CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the conclusions and recommendations for further studies will be focused.

1. The quantity of phenolic antioxidant directly affected the OIT. A greater amount of the phenolic antioxidant leads to a longer oxidative induction time. This is because the phenolic antioxidant is capable of terminating the chain propagation by trapping the free radicals formed during thermal oxidation of the compounded HDPE. Hence, molecules of stable radicals are formed and provide a prolong induction period to the compounded HDPE.

2. An additive system of the blended antioxidant and the OBA shows a strong synergistic interaction on the OIT. In addition, the HDPE formulation containing 0.06% of ODHP, 0.02% of DSTDP and 0.0007% of the OBA gave the best performance on the OIT.

3. Thioester decreases the performance of hindered amine light stabilizers (HALS).

4. An increase in the phenolic antioxidant leads to a reduction in the Lightness index. The thioester antioxidant and the OBA help improving the color while DAT which has the worst color stability than any other antioxidants used in the present study, does not help improving the color even when the thioester antioxidant or the OBA is added.

5. Re-processing of compounded HDPE increases the MFR, discoloration in the form of yellowness. It also tends to shorten the OIT because the degree of degradation is raised upon re-processing that the compounded HDPE was repeatedly exposed to prolongly high temperature coupled with the high shear stress in the extrusion upon each pass. The effect is more pronounced upon further passes of re-processing.

6. Formulation design of compounded HDPE can be achieved by Central Composite Rotatable (CCR) technique. The result obtained from the design can be analyzed statistically. Regression analysis and the analysis of variance test the suitability of the model of response surface equation in order to get the response surface equation with statistical confidence. This can lead to a response surface and the contour curve showing the relationship between the properties of compounded HDPE and the additives quantities. Models in the form of response surface equation can be achieved by applying Response Surface Methodology (RSM) of the CCR experimental design as shown is Tables 6.1 to 6.7.

Table 6.1 : Interaction between the Blended AO (X_1) and the OBA (X_2).

Properties	Models in the form of response surface equation	
MFR	1^{st} pass	$MFR = 0.13341+0.737X_1+125.2X_2-6.3333X_1^2-72800.0X_2^2$
	3^{rd} pass	$MFR = 0.14093+1.725X_1+170.6X_2-1080.0X_1X_2-12.0333X_1^2-67680.0X_2^2$
	5^{th} pass	$MFR = 0.23783+1.12178X_1+39.8667X_2-797.333X_1X_2-10.1778X_1^2$
Lightness Index	1^{st} pass	$L_c = 63.82-75.93X_1+50428.0X_2-333.33X_1^2-2.656x10^7 X_2^2$
	3^{rd} pass	$L_c = 74.64-93.87X_1+12480.0X_2$
	5^{th} pass	$L_c = 73.98-123.0X_1+9148.0X_2$
OIT	1^{st} pass	$OIT = 152.76-1360.4X_1-1.19x10^5 X_2+2.38x10^6 X_1X_2$
	3^{rd} pass	$OIT = 75.30-363.2X_1-28062.7X_2+1.0433x10^6 X_1X_2$
	5^{th} pass	$OIT = 69.94-501.34X_1+8154.44X_1^2$

Table 6.2 : Interaction between the PATHP (X_1), DLTDP (X_2) and the OBA (X_3).

Properties	Models in the form of response surface equation	
MFR	1^{st} pass	$MFR = 0.21834-1.3304X_1+0.1553X_2-0.6256X_3+10.3778X_1^2+6.2556X_3^2$
	3^{rd} pass	$MFR = 0.2528-0.6609X_1+0.1020X_2-0.40X_3+4.6889X_1^2+4.0X_3^2$
	5^{th} pass	$MFR = 0.33094-2.0681X_1-0.7389X_3+15.3444X_1^2+7.3889X_3^2$
Lightness index	1^{st} pass	$L_c = 81.28-429.73X_1+208.44X_2+8597.6X_3+1673.11X_1^2-2084.44X_2^2$
	3^{rd} pass	$L_c = 75.97-367.98X_1+208.44X_2+8152.0X_3+1254.44X_1^2-2084.44X_2^2$
	5^{th} pass	$L_c = 70.31-233.97X_1+147.22X_2+8004.0X_3-1472.22X_2^2$
OIT	1^{st} pass	$OIT = 102.09-197.71X_1-1026.17X_2-577.33X_3+5517.78X_1^2+6126.67X_2^2$ $+5773.33X_3^2$
	3^{rd} pass	$OIT = 90.78+222.67X_1-1543.49X_2-304.89X_3+2440.0X_1^2+12005.56X_2^2$ $+3048.89X_3^2$
	5^{th} pass	$OIT = 62.53+891.17X_1-926.67X_2-572.44X_3-7583.33X_1X_2+9397.78X_2^2$ $+5724.44X_3^2$

Table 6.3 : Interaction between the PATHP (X_1), DSTDP (X_2) and the OBA (X_3).

Properties	Models in the form of response surface equation	
MFR	1st pass	$MFR = 0.19113-0.46733X_1-0.04277X_2-8.2111X_1X_2+6.7889X_1^2+4.5333X_2^2$
	3rd pass	$MFR = 0.23557-0.40611X_1-0.78389X_2+20.04167X_3-6.4333X_1X_3$ $+7.2778X_1^2+6.2222X_2^2$
	5th pass	$MFR = 0.30961-1.45922X_1+10.72889X_1^2$
Lightness Index	1st pass	$L_c = 80.47-23.03X_1+60.83X_2+4624.0X_3-1216.67X_1X_2-1530.0X_1^2$
	3rd pass	$L_c = 82.32-49.18X_1-1752.22X_1^2$
	5th pass	$L_c = 72.54+29.06X_1+202.89X_2-2415.56X_1^2-2028.89X_2^2$
OIT	1st pass	$OIT = 78.46+887.15X_1-924.88X_2-588.23X_3-6958.89X_1X_2+11764.44X_2X_3$ $+3643.33X_2^2$
	3rd pass	$OIT = 86.42-75.16X_1-1126.67X_2+5355.56X_1^2+6003.33X_2^2$
	5th pass	$OIT = 82.22+405.10X_1-1524.72X_2+10498.89X_2^2$

Table 6.4 : Interaction between the ODHP (X_1), DLTDP (X_2) and the OBA (X_3).

Properties	Models in the form of response surface equation	
MFR	1st pass	$MFR = 0.14941+0.82556X_2+0.82556X_3-16.51111X_2X_3$
	3rd pass	$MFR = 0.20224+0.8189X_2+0.76779X_3-27.5556X_2X_3+5.8889X_2^2+6.10X_3^2$
	5th pass	$MFR = 0.25541+0.49945X_2+0.3739X_3-23.9889X_2X_3+7.0X_2^2+8.2556X_3^2$
Lightness Index	1st pass	$L_c = 84.03-106.73X_1+5480.0X_3$
	3rd pass	$L_c = 76.72-106.10X_1+7302.56X_3-905.56X_3^2$
	5th pass	$L_c = 75.32-105.07X_1+8016.0X_3$
OIT	1st pass	$OIT = 55.22+905.01X_1-179.47X_2-13583.89X_3-7677.78X_1^2-5281.11X_3^2$
	3rd pass	$OIT = 38.59+735.49X_1-195.9X_2+528.11X_3-5172.22X_1^2-5281.11X_3^2$
	5th pass	$OIT = 45.25+547.58X_1-309.2X_2+343.781X_3-6875.56X_1X_3$

Table 6.5 : Interaction between the ODHP (X_1), DSTDP (X_2) and the OBA (X_3).

Properties		**Models in the form of response surface equation**
MFR	1^{st} pass	$MFR = 0.17276+0.33611X_1+0.60034X_2-17.930X_3-6.7222X_1X_3-8.0333X_2X_3+3.87778X_3^2$
	3^{rd} pass	$MFR = 0.22168+0.19722X_1+0.76556X_2+27.40389X_3-3.9444X_1X_3-7.6556X_2^2+7.9333X_3^2$
	5^{th} pass	$MFR = 0.30071-0.666X_1+0.98778X_2-9.8778X_2^2$
Lightness Index	1^{st} pass	$L_c = 87.23-177.91X_1+6810.22X_3+1795.56X_1X_3$
	3^{rd} pass	$L_c = 79.47-32.37X_1+6842.83X_3+1698.89X_1X_3-1317.78X_1^2+82.22X_3^2$
	5^{th} pass	$L_c = 70.77+179.57X_1+7002.44X_3+1711.11X_1X_3-3375.56X_1^2$
OIT	1^{st} pass	$OIT = -1.10+1713.97X_1+384.37X_2+17728.06X_3-5403.33X_1X_2-9681.11X_1X_3-7931.11X_1^2-4690.0X_2^2$
	3^{rd} pass	$OIT = 43.31+958.78X_1-355.23X_2+325.0X_3-6500.0X_1X_3-5177.78X_1^2$
	5^{th} pass	$OIT = 35.37+1067.45X_1+220.82X_2+241.0X_3-4820.0X_1X_3-8264.44X_1^2-5435.56X_2^2$

Table 6.6 : Interaction between the DAT (X_1), DLTDP (X_2) and the OBA (X_3).

Properties		**Models in the form of response surface equation**
MFR	1^{st} pass	$MFR = 0.2559-1.779X_1-1.090X_2-1.1444X_3+14.8333X_1^2+10.90X_2^2$
	3^{rd} pass	$+11.4444X_3^2$
		$MFR = 0.25074-1.61944X_1-0.21555X_2-0.50222X_3-0.4889X_2X_3+13.3111X_1^2$
	5^{th} pass	$+7.40X_2^2+10.2667X_3^2$
		$MFR = 0.29656-2.45633X_1-0.9889X_3+20.4667X_1^2+9.8889X_3^2$
Lightness Index	1^{st} pass	$L_c = 78.68-290.23X_1+261.33X_3-2613.33X_3^2$
	3^{rd} pass	$L_c = 69.32-169.93X_1+151.33X_2-3026.67X_1X_2$
	5^{th} pass	$L_c = 59.69-104.64X_1+202.56X_2-4051.11X_1X_2$
OIT	1^{st} pass	$OIT = 58.41+466.93X_1-185.83X_2+15716.0X_3$
	3^{rd} pass	$OIT = 70.97+1331.58X_1-767.98X_2-404.0X_3-6514.44X_1X_2-6055.56X_1^2+8086.67X_2^2+4040.0X_3^2$
	5^{th} pass	$OIT = 81.38+1324.58X_1-1328.06X_2-425.0X_3+8500.0X_2X_3-8387.78X_1^2+6775.56X_2^2$

Table 6.7 : Interaction between the DAT (X_1), DSTDP (X_2) and the OBA (X_3).

Properties	Models in the form of response surface equation	
MFR	1st pass	$MFR = 0.18804-0.20233X_1-0.19222X_2-0.19222X_3+3.8444X_2X_3$
	3rd pass	$MFR = 0.20337-0.16489X_1-3.89667X_3-2.0667X_1X_3+1.3222X_1^2$
	5th pass	$MFR = 0.23869-1.08156X_1+0.44333X_3+7.5556X_1^2-4.4333X_2^2$
Lightness Index	1st pass	$L_c = 87.88-487.93X_1+2096.67X_1^2$
	3rd pass	$L_c = 79.09-531.52X_1+6956.0X_3+1872.22X_1^2$
	5th pass	$L_c = 75.80-351.60X_1$
OIT	1st pass	$OIT = 68.89+1525.06X_1-707.64X_2-11612.22X_1^2+5161.11X_2^2$
	3rd pass	$OIT = 57.96+1011.31X_1-162.13X_2-5451.11X_1^2$
	5th pass	$OIT = 71.05+430.77X_1-251.73X_2$

Recommendations for Further Studies

Polymer mixing formulation design can be extended and modified for further studies, such as by changing the category of antioxidants and the types of polymer to be studied.