Scientific Software

Performance analysis of reactive dyes on cotton

Research Report No 5

Research report no 5: reactive dyes

Reactive dyes constitute the by far most important dyestuff class for the dyeing of cotton and other cellulosic fibres. While dye manufacturers usually provide information about the various types of colour fastness for each dye, information about other important application properties is often not available. They include, for example, the sensitivity to salt and alkali, the dye exhaustion and fixation values and the ease of washing off unfixed dyestuff.

If a dye is ***sensitive to salt***, it means that adding salt to the dyebath significantly increases dye exhaustion. If it is sensitive to ***alkali***, most of the dye is exhausted after adding alkali to the dyebath. Knowing the sensitivity to salt and alkali, a dyer can adjust the dyeing process to ensure that unlevelness is avoided without unnecessarily long dyeing cycles. If all the dyes in a recipe are insensitive to salt, for example, all the salt may be added at the start of the dyeing. If any dye in the recipe is sensitive to alkali, the alkali dosing time may have to be extended. Sensitivity to salt and alkali is not a constant for each dye. Both normally increase notably as the dye amount in the recipe reduces. Thus, a dye may be sensitive to salt at low amounts and insensitive at high amounts.

Knowing the ***exhaustion and fixation value*** of a dye is useful since unfixed dye ends up in the wastewater. In the best possible scenario, the fixation value is very high, e.g. above 90%, and the exhaustion value only slightly higher. Then, only little dye must be removed from the fabric. A high exhaustion value alone is only positive if the fixation value is also high. Otherwise, a lot of unfixed dye must be removed from the fibre.

Finally, the easier it is to ***wash off*** a dye, the less water is required. Several parameter influence the ease of washing off, among them how much unfixed dye on the fibre must be removed, how easily the dye is separated from the fibre and how easily the dye stains the clean cloth used in wash fastness tests.

In the current report, we analysed the above-mentioned application properties of 56 reactive dyes of three well-known suppliers: Archroma, DyStar and Huntsman (see appendix 1, sorted alphabetically by brand and then by dyestuff).

This report summarises key findings. Dye-specific results are available via our ***DyeProfiler*** app which can be downloaded from our website for a fee: https://www.scientificsoftware.in/DyeProfiler%20Reactive.

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Test methods

All ***dyeings*** were carried out at a liquor-to-goods-ratio of 8l/kg on bleached 100% cotton jersey with a single dyestuff per dyeing and a fabric weight of 10g on a Mathis Labomat IR beaker dyer. Other than the dyestuffs, only sodium chloride, soda ash and caustic soda were used in the dyeings and acetic acid for neutralization during the washing. We used the dyeing temperature as well as the salt and alkali concentrations recommended by the manufacturers. Dyeings of medium depth were carried out at 1/3 SDD and those of high depth at 2/1 SDD. 'SDD' is short for 'Standard Depth of Dyeing' and refers to the dye amount that is needed to produce an internationally defined colour impression. The lower the dye amount at a given SDD, the higher is the tinctorial strength of the dye.

The ***neutral salt exhaustions*** were determined using the dyeing temperature and salt concentrations recommended by the manufacturer with the pH varying between 5 and 8. After 30 minutes at constant temperature, the fabric was removed, and the exhaustion value determined from the residual liquor with a Mathis SmartLiquor dyebath analysor.

The ***exhaustion values*** were calculated with SmartLiquor from the residual liquor at the end of the dyeing. The ***fixation values*** were calculated with SmartLiquor by measuring each of four wash liquors (50°C, 50°C, 95°C, 75°C, liquor ratio 10l/kg) and considering the carry-over of water from one wash bath to the next. The fabric after the fourth and final wash was subject to extraction(s) with a Mathis Morapex unit to remove any remaining unfixed dye. The dye concentration in the extracted liquor was measured with SmartLiquor and converted to a dye amount in % omf.

The ***wash-off ratings*** range from one (very poor) to five (excellent). They correspond to the colour fastness grading to washing according to ISO 105 C06 after a dyeing with a dye amount of 1/3 SDD and two 10-minute washes at 50°C (the second wash with acid to neutralise) and a liquor ratio of 10l/kg. The fastness rating was measured with a Mathis SmartScan digital fastness grader.

Results

On average, at medium depth, most exhaustion occurred after salt addition (58.7%) while at high depth, salt (40.2%) and alkali (77.7 – 40.2 = 37.5%) contributed roughly equally to the final exhaustion (table 1). Very salt sensitive dyes exhausted over 90% at medium depth in the neutral phase and still around 75% at high depth. Alkali-sensitive dyes, on the other hand, exhausted merely between 14 (high depth) and 29% (medium depth) when salt was added.

As expected, dye exhaustion and fixation dropped when the dye amount increased. At medium depth, between 41.2 and 91.8% of the dye was fixed on the fibre. At high depth, these values dropped to 15.1 and 79.1%, respectively. Thus, the difference between the best and worst dyes was even more pronounced at high depth. Average exhaustion was 87% at medium depth and 78% at high depth. Average fixation was 70% at medium depth and 51% at high depth, i.e. 17% of the dye applied (or 20% of the dye on the fibre) had to be removed at medium depth and 27% (35%) at high depth.

The ease of washing off also varied greatly among dyes, ranging across most of the scale of possible values of one to five.

	Medium depth			High depth			
	Neutral exhaustion, %	Final exhaustion, %	Fixation, %	Neutral exhaustion, %	Final exhaustion, %	Fixation, %	Wash-off
Average	58.7	86.6	70.4	40.2	77.7	50.7	4.1
Maximum	92.3	97.9	91.8	75.3	94.7	79.1	5.0
Minimum	28.9	66.1	41.2	14.3	46.7	15.1	2.0

Table 1: Summary of results

Below, histograms depict for each of the four parameters (neutral and final exhaustion, fixation, wash off) how the dyes were distributed according to their performance. On the x-axis, the range of possible values is categorised either in ten-percent steps (neutral and final exhaustion, fixation) or in steps of one grade (wash off). The y-axis shows in each case the percentage of dyes falling into each of the x-axis categories.

Figure 1 shows that most of the neutral exhaustion values at medium depth lay between 40 and 70% (high salt sensitivity!) and at high depth between 20 and 60%.

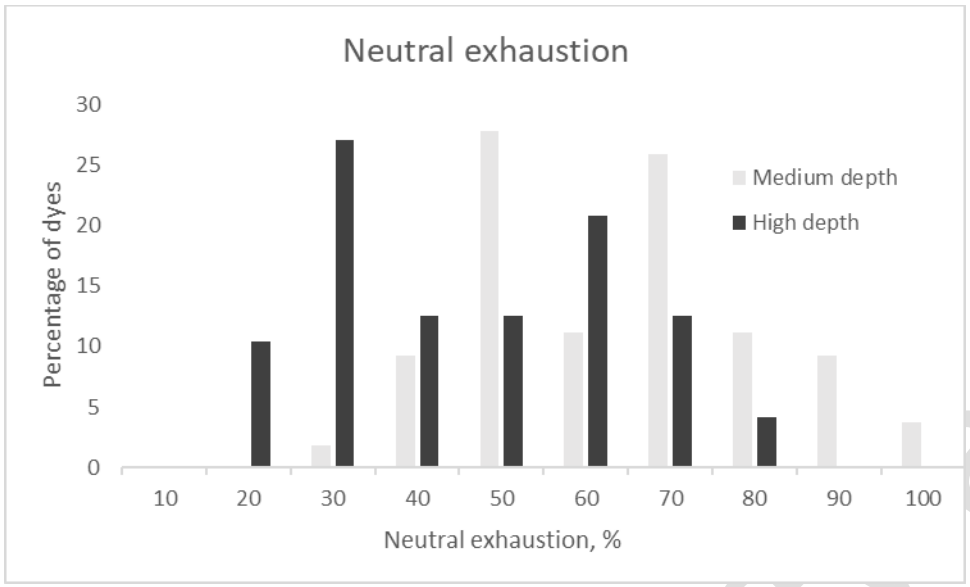

Figure 1: Histogram of neutral exhaustion values

The final exhaustion values were in nearly nine cases out of ten higher than 80% at medium depth but much more broadly distributed between 50 and 100% at high depth (figure 2).

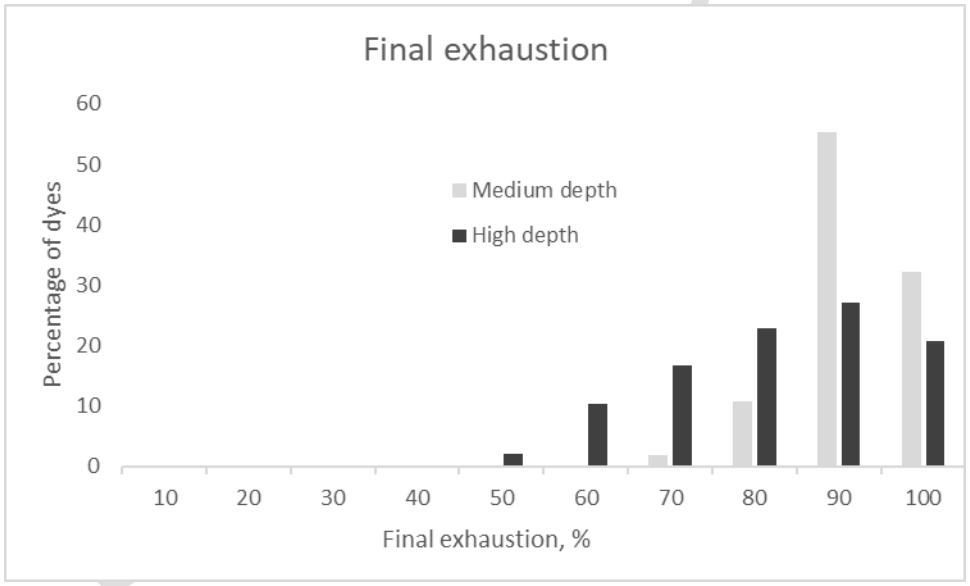

Figure 2: Histogram of final exhaustion values

85% of all dyes had a fixation value of at least 60% at medium depth but, at high depth that value dropped to 40% of all dyes. None of the dyes fixed more than 80% at high depth (figure 3).

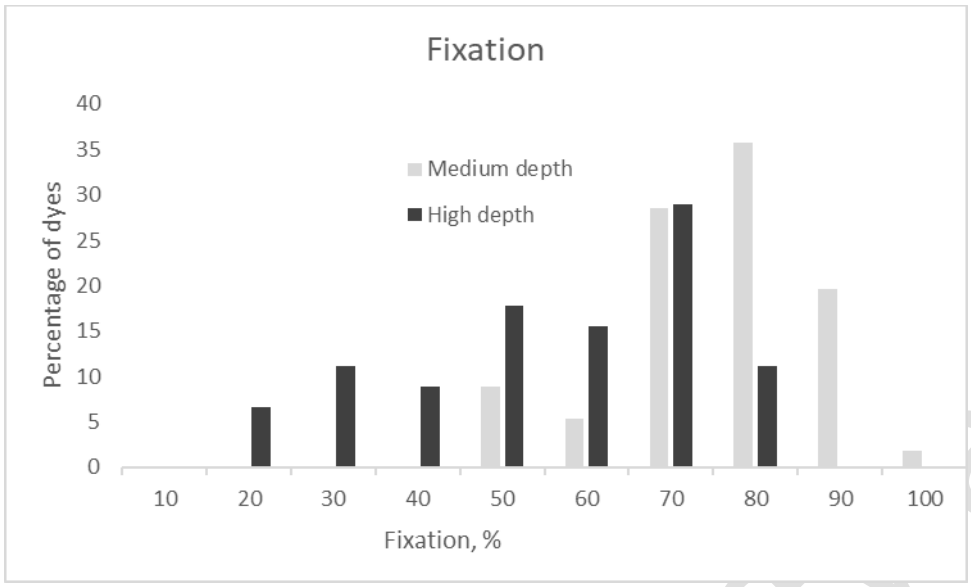

Figure 3: Histogram of fixation values

When it came to washing off, more than 90% of all dyes had a rating between three and five and around 60% one of more than four (figure 4).

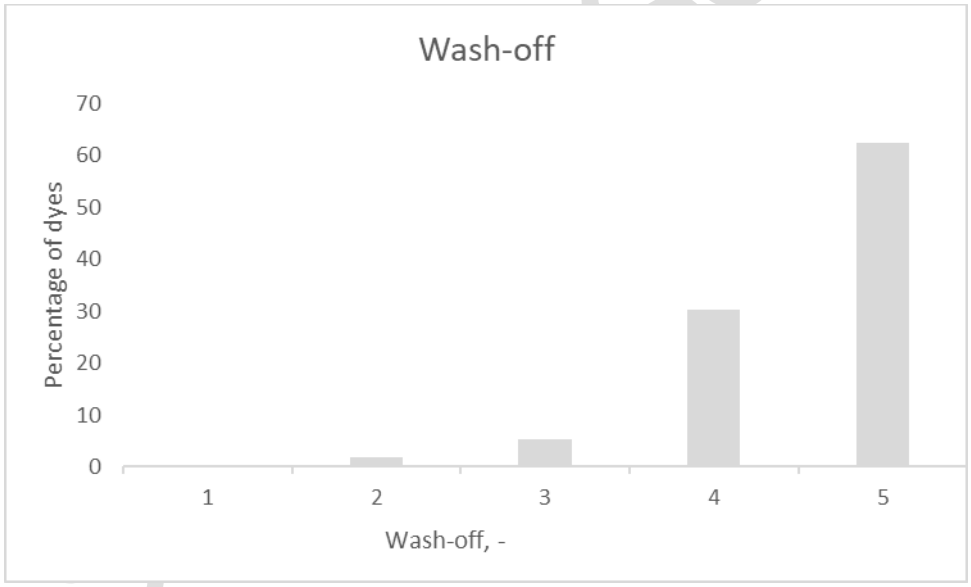

Figure 4: Histogram of wash-off ratings

Appendices

Appendix I: List of dyes examined

Manufacturer	Brand	Dyestuff
Huntsman	Avitera	Black SE
Huntsman	Avitera	Blue SE
Huntsman	Avitera	Cardinal SE
Huntsman	Avitera	Deep Sea SE
Huntsman	Avitera	Gold SE
Huntsman	Avitera	Navy SE
Huntsman	Avitera	Orange SE
Huntsman	Avitera	Red SE
Archroma	Drimarene	Black CL-S
Archroma	Drimarene	Blue CL-BR
Archroma	Drimarene	Blue HF-RL
Archroma	Drimarene	Dark Red HF-CD
Archroma	Drimarene	Navy CL-R
Archroma	Drimarene	Navy HF-B
Archroma	Drimarene	Navy HF-GN
Archroma	Drimarene	Orange HF-2GL
Archroma	Drimarene	Red HF-3B
Archroma	Drimarene	Red HF-6BL
Archroma	Drimarene	Scarlet HF-3G
Archroma	Drimarene	Turquoise CL-B
Archroma	Drimarene	Yellow CL-2R
Archroma	Drimarene	Yellow HF-3GL
DyStar	Levafix	Amber CA-N
DyStar	Levafix	Blue CA
DyStar	Levafix	Fast Red CA
DyStar	Levafix	Navy CA
DyStar	Levafix	Red CA-N
Huntsman	Novacron	Black LS-N01

Huntsman	Novacron	Blue EC-R
Huntsman	Novacron	Blue LS-3R HC
Huntsman	Novacron	Dark Blue S-GL
Huntsman	Novacron	Navy LS-G
Huntsman	Novacron	Navy S-G
Huntsman	Novacron	Orange LS-BR
Huntsman	Novacron	Red EC-2BL
Huntsman	Novacron	Red FN-R
Huntsman	Novacron	Red LS-6G HC
Huntsman	Novacron	Red S-B
Huntsman	Novacron	Super Black G
Huntsman	Novacron	Yellow EC-2R
Huntsman	Novacron	Yellow LS-R HC
Huntsman	Novacron	Yellow S-3R
DyStar	Procion	Crimson HEXL
DyStar	Procion	Navy HEXL
DyStar	Procion	Yellow HEXL
DyStar	Remazol	Black B 133
DyStar	Remazol	Blue RGB
DyStar	Remazol	Blue RR
DyStar	Remazol	Deep Black GWF
DyStar	Remazol	Golden Yellow RGB
DyStar	Remazol	Navy RGB
DyStar	Remazol	Red RGB
DyStar	Remazol	Red RR
DyStar	Remazol	Ultra Red RGB
DyStar	Remazol	Ultra Yellow RGBN
DyStar	Remazol	Yellow RR

Appendix II: Equipment

Mathis SmartLiquor dyebath analysor

Mathis Labomat beaker dyeing machine