

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Size

The size is shown in Table 4-1 through 4-7. The results of the ruby from Beauty Gems Co., Ltd. are shown in Table 4-1a and 4-1b, those from C.Siamese Gems Co., Ltd in Table 4-2a and 4-2b, those from Paragon Co., Ltd. in Table 4-3a and 4-3b, and those from SWD import & export Co., Ltd. in Table 4-4. Results of the blue sapphire from Beauty Gems Co., Ltd. are shown in Table 4-5a and 4-5b, those from Primeir Co., Ltd. in Table 4-6, and those from SWD import & export Co., Ltd. in Table 4-7.

The first column in each table shows the color code, the second the shape, the third to fifth the size in mm, the sixth the ratio of length and width, and the last carats as provided by companies.

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Table 4-1a Shape, proportion and carat weight of CRA, CRB, CRC

Code	Shape	Length	Width	Height	L/W	Carats
CRA 1	Oval	4.10	3.18	1.80	1.29	0.218
CRA 2	Oval	4.00	3.11	2.29	1.29	0.261
CRA 3	Oval	4.00	3.00	2.21	1.33	0.238
CRA 4	Oval	4.25	3.28	2.00	1.30	0.259
CRA 5	Oval	3.89	2.95	1.89	1.32	0.206
CRB 1	Oval	4.01	3.08	1.92	1.30	0.214
CRB 2	Oval	3.95	3.05	2.25	1.30	0.251
CRB 3	Oval	4.20	3.10	2.20	1.35	0.255
CRB 4	Oval	3.95	3.08	2.20	1.28	0.252
CRB 5	Oval	3.90	3.15	1.91	1.24	0.209
CRC 1	Oval	4.00	3.10	2.10	1.29	0.208
CRC 2	Oval	4.00	3.20	2.08	1.25	0.249
CRC 3	Oval	3.90	3.04	2.17	1.28	0.237
CRC 4	Oval	3.91	3.11	1.85	1.26	0.206
CRC 5	Oval	4.00	3.12	1.85	1.28	0.206

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Table 4-1b Shape, proportion and carat weight of CRD, CRE and CRF

Code	Shape	Length	Width	Height	L/W	Carats
CRD1	Oval	3.98	3.15	1.92	1.26	0.224
CRD2	Oval	4.00	2.98	1.20	1.34	0.187
CRD3	Oval	4.28	2.85	2.00	1.50	0.223
CRD4	Oval	3.85	3.00	2.20	1.28	0.211
CRD5	Oval	4.05	3.15	1.95	1.29	0.245
CRE 1	Oval	4.18	3.20	2.20	1.31	0.288
CRE 2	Oval	4.22	2.94	2.10	1.44	0.244
CRE 3	Oval	3.98	3.00	2.15	1.33	0.237
CRE 4	Oval	4.12	3.20	2.20	1.29	0.277
CRE 5	Oval	3.80	3.31	2.26	1.15	0.279
CRF 1	Oval	4.31	3.31	2.10	1.30	0.274
CRF 2	Oval	4.08	3.18	2.05	1.28	0.251
CRF 3	Oval	3.92	3.01	2.00	1.30	0.213
CRF 4	Oval	4.15	3.20	2.25	1.30	0.260
CRF 5	Oval	4.01	3.18	2.15	1.26	0.243

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Table 4-2a Shape, proportion and carat weight of CSGA, CSGB, CSGC

Code	Shape	Length	Width	Height	L/W	Carats
CSGA1	Oval	6.25	4.29	3.31	1.46	0.751
CSGA2	Oval	6.05	4.18	3.00	1.45	0.682
CSGA3	Oval	6.05	4.11	2.89	1.47	0.596
CSGA4	Oval	5.98	4.15	1.88	1.44	0.443
CSGA5	Oval	6.14	3.95	2.52	1.55	0.463
CSGB1	Oval	7.09	5.18	2.15	1.37	0.830
CSGB2	Oval	7.19	5.19	3.52	1.39	0.574
CSGB3	Oval	7.00	4.79	1.69	1.46	1.144
CSGB4	Oval	7.04	5.13	2.11	1.37	0.905
CSGB5	Oval	7.20	5.04	2.65	1.43	0.876
CSGC1	Oval	4.71	3.45	2.38	1.37	0.345
CSGC2	Oval	4.50	3.55	1.62	1.27	0.240
CSGC3	Oval	4.40	3.69	2.32	1.19	0.329
CSGC4	Oval	4.81	3.71	2.35	1.30	0.394
CSGC5	Oval	4.35	3.42	1.89	1.27	0.263

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Table 4-2b Shape, proportion and carat weight of CSGD, CSGE and CSGF

Code	Shape	Length	Width	Height	L/W	Carats
CSGD1	Oval	4.61	3.69	2.32	1.25	0.346
CSGD2	Oval	4.50	3.60	1.70	1.25	0.255
CSGD3	Oval	4.55	3.60	2.61	1.26	0.382
CSGD4	Oval	4.41	3.45	1.85	1.28	0.257
CSGD5	Oval	4.50	3.40	2.19	1.32	0.325
CSGE1	Oval	4.69	3.71	2.62	1.26	0.446
CSGE2	Oval	4.40	3.42	2.00	1.29	0.261
CSGE3	Oval	4.70	3.69	2.41	1.27	0.327
CSGE4	Oval	4.38	3.32	1.65	1.32	0.189
CSGE5	Oval	4.30	3.30	1.45	1.30	0.200
CSGF1	Oval	4.30	3.22	1.31	1.34	0.175
CSGF2	Oval	4.42	3.29	1.28	1.34	0.265
CSGF3	Oval	4.44	3.00	1.69	1.48	0.235
CSGF4	Oval	4.42	3.42	1.38	1.29	0.185
CSGF5	Oval	4.70	3.79	2.67	1.24	0.442

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Table 4-3a Shape, proportion and carat weight of PRA, PRB, PRC

Code	Shape	Length	Width	Height	L/W	Carats
PGRA1	Oval	5.10	4.10	1.92	1.24	0.53
PGRA2	Oval	5.05	3.75	2.90	1.35	0.35
PGRA3	Oval	4.90	4.00	2.60	1.23	0.44
PGRA4	Oval	5.00	4.21	3.10	1.19	0.61
PGRA5	Oval	5.24	4.01	2.10	1.31	0.43
PGRB1	Oval	5.35	4.29	2.25	1.25	0.51
PGRB2	Oval	4.33	3.95	2.40	1.10	0.43
PGRB3	Oval	4.80	4.00	2.80	1.20	0.50
PGRB4	Oval	5.60	3.85	2.55	1.45	0.56
PGRB5	Oval	5.10	4.00	2.30	1.28	0.43
PGRC1	Oval	5.20	4.10	1.35	1.27	0.35
PGRC2	Oval	5.10	3.81	1.40	1.34	0.26
PGRC3	Oval	5.25	4.10	2.35	1.28	0.48
PGRC4	Oval	5.30	3.90	2.35	1.36	0.48
PGRC5	Oval	5.25	4.30	3.00	1.22	0.67

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Table 4-3b Shape, proportion and carat weight of PGRD, PGRE and PGRF

Code	Shape	Length	Width	Height	L/W	Carats
PGRD1	Oval	5.10	4.25	2.30	1.20	0.47
PGRD2	Oval	5.20	3.92	2.72	1.33	0.53
PGRD3	Oval	5.10	4.00	2.30	1.28	0.42
PGRD4	Oval	5.12	4.12	3.00	1.24	0.60
PGRD5	Oval	4.90	3.85	1.95	1.27	0.36
PGRE1	Oval	5.12	4.01	2.13	1.28	0.41
PGRE2	Oval	5.01	3.98	2.68	1.26	0.58
PGRE3	Oval	4.87	4.28	2.00	1.14	0.42
PGRE4	Oval	5.14	4.01	2.12	1.28	0.36
PGRE5	Oval	5.12	4.21	2.98	1.22	0.47
PGRF1	Oval	5.21	4.11	3.02	1.27	0.62
PGRF2	Oval	5.20	4.03	3.21	1.29	0.50
PGRF3	Oval	5.23	4.12	2.96	1.27	0.47
PGRF4	Oval	5.13	4.32	3.02	1.19	0.63
PGRF5	Oval	5.12	4.10	3.21	1.25	0.62

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Table 4-4 Shape, proportion and carat weight of RSWDA, RSWDB, RSWDC, RSWDD and RSWDE

Code	Shape	Length	Width	Height	L/W	Carats
RSWDA1	Oval	4.50	3.40	2.20	1.32	0.345
RSWDA2	Oval	4.48	3.50	2.75	1.28	0.380
RSWDA3	Oval	4.50	3.60	2.70	1.25	0.456
RSWDA4	Oval	4.55	3.60	2.35	1.26	0.370
RSWDA5	Oval	4.75	3.43	2.10	1.38	0.333
RSWDB1	Oval	4.90	3.33	2.40	1.47	0.389
RSWDB2	Oval	4.80	3.28	2.26	1.46	0.353
RSWDB3	Oval	4.95	3.18	2.45	1.55	0.396
RSWDB4	Oval	4.85	2.95	2.28	1.64	0.342
RSWDB5	Oval	5.20	3.30	1.88	1.57	0.330
RSWDC1	Oval	4.50	3.60	2.40	1.25	0.362
RSWDC2	Oval	4.58	3.60	2.40	1.27	0.407
RSWDC3	Oval	4.51	3.69	2.98	1.22	0.461
RSWDC4	Oval	4.30	3.45	2.50	1.24	0.334
RSWDC5	Oval	4.51	3.60	2.50	1.25	0.373
RSWDD1	Oval	4.95	4.00	2.10	1.23	0.364
RSWDD2	Oval	4.82	4.00	2.10	1.20	0.370
RSWDD3	Oval	5.32	4.00	2.40	1.33	0.522
RSWDD4	Oval	5.25	4.15	2.85	1.26	0.556
RSWDD5	Oval	5.15	3.95	2.00	1.30	0.414
RSWDE1	Oval	6.05	4.05	2.15	1.49	0.513
RSWDE2	Oval	6.02	4.04	1.95	1.49	0.491
RSWDE3	Oval	5.87	4.00	2.12	1.46	0.536
RSWDE4	Oval	6.00	4.20	2.30	1.42	0.540
RSWDE5	Oval	5.85	4.15	1.70	1.41	0.400

Table 4-5a Shape, proportion and carat weight of CSA, CSB, CSC

Code	Shape	Length	Width	Height	L/W	Carats
CSA 1	Oval	4.29	3.65	2.90	1.18	0.402
CSA 2	Oval	4.51	3.78	2.60	1.19	0.401
CSA 3	Oval	4.50	3.65	2.81	1.23	0.440
CSA 4	Oval	4.52	3.21	2.69	1.41	0.374
CSA 5	Oval	4.20	3.40	2.61	1.24	0.352
CSB 1	Oval	4.50	3.49	2.81	1.29	0.413
CSB 2	Oval	4.35	3.58	2.60	1.22	0.381
CSB 3	Oval	4.71	3.48	2.70	1.35	0.410
CSB 4	Oval	4.28	3.81	2.50	1.12	0.377
CSB 5	Oval	4.38	3.52	2.45	1.24	0.360
CSC 1	Oval	4.70	3.28	2.70	1.43	0.405
CSC 2	Oval	4.42	3.40	2.48	1.30	0.341
CSC 3	Oval	4.80	3.50	2.75	1.37	0.414
CSC 4	Oval	4.41	3.55	2.65	1.24	0.374
CSC 5	Oval	4.31	3.50	2.61	1.23	0.376

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Table 4-5b Shape, proportion and carat weight of CSD, CSE and CSF

Code	Shape	Length	Width	Height	L/W	Carats
CSD1	Oval	4.12	3.25	2.49	1.27	0.298
CSD2	Oval	4.20	3.15	2.25	1.33	0.279
CSD3	Oval	4.20	3.25	2.41	1.29	0.320
CSD4	Oval	3.90	3.00	2.15	1.30	0.229
CSD5	Oval	3.98	3.35	2.71	1.19	0.330
CSE 1	Oval	4.01	3.10	2.05	1.29	0.228
CSE 2	Oval	4.15	3.30	2.42	1.26	0.291
CSE 3	Oval	4.12	3.12	2.50	1.32	0.292
CSE 4	Oval	4.21	3.23	2.30	1.30	0.269
CSE 5	Oval	3.96	3.25	2.10	1.22	0.249
CSF 1	Oval	4.10	3.00	2.09	1.37	0.237
CSF 2	Oval	4.10	3.10	2.15	1.32	0.250
CSF 3	Oval	4.30	3.20	2.10	1.34	0.264
CSF 4	Oval	4.20	3.10	2.38	1.35	0.289
CSF 5	Oval	4.00	2.95	2.05	1.36	0.218

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Table 4-6 Shape, proportion and carat weight of PMSA and PMSB

Code	Shape	Length	Width	Height	L/W	Carats
PMSA1	Oval	6.01	5.00	3.50	1.20	0.931
PMSA2	Oval	6.35	4.92	2.90	1.29	0.763
PMSA3	Oval	6.10	4.70	3.60	1.30	0.875
PMSA4	Oval	6.10	4.40	4.00	1.39	0.972
PMSA5	Oval	6.51	4.30	3.20	1.51	0.951
PMSB1	Oval	6.51	5.32	2.90	1.22	0.904
PMSB2	Oval	6.09	4.85	3.20	1.26	0.840
PMSB3	Oval	6.10	5.00	2.55	1.22	0.773
PMSB4	Oval	6.05	4.45	2.50	1.36	0.662
PMSB5	Oval	6.07	4.95	2.60	1.30	0.808

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Table 4-7 Shape, proportion and carat weight of BSWDA, BSWDB, BSWDC, BSWDD and BSWDE

Code	Shape	Length	Width	Height	L/W	Carats
BSWDA1	Oval	7.10	5.25	2.60	1.35	0.855
BSWDA2	Oval	7.10	5.16	3.19	1.37	1.153
BSWDA3	Oval	7.05	5.15	3.15	1.36	1.093
BSWDA4	Oval	6.92	4.95	2.42	1.39	0.755
BSWDA5	Oval	6.70	4.87	2.50	1.37	0.737
BSWDB1	Oval	6.14	5.22	2.57	1.17	0.832
BSWDB2	Oval	6.55	5.05	2.29	1.29	0.750
BSWDB3	Oval	6.55	4.66	2.70	1.40	0.818
BSWDB4	Oval	6.65	4.48	2.68	1.48	0.773
BSWDB5	Oval	5.90	5.45	2.25	1.08	0.667
BSWDC1	Oval	6.05	4.30	2.90	1.40	0.725
BSWDC2	Oval	5.30	4.58	2.00	1.15	0.451
BSWDC3	Oval	5.85	4.17	2.70	1.40	0.633
BSWDC4	Oval	5.95	4.60	2.65	1.29	0.711
BSWDC5	Oval	5.95	4.10	2.58	1.45	0.548
BSWDD1	Oval	6.05	4.15	2.90	1.45	0.701
BSWDD2	Oval	5.82	4.02	2.58	1.44	0.566
BSWDD3	Oval	6.15	4.16	2.75	1.47	0.669
BSWDD4	Oval	5.60	4.30	2.58	1.30	0.565
BSWDD5	Oval	5.75	4.00	2.68	1.43	0.535
BSWDE1	Oval	5.95	4.10	2.00	1.45	0.457
BSWDE2	Oval	6.15	4.15	2.35	1.48	0.590
BSWDE3	Oval	6.25	4.30	2.05	1.45	0.545
BSWDE4	Oval	5.95	4.10	2.20	1.45	0.533
BSWDE5	Oval	6.02	4.08	2.30	1.47	0.561

4.1.2 Color quality given by Munsell Notation

Results are shown in Table A-1 through A-12. The first column gives the subjects' name, the second the color code with number at the end to identify different samples and the third the Munsell notation. The results of "Dark Red" ruby are shown in Table A-1a through A-1d, those of "Deep Red" ruby in Table A-2a through A-2d, those of "Vivid Red" ruby in Table A-3a through A-3d, those of "Strong Red" ruby in Table A-4a through A-4d, those of "Purplish Red" ruby in Table A-5a through A-5d, and those from "Pinkish Red" ruby in Table A-6a and A-6c. The results of "Dark Blue" blue sapphire are shown in Table A-7a through A-7c, those of "Deep Blue" blue sapphire in Table A-8a through A-8c, those of "Vivid Blue" blue sapphire in Table A-9a through A-9b, those of "Strong Blue" blue sapphire in Table A-10a through A-10b, those of "Purplish Blue" blue sapphire in Table A-11a through A-11b, those of "Greenish Blue" blue sapphire in Table A-12. (All of these Table can see in Appendix A)

4.2 Representation of colors of ruby and blue sapphire by CIELUV color system

4.2.1 The results of visual evaluation of color ruby in the CIE 1976 u' v' diagram

To see the results quantitatively the Munsell HVC were converted to L^* u' v' values in the CIELUV color system. Then the L^* u' v' values of each ruby and blue sapphire were plotted in the CIE1976 u' v' uniform chromaticity scale diagram.

4.2.1.1 Chromaticity diagram presentation for rubies with $L^*=20.54$

The color coordinates u' and v' of rubies are plotted in Figure 4-1 for the lightness $L^*=20.54$. The color of a rubies of 7.5R2/8 in Munsell color system became $u'=0.39$ and $v'=0.49$ in the CIELUV system and we can see that this color is very highly saturated because the point in the u' v' diagram locates at a large distance from the

white shown by a cross. This color was found in the “Dark Red” and “Deep Red” ruby (shown in Table 4-13).

4.2.1.2 Chromaticity diagram presentation for rubies with $L^*=30.77$

The color coordinates u' and v' of rubies are plotted in Figure 4-2 for the lightness $L^*=30.77$. The color of a rubies of 7.5R3/12 in Munsell color system became $u'=0.44$ and $v'=0.51$ in the CIELUV system and we can see that this color is very highly saturated because the point in the $u' v'$ diagram locates at a large distance from the white shown by a cross. This color was found in the “Deep Red” ruby (shown in Table 4-14).

4.2.1.3 Chromaticity diagram presentation for rubies with $L^*=41.21$

The color coordinates u' and v' of rubies are plotted in Figure 4-3 for the lightness $L^*=41.21$. The color of a rubies of 5R4/14 in Munsell color system became $u'=0.41$ and $v'=0.49$ in the CIELUV system and we can see that this color is very highly saturated because the point in the $u' v'$ diagram locates at a large distance from the white shown by a cross. This color was found in the “Deep Red” ruby (shown in Table 4-15).

4.2.1.4 Chromaticity diagram presentation for rubies with $L^*=51.57$

The color coordinates u' and v' of rubies are plotted in Figure 4-4 for the lightness $L^*=51.57$. The color of a rubies of 7.5RP5/14 in Munsell color system became $u'=0.34$ and $v'=0.44$ in the CIELUV system and we can see that this color is very highly saturated because the point in the $u' v'$ diagram locates at a large distance from the white shown by a cross. This color was found in the “Vivid Red” and “Pinkish Red” ruby (shown in Table 4-16).

4.2.2 The results of visual evaluation of color blue sapphire in the CIE 1976 u' v' diagram

4.2.2.1 Chromaticity diagram presentation for blue sapphires with $L^*=20.54$

The color coordinates u' and v' of rubies are plotted in Figure 4-5 for the lightness $L^*=20.54$. The color of a rubies of 7.5PB2/10 in Munsell color system became $u'=0.18$ and $v'=0.27$ in the CIELUV system and we can see that this color is very highly saturated because the point in the u' v' diagram locates at a large distance from the white shown by a cross. This color was found in the "Dark Blue", "Deep Blue", "Vivid Blue", "Strong Blue" and "Purplish Blue" blue sapphire (shown in Table 4-17).

4.2.2.2 Chromaticity diagram presentation for blue sapphires with $L^*=30.77$

The color coordinates u' and v' of rubies are plotted in Figure 4-6 for the lightness $L^*=30.77$. The color of a rubies of 7.5PB3/10 in Munsell color system became $u'=0.18$ and $v'=0.31$ in the CIELUV system and we can see that this color is very highly saturated because the point in the u' v' diagram locates at a large distance from the white shown by a cross. This color was found in the "Vivid Blue" and "Strong Blue" blue sapphire (shown in Table 4-18).

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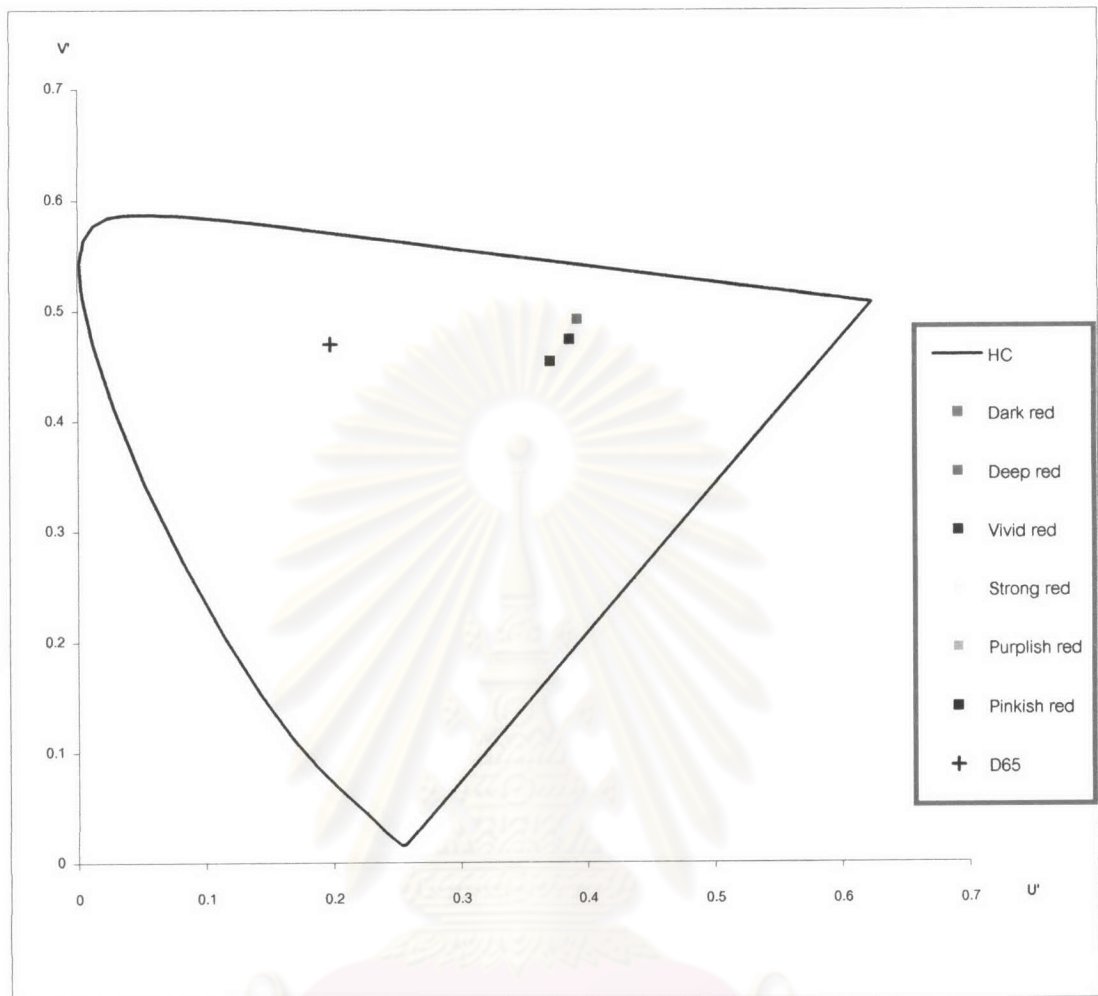


Figure 4-1 CIE 1976 uniform chromaticity scale diagram showing the saturation all of the color coordinate classification of ruby on lightness 20.54

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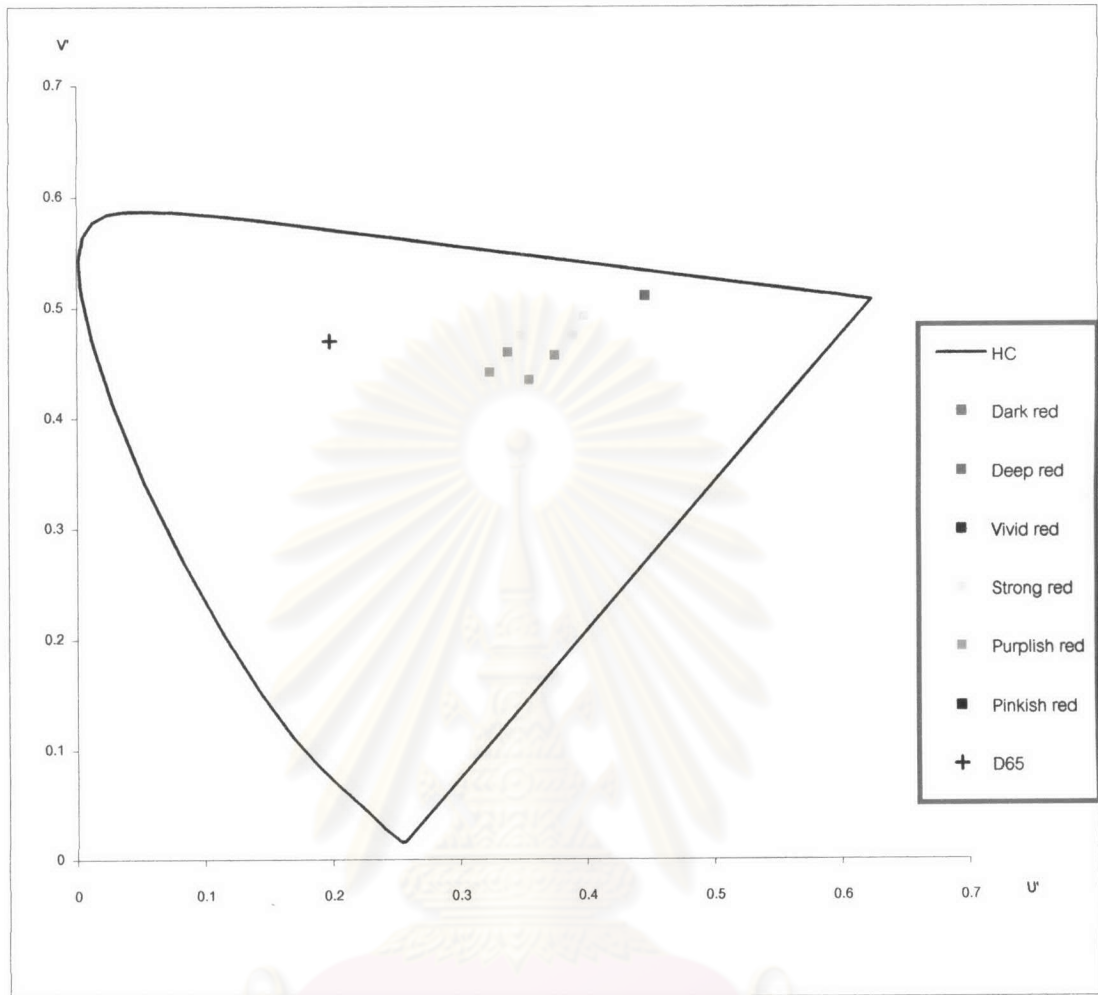


Figure 4-2 CIE 1976 uniform chromaticity scale diagram showing the saturation all of the color coordinate classification of ruby on lightness 30.77

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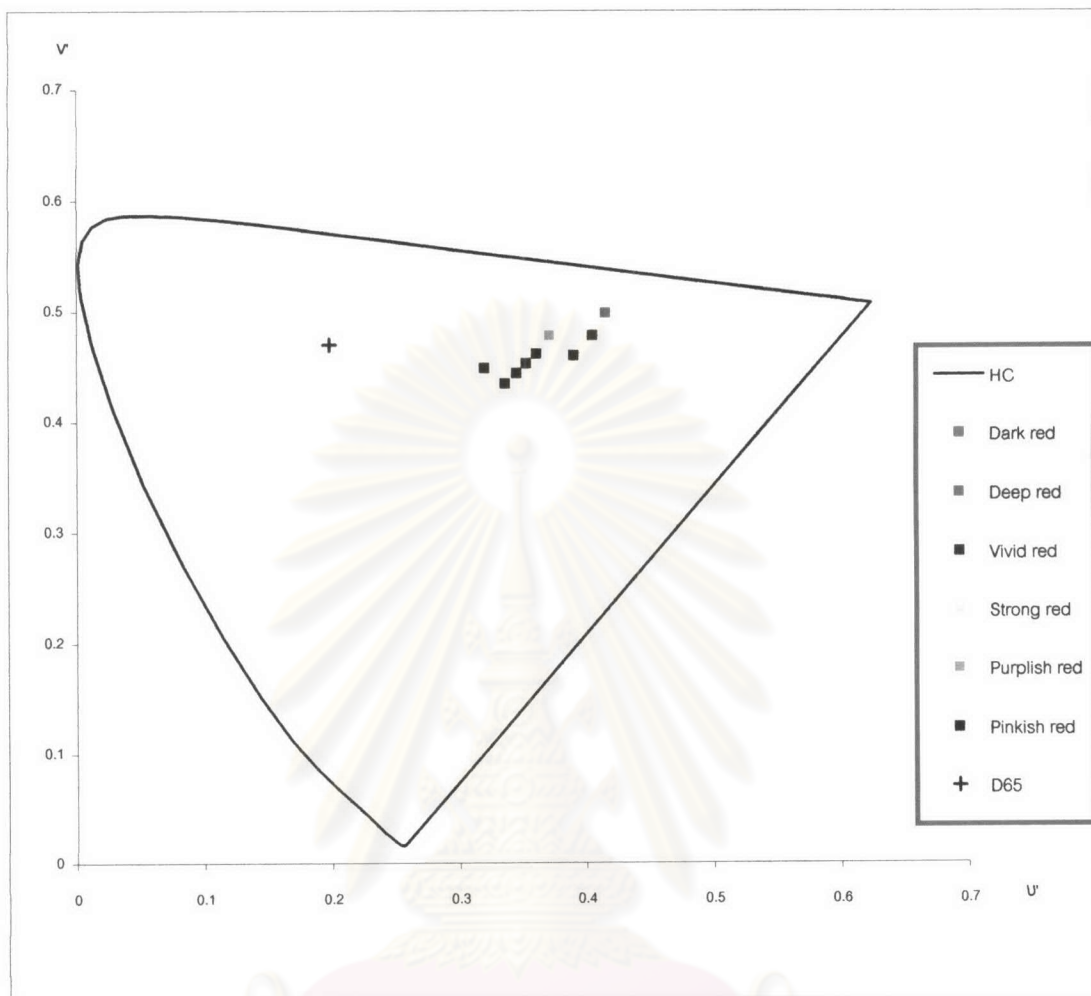


Figure 4-3 CIE 1976 uniform chromaticity scale diagram showing the saturation all of the color coordinate classification of ruby on lightness 41.21

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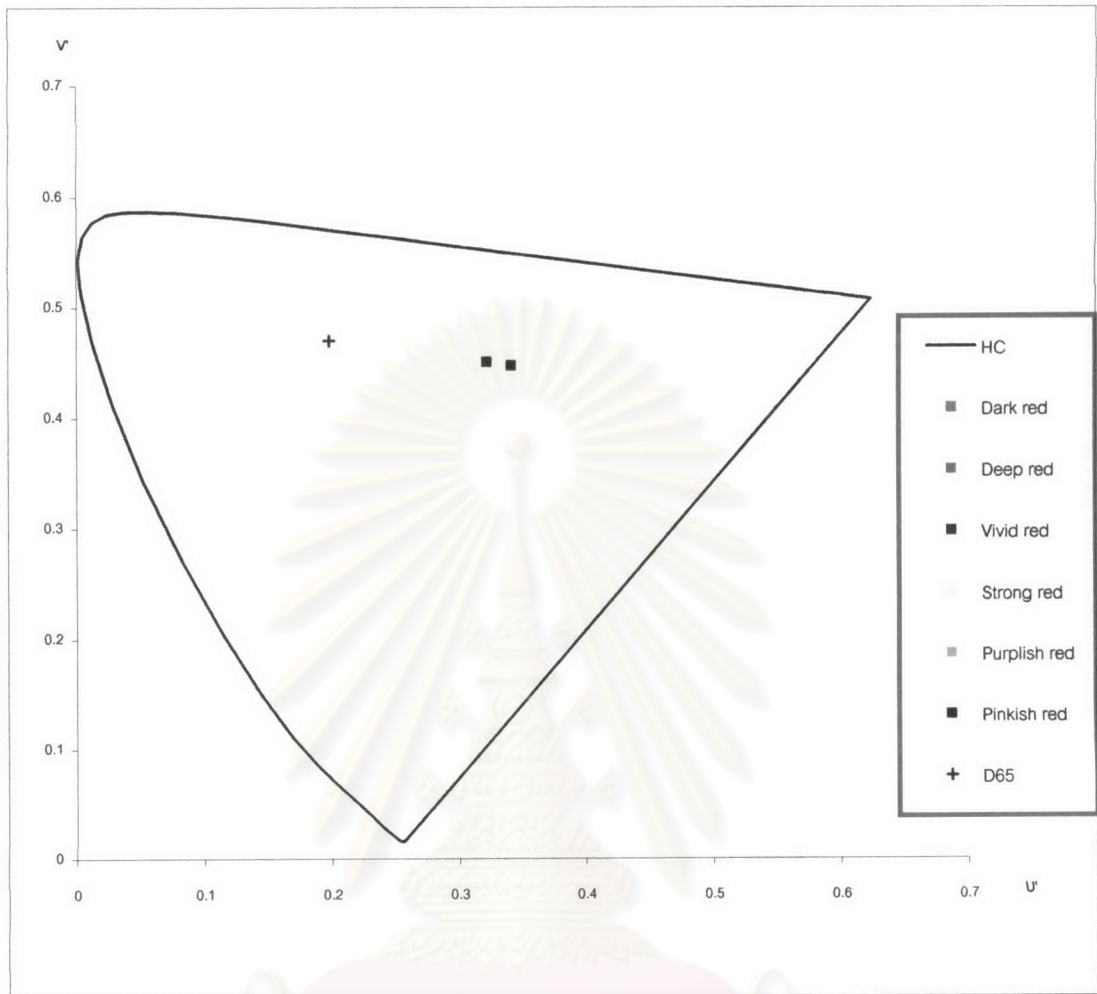


Figure 4-4 CIE 1976 uniform chromaticity scale diagram showing the saturation all of the color coordinate classification of ruby on lightness 51.57

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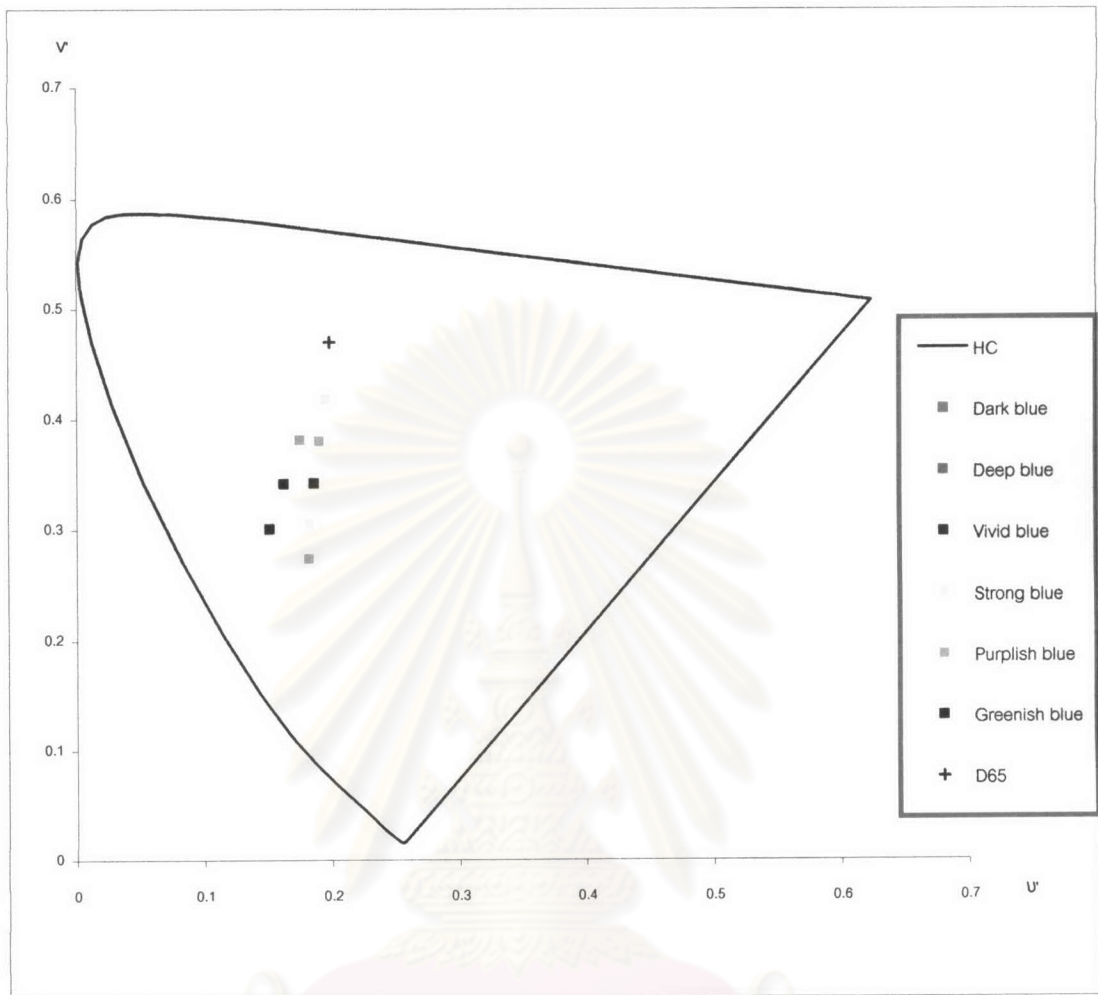


Figure 4-5 CIE 1976 uniform chromaticity scale diagram showing the saturation all of the color coordinate classification of blue sapphire on lightness 20.54

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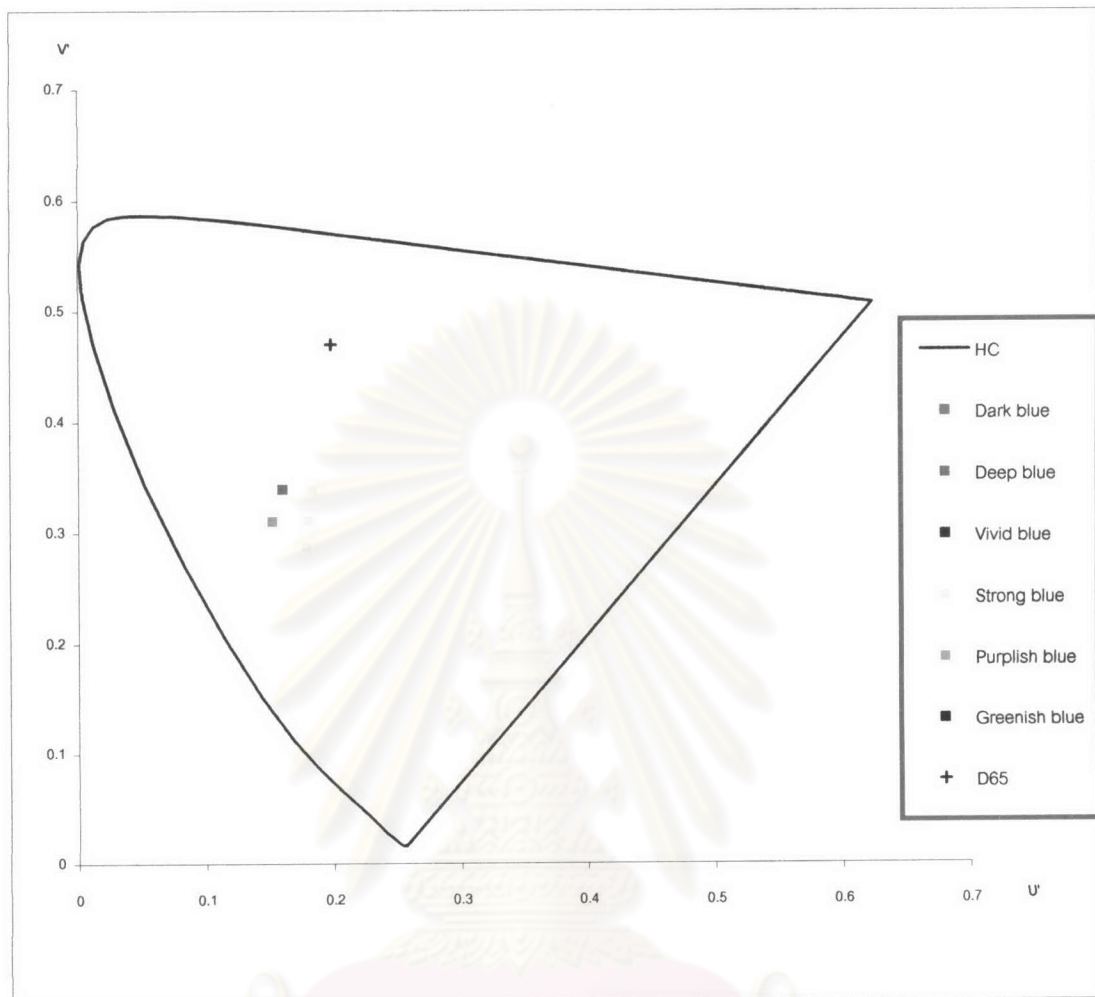


Figure 4-6 CIE 1976 uniform chromaticity scale diagram showing the saturation all of the color coordinate classification of blue sapphire on lightness 30.77

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Table 4-8 The lightness 20.54 can be found the visual evaluation results of color quality classification of ruby in three levels.

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Dark Red"	2.5R 2/8	20.54	0.37	0.45
	5R 2/8	20.54	0.38	0.47
	7.5R 2/8	20.54	0.39	0.49
"Deep Red"	2.5R 2/8	20.54	0.37	0.45
	5R 2/8	20.54	0.38	0.47
	7.5R 2/8	20.54	0.39	0.49
"Vivid Red"	2.5R 2/8	20.54	0.37	0.45
	5R 2/8	20.54	0.38	0.47

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Table 4-9 The lightness 30.77 can be found the visual evaluation results of color quality classification of ruby in five levels.

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Dark Red"	2.5R 3/8	30.77	0.34	0.47
	2.5R 3/10	30.77	0.38	0.47
	5R 3/10	30.77	0.39	0.49
	10RP 3/8	30.77	0.33	0.45
"Deep Red"	2.5R 3/8	30.77	0.34	0.47
	2.5R 3/10	30.77	0.38	0.47
	5R 3/10	30.77	0.39	0.49
	7.5RP 3/8	30.77	0.32	0.44
	7.5R 3/12	30.77	0.44	0.51
	10RP 3/10	30.77	0.37	0.45
"Vivid Red"	2.5R 3/8	30.77	0.34	0.47
	2.5R 3/10	30.77	0.38	0.47
	5R 3/10	30.77	0.39	0.49
	10RP 3/10	30.77	0.37	0.45
"Strong Red"	2.5R 3/8	30.77	0.34	0.47
	2.5R 3/10	30.77	0.38	0.47
	5R 3/10	30.77	0.39	0.49
	10RP 3/10	30.77	0.37	0.45
"Purplish Red"	7.5RP 3/8	30.77	0.32	0.44
	7.5RP 3/10	30.77	0.35	0.43
	10RP 3/8	30.77	0.33	0.45
	10RP 3/10	30.77	0.37	0.45

Table 4-10 The lightness 41.21 can be found the visual evaluation results of color quality classification of ruby in five levels.

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Deep Red"	2.5R 4/14	41.21	0.40	0.47
	5R 4/14	41.21	0.41	0.49
"Vivid Red"	2.5R 4/14	41.21	0.40	0.47
	10RP 4/14	41.21	0.39	0.45
"Strong Red"	7.5RP 4/12	41.21	0.34	0.44
	10RP 4/12	41.21	0.36	0.46
	10RP 4/14	41.21	0.39	0.45
"Purplish Red"	2.5R 4/12	41.21	0.37	0.47
	7.5RP 4/10	41.21	0.32	0.44
	7.5RP 4/12	41.21	0.34	0.44
	10RP 4/12	41.21	0.36	0.46
	10RP 4/14	41.21	0.39	0.45
"Pinkish Red"	6.25RP 4/12	41.21	0.33	0.43
	7.5RP 4/10	41.21	0.32	0.44
	7.5RP 4/12	41.21	0.34	0.44
	8.75RP 4/12	41.21	0.35	0.45
	10RP 4/12	41.21	0.36	0.46
	10RP 4/14	41.21	0.39	0.45

Table 4-11 The lightness 51.57 can be found the visual evaluation results of color quality classification of ruby in two levels.

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Strong Red"	7.5RP 5/14	51.57	0.34	0.44
"Pinkish Red"	7.5RP 5/12	51.57	0.32	0.45
	7.5RP 5/14	51.57	0.34	0.44



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Table 4-12 The lightness 20.54 can be found the visual evaluation results of color quality classification of blue sapphire in six levels.

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Dark Blue"	5PB 2/6	20.54	0.16	0.34
	5PB 2/8	20.54	0.15	0.30
	7.5PB 2/6	20.54	0.18	0.34
	7.5PB 2/8	20.54	0.18	0.30
	7.5PB 2/10	20.54	0.18	0.27
"Deep Blue"	5PB 2/6	20.54	0.16	0.34
	5PB 2/8	20.54	0.15	0.30
	7.5PB 2/6	20.54	0.18	0.34
	7.5PB 2/8	20.54	0.18	0.30
	7.5PB 2/10	20.54	0.18	0.27
"Vivid Blue"	5PB 2/4	20.54	0.17	0.38
	5PB 2/6	20.54	0.16	0.34
	5PB 2/8	20.54	0.15	0.30
	7.5PB 2/2	20.54	0.19	0.41
	7.5PB 2/4	20.54	0.19	0.38
	7.5PB 2/10	20.54	0.18	0.27
"Strong Blue"	5PB 2/6	20.54	0.16	0.34
	5PB 2/8	20.54	0.15	0.30
	7.5PB 2/2	20.54	0.19	0.41
	7.5PB 2/8	20.54	0.18	0.30
	7.5PB 2/10	20.54	0.18	0.27

Table 4-12 The lightness 20.54 can be found the visual evaluation results of color quality classification of blue sapphire in six levels.(continued)

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Purplish Blue"	5PB 2/4	20.54	0.17	0.38
	5PB 2/6	20.54	0.16	0.34
	5PB 2/8	20.54	0.15	0.30
	7.5PB 2/4	20.54	0.19	0.38
	7.5PB 2/6	20.54	0.18	0.34
	7.5PB 2/10	20.54	0.18	0.27
"Greenish Blue"	5PB 2/6	20.54	0.16	0.34
	5PB 2/8	20.54	0.15	0.30
	7.5PB 2/6	20.54	0.18	0.34

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Table 4-13 The lightness 30.77 can be found the visual evaluation results of color quality classification of blue sapphire in four levels.

Color Quality Classifications	Munsell System Values	CIELUV System Values		
		L*	U'	V'
"Deep Blue"	5PB 3/8	30.77	0.16	0.34
"Vivid Blue"	7.5PB 3/8	30.77	0.18	0.34
	7.5PB 3/10	30.77	0.18	0.31
	7.5PB 3/12	30.77	0.18	0.29
"Strong Blue"	7.5PB 3/8	30.77	0.18	0.34
	7.5PB 3/10	30.77	0.18	0.31
	7.5PB 3/12	30.77	0.18	0.29
"Purplish Blue"	5PB 3/10	30.77	0.15	0.31

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4.3 Representation of colors of ruby and blue sapphire by CIELAB color system

4.3.1 The results of visual evaluation of color quality classification of the ruby in the CIE $L^* a^* b^*$ diagrams

4.3.1.1 The “Dark Red” ruby were plotted in the CIE $L^* a^* b^*$ diagrams with the average values (23.09, 40.33, 8.74) and standard deviation values (4.46, 3.95, 4.18) of L^* , a^* , and b^* , respectively (shown in Figure 4-7 and 4-8, respectively). The visual evaluation of “Dark Red” ruby were shown in table 4-14.

4.3.1.2 The “Deep Red” ruby were plotted in the CIE $L^* a^* b^*$ diagrams with the average values (29.88, 44.82, 10.73) and standard deviation values (6.55, 7.81, 6.14) of L^* , a^* , and b^* , respectively (shown in Figure 4-9 and 4-10, respectively). The visual evaluation of “Deep Red” ruby were shown in table 4-15.

4.3.1.3 The “Vivid Red” ruby were plotted in the CIE $L^* a^* b^*$ diagrams with the average values (29.93, 48.90, 11.60) and standard deviation values (5.12, 6.37, 4.59) of L^* , a^* , and b^* , respectively (shown in Figure 4-11 and 4-12, respectively). The visual evaluation of “Vivid Red” ruby were shown in table 4-16.

4.3.1.4 The “Strong Red” ruby were plotted in the CIE $L^* a^* b^*$ diagrams with the average values (33.72, 51.53, 6.54) and standard deviation values (5.46, 4.98, 6.70) of L^* , a^* , and b^* , respectively (shown in Figure 4-13 and 4-14, respectively). The visual evaluation of “Strong Red” ruby were shown in table 4-17.

4.3.1.5 The “Purplish Red” ruby were plotted in CIE $L^* a^* b^*$ diagrams with the average values (37.37, 52.07, 2.22) and standard deviation values (5.19, 5.91, 4.54) of L^* , a^* , and b^* , respectively (shown in Figure 4-15 and 4-16, respectively). The visual evaluation of “Purplish Red” ruby were shown in table 4-18.

4.3.1.6 The “Pinkish Red” ruby were plotted in CIE $L^* a^* b^*$ diagrams with the average values (42.82, 56.27, -0.49) and standard deviation values (3.79, 4.37, 3.30) of L^* , a^* , and b^* , respectively (shown in Figure 4-17 and 4-18, respectively). The visual evaluation of “Pinkish Red” ruby were shown in table 4-19.

4.3.2 The results of visual evaluation of color quality classification of the **blue sapphire** in the CIE $L^* a^* b^*$ diagrams

4.3.2.1 The “Dark Blue” blue sapphires were plotted in CIE $L^* a^* b^*$ diagrams with the average values (20.54, 16.00, -34.98) and standard deviation values (0, 5.90, 5.80) of L^* , a^* , and b^* , respectively (shown in Figure 4-19 and 4-20, respectively). The visual evaluation of “Dark Blue” blue sapphire were shown in table 4-20.

4.3.2.2 The “Deep Blue” blue sapphires were plotted in CIE $L^* a^* b^*$ diagrams with the average values (21.90, 13.67, -35.42) and standard deviation values (3.50, 7.20, 5.90) of L^* , a^* , and b^* , respectively (shown in Figure 4-21 and 4-22, respectively). The visual evaluation of “Deep Blue” blue sapphire were shown in table 4-21.

4.3.2.3 The “Vivid Blue” blue sapphires were plotted in CIE $L^* a^* b^*$ diagrams with the average values (23.95, 15.49, -37.21) and standard deviation values (4.90, 8.60, 10.67) of L^* , a^* , and b^* , respectively (shown in Figure 4-23 and 4-24, respectively). The visual evaluation of “Vivid Blue” blue sapphire were shown in table 4-22.

4.3.2.4 The “Strong Blue” blue sapphires were plotted in CIE $L^* a^* b^*$ diagrams with the average values (20.54, 17.94, -41.31) and standard deviation values

(5.20, 9.05, 11.38) of L^* , a^* , and b^* , respectively (shown in Figure 4-25 and 4-26, respectively). The visual evaluation of “Strong Blue” blue sapphire were shown in table 4-23.

4.3.2.5 The “Purplish Blue” blue sapphires were plotted in CIE L^* a^* b^* diagrams with the average values (21.56, 10.45, -33.64) and standard deviation values (3.12, 4.95, 7.83) of L^* , a^* , and b^* , respectively (shown in Figure 4-27 and 4-28, respectively). The visual evaluation of “Purplish Blue” blue sapphire were shown in table 4-24.

4.3.2.6 The “Greenish Blue” blue sapphires were plotted in CIE L^* a^* b^* diagrams with the average values (20.54, 7.94, -30.53) and standard deviation values (0, 3.27, 3.32) of L^* , a^* , and b^* , respectively (shown in Figure 4-29 and 4-30, respectively). The visual evaluation of “Greenish Blue” blue sapphire were shown in table 4-25.



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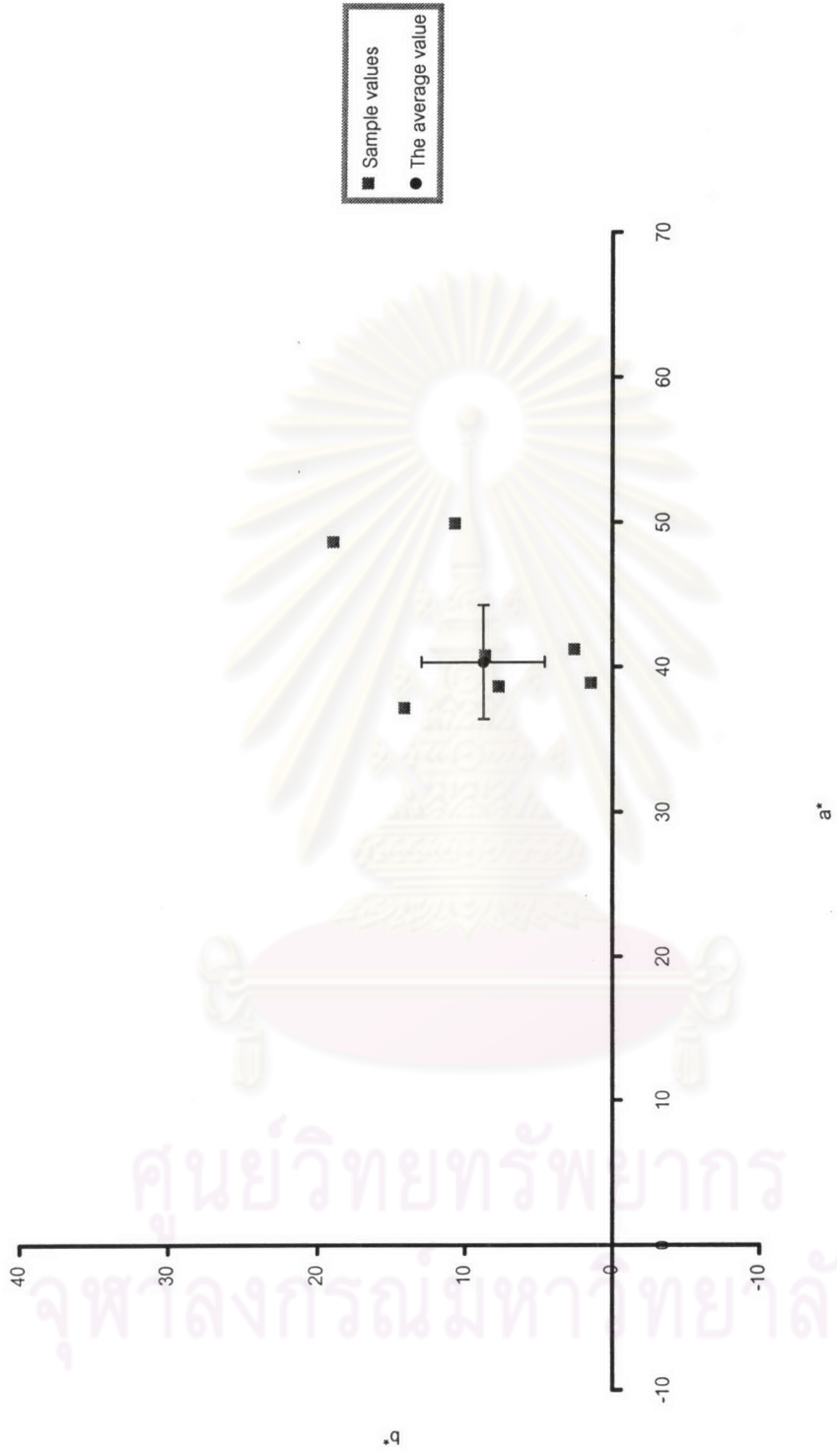


Figure 4-7 The results of "Dark Red" ruby were shown on CIE a* b* diagram with the average sample and standard deviation values.

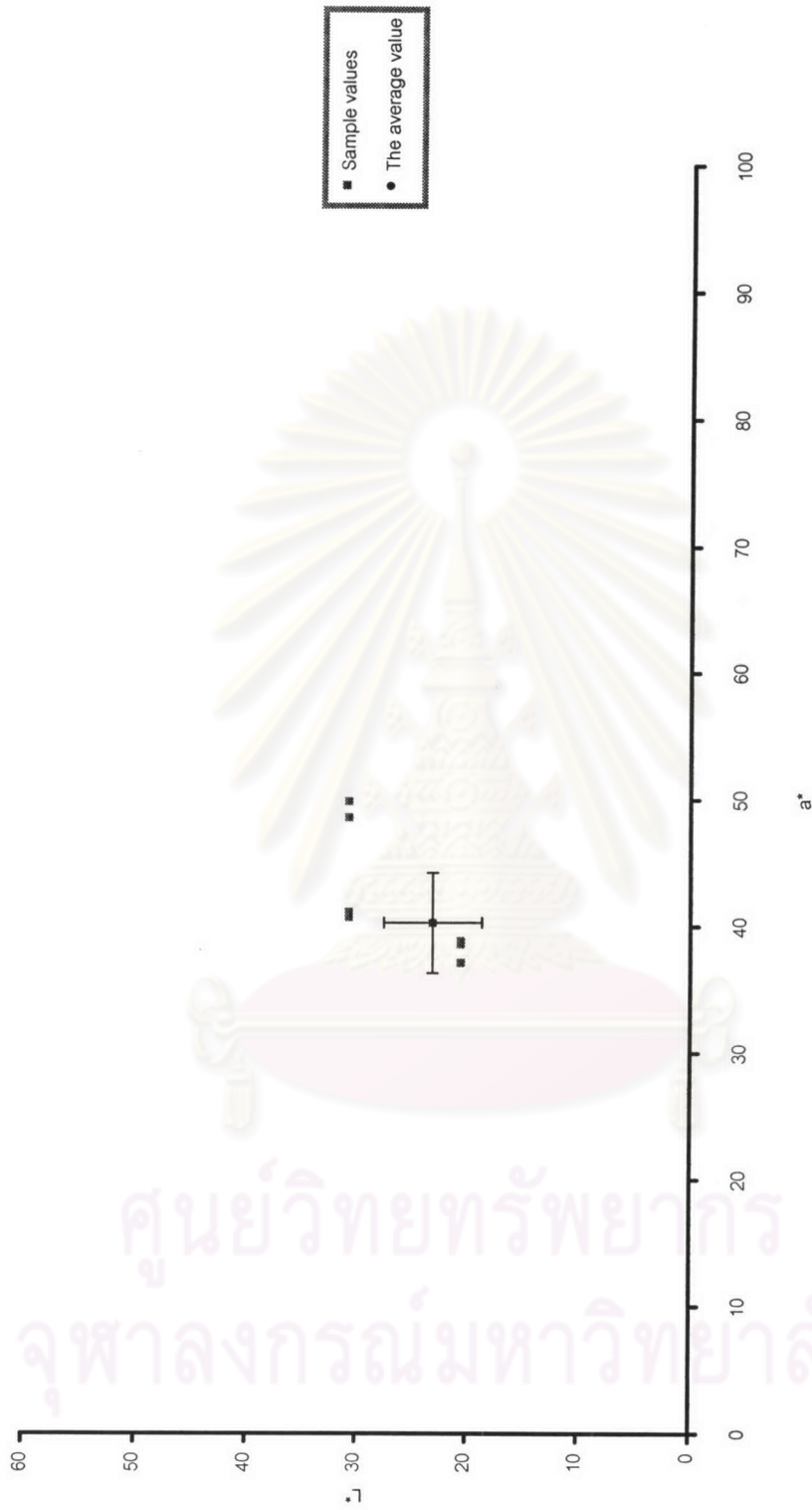


Figure 4-8 The results of "Dark Red" ruby were shown on CIE L* a* diagram with the average sample and standard deviation values.

Table 4-14 The visual evaluation results of "Dark Red" ruby

Munsell System Values	CIELAB System Values			Frequency of values
	L*	a *	b*	
2.5R 2/8	20.54	38.86	1.46	4
5R 2/8	20.54	38.63	7.74	34
7.5R 2/8	20.54	37.17	14.11	8
2.5R 3/8	30.77	40.79	8.64	2
2.5R 3/10	30.77	49.95	10.69	5
5R 3/10	30.77	48.68	18.92	4
10RP 3/8	30.77	41.21	2.58	4
The average value	23.09	40.33	8.74	$\Sigma f = 60$

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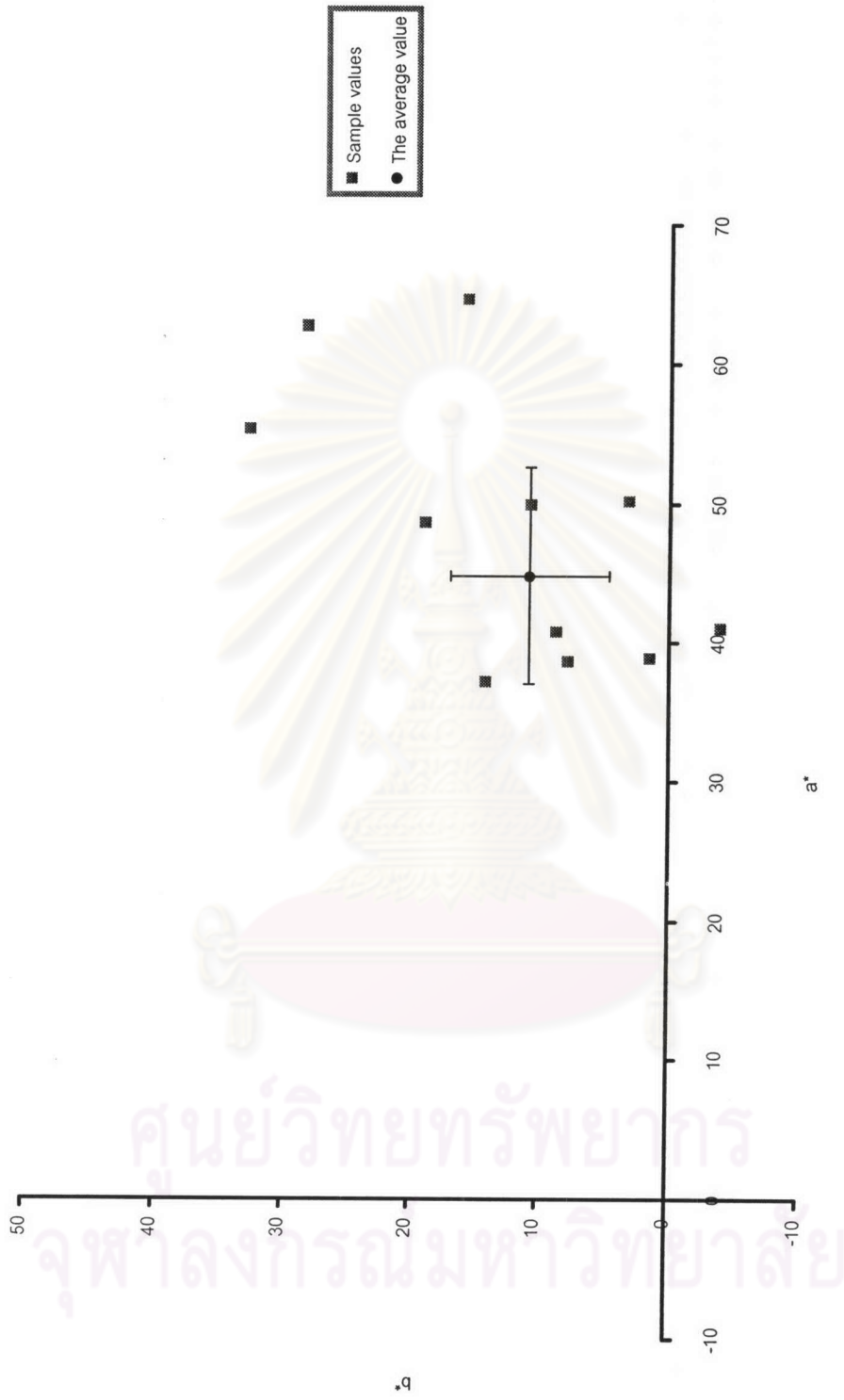


Figure 4-9 The results of "Deep Red" ruby were shown on CIE a* b* diagram with the average sample and standard deviation values.

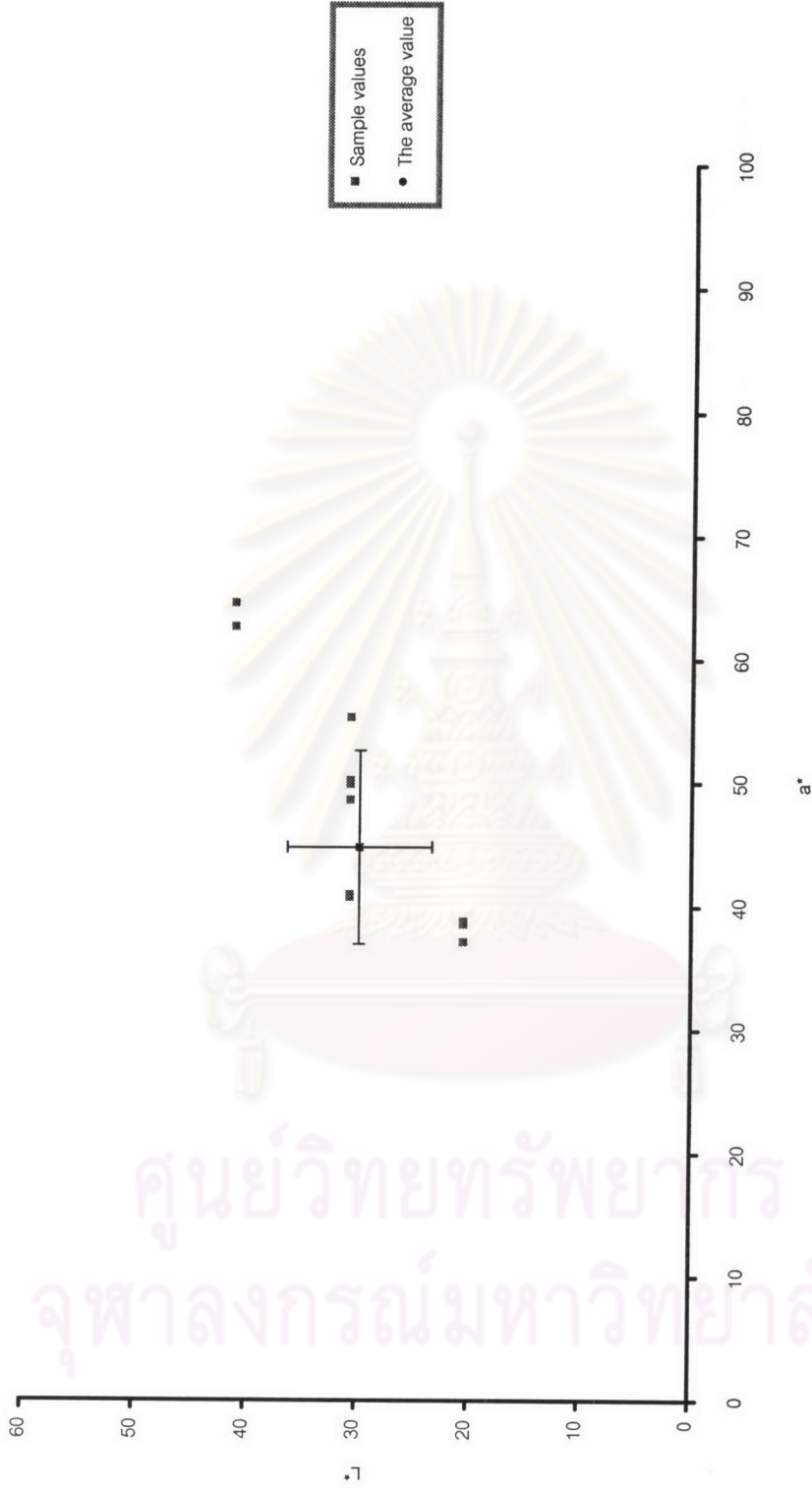


Figure 4-10 The results of "Deep Red" ruby were shown on CIE L* a* diagram with the average sample and standard deviation values.

Table 4-15 The visual evaluation results of "Deep Red" ruby

Munsell System Values	CIELAB System Values			Frequency of values
	L*	a*	b*	
2.5R 2/8	20.54	38.86	1.46	3
5R 2/8	20.54	38.63	7.74	20
7.5R 2/8	20.54	37.17	14.11	4
2.5R 3/8	30.77	40.79	8.64	5
2.5R 3/10	30.77	49.95	10.69	11
5R 3/10	30.77	48.68	18.92	7
7.5R 3/8	30.77	41.00	-3.92	2
7.5R 3/12	30.77	55.35	32.76	1
10 RP 3/10	30.77	50.24	3.13	2
2.5R 4/14	41.21	64.63	15.67	3
5R 4/14	41.21	62.71	28.26	2
The average value	29.88	44.82	10.73	$\Sigma f = 60$

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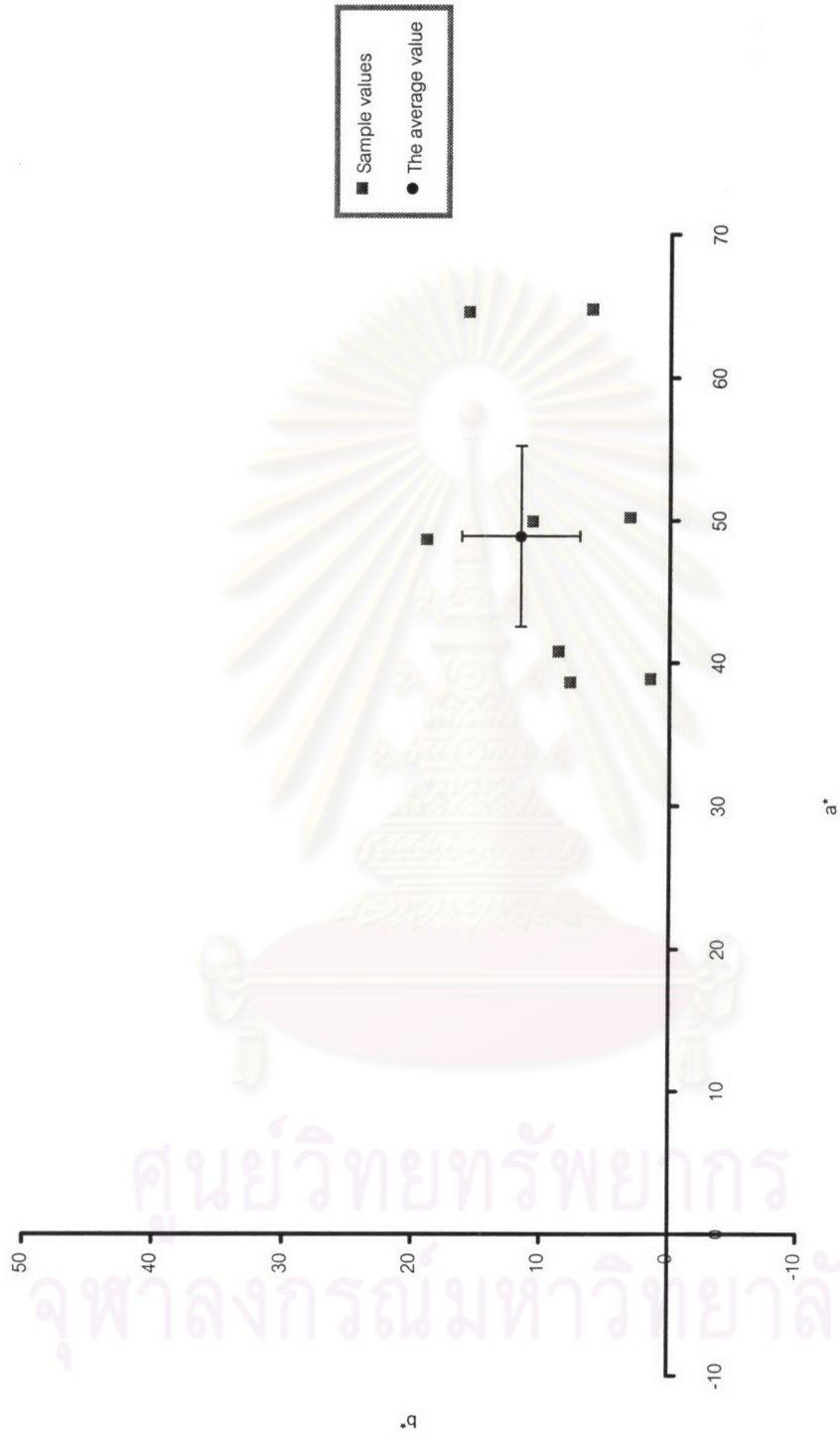


Figure 4-11 The results of "Vivid Red" ruby were shown on CIE a^* b^* diagram with the average sample and standard deviation values.

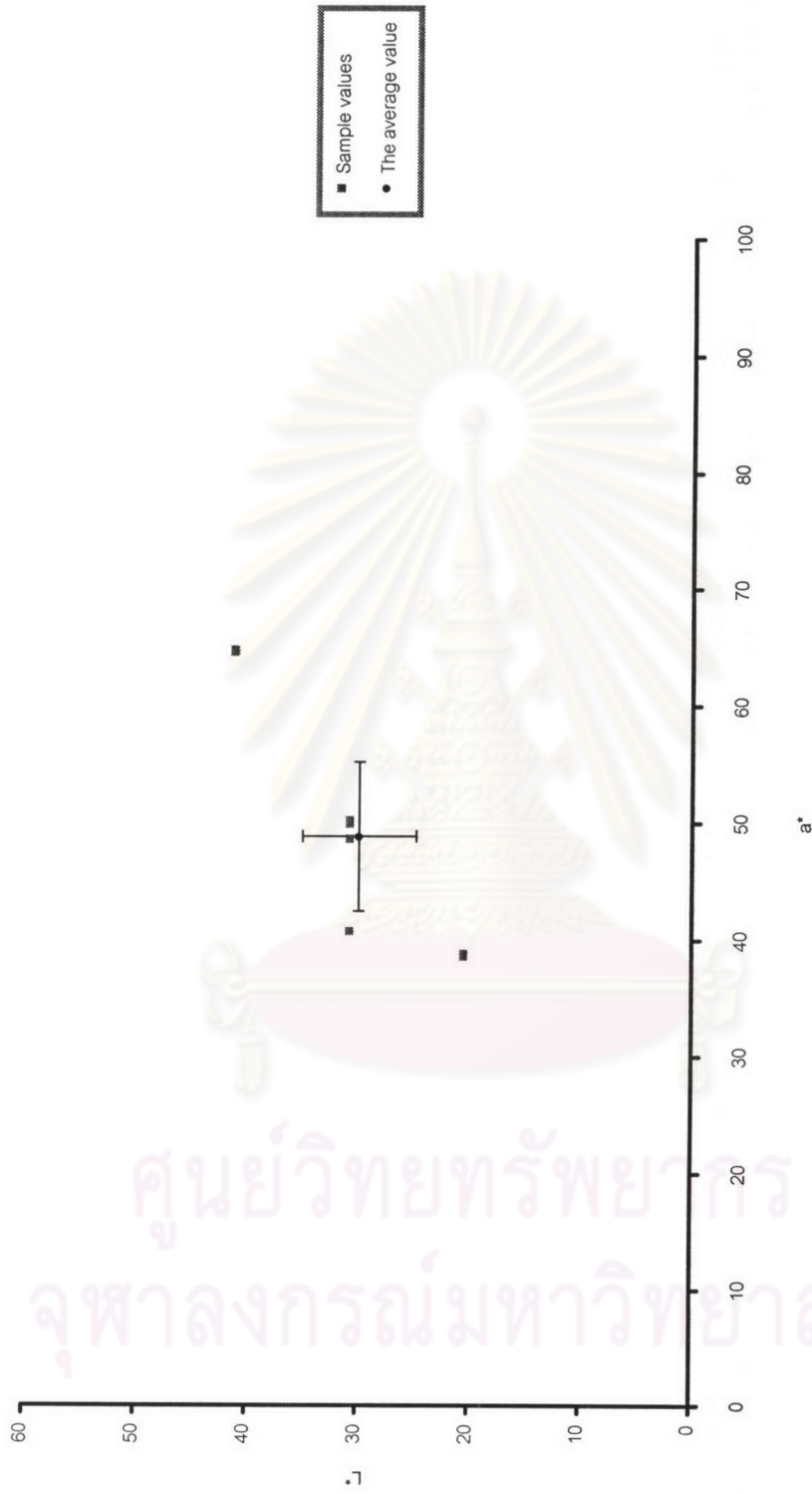


Figure 4-12 The results of "Vivid Red" ruby were shown on CIE L* a* diagram with the average sample and standard deviation values.

Table 4-16 The visual evaluation results of "Vivid Red" ruby

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
2.5R 2/8	20.54	38.86	1.46	2
5R 2/8	20.54	38.63	7.74	8
2.5R 3/8	30.77	40.79	8.64	1
2.5R 3/10	30.77	49.95	10.69	30
5R 3/10	30.77	48.68	18.92	12
2.5R 4/14	41.21	64.63	15.67	4
10RP 3/10	30.77	50.24	3.13	2
10RP 4/14	41.21	64.80	6.12	1
The average value	29.93	48.90	11.60	$\Sigma f = 60$

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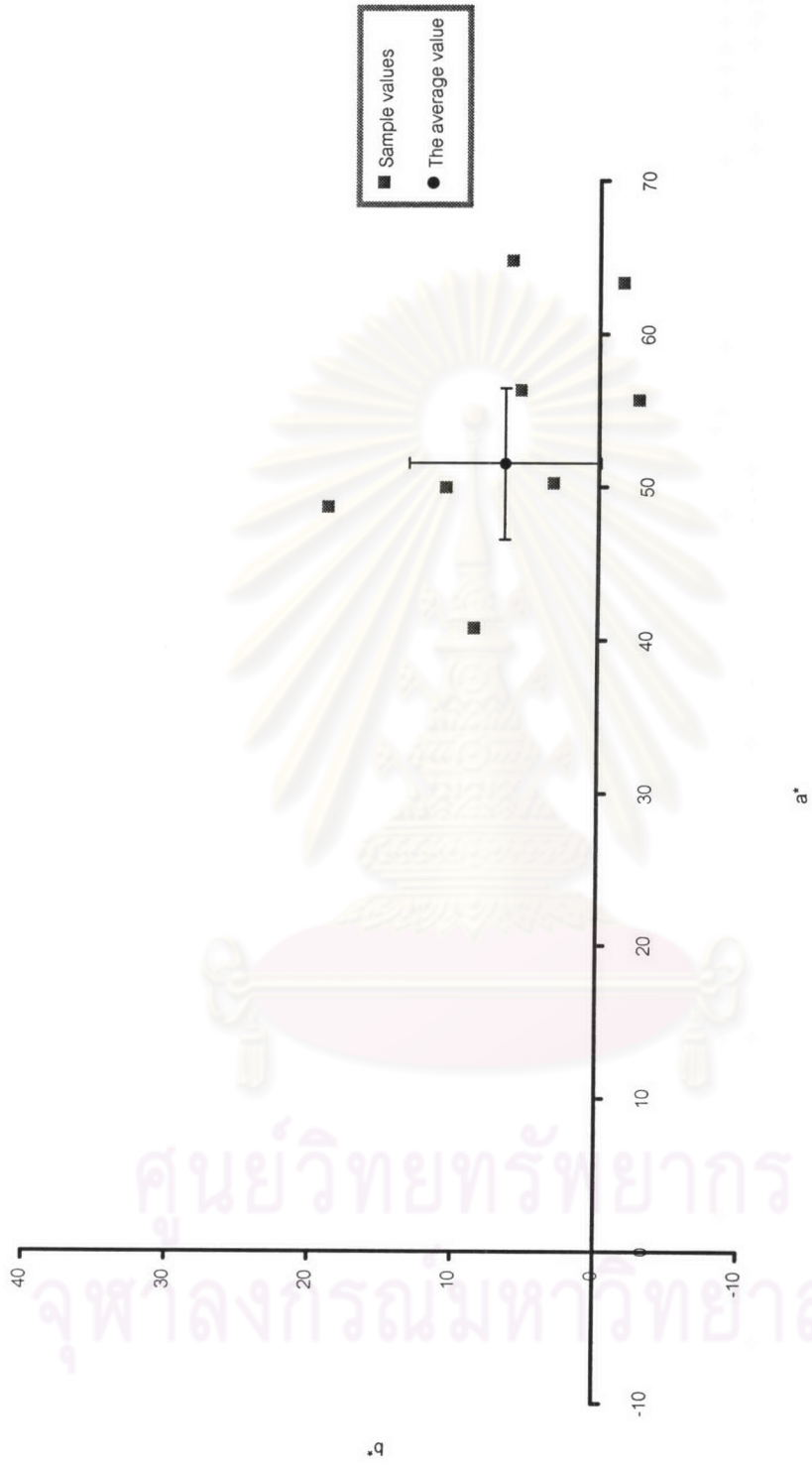


Figure 4-13 The results of "Strong Red" ruby were shown on CIE $a^* b^*$ diagram with the average sample and standard deviation values.

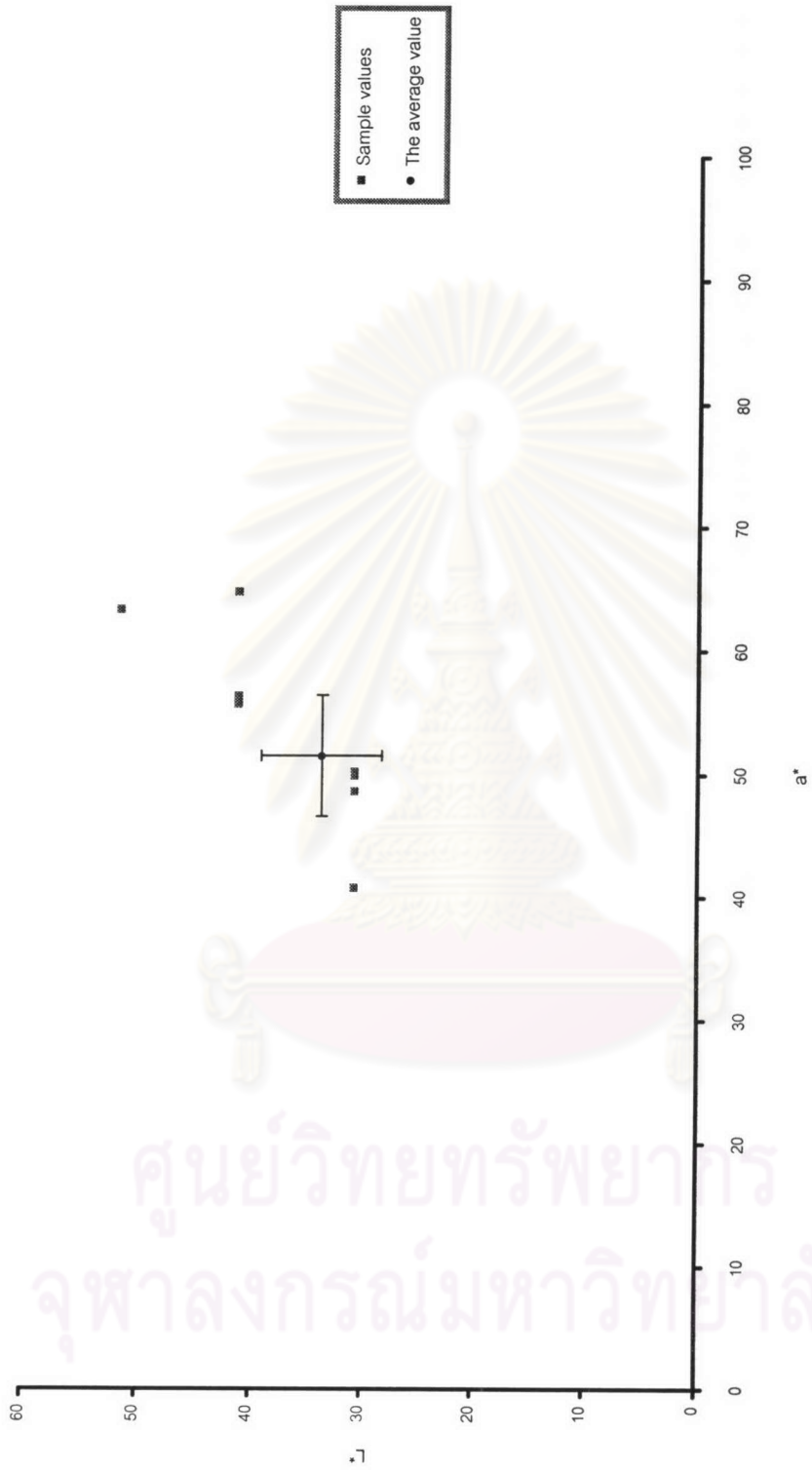


Figure 4-14 The results of "Strong Red" ruby were shown on CIE L* a* diagram with the average sample and standard deviation values.

Table 4-17 The visual evaluation results of "Strong Red" ruby

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
2.5R 3/8	30.77	40.79	8.64	8
2.5R 3/10	30.77	79.95	10.69	16
5R 3/10	30.77	48.68	18.92	3
10RP 3/10	30.77	50.24	3.13	18
7.5RP 4/12	41.21	55.72	-2.79	4
10RP 4/12	41.21	56.37	5.46	2
10RP 4/14	41.21	64.80	6.12	7
7.5RP 5/14	51.57	63.37	-1.66	2
The average value	33.72	51.53	6.54	$\Sigma f = 60$

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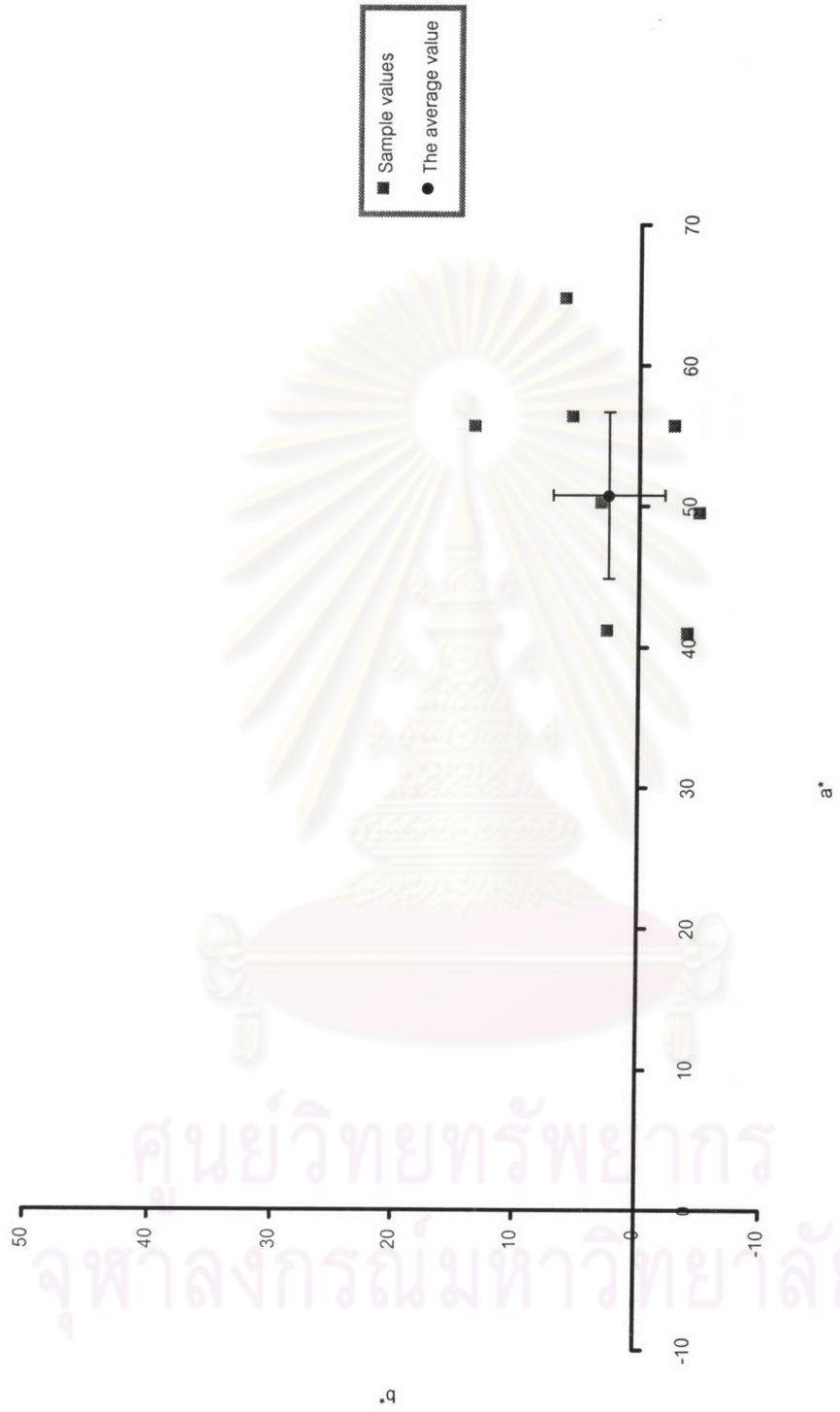


Figure 4-15 The results of "Purplish Red" ruby were shown on CIE $a^* b^*$ diagram with the average sample and standard deviation values.

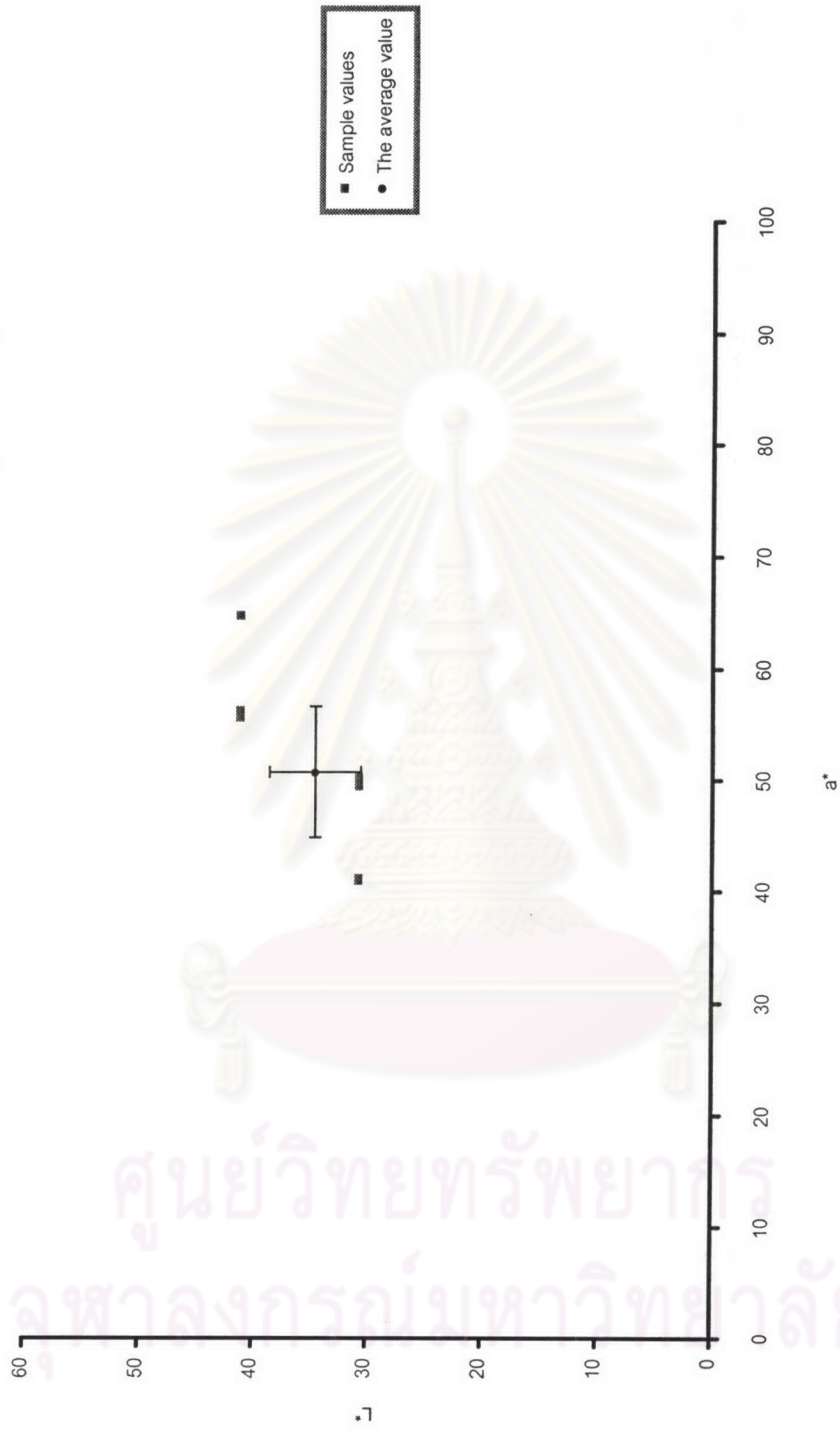


Figure 4-16 The results of "Purplish Red" ruby were shown on CIE L* a* diagram with the average sample and standard deviation values.

Table 4-18 The visual evaluation results of "Purplish Red" ruby

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
7.5RP 3/8	30.77	41.00	-3.92	2
7.5RP 3/10	30.77	49.54	-4.82	8
10RP 3/8	30.77	41.21	2.58	11
10RP 3/10	30.77	50.24	3.13	17
2.5R 4/12	41.21	55.69	13.46	2
7.5RP 4/12	41.21	55.72	-2.79	3
10RP 4/12	41.21	56.37	5.46	14
10RP 4/14	41.21	64.80	6.12	3
The average value	37.37	52.07	2.22	$\Sigma f = 60$

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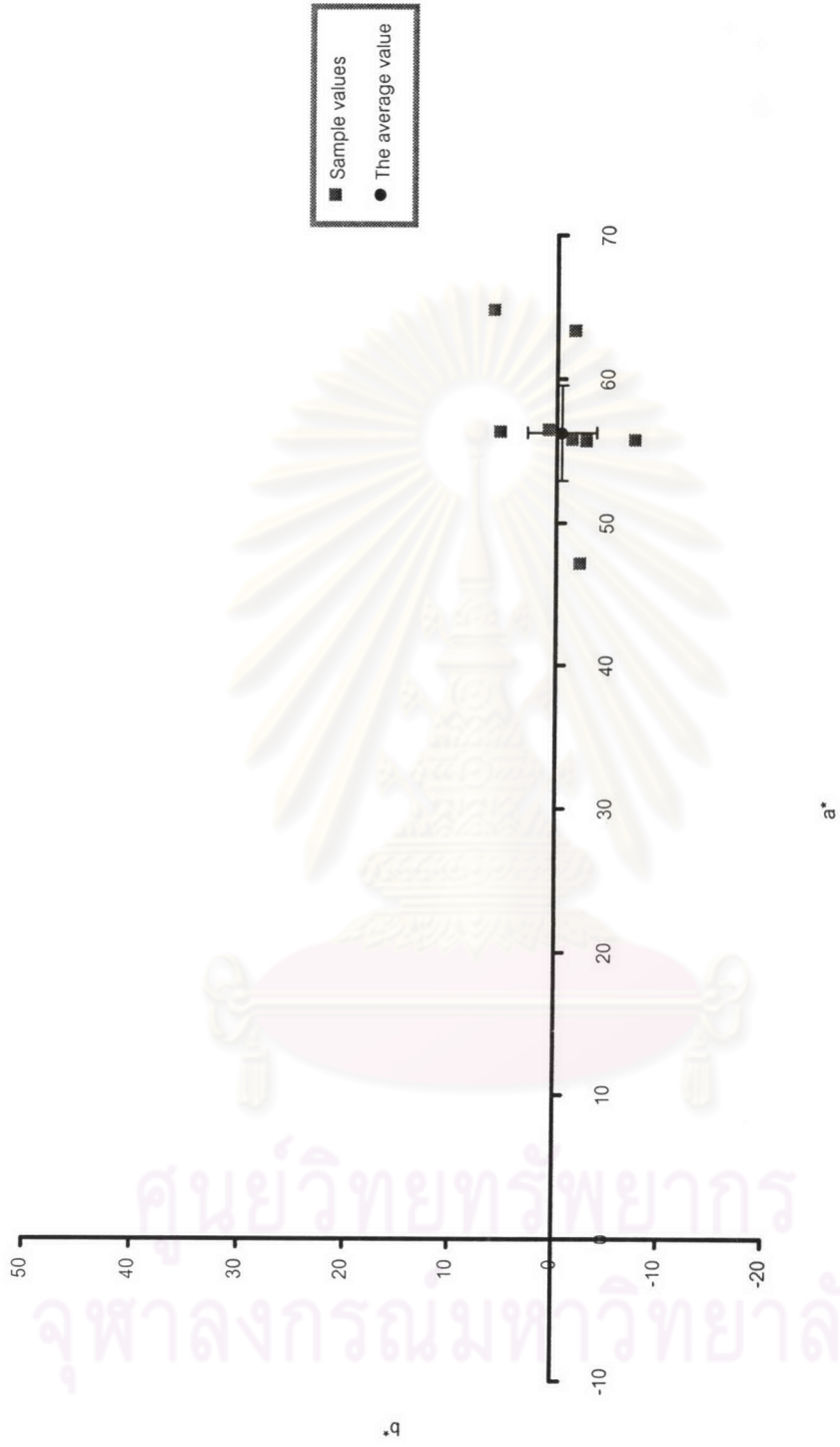


Figure 4-17 The results of “Pinkish Red” ruby were shown on CIE a* b* diagram with the average sample and standard deviation values.

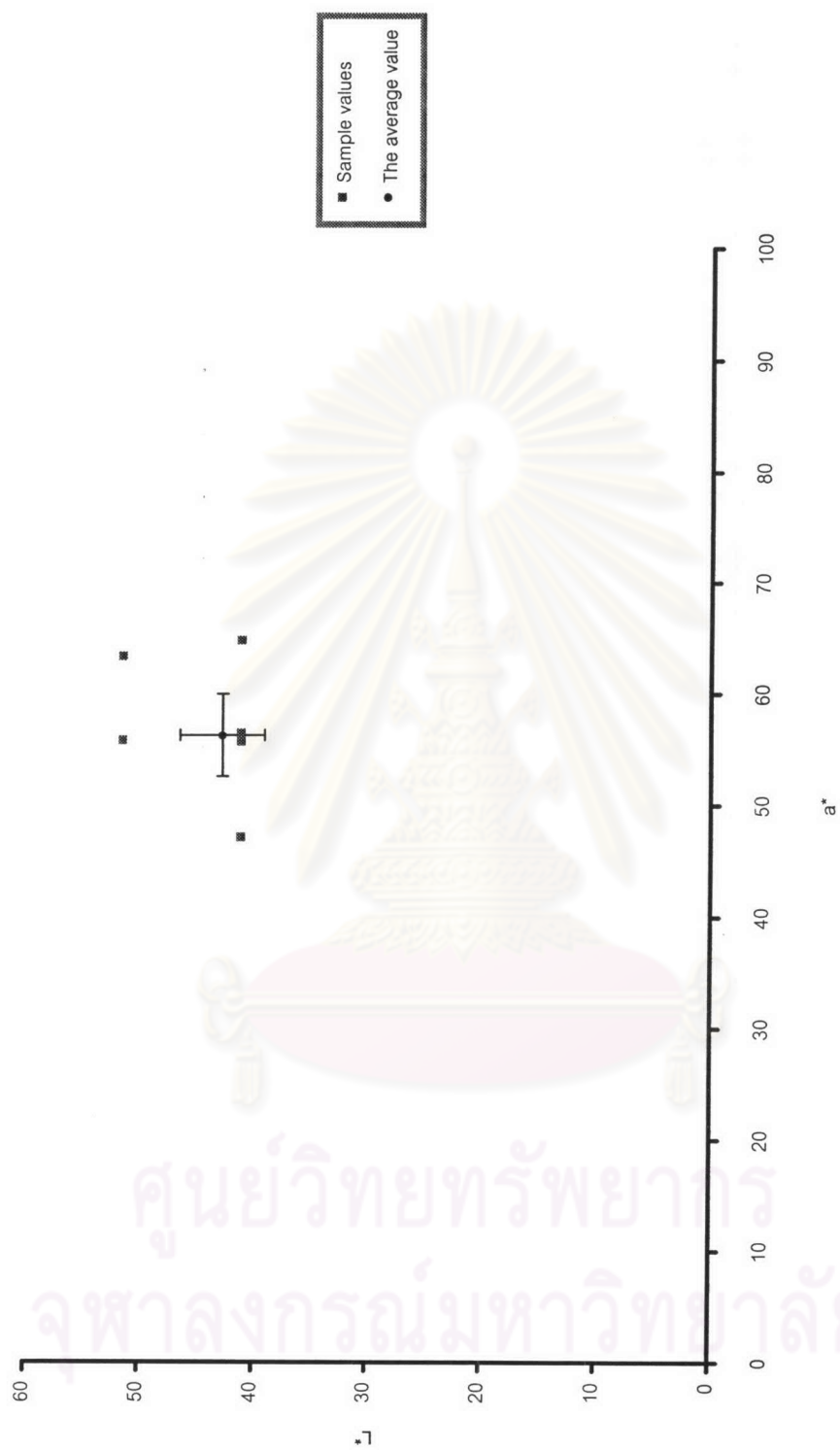


Figure 4-18 The results of "Pinkish Red" ruby were shown on CIE L* a* diagram with the average sample and standard deviation values.

Table 4-19 The visual evaluation results of "Pinkish Red" ruby

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
6.25RP 4/12	41.21	55.79	-7.46	1
7.5RP 4/10	41.21	47.15	-2.26	5
7.5RP 4/12	41.21	55.72	-2.79	16
8.75RP 4/12	41.21	56.50	0.80	8
10RP 4/12	41.21	56.37	5.46	5
10RP 4/14	41.21	64.80	6.12	3
7.5RP 5/12	51.57	55.83	-1.43	3
7.5RP 5/14	51.57	63.37	-1.66	4
The average value	42.82	56.27	-0.49	$\Sigma f = 45$

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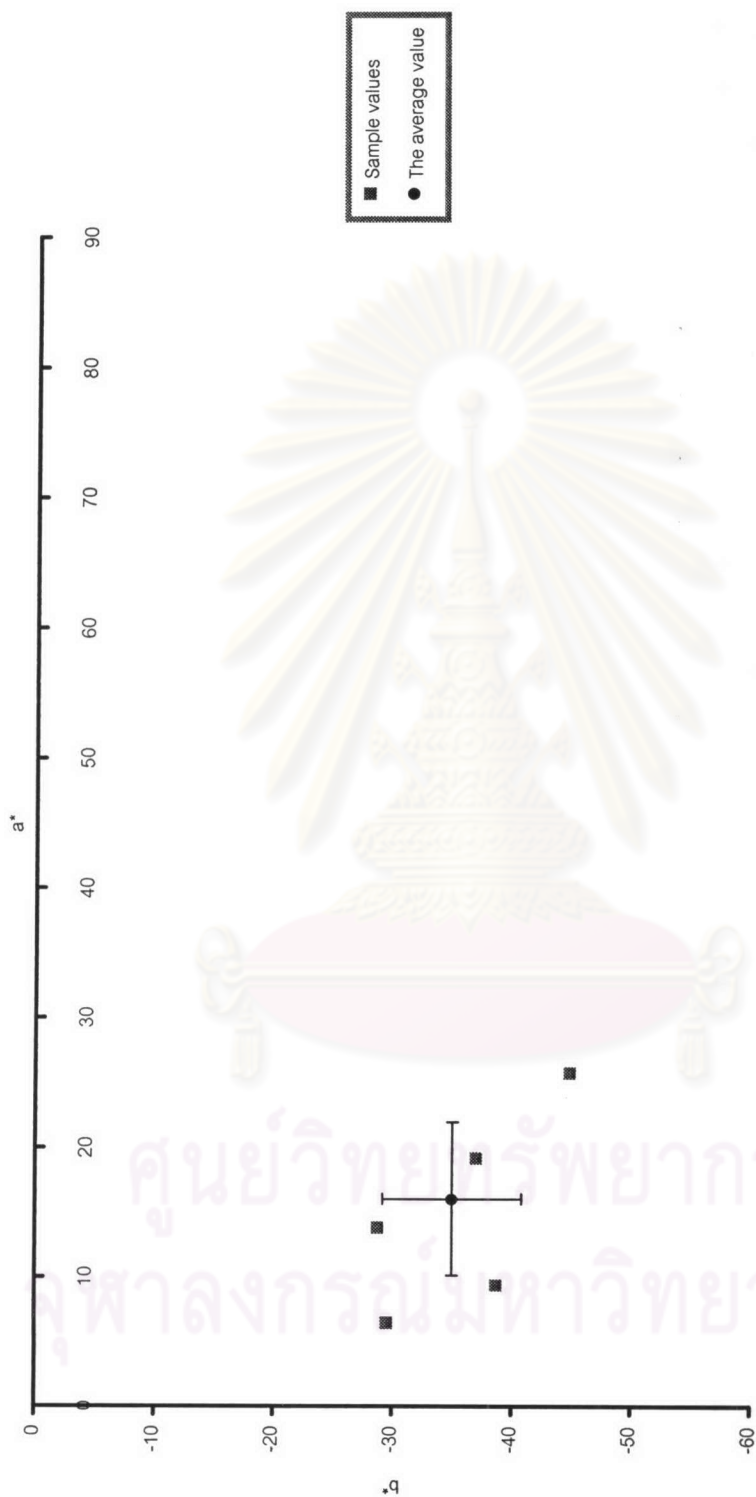


Figure 4-19 The results of "Dark Blue" blue sapphire were shown on CIE $a^* b^*$ diagram with the average sample and standard deviation values.

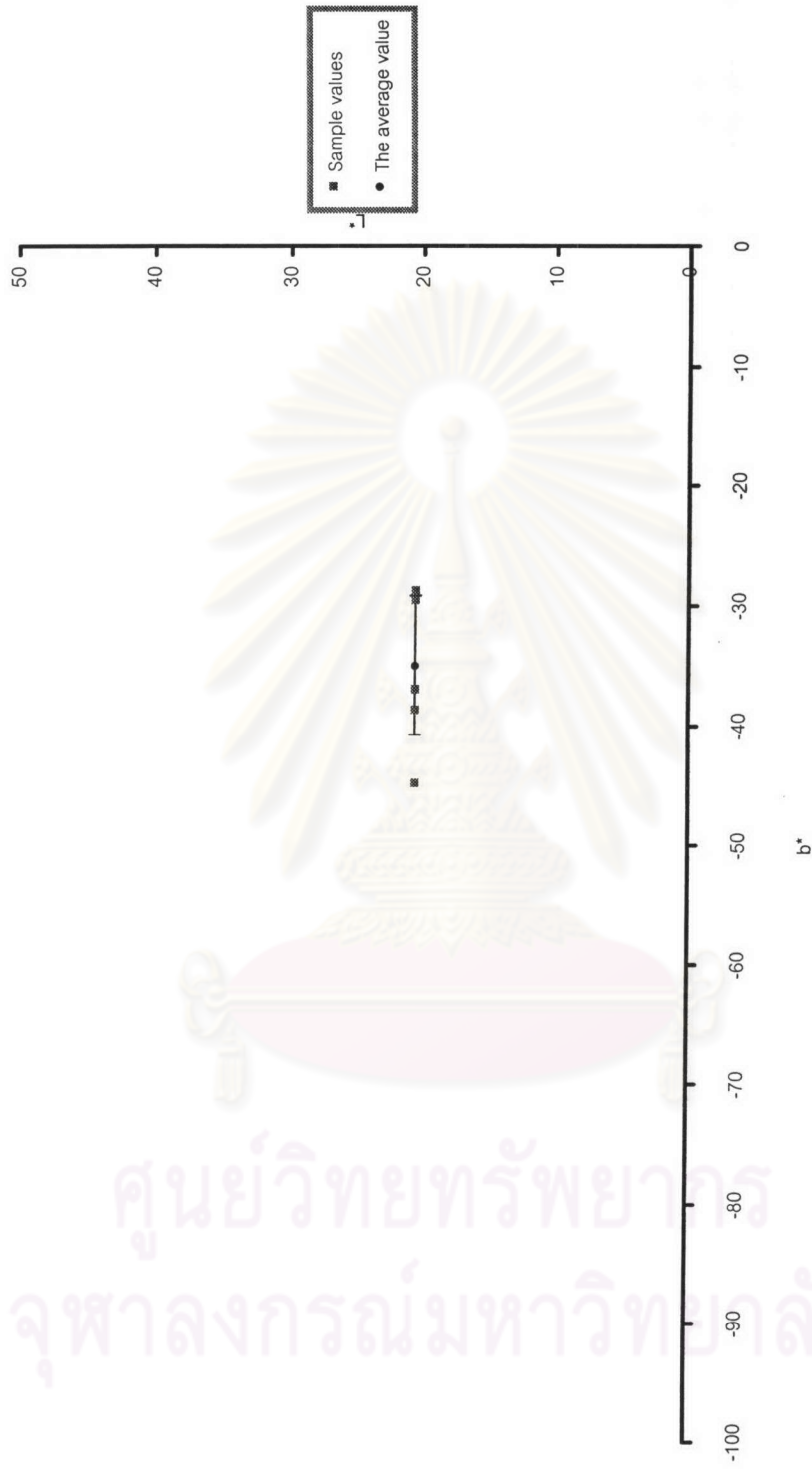


Figure 4-20 The results of "Dark Blue" blue sapphire were shown on CIE L* a* b* diagram with the average sample and standard deviation values.

Table 4-20 The visual evaluation results of "Dark Blue" blue sapphire

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
7.5PB 2/6	20.54	13.80	-28.75	14
7.5PB 2/8	20.54	19.15	-36.94	14
7.5PB 2/10	20.54	25.70	-44.78	7
5PB 2/6	20.54	6.46	-29.52	5
5PB 2/8	20.54	9.35	-38.67	5
The average value	20.54	16.00	-34.98	$\Sigma f = 45$



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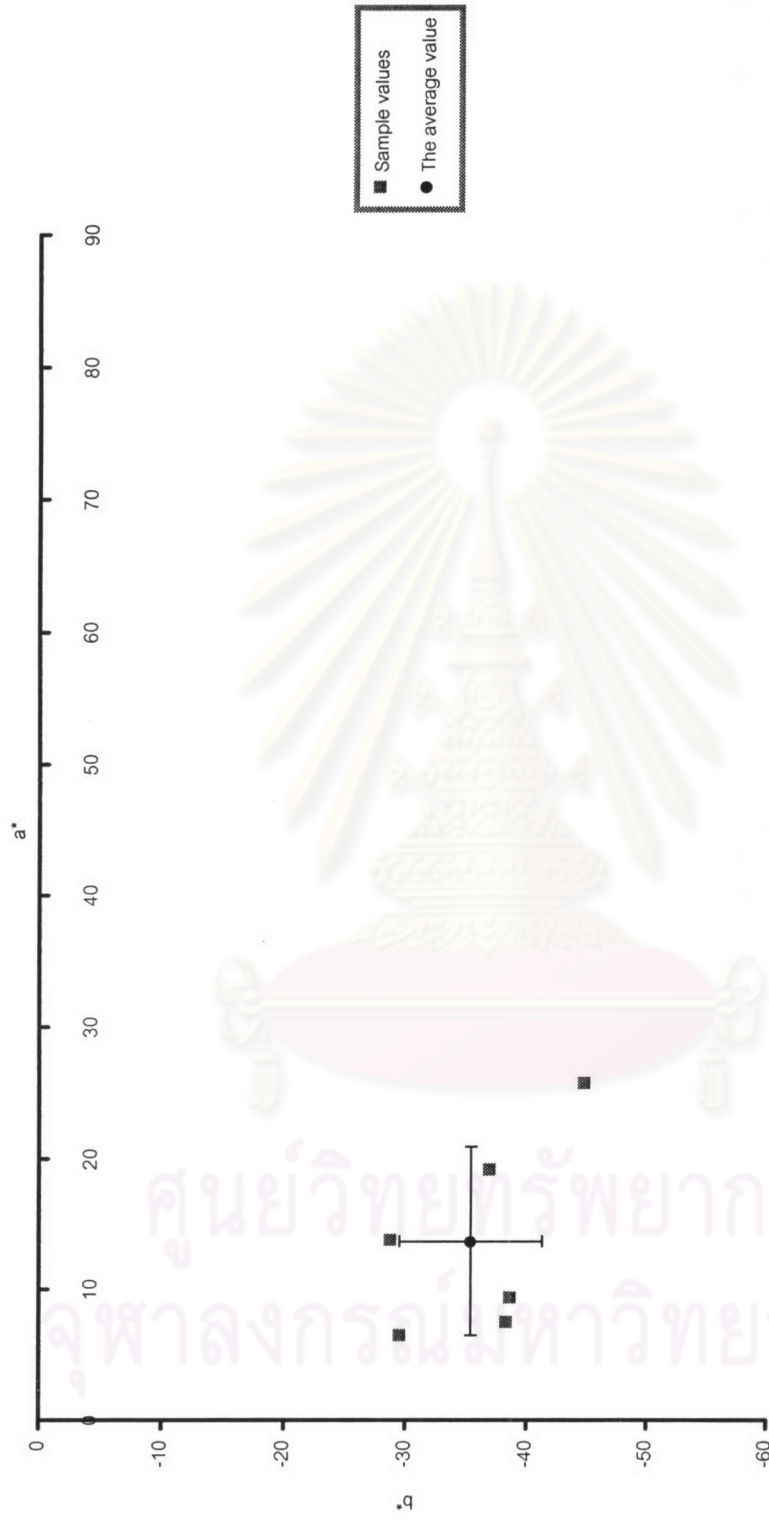


Figure 4-21 The results of "Deep Blue" blue sapphire were shown on CIE a* b* diagram with the average sample and standard deviation values.

Table 4-21 The visual evaluation results of "Deep Blue" blue sapphire

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
7.5PB 2/10	20.54	25.70	-44.78	8
7.5PB 2/6	20.54	13.80	-28.75	7
7.5PB 2/8	20.54	19.15	-36.94	8
5PB 2/6	20.54	6.46	-29.52	12
5PB 2/8	20.54	9.35	-38.67	4
5PB 3/8	30.77	7.50	-38.34	6
The average value	21.90	13.67	-35.42	$\Sigma f = 45$

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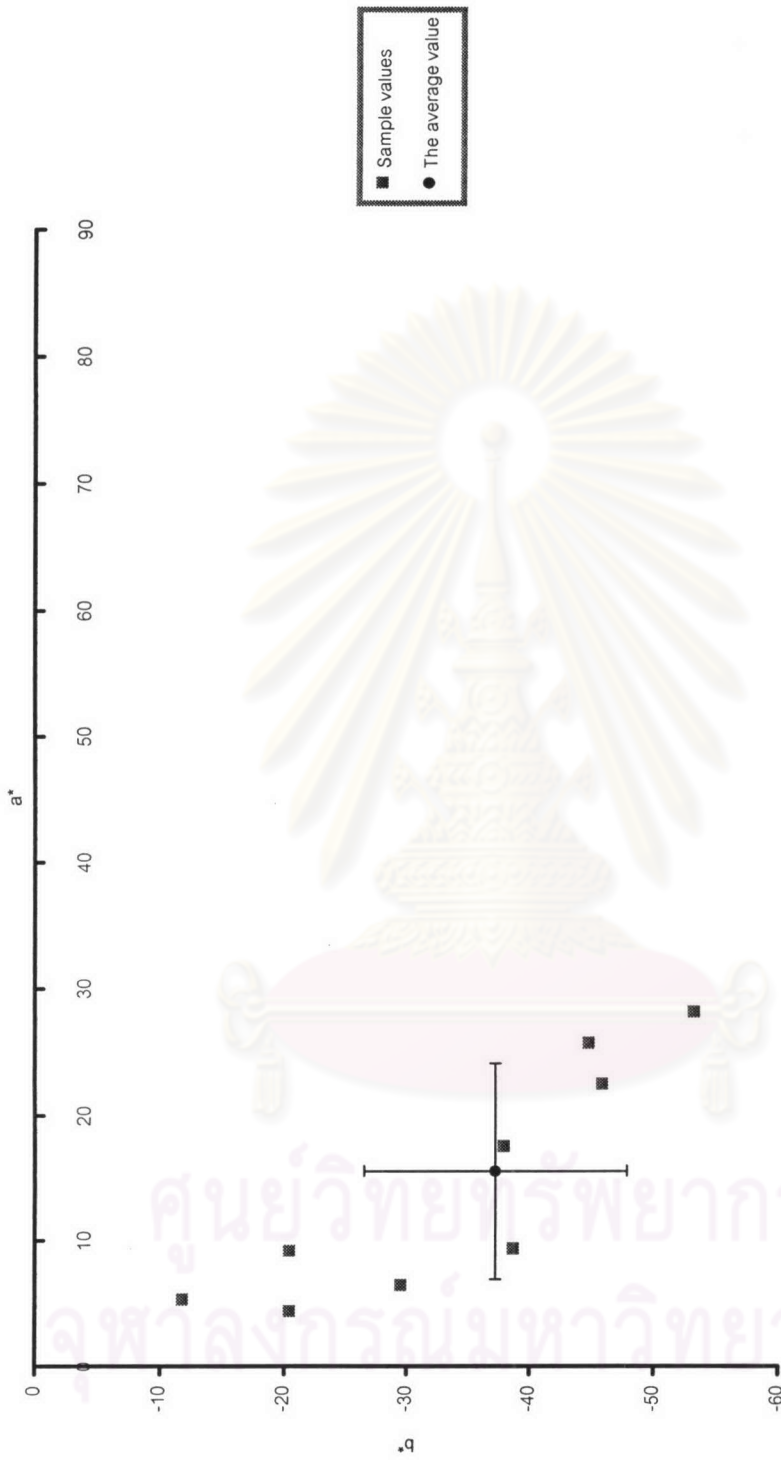


Figure 4-23 The results of “Vivid Blue” blue sapphires were shown on CIE a* b* diagram with the average sample and standard deviation values.

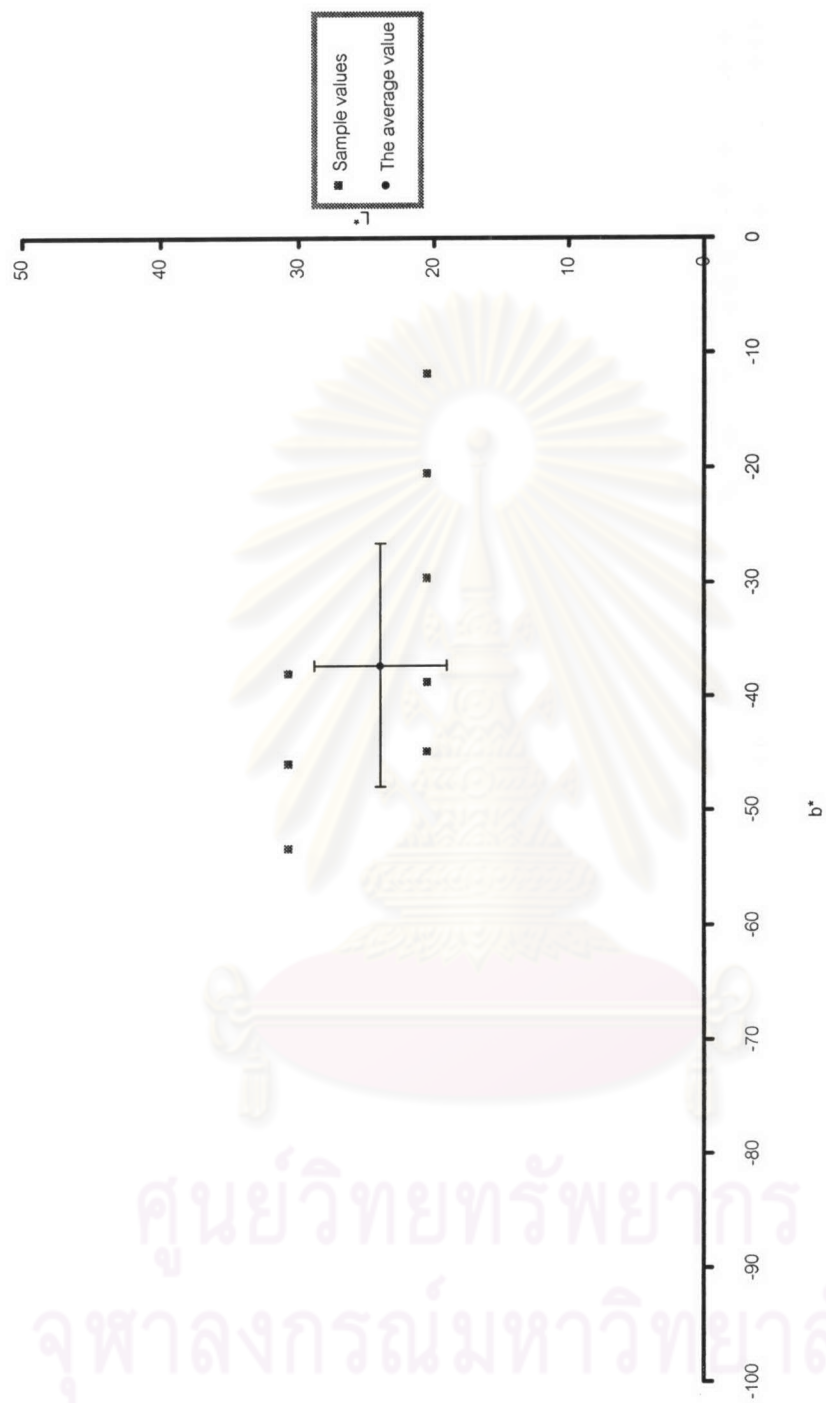


Figure 4-24 The results of “Vivid Blue” blue sapphire were shown on CIE L* a* b* diagram with the average sample and standard deviation values.

Table 4-22 The visual evaluation results of "Vivid Blue" blue sapphire

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
7.5PB 3/10	30.77	22.48	-45.87	3
7.5PB 2/10	20.54	25.70	-44.78	5
7.5PB 3/12	30.77	28.13	-53.25	3
7.5PB 3/8	30.77	17.51	-37.89	4
5PB 2/6	20.54	6.46	-29.52	4
5PB 2/8	20.54	9.35	-38.67	6
7.5PB 2/4	20.54	9.18	-20.42	2
5PB 2/4	20.54	4.39	-20.43	2
7.5PB 2/2	20.54	5.33	-11.79	1
The average value	23.95	15.49	-37.21	$\Sigma f = 30$

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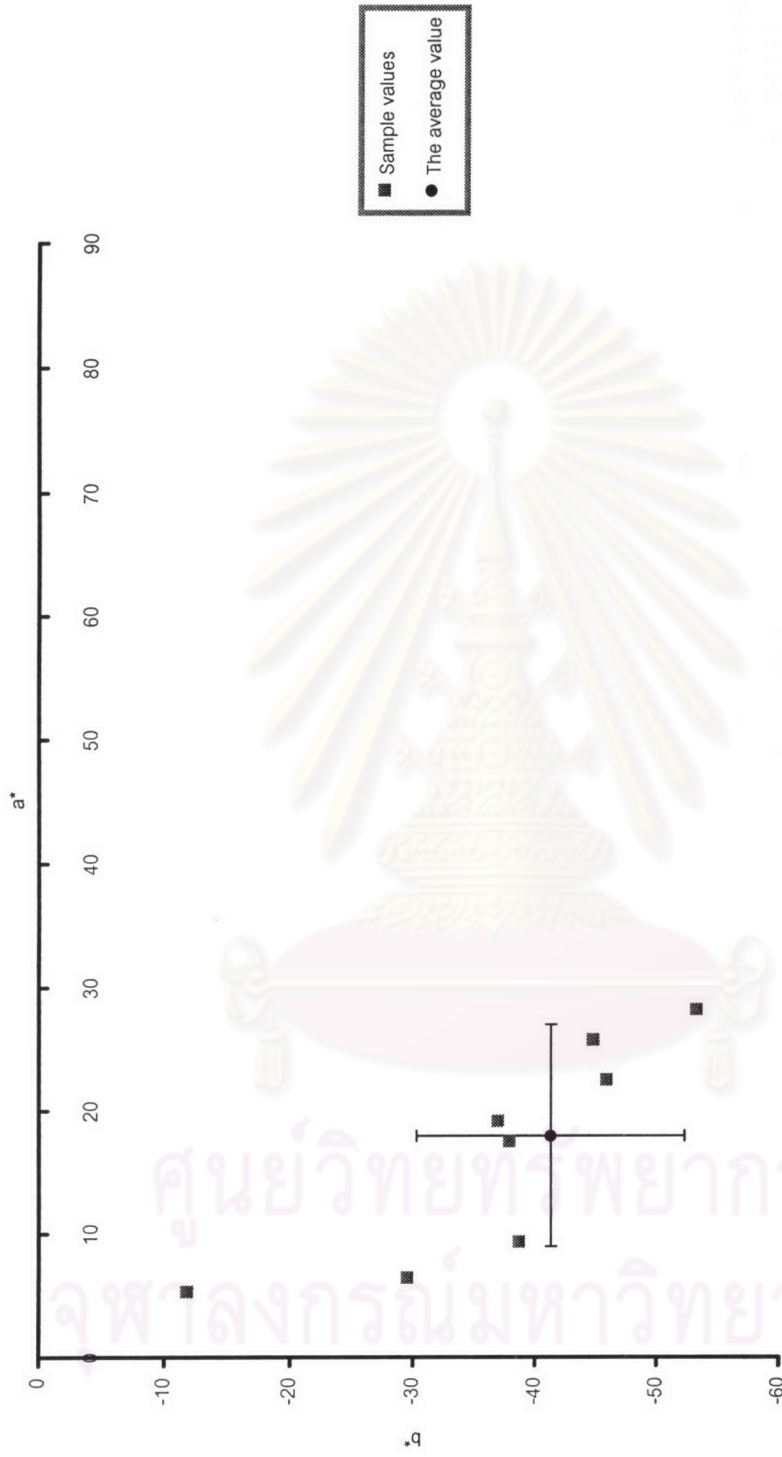


Figure 4-25 The results of "Strong Blue" blue sapphire were shown on CIE a* b* diagram with the average sample and standard deviation values.

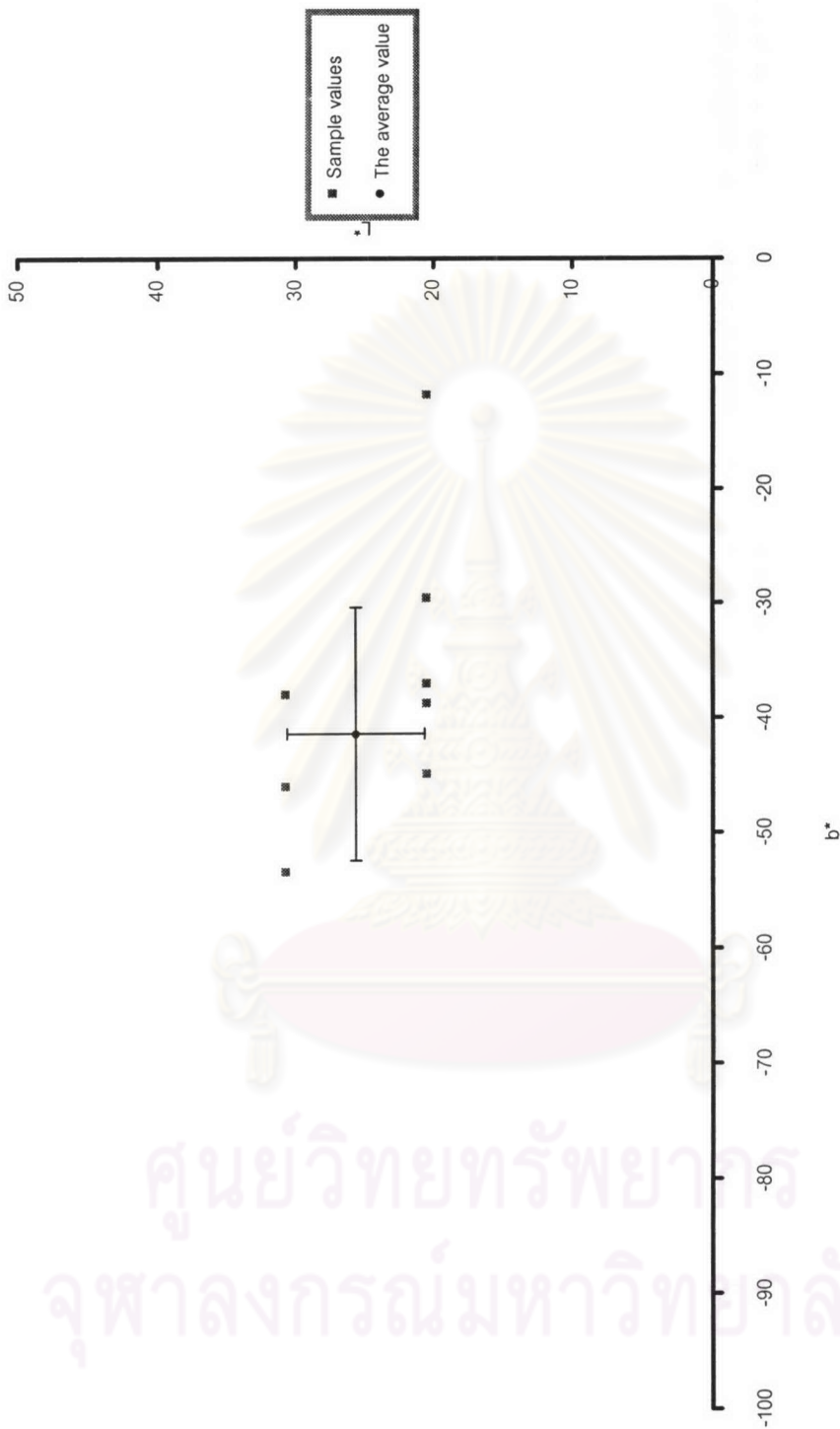


Figure 4-26 The results of “Strong Blue” blue sapphire were shown on CIE L* b* diagram with the average sample and standard deviation values.

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Table 4-23 The visual evaluation results of "Strong Blue" blue sapphire

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
5PB 2/8	20.54	9.35	-38.67	7
7.5PB 2/10	20.54	25.70	-44.78	1
7.5PB 2/8	20.54	19.15	-36.94	2
5PB 2/6	20.54	6.46	-29.52	3
7.5PB 2/2	20.54	5.33	-11.79	2
7.5PB 3/8	30.77	17.51	-37.89	3
7.5PB 3/10	30.77	22.48	-45.87	2
7.5PB 3/12	30.77	28.13	-53.25	10
The average value	20.54	17.94	-41.31	$\Sigma f = 30$

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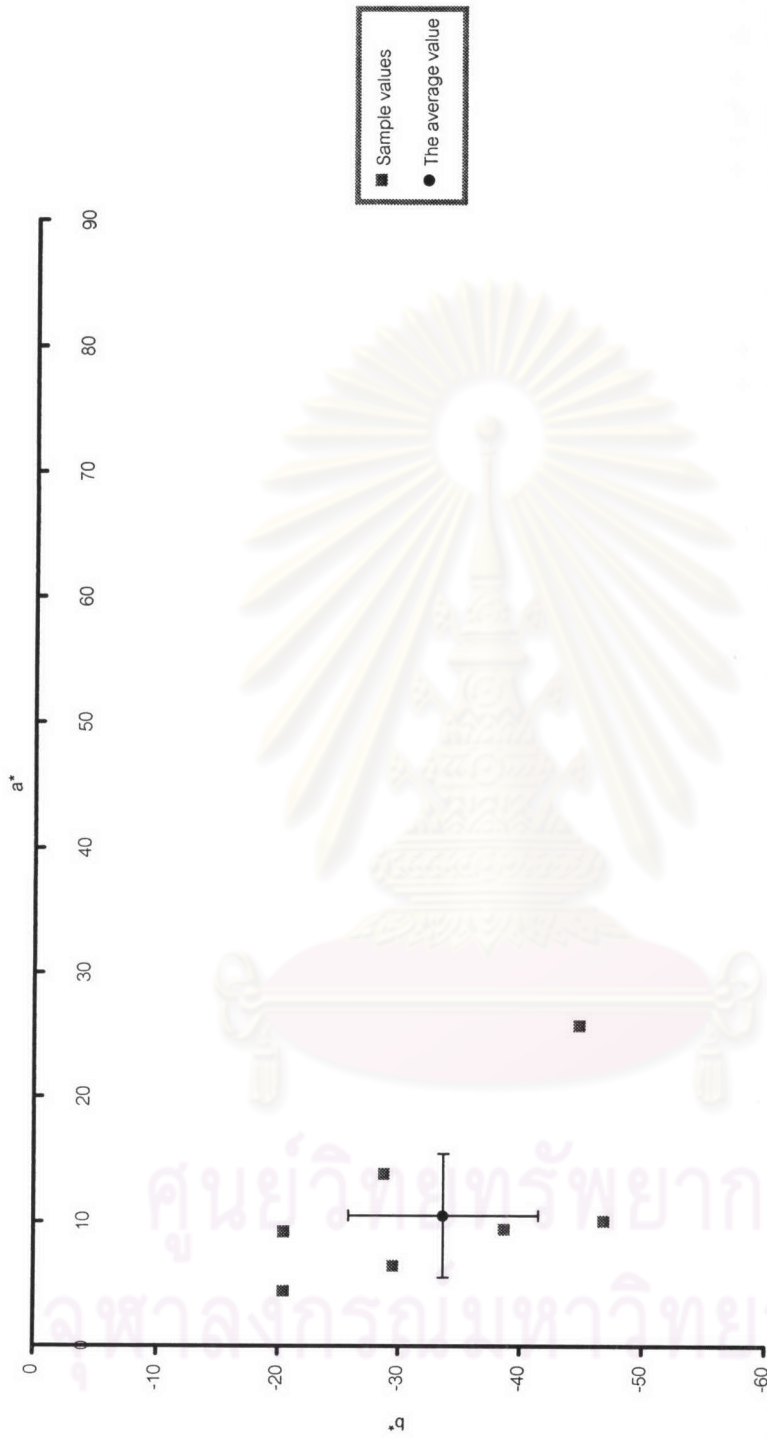


Figure 4-27 The results of "Purplish Blue" blue sapphire were shown on CIE a* b* diagram with the average sample and standard deviation values.

Table 4-24 The visual evaluation results of "Purplish Blue" blue sapphire

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
7.5PB 2/6	20.54	13.80	-28.75	6
7.5PB 2/10	20.54	25.70	-44.78	2
5PB 2/8	20.54	9.35	-39.67	8
5PB 3/10	30.77	10.05	-46.83	3
5PB 2/6	20.54	6.46	-29.52	8
7.5PB 2/4	20.54	9.18	-20.42	2
5PB 2/4	20.54	4.39	-20.43	1
The average value	21.56	10.45	-33.64	$\Sigma f = 30$

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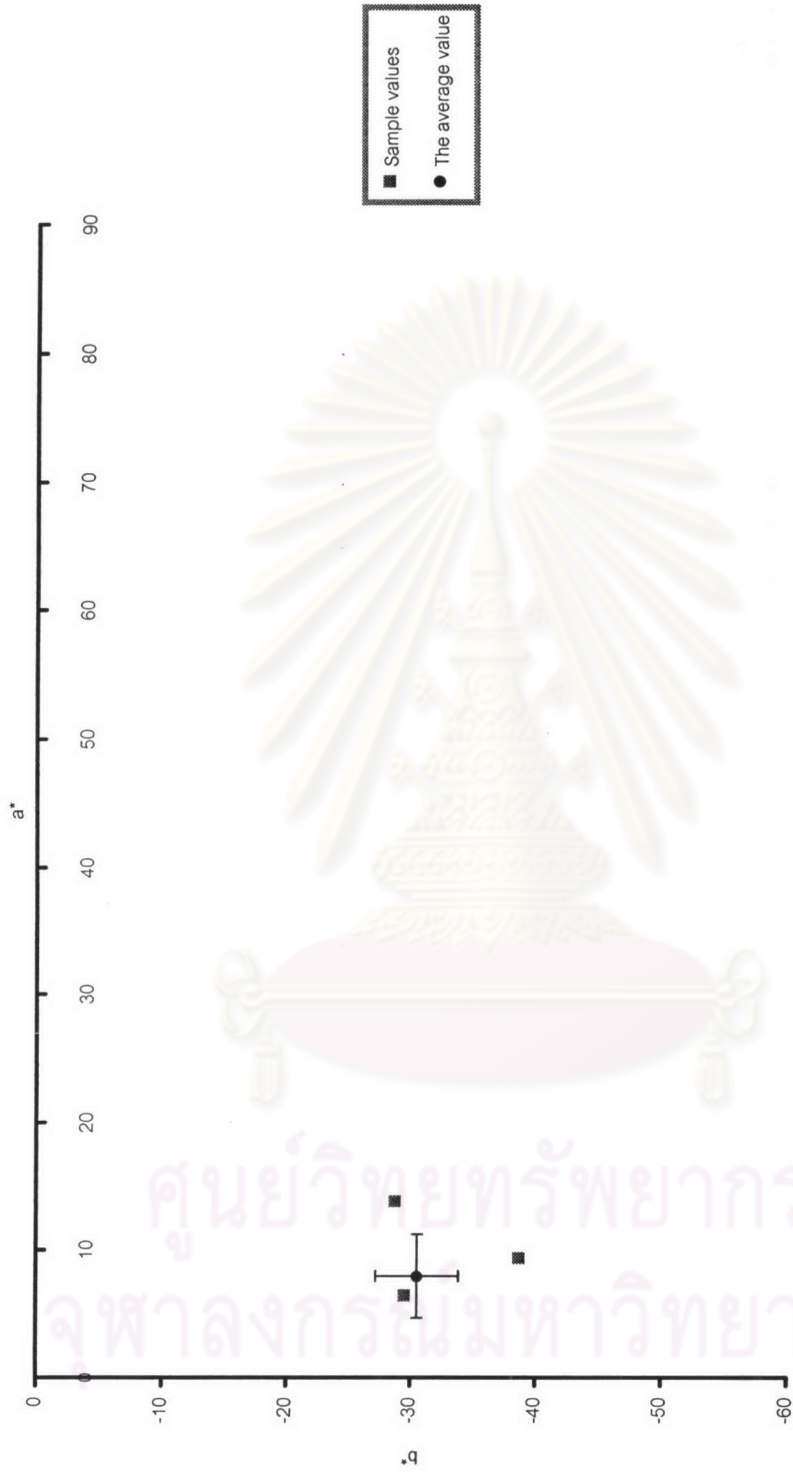


Figure 4-29 The results of “Greenish Blue” blue sapphire were shown on CIE a* b* diagram with the average sample and standard deviation values.

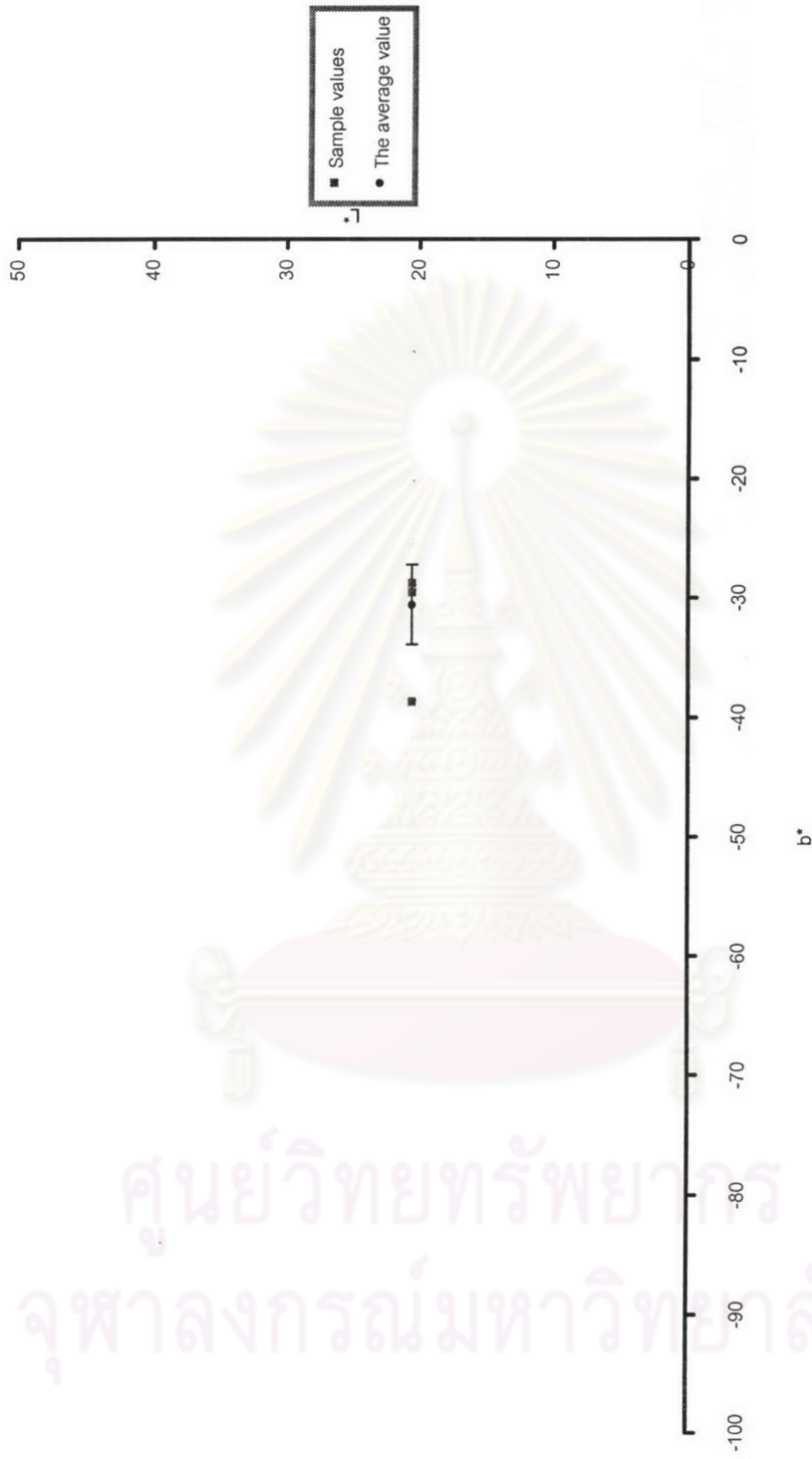


Figure 4-30 The results of “Greenish Blue” blue sapphire were shown on CIE L* b* diagram with the average sample and standard deviation values.

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Table 4-25 The visual evaluation results of "Greenish Blue" blue sapphire

Munsell System Values	CIE LAB System Values			Frequency of values
	L*	a *	b *	
7.5PB 2/6	20.54	13.80	-28.75	4
5PB 2/8	20.54	9.35	-38.67	2
5PB 2/6	20.54	6.46	-29.52	9
The average value	20.54	7.94	-30.53	$\Sigma f = 15$



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