23-36°Tw (11-19% w/v), [34]

The main focus of the present paper is limited to systematically establish the most appropriate choice of caustic soda concentration for causticization for increased dye uptake, experimental details of which are missing in the literature.

Materials

Commercially bleached cotton fabric supplied by Bahir Dar Textile share company, Ethiopia was used. The fabric had following specifications

63 Ends/in, 43 picks/in, 134 GSM

Commercial caustic soda in flake form

Tubantin Blue FF2GL 200 (direct dye) supplied by Bezema, Switzerland.

Experimental methods

Treatment with caustic soda solution: The strength of the commercial caustic soda flakes was determined by titration with standard sulfuric acid and caustic soda solutions were prepared by converting the commercial caustic soda strength to 100% purity. The caustic soda strength is expressed in % (w/v) meaning g/100 ml.

Commercially bleached cotton fabric was treated with caustic soda solution of concentrations varying from 5-30% containing 1 g/l wetting agent by two dip two nip padding technique. The % wet pick up was noted in each case. The padded fabric samples were rolled on glass rods, covered with plastic sheet and batched for 30 minutes. The padding and batching were done at room temperature (20-25°C). After the batching period the samples were repeatedly rinsed in cold water until the samples showed neutral pH as indicated by universal indicator test.

Causticization: The treatment given was similar to that mentioned above except the caustic soda concentration varied from 8-20%.

Dyeing: The cotton samples treated with varying concentrations of caustic soda including those used for causticization were dyed with a direct dye in wet-on wet (without drying) and after drying. For wet on wet dyeing the samples after final rinsing were squeezed, and for dyeing after drying, the samples were allowed to air dry. The dyeing were carried out in high temperature dyeing machine under following conditions

Tubantin Blue FF2GL 200 (Direct dye) ------2% (o.w.f)

Sodium chloride------10g/L

MLR--------------------1:30

Temperature---------80°C

Time-----------------45 minutes.

The dyeing was commenced at room temperature. The temperature was raised to 80°C and dyeing continued at this temperature for 45 minutes. After dyeing the fabrics were rinsed three times with cold water, squeezed, air dried, pressed with hot iron and conditioned before K/S measurement.

Shrinkage measurement: An area of 7 cm*7 cm was marked at the center of each sample by stitching with white thread. The changes in the dimensions of the marked area were recorded in terms of warp and weft shrinkages from which average shrinkage was calculated by taking the average of warp and weft shrinkage.

Determination of color yield (K/S): The color yield or dye-uptake was determined by measurement of the K/S value of the dyed samples on Gretag Macbeth color-eye 3100 spectrophotometer by following the standard procedure.

Experimental Results: The effect of causticization on improvement of color yield is well known. Measurements of color in dyed fabrics are analyzed in various ways, but for the purpose of comparing color yield changes due to mercerization as well as causticization most workers have used the Kubelka-Munk function K/S where K is an absorption coefficient and S is a scattering coefficient [35]. The ratio K/S increases with increasing depth of shade. The measurement of K/S gives the comparative color yield or dye uptake and not the absolute quantity of dye present on dyed sample.

The caustic soda concentration for causticization as reported in the literature [32-34] varies from 11-19% (W/V). Obviously there

Run #	caustic soda Concentration (%)	K/S	% Increase in K/S
1	10	13.9125	8.2449
2	15	16.4765	28.1939
3	30	22.5955	75.8022
4	10	15.0584	17.1605
5	25	20.7506	61.4481
6	20	19.3651	50.6683
7	30	18.318	42.5215
8	0	11.4682	-10.7727
9	0	14.1527	10.1137
10	25	20.8138	61.9398
11	20	20.1982	57.1502
12	5	13.3168	3.61011
13	5	12.0853	-5.97146
14	30	18.9329	47.3056
15	25	20.3792	58.5584
16	10	12.3877	-3.61867
17	15	18.7236	45.6772
18	15	18.4681	43.6893
19	15	17.6701	37.4805
20	20	21.4327	66.7551
21	20	21.5675	67.8039
22	30	23.1649	80.2323
23	5	12.4115	-3.43349
24	5	12.1884	-5.1693
25	0	12.4115	-3.43349
26	0	13.0365	1.42926
27	25	20.8138	61.9398
28	30	21.8768	70.2104
29	10	12.5931	-2.02057
30	5	12.9197	0.520509
31	25	21.7383	69.1328
32	10	15.4087	19.8859
33	20	22.8924	78.1122
34	15	16.8924	31.4297
35	0	13.1953	2.66479

Table 1: Effect of caustic soda concentration on color yield for wet-on-wet dyeing.

Phase 2: 5-10% slow increase in color yield.

Phase 3: 10-20% rapid increase in color yield.

Phase 4: 20-30% leveling off color yield.

The results can be interpreted on the basis of hydration of sodium hydroxide at different concentrations and its effect on swelling. There is some evidence that the degree of hydration of alkali hydroxide ions affects their ability to enter and swell cellulose fibers. At low concentrations of sodium hydroxide, the diameters of the hydrated ions are too large for easy penetration into the fibers. As the concentration of caustic soda increases, the number of water molecules available for the formation of hydrates decreases and therefore their size decreases. Small hydrates can diffuse into the high order, or crystalline regions, as well as into the pores and low-order regions of cellulose [1,32, 33].

The results of the effect of caustic soda concentrations on color yield can be interpreted on the basis of the above facts. Up to 5% caustic soda concentration effect on color yield is marginally decreased indicating that there may not be further breaking of hydrogen bonds of already water swollen fiber due to high degree of hydration at low concentration caustic soda. From 5%-10% caustic soda concentration, the fiber swelling tends to increase as indicated by the slow increase in color yield. From 10%-20% caustic soda concentration, the increase in color yield can be related to the high rate of swelling along with possibility of hydrogen bond breaking in the inter crystalline regions. Beyond 20% caustic soda concentration, there may be excessive swelling resulting in the jamming of fiber structure with the result, the increase in dye uptake is leveled off. This is the reason for the development of the concept of hot mercerization [31].

Dyeing after drying: The experiments were carried out in triplicate and the authenticity of the experimental design data was tested by plotting residuals plot as in case of wet-on wet dyeing. The results of effect of caustic soda concentration on color yield for dyeing after drying are shown in figure 3.

The observations of the effect of caustic soda concentration on dyeing after drying are different compared to wet-on-wet dyeing. The curve can be divided into three phases

Phase 1: 0-10%, slow increase in color yield.

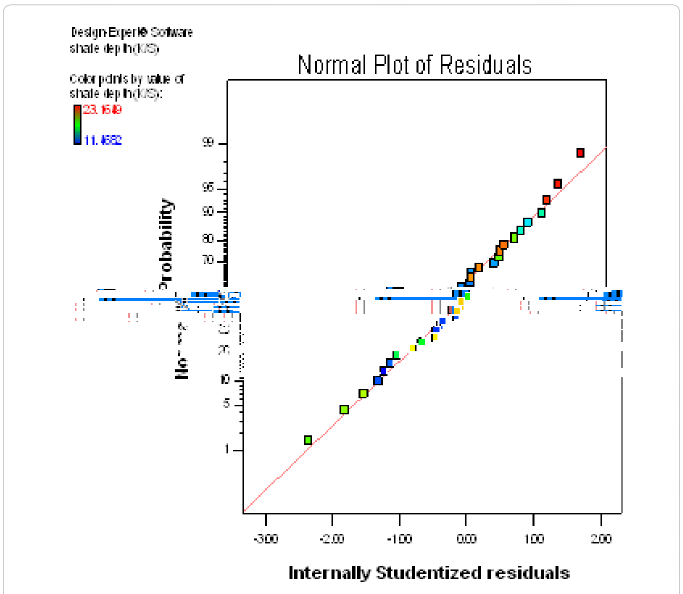

Figure 1: Normal probability plot of residuals for K/S values.

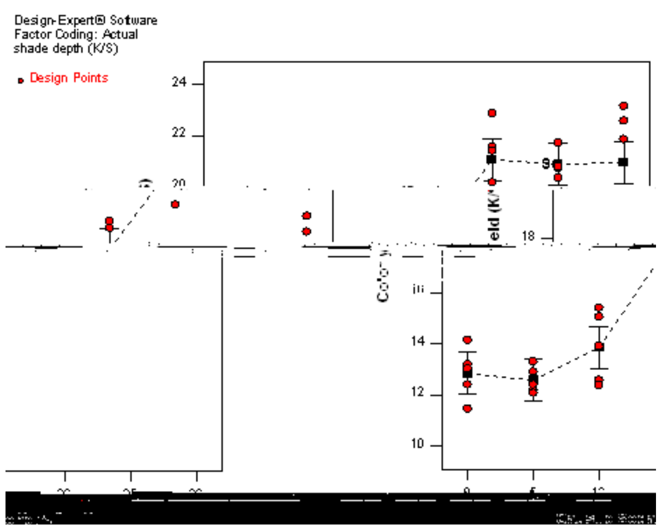

Figure 2: Effect of caustic soda concentration on color yield (K/S) for wet-on-wet dyeing.

is substantial increase in dye uptake between 14-16% caustic soda concentrations. Therefore, the concentration of 14-16 % can be recommended for the causticization of cotton to get the advantage of increase of in color yield. This recommendation is in agreement with the literature values [33-35].

Since causticization is usually carried out without tension shrinkage of the fabric during causticiztion cannot be avoided.

Effect of causticization on color yield: After establishing 14-16%, caustic soda concentration as the appropriate choice for causticization, the effect of causticization on % increase in color yield using 14% concentration on one direct and two reactive dyes was studied. The dyeing was carried out in triplicate and the average K/S values were recorded. The results for dyeing after drying are shown in table 3.

The above results clearly indicated that the causticization at 14% concentration of caustic soda resulted in increase in color yield both in case of direct dye and reactive dyes. The increase in color yield was higher for the reactive dyes compared to direct dye. This may be accounted to the difference in molecular weight of dyes.

Conclusions

1. On the basis of single factor completely randomized experimental design data an optimized choice of caustic soda concentration for causticization suggested is 14-16%.
2. The wet-on-wet dyeing gave higher color yield compared to dyeing after drying. Since the basic aim of the causticization was to get advantage of improved color yield, the exhaust dyeing operation should be carried out without drying after causticization. For this reason the causticization may carried out on padding mangle followed by washing and dyeing on jigger. This option may not be available for pad dyeing due to exchange of liquor during padding resulting in dilution of pad liquor.
3. The increase in color yield after causticization was higher in case of reactive dyes compared to the direct dye.
4. Since the causticization is usually carried out without tension, fabric shrinkage is unavoidable.

References

1. Warwicker JO (1966) A Review of the Literature on the Effect of Caustic Soda and Other Swelling Agents on the Fine Structure of Cotton. Cotton, Silk and Man-Made Fibres Research Association. Manchester, UK.
2. Coward HF, Spencer L (1923) The Absorption of Caustic Soda Solutions by Cotton. J Test Inst 14: 14-32.
3. Willows ES (1922) Changes in Section of Cotton Hairs on Mercerising. J Textile Inst 13: T237-T240.
4. Sadov FI, Korchagin MV, Matetsky AI (1973) Chemical Technology of Fibrous Materials. Mir Pub, Moscow.
5. Bancroft WD,