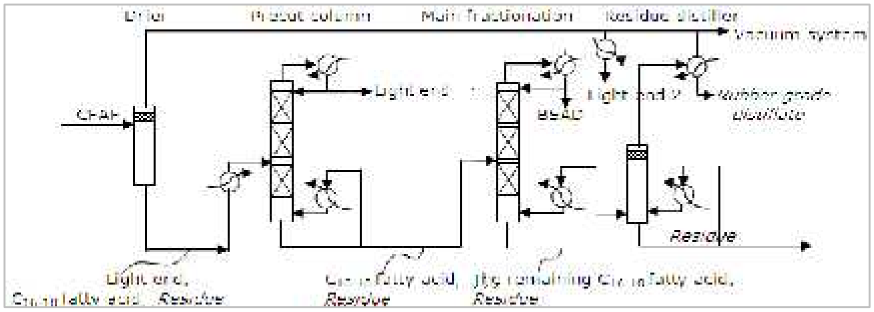
Fig. 7. An idea to modify the present distillation facility to provide BSAD with the better and stable iodine value



the lower BSAD's IV than the result of this study. Improvement of this equipment will be most possible to achieve lower IV and more expansive capacity of BSAD purification through fractional distillation, of course also higher capability to compete in the market of oleo chemical industry.

Replacement of flash distiller column to main fractionator (3^{rd} column in Fig. 7) with special trays (that have higher efficiency) and double condensers or partial condensers will increase efficiency to lower boiling point (includes iodine value or double bond) and increase boiling point in separation of DOA and impurities. The separation of iodine value, lauric and myristic acid or the lower boiling point will be more effective. The decreasing of iodine value, lauric and myristic acid will be followed by better improvement of color that made its color stability and odor better also. The partial condenser will cause easier separation of light end, color and odor, also iodine value (that can't be separated more on the top of 1^{st} column, because of heat stress effect in 1^{st} column) so BSAD quality will be better and more stable. Heat stress is effect to darker color and odor of fatty acid products, includes BSAD.

Table 12. The average of BSAD IV as effect of the interaction of the same IV and increasing of B FD

No	The average values of the increasing of BSAD IV, g/100g		The overall average of the increasing of BSAD IV, g/100 g
	IV 0.7 g/100 g		
1	B FD = 218 °C to 220 °C	B FD = 220 °C to 222 °C	B FD = 218 °C to 222 °C
	0.01	0.005	0,0075
	IV 0.6 g/100g		
2	B FD = 218 °C to 220 °C	B FD = 220 °C to 222 °C	B FD = 218 °C to 222 °C
	0.01	0.0034	0.0067

Table 13. The average of BSAD IV decreasing as the effect of the interaction IV decreasing and the same B FD.

No	The average values of the decreasing of BSAD IV, g/100g			The *overall* average of the decreasing of BSAD IV, g/100g
1	B FD 218 °C	B FD 220 °C	B FD 222 °C	
	IV = 0.7 to 0.6 g/100 g	IV = 0.7 to 0.6 g/100 g	IV = 0.7 to 0.6 g/100 g	IV = 0.7 to 0.6 g/100 g
	0.005	0.005	0.00555	0.00518

Conclusions

The optimum conditions of the BSAD purification through distillation are: 0.60 g/100 g of feed IV, 6.0 ton/hour of feed flow rate F, 222°C of the temperature of the bottom flush distiller (B FD) on the BSAD IV 0.175 g/100 g. Blended Stearic Acid Distillate of RBDPS which was obtained in this optimization met the BSAD's IV quality standard by separating rubber grade distillate as byproduct. All the main factors of the distillation process in this research affected the BSAD IV. These factors can be manipulated and controlled to achieve better and more stable BSAD IV. Increasing of the feed flow rate F, temperature of bottom flash distiller BFD and feed IV had significant effect to the increasing of BSAD IV or on the contrary. The interactions between the main factors had impact on the BSAD IV, although some of the interaction effects were not significant. These interactions had to be manipulated and controlled carefully and exactly to achieve BSAD IV which is according to the specs.

Suggestions

The BSAD IV obtained in this research was so close to the quality standard of IV. So it's advised strongly to choose these two alternatives:

1. To use CFAF with the iodine value of 0.6 g/100 g or lower by improving the present hydrogenation operating conditions.
2. To improve 2nd column of the present distillation facility becomes fractionation column with partial condenser to get lower BSAD IV, higher plant capacity and BSAD yield, better and more stable quality of BSAD.

The improvement is believed will be able to cover usage of the other bed quality of raw material, such as CPS (Crude Palm Stearin) or PFAD (Palm Fatty Acid Distillate) to produce the better of others main distillate products.

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