Supplementary materials

Table S1

Training data for exhaustion dyeing.

No.	Sodium sulphate conc. (g/L)	Sodium carbonate conc. (g/L)	Fixing temperature (°C)	Dyeing time (min)	Fixing time (min)	Dye conc. (g/L)	K/S value
1	32	16	50	60	60	0.6	9.65
2	60	15.2	70	40	90	0.72	11.48
3	60	16	60	60	40	0.4	8.38
4	72	16	50	60	80	0.76	15.42
5	24	8	50	60	50	0.08	1.70
6	60	16	50	60	40	0.4	8.71
7	40	12	60	60	40	0.2	3.78
8	32	16	50	20	60	0.6	9.85
9	32	10	70	60	70	0.2	3.22
10	40	12	70	60	40	0.2	3.55
11	32	16	60	60	60	0.6	8.69
12	32	16	70	40	60	0.6	8.02
13	60	15.2	50	60	90	0.72	13.88
14	80	20	60	10	50	0.8	14.31
15	20	5.2	70	60	30	0.12	1.63
16	24	8	60	40	50	0.08	1.62
17	80	20	60	40	50	0.8	15.97
18	72	16	60	60	80	0.76	14.11
19	80	20	50	20	50	0.8	16.24
20	60	15.2	50	40	90	0.72	13.80
21	60	16	70	40	40	0.4	7.79
22	32	16	50	40	60	0.6	9.52
23	92	18	70	60	60	0.84	13.72

24	40	12	50	20	40	0.2	3.90
25	92	18	70	40	60	0.84	15.58
26	60	16	70	60	40	0.4	7.42
27	32	10	60	60	70	0.2	3.70
28	40	12	70	40	40	0.2	3.62
29	72	16	70	40	80	0.76	12.94
30	40	12	50	60	40	0.2	3.78
31	32	10	50	20	70	0.2	4.09
32	60	15.2	70	60	90	0.72	11.07
33							14.75
34	80	20	70	60	50	0.8	15.19
35	60	16	60	40	40	0.4	8.39
36	20	5.2	60	20	30	0.04	0.78
37	24	8	70	60	50	0.08	1.44
38	72	16	70	60	80	0.76	12.09
39	72	16	60	20	80	0.76	13.99
40	32	16	70	20	60	0.6	8.00
41	60	15.2	50	20	90	0.72	14.16
42	60	15.2	60	20	90	0.72	13.77
43	80	20	60	60	50	0.8	14.04
44	24	8	50	20	50	0.08	1.67
45	92	18	70	20	60	0.84	14.91
46	24	8	50	40	50	0.08	1.58
47	20	5.2	50	20	30	0.04	0.65
48	60	16	60	0	40	0.4	8.27
49	32	10	60	40	70	0.2	3.77
50	72	16	60	40	80	0.76	14.49
51	24	8	60	60	50	0.08	1.57

52	24	8	70	20	50	0.08	1.44
53	24	8	60	20	50	0.08	1.62
54	72	16	70	20	80	0.76	13.24
55	60	16	60	20	40	0.4	8.72
56	20	5.2	60	40	30	0.04	0.76
57	32	10	70	40	70	0.2	3.22
58	92	18	50	20	60	0.84	16.72
59	72	16	60	50	80	0.76	14.25
60	32	10	60	50	70	0.2	3.61
61	92	18	60	30	60	0.84	15.54
62	20	5.2	70	20	30	0.04	0.70
63	32	10	50	40	70	0.2	4.25
64	72	16	50	20	80	0.76	14.95
65	92	18	60	40	60	0.84	16.06
66	92	18	60	60	60	0.84	16.35
67	32	16	60	20	60	0.6	9.35
68	20	5.2	50	60	30	0.04	0.69
69	32	10	70	20	70	0.2	3.15
70	80	20	60	20	50	0.8	15.61
71	60	16	50	40	40	0.4	8.28
72	20	5.2	60	0	30	0.16	1.90
73	40	12	70	20	40	0.2	3.61
74	60	15.2	60	50	90	0.72	12.43
75	80	20	70	20	50	0.8	16.20
76	32	16	60	40	60	0.6	9.10
77	40	12	60	40	40	0.2	3.81
78	80	20	50	40	50	0.8	15.36
79	60	15.2	60	40	90	0.72	13.37

80	92	18	50	60	60	0.84	17.08

Table S2

Verifying data for exhaustion dyeing.

No.	Sodium sulphate conc. (g/L)	Sodium carbonate conc. (g/L)	Fixing temperature (°C)	Dyeing time (min)	Fixing time (min)	Dye conc. (g/L)	K/S value
1	60	15.2	70	20	90	0.72	11.31
2	60	16	70	20	40	0.4	7.93
3	20	5.2	60	60	30	0.04	0.71
4	24	8	70	40	50	0.08	1.38
5	32	10	60	20	70	0.2	3.84
6	60	15.2	60	60	90	0.72	12.83
7	60	16	50	20	40	0.4	8.30
8	32	10	50	60	70	0.2	4.07
9	32	16	60	30	60	0.6	8.50
10	32	16	70	60	60	0.6	7.63
11	24	8	60	10	50	0.08	1.63
12	40	12	50	40	40	0.2	3.97
13	72	16	50	40	80	0.76	14.46
14	80	20	50	60	50	0.8	16.35
15	20	5.2	50	40	30	0.04	0.67
16	40	12	60	0	40	0.2	3.81
17	40	12	60	20	40	0.2	4.03
18	20	5.2	70	40	30	0.04	0.69
19	92	18	60	20	60	0.84	16.6
20	92	18	50	40	60	0.84	16.77

Table S3

Training data for cold pad-batch dyeing.

No.	Sodium hydroxide conc. (g/L)	Stacking time (h)	Dye conc. (g/L)	K/S value
1	21	9	6.04	7.71
2	16	10	7.96	9.15
3	20.5	9	4.88	5.85
4	6	12	7.76	13.81
5	11	9	6.36	8.98
6	5.5	8	1.52	3.14
7	21.5	8	1.6	2.49
8	18.5	6	7.48	8.20
9	11.5	11	4.8	5.41
10	12.5	8	6.8	10.30
11	7.5	12	5	6.68
12	9	8	5.2	8.12
13	15.5	12	2.8	4.31
14	23	6	2.8	3.55
15	22	11	2.92	3.57
16	13.5	8	0.48	1.51
17	14	9	5.6	7.19
18	15	12	6.4	5.99
19	8	8	7.56	12.57
20	16	9	2.52	3.82
21	17.5	10	1.88	2.96
22	22	6	3.92	4.87
23	12	7	4.92	6.78
24	23.5	6	3.68	5.03

25	7	9	7.32	10.45
26	25	11	4.32	4.58
27	23.5	6	0.88	1.75
28	22.5	10	6.76	6.67
29	17.5	7	1	1.95
30	9.5	7	5.52	10.60
31	20.5	9	4.16	5.70
32	16	11	4.24	6.18
33	22.5	7	4.08	4.90
34	10.5	10	2.2	3.84
35	14	8	2.36	3.64
36	6.5	8	4.48	7.19
37	13.5	8	1.44	2.73
38	19	8	3.52	4.85
39	10	9	7	9.09
40	13.5	10	6.84	8.41
41	24	8	7.4	8.21
42	24.5	10	4.76	2.43
43	12	8	6.72	9.05
44	23	7	2.4	3.18
45	19	6	6.6	8.03
46	21.5	11	3.2	3.11
47	14.5	10	2.56	3.04
48	9	11	0.8	1.65
49	14.5	10	5.16	6.56
50	7.5	12	2.76	6.19
51	13	11	5.68	6.82
52	13	9	3	4.82

53	5.5	9	5.32	9.60
54	21.5	11	5.8	7.02
55	23.5	11	0.36	0.81
56	8.5	12	4.4	5.82
57	7	11	1.8	3.90
58	10	6	2	3.66
59	5	9	5.56	8.94
60	15	6	6.2	8.27
61	19.5	8	0.04	0.19
62	18.5	7	5.4	5.23
63	7	11	4.28	6.75
64	23	12	5.88	6.63
65	8	11	6.64	8.02
66	21	11	4.36	5.31
67	11	9	8	11.46
68	22	8	2.16	3.29
69	6.5	7	2.08	4.03
70	5	10	0.16	0.73
71	25	10	5.92	5.65
72	20	11	3.76	4.88
73	9.5	9	4.64	7.98
74	18	11	6.8	8.27
75	17	9	6.88	8.60
76	24.5	11	1.08	1.82
77	19.5	11	1.96	3.21
78	20	9	1.68	2.77
79	16.5	11	7.24	6.07
80	9.5	10	7.92	10.58

Table S4

Verifying data for cold pad-batch dyeing.

No.	Sodium hydroxide conc. (g/L)	Stacking time (h)	Dye conc. (g/L)	K/S value
1	9	10	3.44	5.11
2	21	10	6.48	6.78
3	19.5	9	1.32	1.91
4	16.5	8	0.64	1.40
5	11.5	9	0.56	1.68
6	16.5	11	2.64	3.20
7	15.5	9	6.08	8.08
8	18	11	4.52	5.55
9	6	12	3.64	6.44
10	8.5	10	3.6	5.25
11	8.5	7	6.52	10.21
12	12.5	6	4	5.83
13	20.5	12	7.64	7.54
14	11	9	1.2	2.51
15	10.5	7	6.92	9.85
16	8	10	2.28	3.69
17	24	7	5.96	6.47
18	17	7	7.12	8.43
19	6	10	6	9.87
20	17	7	3.28	4.48

Table S5

Training data for pad-dry-pad-steam dyeing.

No.	Sodium chloride conc. (g/L)	Sodium carbonate conc. (g/L)	Steaming time (s)	Drying time (s)	Dye conc. (g/L)	K/S value
1	133	25	90	135	17	12.49
2	144	41	175	125	19.1	13.77
3	155	46	175	145	14.7	12.16
4	127	18	90	120	13	9.35
5	140	37	60	105	13.5	10.48
6	146	12	180	70	19.4	11.90
7	143	44	95	120	5.4	5.44
8	145	34	65	90	8.2	6.37
9	143	20	115	115	17.5	13.06
10	128	27	75	140	1.2	1.12
11	178	43	150	150	8	6.76
12	131	25	40	70	10	5.81
13	166	46	65	150	6	4.96
14	182	49	125	80	11.9	10.28
15	184	23	110	140	1.4	1.22
16	141	16	85	100	18.9	10.81
17	139	16	145	115	16.6	12.83
18	131	22	100	140	20	13.04
19	172	15	180	70	6.9	5.67
20	196	14	165	90	4.5	4.03
21	167	12	180	75	9.1	8.52
22	195	22	120	125	15.9	13.96
23	190	45	60	140	10.2	8.81
24	153	32	130	145	19.9	13.57

25	185	41	100	120	10.4	9.48
26	186	34	60	85	17.8	13.00
27	169	37	40	155	18.7	11.47
28	161	47	40	150	2.2	1.83
29	177	27	80	80	3.6	3.22
30	152	34	120	125	17.2	13.53
31	164	22	115	85	3	2.66
32	129	41	105	130	12.2	10.01
33	150	42	110	95	15.1	11.19
34	192	47	145	120	0.9	0.82
35	149	50	125	75	14.8	11.75
36	127	48	55	150	14.9	10.41
37	126	29	130	145	12.9	9.73
38	190	36	145	100	11.3	9.11
39	147	24	80	75	16.8	11.87
40	177	32	155	140	10.6	10.22
41	200	36	160	145	17.7	13.12
42	139	47	45	95	9.2	6.84
43	130	38	75	150	8.8	7.11
44	137	11	90	100	3.8	3.39
45	168	43	85	110	4	4.12
46	194	35	70	105	2.5	2.48
47	181	17	135	125	9	8.75
48	189	16	135	135	5.7	5.02
49	153	14	155	140	10.7	8.69
50	174	50	160	110	10.8	9.89
51	129	23	160	155	12	8.44
52	151	18	145	105	2	2.12
53	188	35	125	150	4.7	4.08

54	179	26	155	135	14.2	12.13
55	133	20	45	70	5	3.37
56	160	28	100	75	14	10.61
57	142	10	115	120	13.9	9.83
58	148	17	65	130	16.3	11.44
59	151	39	75	80	0.1	0.10
60	159	40	110	90	4.2	3.65
61	176	18	135	85	8.6	6.68
62	175	32	120	130	6.3	5.99
63	199	19	120	95	11.6	10.04
64	173	43	165	140	14.5	13.22
65	135	42	130	145	16.2	10.95
66	161	13	70	130	5.2	4.59
67	132	11	105	110	13.3	9.63
68	136	40	150	155	9.4	8.00
69	197	19	70	115	13.8	11.57
70	182	15	170	85	12.5	10.46
71	154	14	105	105	18.3	13.34
72	130	48	80	155	18.5	12.84
73	159	21	55	105	17.3	11.45
74	157	12	140	110	15	10.8
75	176	33	95	150	1.6	1.73
76	158	30	50	85	15.5	10.34
77	183	33	150	155	18.1	14.22
78	180	27	125	90	17.1	12.7
79	199	38	50	130	16.5	12.85
80	165	39	115	145	3.3	2.95

Table S6

Verifying data for pad-dry-pad-steam dyeing.

No.	Sodium chloride conc. (g/L)	Sodium carbonate conc. (g/L)	Steaming time (s)	Drying time (s)	Dye conc. (g/L)	K/S value
1	173	26	110	70	7.5	6.43
2	174	24	55	100	12.3	9.26
3	171	17	170	135	11	9.66
4	191	13	85	160	11.2	8.75
5	180	39	155	100	4.9	4.85
6	187	46	45	155	7	5.37
7	194	33	150	95	6.6	6.09
8	198	45	140	80	16.9	13.34
9	134	49	165	145	2.7	2.98
10	156	28	95	90	5.9	4.78
11	134	30	170	110	16	11.45
12	193	31	175	115	7.7	6.93
13	189	44	50	155	9.8	7.77
14	125	29	135	80	6.4	5.26
15	138	10	140	75	0.4	0.88
16	163	31	105	95	15.2	11.74
17	162	42	160	125	10.9	9.52
18	132	21	140	115	5.5	4.96
19	187	19	130	160	19.8	14.31
20	170	44	165	135	7.3	7.21

Table S7

Absolute errors of three predicted results for exhaustion dyeing.

No.	Actual data	PSO-LSSVM			LSSVM			BPNN		
		Predicted results	Errors	Relative errors	Predicted results	Errors	Relative errors	Predicted results	Errors	Relative errors
1	11.31	11.91	0.60	5.31	12.13	0.82	7.25	12.26	0.95	8.40
2	7.93	8.01	0.08	1.01	8.36	0.43	5.42	7.59	-0.34	4.29
3	0.71	0.81	0.10	14.08	0.96	0.25	35.21	0.86	0.15	21.13
4	1.38	1.36	-0.02	1.45	1.19	-0.19	13.77	1.21	-0.17	12.32
5	3.84	3.78	-0.06	1.56	3.95	0.11	2.86	3.67	-0.17	4.43
6	12.83	12.69	-0.14	1.09	12.55	-0.28	2.18	12.86	0.03	0.23
7	8.30	8.46	0.16	1.93	8.56	0.26	3.13	9.24	0.94	11.33
8	4.07	4.19	0.12	2.95	4.51	0.44	10.81	4.29	0.22	5.41
9	8.50	9.14	0.64	7.53	8.91	0.41	4.82	8.90	0.40	4.71
10	7.63	7.93	0.30	3.93	8.04	0.41	5.37	7.92	0.29	3.80
11	1.63	1.55	-0.08	4.91	1.88	0.25	15.34	1.54	-0.09	5.52
12	3.97	4.01	0.04	1.01	3.90	-0.07	1.76	4.61	0.64	16.12
13	14.46	15.09	0.63	4.36	15.36	0.90	6.22	14.80	0.34	2.35
14	16.35	15.76	-0.59	3.61	15.74	-0.61	3.73	15.79	-0.56	3.43
15	0.67	0.68	0.01	1.49	0.35	-0.32	47.76	1.10	0.43	64.18
16	3.81	3.92	0.11	2.89	4.39	0.58	15.22	4.01	0.20	5.25
17	4.03	3.92	-0.11	2.73	4.01	-0.02	0.50	3.97	-0.06	1.49
18	0.69	0.81	0.12	17.39	0.74	0.05	7.25	0.36	-0.33	47.83
19	16.60	16.25	-0.35	2.11	15.92	-0.68	4.10	16.07	-0.53	3.19
20	16.77	16.85	0.08	0.48	16.97	0.20	1.19	16.65	-0.12	0.72

Table S8

Absolute errors of three predicted results for cold pad-batch dyeing.

No.r	Actual data	PSO-LSSVM			LSSVM			BPNN		
		Predicted results	Errors	Relative errors	Predicted results	Errors	Relative errors	Predicted results	Errors	Relative errors
1	5.11	5.47	0.36	7.05	5.49	0.38	7.44	5.49	0.38	7.44
2	6.78	6.87	0.09	1.33	6.93	0.15	2.21	6.99	0.21	3.10
3	1.91	2.13	0.22	11.52	2.06	0.15	7.85	2.01	0.10	5.24
4	1.40	1.62	0.22	15.71	1.50	0.10	7.14	1.71	0.31	22.14
5	1.68	1.71	0.03	1.79	1.66	-0.02	1.19	1.95	0.27	16.07
6	3.20	3.47	0.27	8.44	3.59	0.39	12.19	3.31	0.11	3.44
7	8.08	7.73	-0.35	4.33	7.69	-0.39	4.83	7.62	-0.46	5.69
8	5.55	5.36	-0.19	3.42	5.35	-0.20	3.60	5.10	-0.45	8.11
9	6.44	5.98	-0.46	7.14	6.04	-0.40	6.21	6.25	-0.19	2.95
10	5.25	5.77	0.52	9.90	5.77	0.52	9.90	5.80	0.55	10.48
11	10.21	10.04	-0.17	1.67	10.08	-0.13	1.27	9.91	-0.30	2.94
12	5.83	6.18	0.35	6.00	6.22	0.39	6.69	6.08	0.25	4.29
13	7.54	7.48	-0.06	0.80	7.70	0.16	2.12	8.02	0.48	6.37
14	2.51	2.43	-0.08	3.19	2.50	-0.01	0.40	2.67	0.16	6.37
15	9.85	10.03	0.18	1.83	10.14	0.29	2.94	9.92	0.07	0.71
16	3.69	4.01	0.32	8.67	4.14	0.45	12.20	4.26	0.57	15.45
17	6.47	6.38	-0.09	1.39	6.52	0.05	0.77	6.63	0.16	2.47
18	8.43	8.64	0.21	2.49	8.96	0.53	6.29	8.78	0.35	4.15
19	9.87	9.49	-0.38	3.85	9.33	-0.54	5.47	9.64	-0.23	2.33
20	4.48	4.55	0.07	1.56	4.61	0.13	2.90	4.52	0.04	0.89

Table S9

Absolute errors of three predicted results for pad-dry-pad-steam dyeing.

No.	Actual data	PSO-LSSVM			LSSVM			BPNN		
		Predicted results	Errors	Relative errors	Predicted results	Errors	Relative errors	Predicted results	Errors	Relative errors
1	6.43	6.19	-0.24	3.73	6.12	-0.31	4.82	6.33	-0.10	1.56
2	9.26	9.43	0.17	1.84	9.59	0.33	3.56	9.61	0.35	3.78
3	9.66	9.37	-0.29	3.00	9.49	-0.17	1.76	9.33	-0.33	3.42
4	8.75	8.89	0.14	1.60	9.14	0.39	4.46	8.07	-0.68	7.77
5	4.85	4.89	0.04	0.82	4.66	-0.19	3.92	4.86	0.01	0.21
6	5.37	5.58	0.21	3.91	5.72	0.35	6.52	4.93	-0.44	8.19
7	6.09	6.22	0.13	2.13	5.97	-0.12	1.97	6.26	0.17	2.79
8	13.34	13.28	-0.06	0.45	12.88	-0.46	3.45	13.27	-0.07	0.52
9	2.98	3.17	0.19	6.38	3.29	0.31	10.40	2.91	-0.07	2.35
10	4.78	5.09	0.31	6.49	5.01	0.23	4.81	4.88	0.10	2.09
11	11.45	11.99	0.54	4.72	12.06	0.61	5.33	11.79	0.34	2.97
12	6.93	7.20	0.27	3.90	7.05	0.12	1.73	7.35	0.42	6.06
13	7.77	7.70	-0.07	0.90	7.84	0.07	0.90	6.82	-0.95	12.23
14	5.26	5.25	-0.01	0.19	5.44	0.18	3.42	5.23	-0.03	0.57
15	0.88	0.73	-0.15	17.05	1.20	0.32	36.36	1.00	0.12	13.64
16	11.74	11.87	0.13	1.11	12.06	0.32	2.73	11.61	-0.13	1.11
17	9.52	9.60	0.08	0.84	9.80	0.28	2.94	9.41	-0.11	1.16
18	4.96	4.91	-0.05	1.01	4.93	-0.03	0.60	4.70	-0.26	5.24
19	14.31	14.40	0.09	0.63	14.17	-0.14	0.98	13.39	-0.92	6.43
20	7.21	6.84	-0.37	5.13	6.87	-0.34	4.72	6.78	-0.43	5.96