Dyeing Process of Cotton-Eqwools Blended Materials (Yarns & Fabrics)

Dr. Md Abdullah Al Faruque
Associate Research Fellow
Institute for Frontier Materials – Deakin University

Do You Know?

The **UNEP/WMO 2018 Scientific Assessment** confirmed the first clear signs of ozone recovery.

•In **2023**, the **UN** reported that if current policies continue, the **ozone layer will return to 1980 levels by around:**

- **2040** for most of the world
- **2045** for the Arctic
- **2066** for the Antarctic

Where Am I From?

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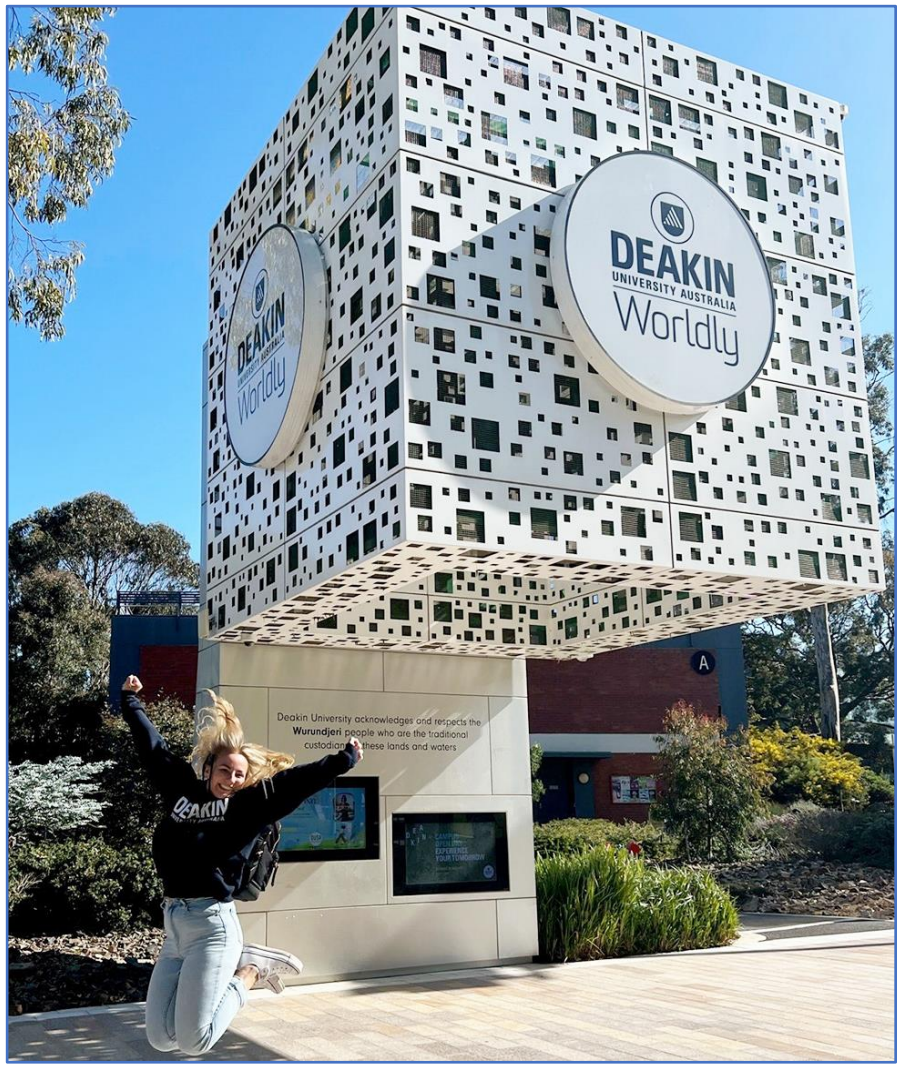

Institute for Frontier Materials (IFM)

- Engineering research
- Innovation in materials design
- Imparting materials with extraordinary functionality
- Redesigning materials for a circular economy

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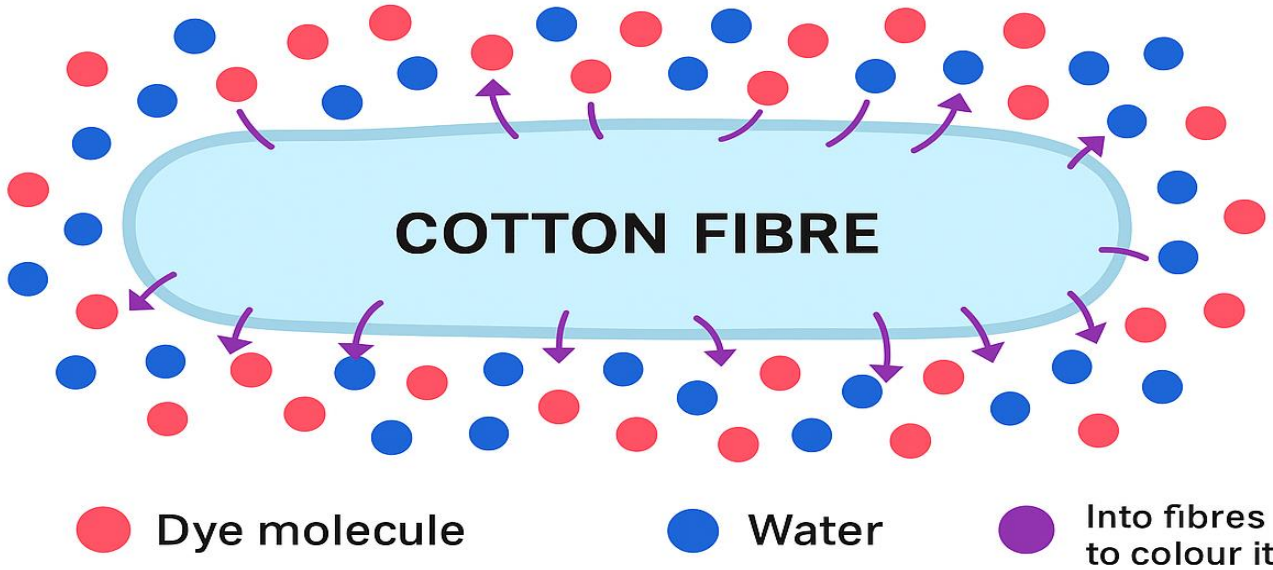
Textile Dyeing Process

The textile dyeing process is the application of **colours to textile materials** in a way that ensures the colour is **evenly distributed and firmly fixed.**

The primary objective of dyeing is to impart the **desired colour, shade, and fastness properties** to the textiles using suitable dyes and auxiliaries.

The process involves the **interaction between dye molecules and textile fibres,** where the dye penetrates and bonds chemically or physically, depending on the fibre type and dye class.



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Textile Dyeing Process

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GENERAL STEPS IN THE DYEING PROCESS

1. PREPARATION (PRE-TREATMENT)

Removal of impurities, oils, and waxes.
Ensures even dye absorption.
Processes include scouring, bleaching and mercerization (for cotton).

2. DYEING

Application of dye in aqueous or solvent medium using various methods.
Conditions (temperature, pH, time) are adjusted for dye-tibre affinity.

3. RINSING AND WASHING

Removes unfixed dye molecules and residual chemicals

4. FINISHING

Application of softeners, resins, or functional finishes to improve handle, appearance

COMMON DYEING MACHINES

FIBRE DYEING MACHINES

Loose Fibre Dyeing Machine (HTHP Typel. Used for wool, cotton. and acryllc fibres. Operates uder high temperature and pressure for uniform dyeing

YARN DYEING MACHINES

Package Dyeing Machine
Dye liquor is circulated through yarn wound on perforated cones

FABRIC DYEING MACHINES

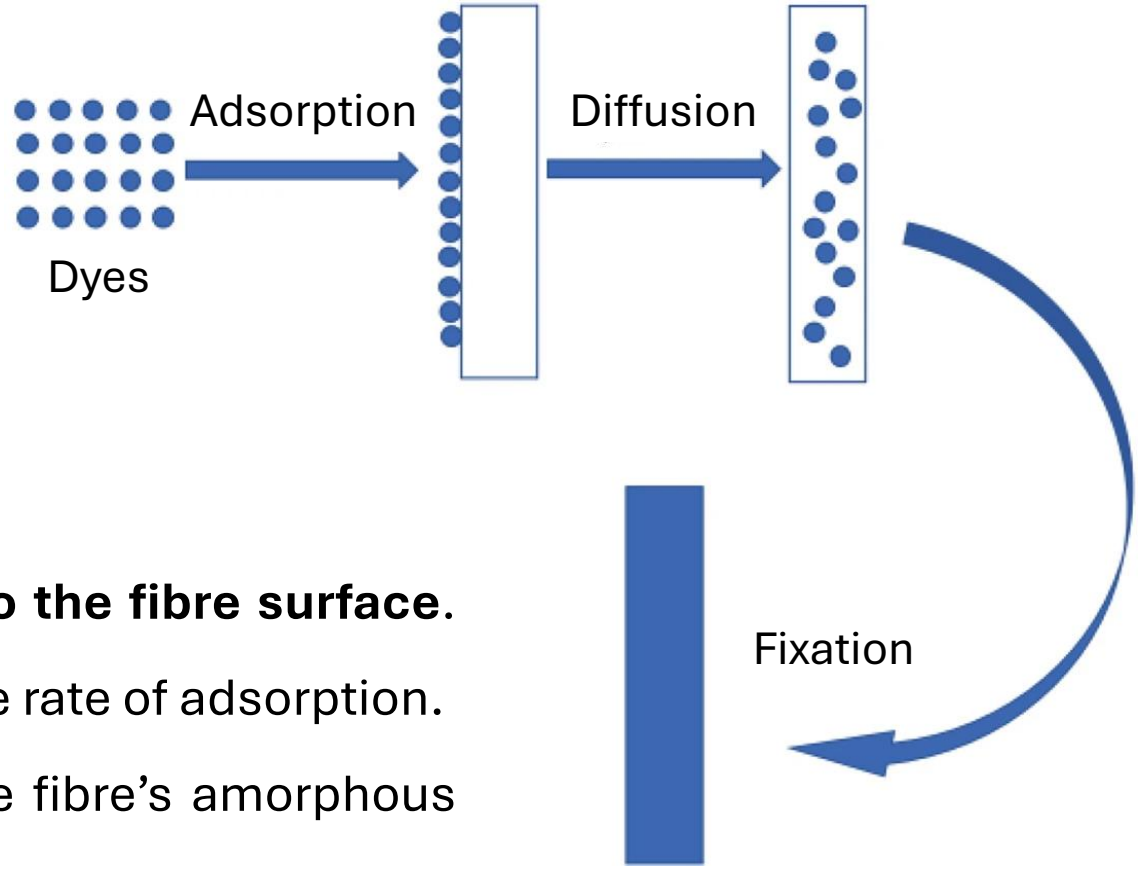
Jet Dyeing Machine
Used for knitted and woven fabrics: fabric circulates with dye liquor in a closed vessel under pressure

GARMENT DYEING MACHINES

Rotary Drum / Paddle Dyeing Machine

The Dyeing Mechanism

The **dyeing mechanism** describes how dye molecules are transferred from the dye bath to the textile substrate and become **physically or chemically attached** to the fibre. It generally involves three main stages: **adsorption, diffusion, and fixation**.



Adsorption: **Dye molecules** move from the **dye solution to the fibre surface**. Temperature, electrolyte concentration, and pH influence the rate of adsorption.

Diffusion: Once adsorbed, **dye molecules diffuse** into the fibre's amorphous regions. Higher temperature generally enhances diffusion.

Fixation: **Dye molecules are fixed** inside the fibre either by Covalent, Ionic, or Hydrogen bonding.

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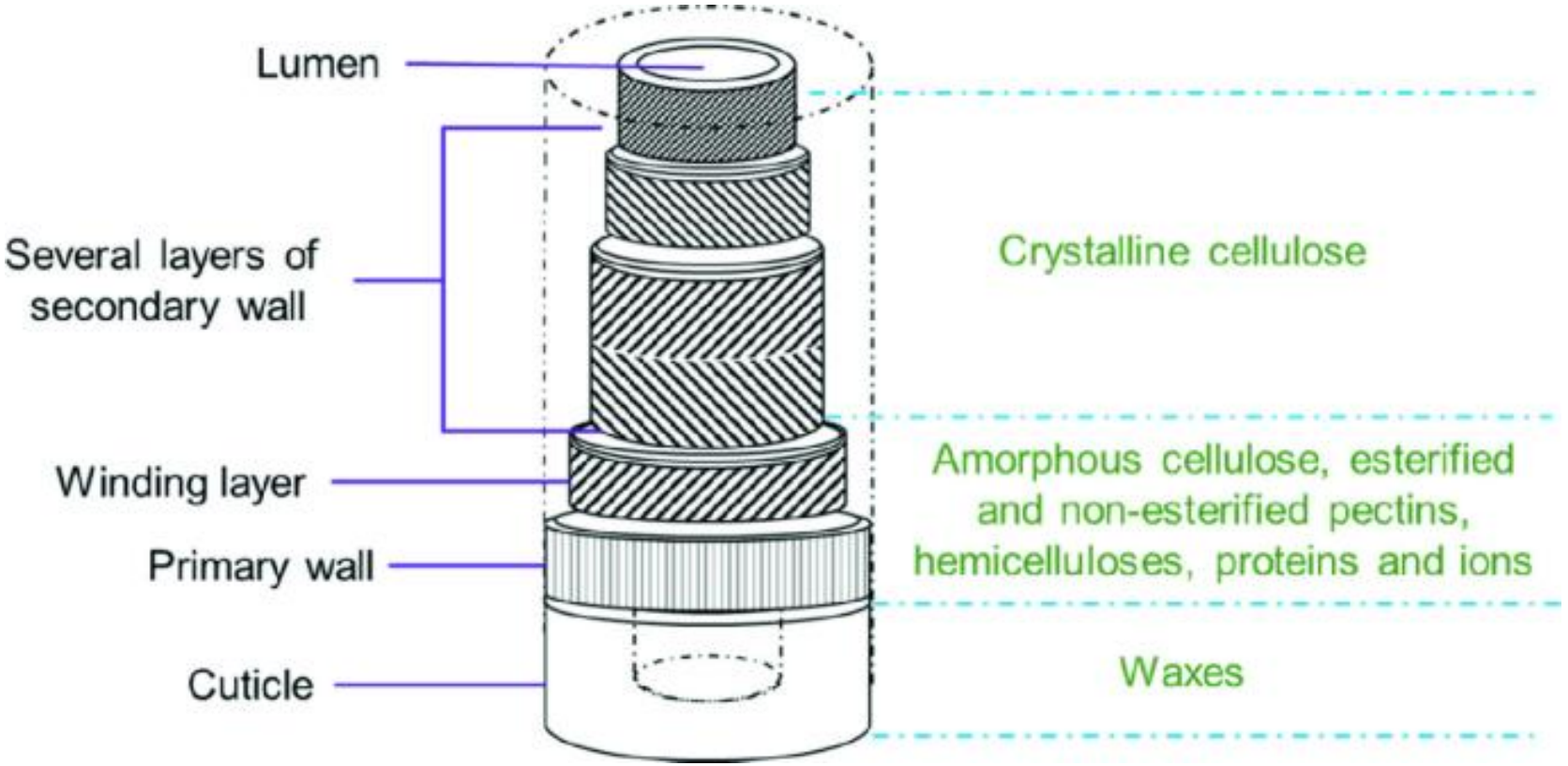
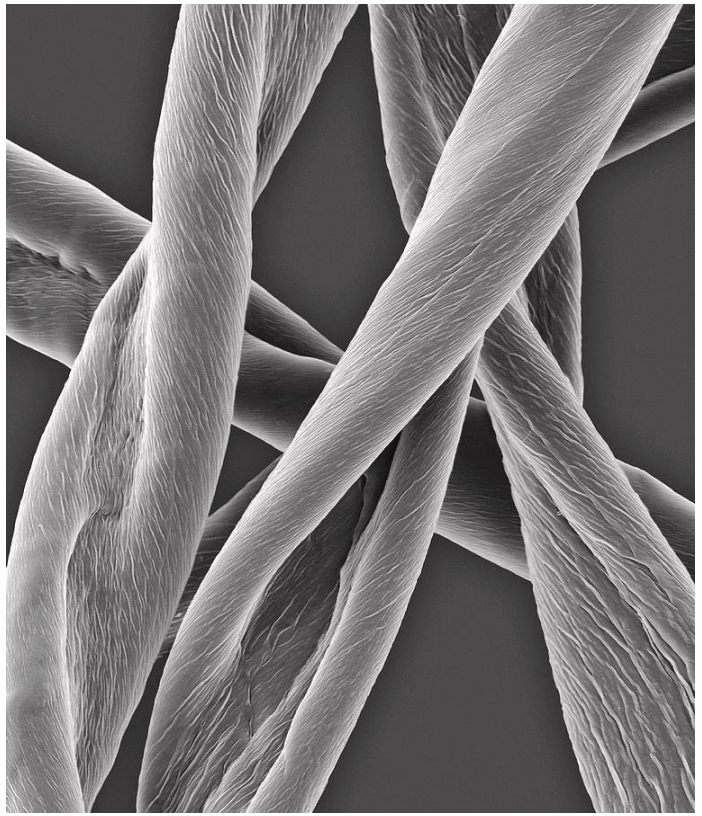
Cotton Dyeing Mechanism

- Cotton is a **cellulose fibre** composed of **hydroxyl (-OH)** groups.
- These hydroxyl groups are **reactive sites** where dye–fibre covalent bonds occur.
- The addition of **alkali (NaOH or Na_2CO_3)** increases pH, activating the hydroxyl (-OH) groups of cellulose.

Cell–**OH** + Dye–**Reactive Group** → **Cell–O–Dye** + By-product

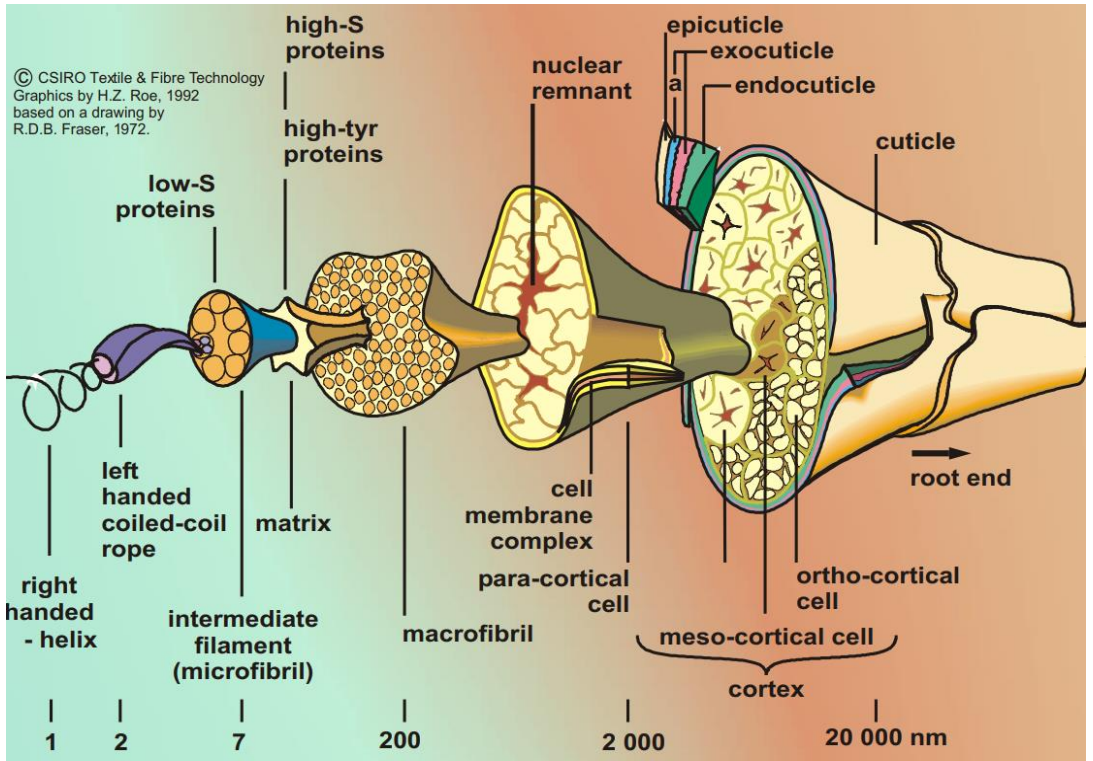




Wool Dyeing Mechanism

- Wool is a **Protein fibre** composed mainly of **keratin**, which contains amino ($–NH_2$), carboxyl (–COOH), hydroxyl (–OH), and thiol (–SH) groups.
- Under slightly **alkaline or neutral conditions**, the **amino groups ($–NH_2$)** of the wool fibre react with the **reactive groups (monochlorotriazine)** of the dye to form **covalent bonds**.

Wool–**NH_2** + Dye–**Cl (reactive group)** → **Wool–NH–Dye** + By-product



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Difference between Cotton and Wool Dyeing

Parameters	Cotton Fibre Dyeing	Wool Fibre Dyeing
Fibre Type	Cellulosic (natural plant fibre)	Protein-based (natural animal fibre)
Chemical Nature	Mainly cellulose (–OH groups)	Mainly keratin (–NH_2 and –COOH groups)
Dyes	Reactive, vat, direct, and sulphur dyes	Acid, metal complex, and reactive dyes
Dye–Fibre Interaction	Covalent bonding, hydrogen bonding, and Van der Waals forces	Ionic bonding, covalent bonding, and hydrogen bonding.
pH of Dye Bath	Alkaline (pH 10–11 for reactive dyes)	Acidic (pH 4–5 for acid dyes)
Temperature	Usually 60°C–80°C for reactive dyeing	Usually 85°C–98°C
Dyeing Auxiliaries	Electrolytes (NaCl, Na_2SO_4), alkali (NaOH, Na_2CO_3) to fix the dye	Acid (acetic acid), levelling and wetting agents
Fixation Mechanism	Formation of covalent bonds between reactive dye and cellulose hydroxyl groups	Ionic interaction between acidic dye groups and basic amino groups in wool

Pretreatment process for Cotton-Eqwools blended textiles

Pretreatment for 100% Cotton:

Chemicals: Caustic Soda, Soda Ash, Wetting agent, Sequestering agent, Hydrogen peroxide, etc.

Parameters: 95°C–100°C for 60-70 mins at pH 10-12.

Pretreatment for 100% Wool:

Chemicals: Non-ionic detergent, Soda Ash, Ammonia solution, Wetting agent, Hydrogen peroxide, etc.

Parameters: 55°C–60°C for 40-50 mins at pH 7-8.

Pretreatment for Cotton-Ewqools textiles (CHT Chemicals):

Chemicals: Detergent, Hydrogen peroxide, Peroxide stabilizer, Deaerating and Wetting agent, etc.

Parameters: 45°C–50°C for 60-70 mins at pH 11-12.

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Dyeing process for Cotton-Eqwools blended textiles

One-bath dyeing with Wool reactive & Cotton direct dyes

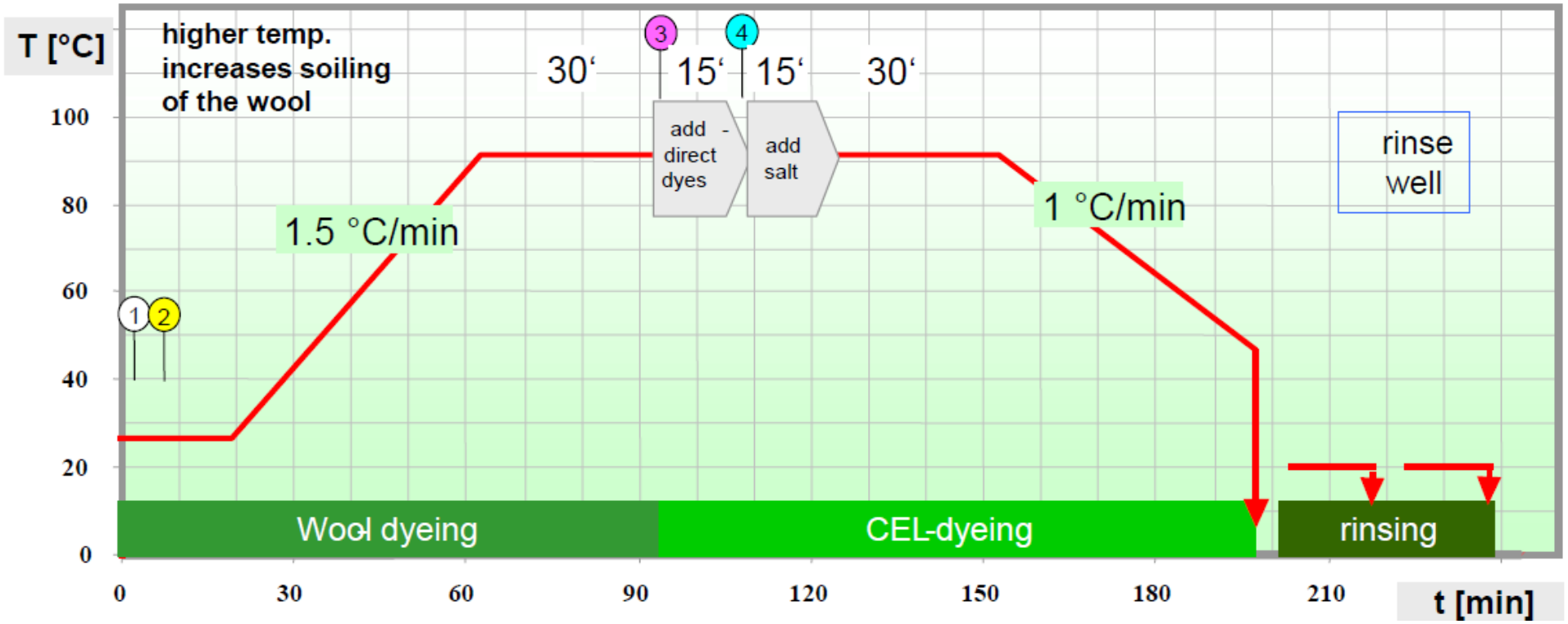
(1)

0.3 - 0.5 g/l BIAVIN BPA
0.5 - 1.0 g/l MEROPAN KP
0.3 - 0.5 g/l KERIOLAN A 2 N
0.0 - 2.0 % REWIN KNR

(2) x % BEZAKTIV WO dyes

(3) y % TUBANTIN dyes/ direct dyes

(4) z g/l Glauber salt (depending on the colour depth. Salt has a levelling effect on wool and on CO it boosts the absorption of dyes)



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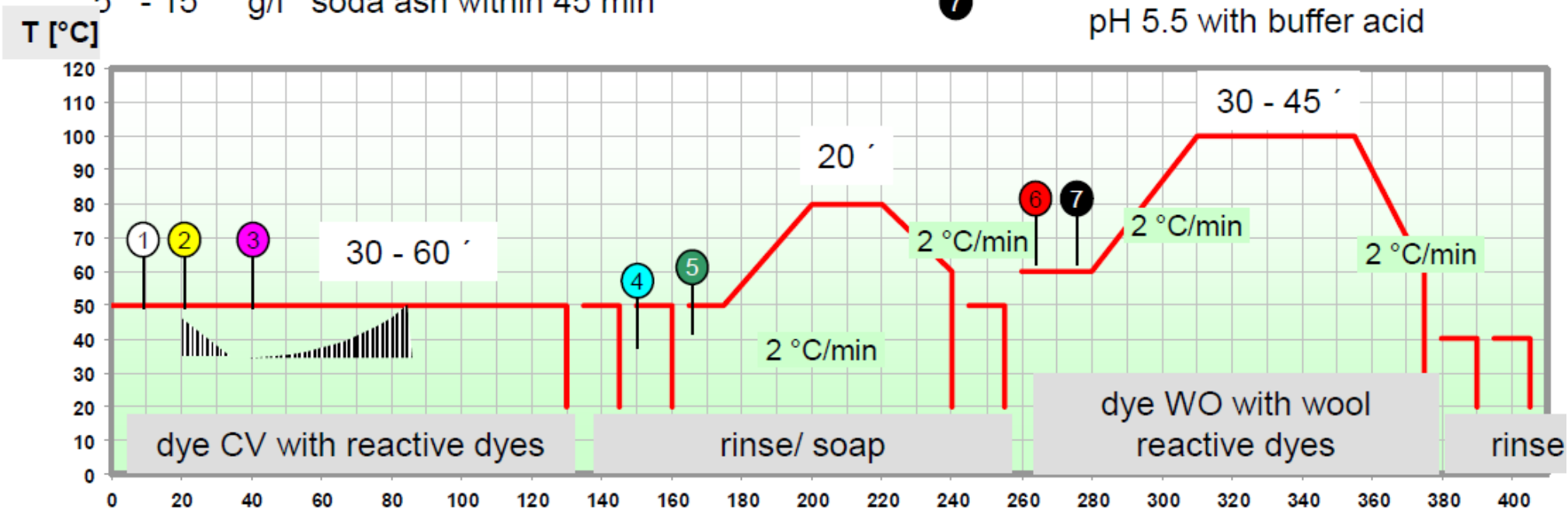
Dyeing process for Cotton-Eqwools blended textiles

① 0.5 -1.0 g/l BIAVIN BPA
1 - 2.0 g/l SARABID LDR
20 - 70 g/l Glauber salt
add
② y % BEZAKTIV ONE within 15 min
③ add
5 - 15 g/l soda ash within 45 min

④ 1.0 ml/l acetic acid 60 %
⑤ 1.0 g/l MEROPAN DPE
⑥ 0 - 1.0 g/l KERIOLAN A2N
⑦ x % BEZAKTIV WO dyes
pH 5.5 with buffer acid

Two-bath dyeing with Cotton & Wool reactive dyes



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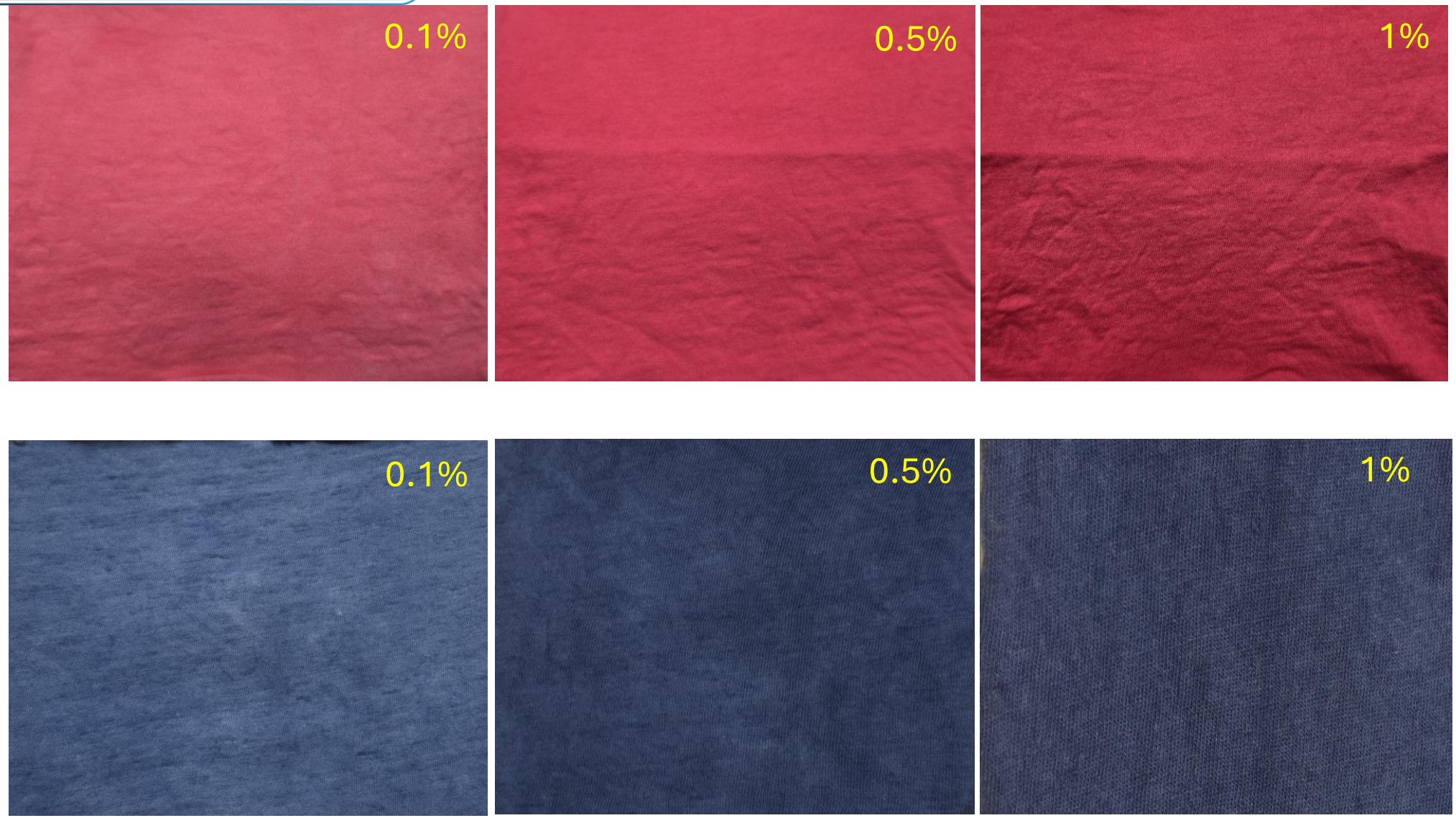
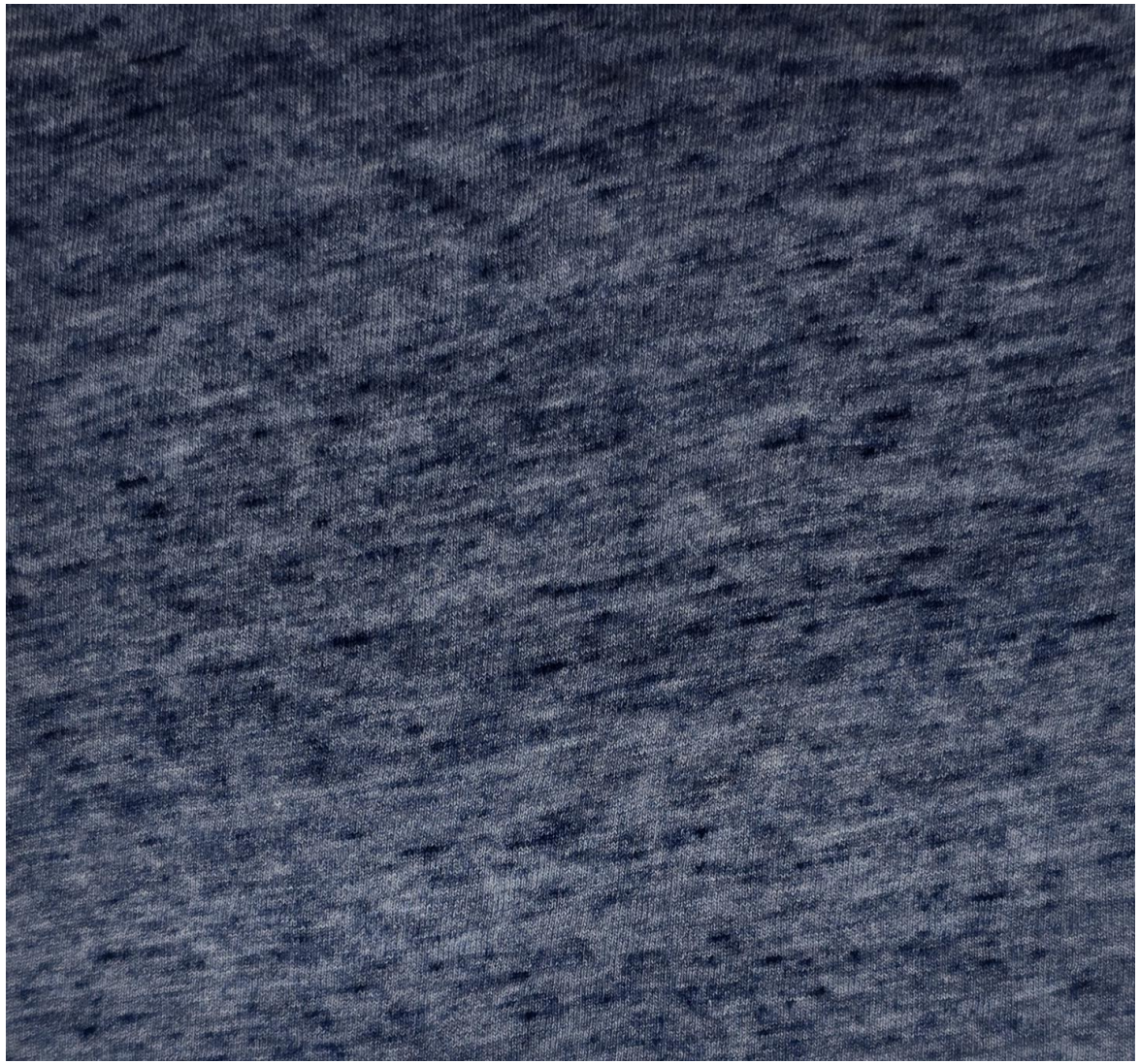
One-bath dyeing process



Wash fastness to colour was **poor – 3 to 3/4** at 60°C **(ISO 105-C06:2010)**

One-bath dyeing process



Dyeing with only **wool-reactive dyes**

Dyeing with only **cotton direct dyes**

Experiments to understand Cotton-Eqwools dyeing chemistry

- Fabric wt. 5g (100% wool fabric #1.5g (30% of 5g) & 100% cotton fabric #3.5 g (70% of 5g) at M:L = 1:10.
- One-bath dyeing process using Ahiba Dyeing machine using **Wool reactive dyes** & **Cotton direct dyes**.

- Dyeing of 100% wool fabric & 100% cotton fabric with **Wool reactive dyes only** at 0.03%, 0.3%, 0.6% & 1.2% (Red + Yellow + Blue). **A total of 12 Samples.**

- Dyeing of 100% wool fabric & 100% cotton fabric with **Cotton direct dyes only** at 0.07%, 0.7%, 1.4% & 2.8% (Red + Yellow + Blue). **A total of 12 Samples.**

- Dyeing of 100% wool fabric & 100% cotton fabric with **both the wool reactive and cotton direct dyes** at 0.1%, 1%, 2% & 4% (Red + Yellow + Blue). **A total of 12 Samples.**

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One-bath dyeing process using CHT chemicals

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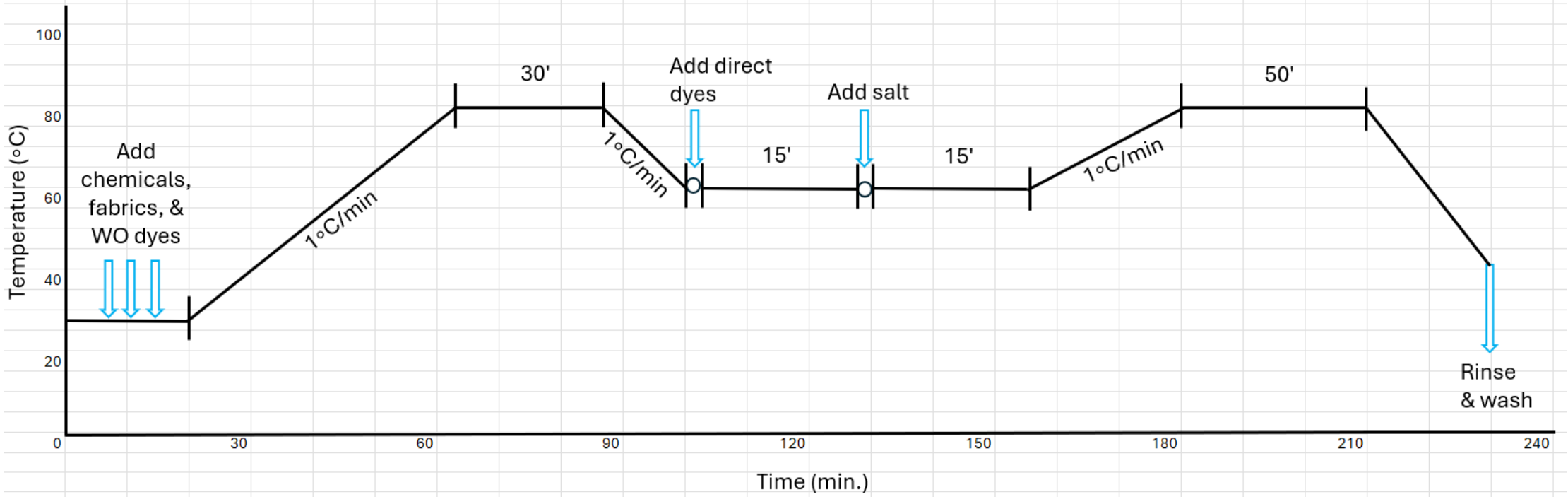
Recipe for the pretreatment process

1. Kollasol CDS (Anti-foaming agent) – 0.5 g/l
2. Felosan Fox (Detergent) – 2.0 g/l
3. Tubotex OW (activator & stabilisator for H_2O_2) – 5.0 g/l
4. Heptol ESW (Sequestering agent) – 1.0 g/l
5. Biavin BPA (Gliding/Levelling agent) – 3.0% (owf)
6. H_2O_2 50% solution (Oxidizing agent for the bleaching) – 20.0 g/l

Recipe for the Single bath dyeing process

1. Biavin BPA (Anti-creasing agent) – 1.0 g/l
2. Meropan KP (pH regulator/Buffer) – 1.0 g/l
3. Keriolan A2N (Levelling agent) – 1.0 g/l
4. Rewin KNR (Fastness improvement agent) – A % (owf)
5. Bezaktiv WO dyes (Reactive dyes for wool) – X % (owf)
6. Tubantin dyes (Direct dyes for cotton) – Y % (owf)
7. Glauber salt – Z g/l



Experiments to understand Cotton-Eqwools dyeing chemistry

0.03% WO dyes only

0.3% WO dyes only

0.6% WO dyes only

1.2% WO dyes only

0.07% Cotton dyes only

0.7% Cotton dyes only

1.4% Cotton dyes only

2.8% Cotton dyes only

Experiments to understand Cotton-Eqwools dyeing chemistry

0.1% both dyes

1% both dyes

2% both dyes

4% both dyes

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Experiments to understand Cotton-Eqwools dyeing chemistry

0.03% WO dyes only

0.3% WO dyes only

0.6% WO dyes only

1.2% WO dyes only

0.07% Cotton dyes only

0.7% Cotton dyes only

1.4% Cotton dyes only

2.8% Cotton dyes only

Experiments to understand Cotton-Eqwools dyeing chemistry

0.1% both dyes

1% both dyes

2% both dyes

4% both dyes

- **Bezaktiv WO** dyes are wool-reactive dyes that can **only dye the wool part**, not the cotton part.
- **Tubantin dyes** are direct dyes for cotton, but they can also **dye the wool part**.

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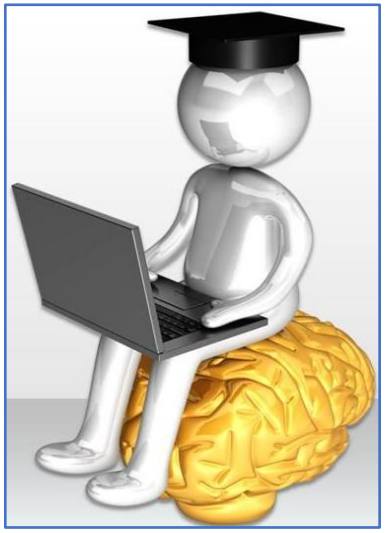
Why does wool have higher dye uptake than cotton?

Functional Groups:

- Wool - protein fibre having **amine ($-NH_2$), carboxyl (-COOH), and hydroxyl (-OH)** groups.
- Cotton – a cellulosic fibre having **hydroxyl (-OH)** groups.

Isoelectric Nature of Wool:

- Wool has an **amphoteric nature** and carries both positive and negative charges. Attracts and binds with the acid and reactive dyes more effectively.
- Cotton **lacks** this **amphoteric behaviour**, needs chemical modification for dyeing.



Porous and Swollen Structure:

- Wool fibres have a **highly porous internal structure (cortex)** and can swell more readily in water, allowing deeper dye penetration.
- Cotton is more **crystalline** and less permeable, resulting in slower and less extensive dye diffusion.

Hydrophilicity and Dye Affinity:

- Wool's keratin structure interacts more strongly with dye molecules through **van der Waals and dipole–dipole forces**.
- Cotton's surface is **smoother and more crystalline**, reducing dye adsorption sites.

Wool's protein chemistry, amphoteric behaviour, and porous structure give it a **higher dye uptake** and **stronger dye–fibre bonding** than cotton.

The Beginning of the Journey

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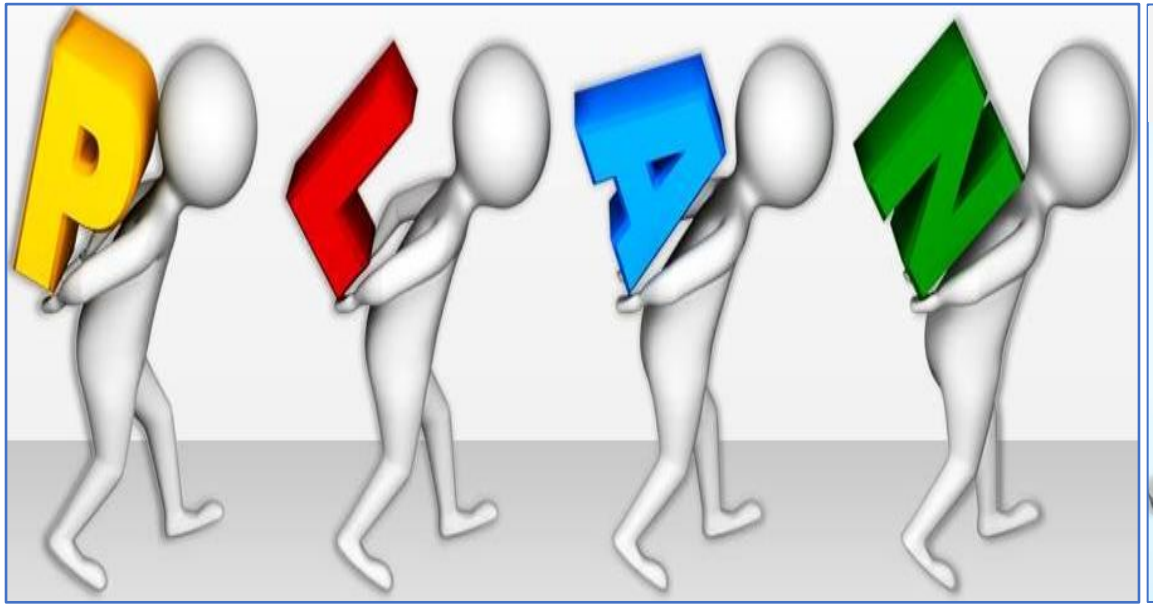

Dyeing trials with Levelling and Blocking agents

Search for Effective Blocking Agent Continues...

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White Magic (Thiotan R): A Revolutionary Anti-staining Agent

Md. Abdullah Al Bishal

June 12, 2023 2:05 PM

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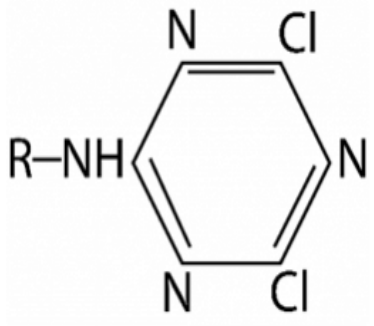
One of the most common problems that the industry has long faced is the cross-staining effect on cotton or cotton blend garments with light and deep colors through piping and sewing. Whenever the garment undergoes through wash process, the light color of the garment catches the deep color bleeding and gets fixed.

So, the light color gets a change which is unexpected and unwanted. To keep the light color vibrant and authentic, Archroma has introduced an anti-staining agent named Thiotan R. They also call it "White Magic" as the result of using this anti-staining agent on white cotton and cotton blended fabric is spectacular.

Figure 1: Khaled Faisal, GM of NAZ Bangladesh explaining the Color Staining problem in the white part of contrast color fabric.

Thiotan R is an anti-staining anionic product and a DCT reactive dyestuff without chromophore. Thiotan R forms a covalent bond with the cotton and polyamide fibers and reduces the affinity of the fiber for anionic dyes. That's how Thiotan R gives a permanent effect.



TECHNICAL INFORMATION
Thiotan® R paste

Thiotan® R pa

Special agent which modifies the affinity of polyamide fibers and wool for dyestuffs and also preventing back staining of dyes on cellulosic fiber.

Thiotan® R pa was specially developed to solve the problem of back staining which occurs during the processing of white, optically brightened or pale coloured textiles together with dyed or printed textiles.

Thiotan® R pa

- reacts with the amino groups of polyamide or wool
- reacts with cellulose like a reactive dye
- the effect is permanent and stable to multiple domestic laundering
- reduces the affinity of the fibers for anionic dyes
- increases the affinity of the fibers for cationic dyes
- can be applied by exhaust, continuous and printing processes.
- Causes no yellowing of the treated goods and has no negative influence on the effect of fluorescent

Thiotan® R pa is a reactive anionic product which reacts like a reactive dye with the amino groups of polyamide or wool and also preventing back staining of dyes on cellulosic fiber.

Thiotan® R pa modifies the affinity of the fibers for dyestuffs. The fibers treated with Thiotan® R pa show reduced affinity for anionic dyes (a white reserve is obtained when the product is used at higher dosage) and increased affinity for cationic dyes; the affinity for disperse dyes is unchanged.

https://www.textiletoday.com.bd/white-magic-thiotan-r-a-revolutionary-anti-staining-agent

Use of Thiotan R Pa – A blocking agent

Thiotan R = 0%

Thiotan R = 3%

Thiotan R = 6%

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Thiotan R = 0%

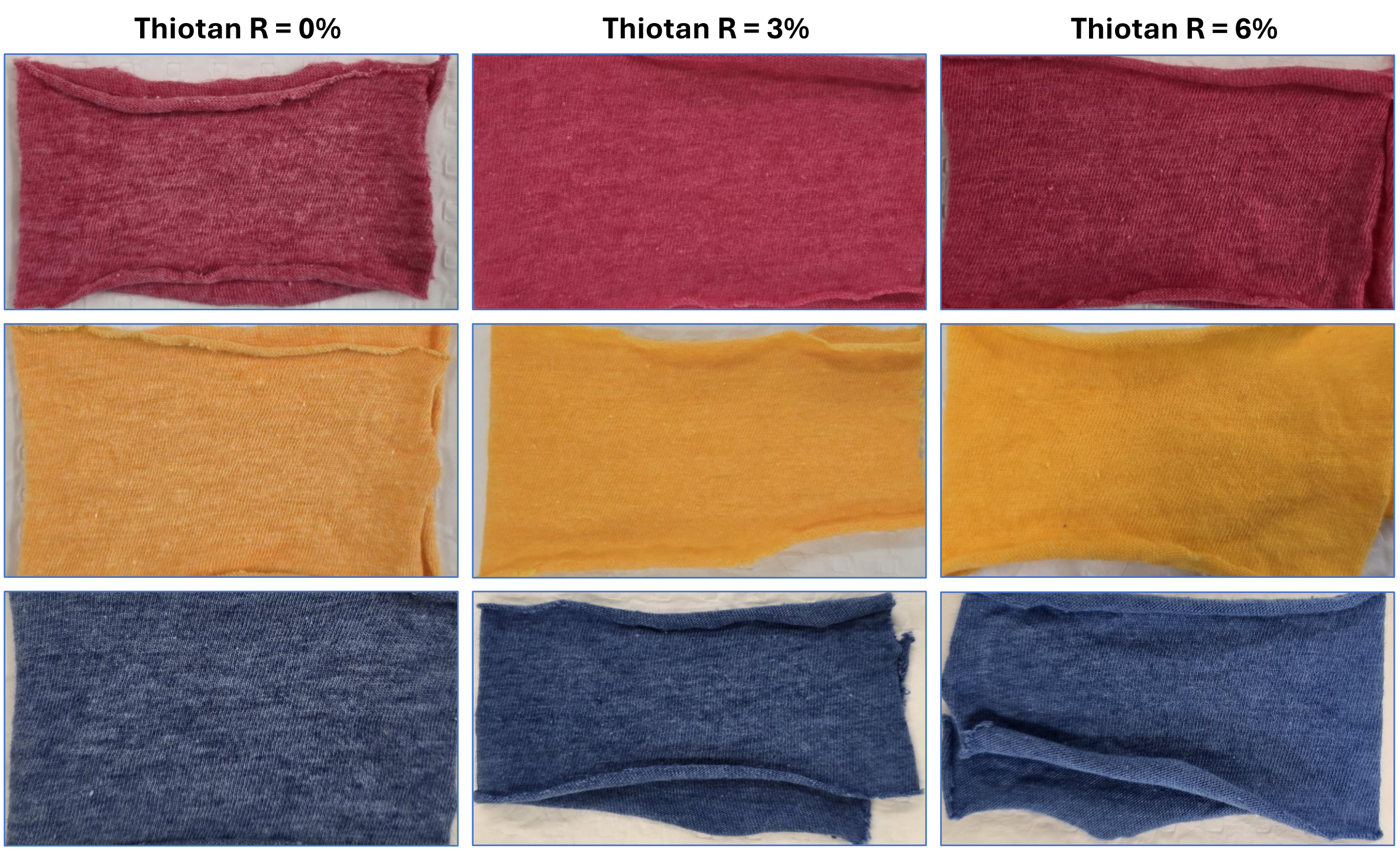
Thiotan R = 3%

Thiotan R = 6%

Thiotan R = 0%

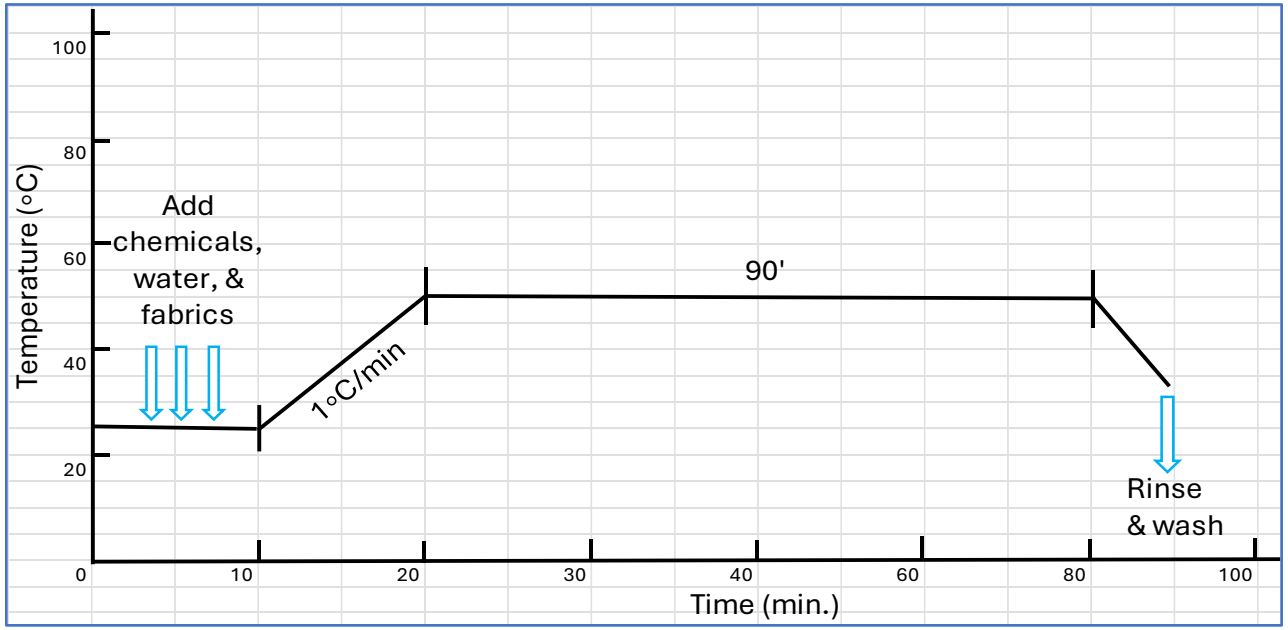
Thiotan R = 3%

Thiotan R = 6%


Thiotan R = 0%
Thiotan R = 3%
Thiotan R = 6%

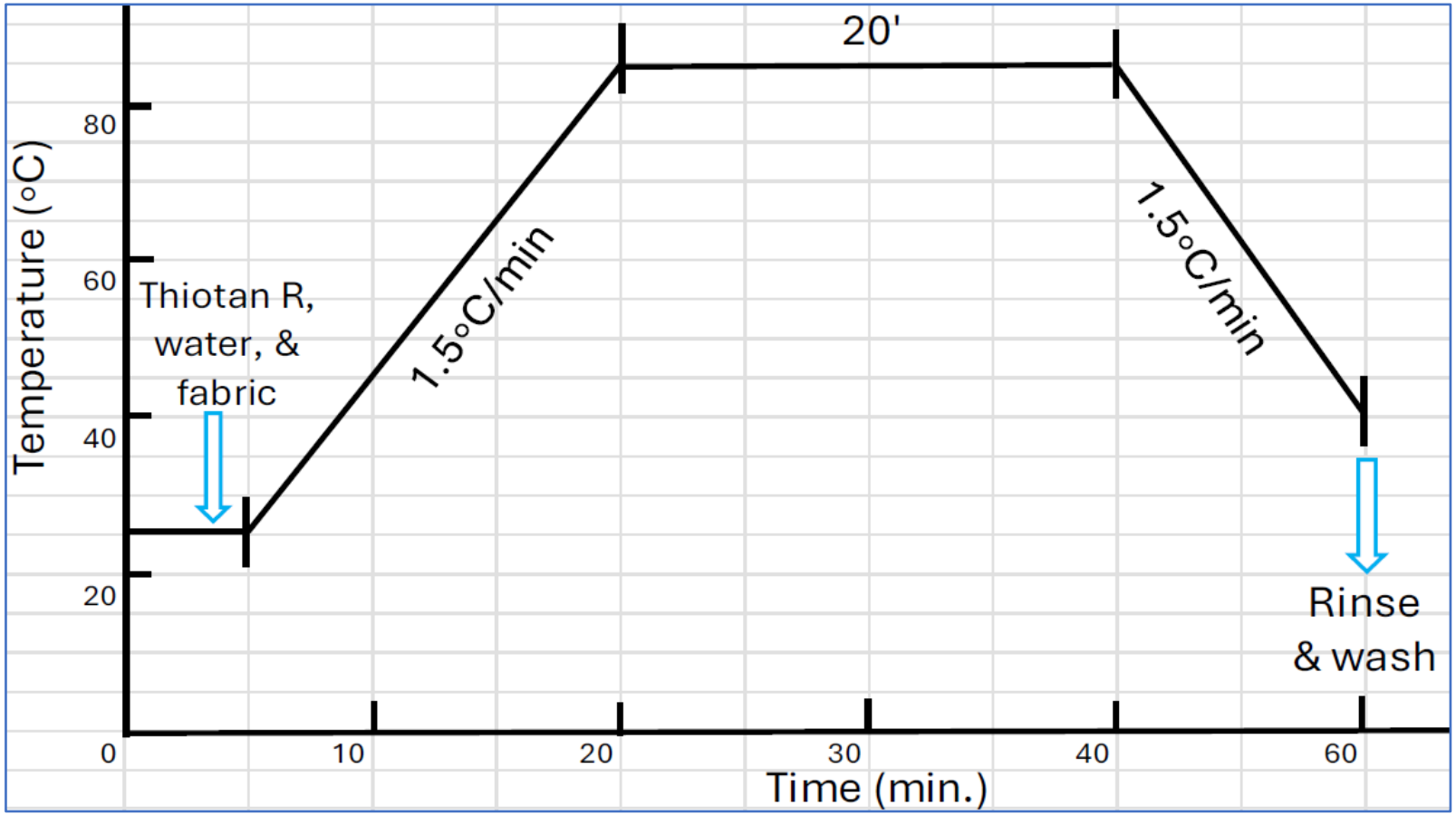
Fabric pretreatment (scouring & bleaching) process

Chemicals	g/l or %
Kollasol CDS (Anti-foaming agent)	0.5 g/l
Felosan Fox (Detergent)	2.0 g/l
Tubotex OW (activator & stabilisator for H_2O_2)	5.0 g/l
Heptol ESW (Sequestering agent)	1.0 g/l
Biavin BPA (Gliding/Levelling agent)	3.0 %
H_2O_2 50% solution (Oxidizing agent for the bleaching)	20.0 g/l



Fabric pretreatment process with Thiotan R Pa

Chemicals	g/l or %
Thiotan R Pa (blocking agent)	6.0 %*
Cotoblanc Sel (Soaping agent)	1.0 g/l



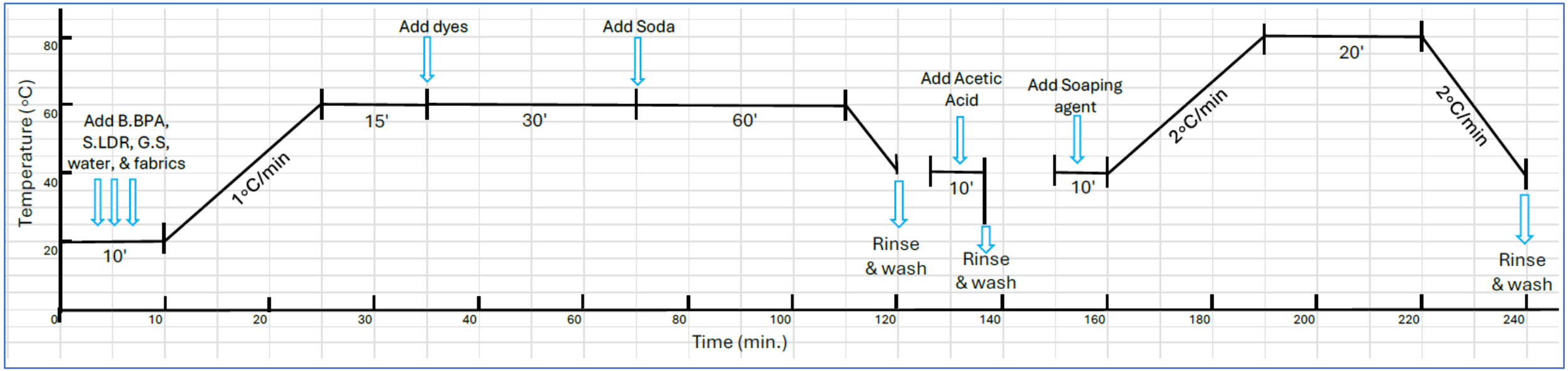
Fabric dyeing process with cotton reactive dyes

Dyes & Chemicals	g/l or %
Biavin BPA (Anti-creasing agent)	1.0 g/l
Sarabid LDR (Levelling agent)	2.0 g/l
Glauber salt	50.0 g/l*
Bezaktiv ONE Dyes (Cotton Reactive dyes)	1.0 %*
Soda Ash	16.0 g/l*
Acetic Acid	1.0 g/l
Heptol ESW (Sequestering agent) / Cotoblanc Sel (Soaping agent)	1.0 g/l

(*) These marked dyes and chemicals will be variable and need to be adjusted according to the dye/shade concentration. Here is the recommended table for salt & soda.

Dye concentration (%)	Glauber's salt (g/l)	Soda Ash (g/l)
<0.01	15	4
0.01-0.1	20	6.5
0.1-0.5	30	8
0.5-1.0	40	12
1.0-2.0	50	16
2.0-3.0	60	16
3.0 and above	80	18

Fabric dyeing process with cotton reactive dyes



Experiments continued with Thiotan R Pa (Optimisation)

Archroma recommends a 6% to 8% Thiotan R Pa solution in Dyebath, with a **pH of 5.0 at 98°C for 15-45 mins.**

- Trials with **3%, 6% and 8% Thiotan R Pa in the Dyebath, pH 5.0 at 98°C for 30 mins.**
- Trials with **3%, 6% and 8% Thiotan R Pa in the Dyebath, pH 4.0 at 85°C for 20 mins.**

- Trials with pretreatment of the fabrics with **3%, 6% and 8% Thiotan R Pa at pH 5.0 at 98°C for 30 mins.**
- Trials with pretreatment of the fabrics with **3%, 6% and 8% Thiotan R Pa at pH 4.0 at 85°C for 20 mins.**

After scouring & bleaching, it requires another **pretreatment with 6% Thiotan R Pa, pH 4.0 at 85°C & 20 mins.**

Trials with pretreatment with **6% Thiotan R Pa at pH 4.0 at 55°C, 65°C, & 75°C for 20 mins.**

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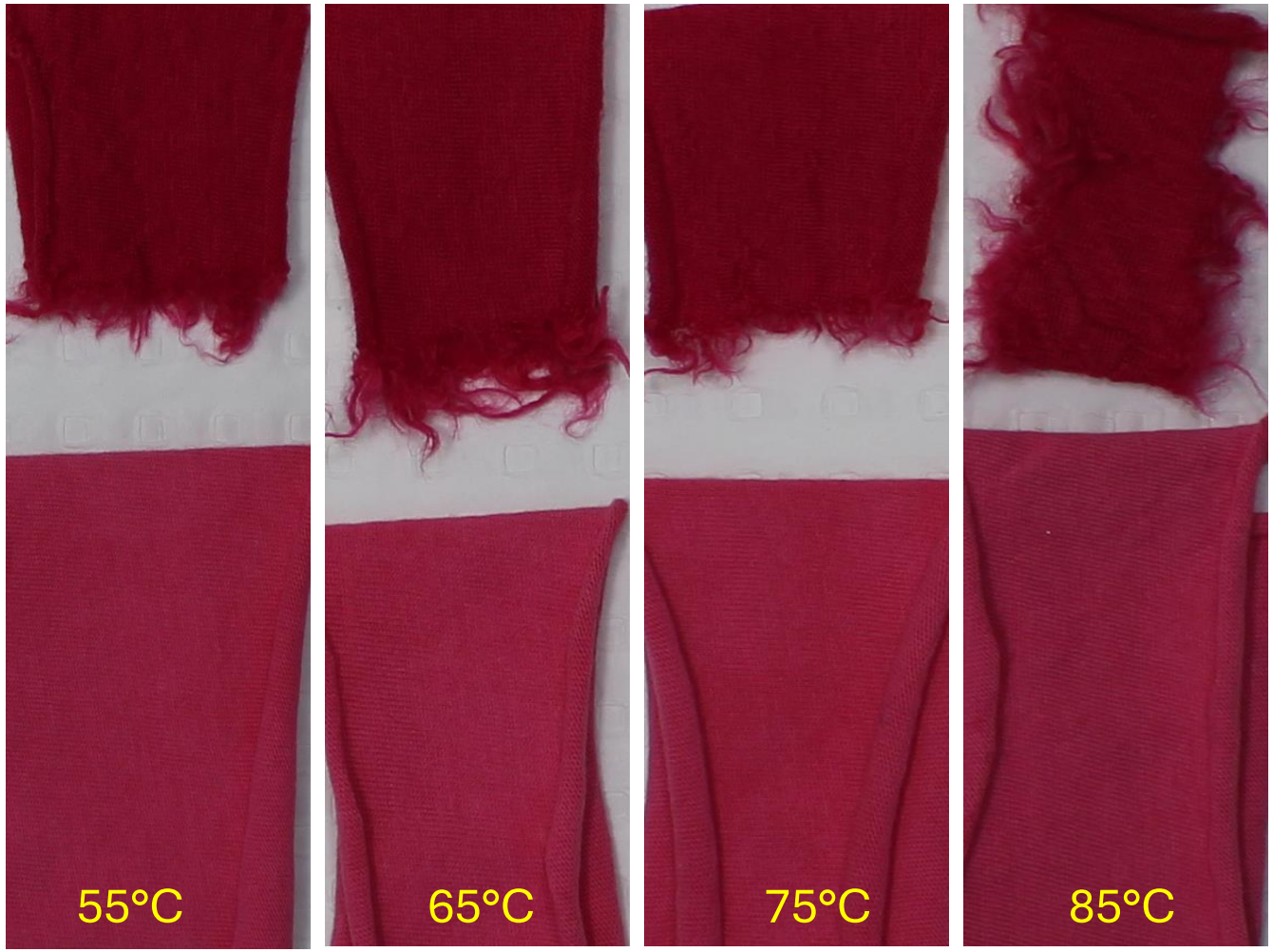
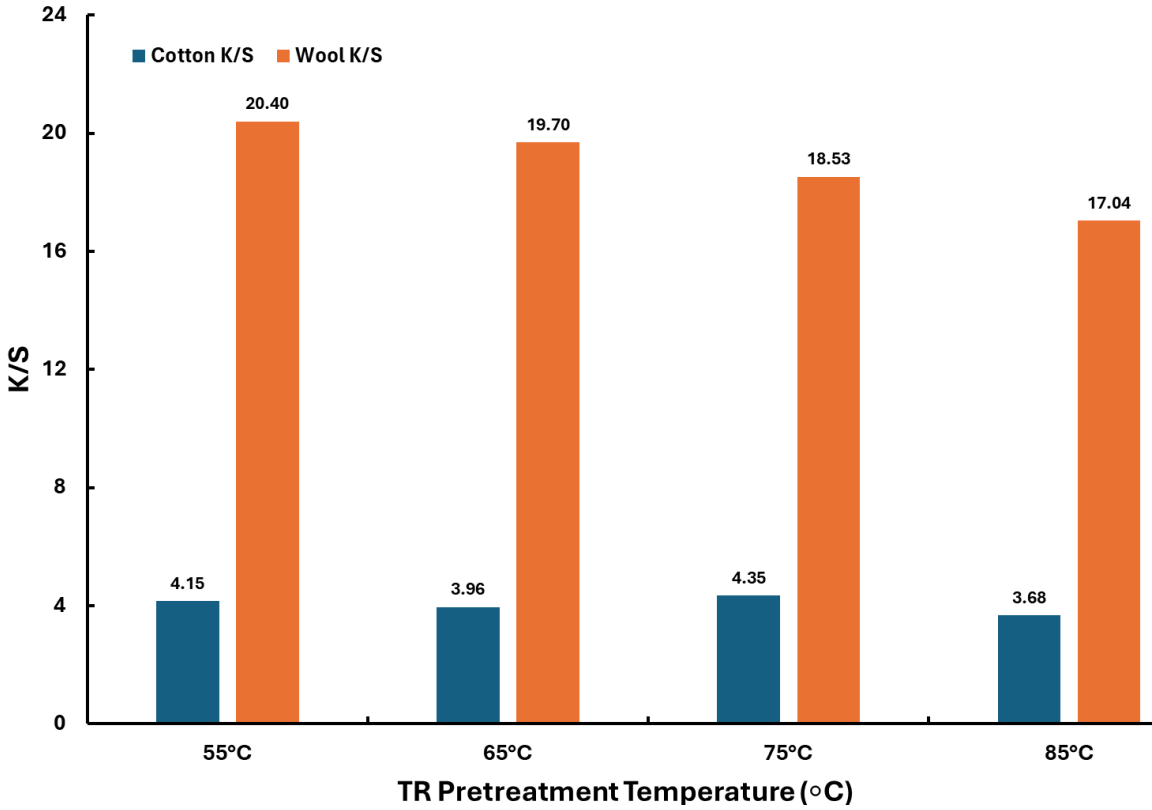
Thiotan R Pre. at various temperatures (Red-1%)





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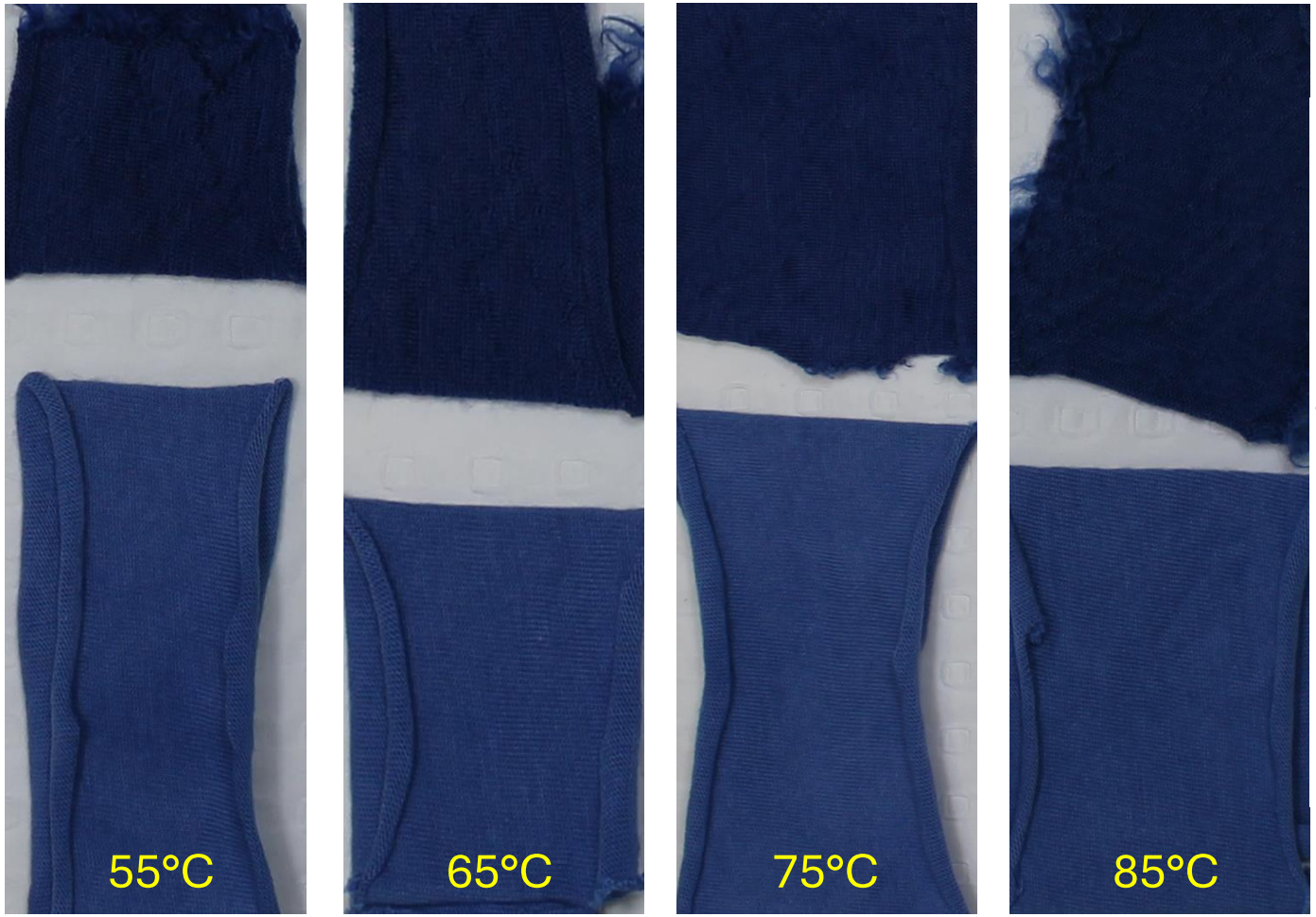
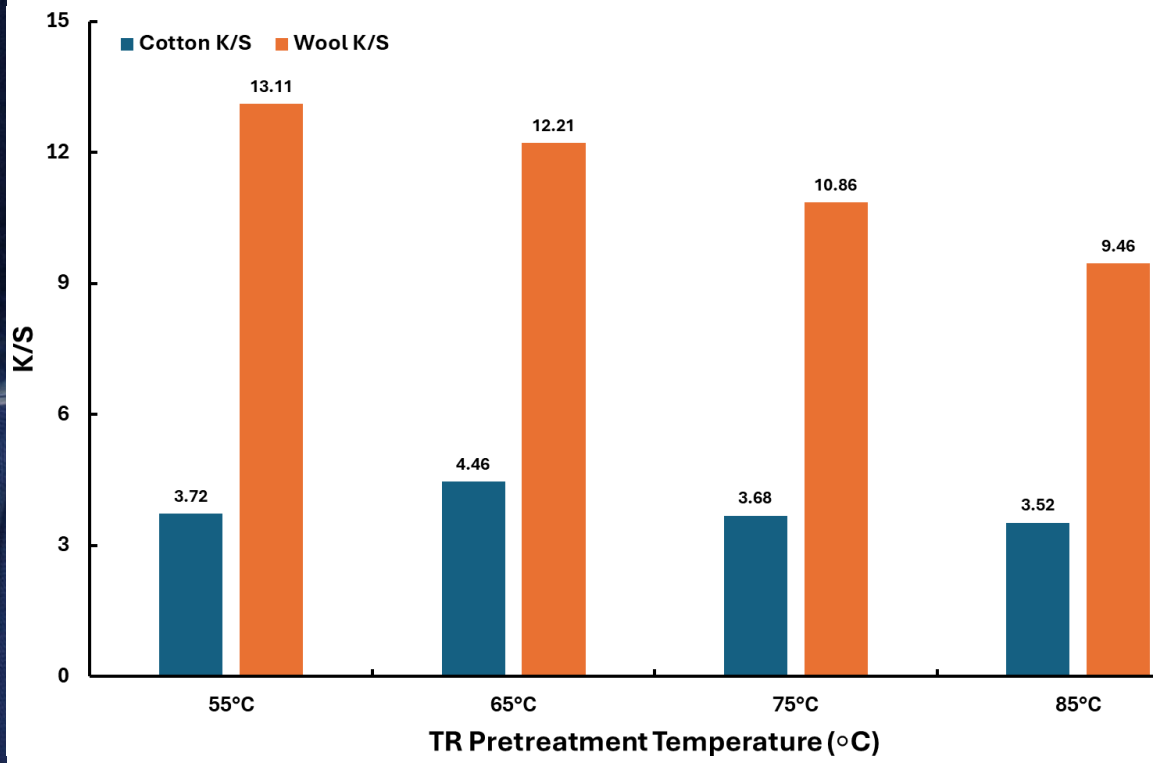
Thiotan R Pre. at various temperatures (Blue-1%)

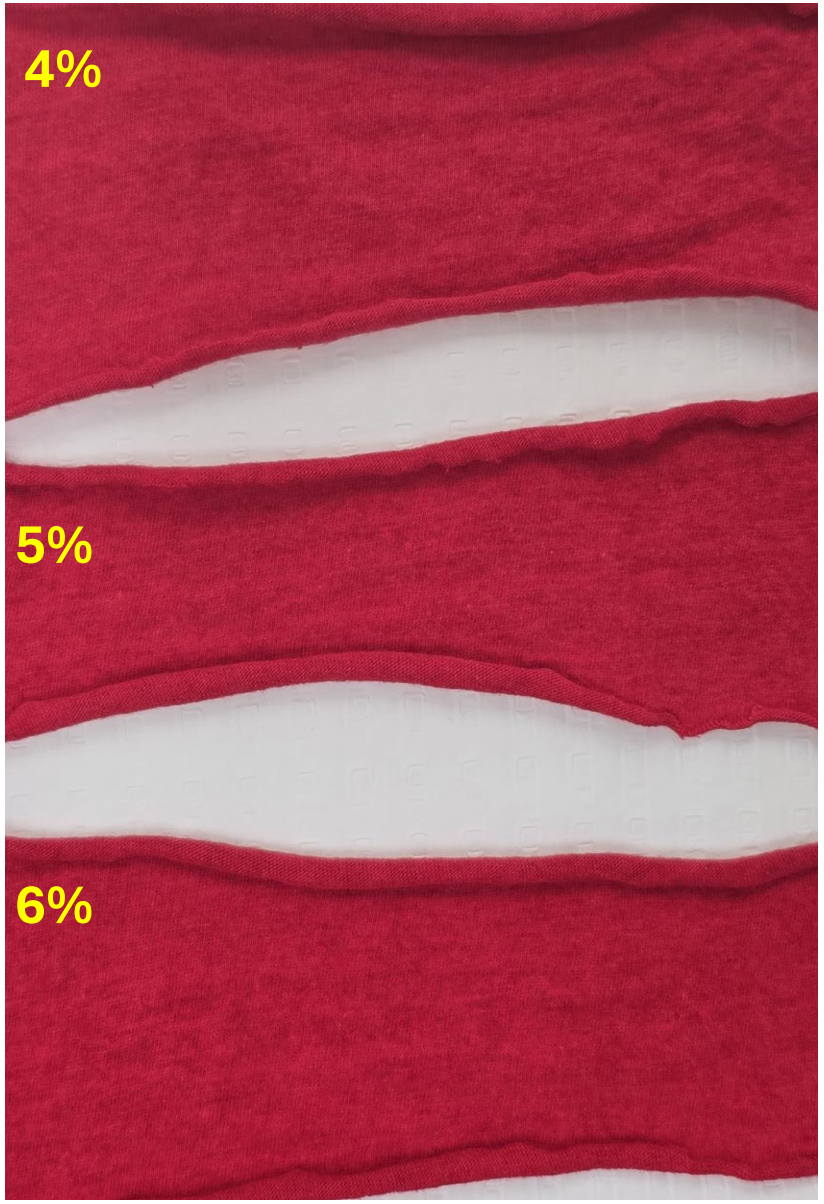


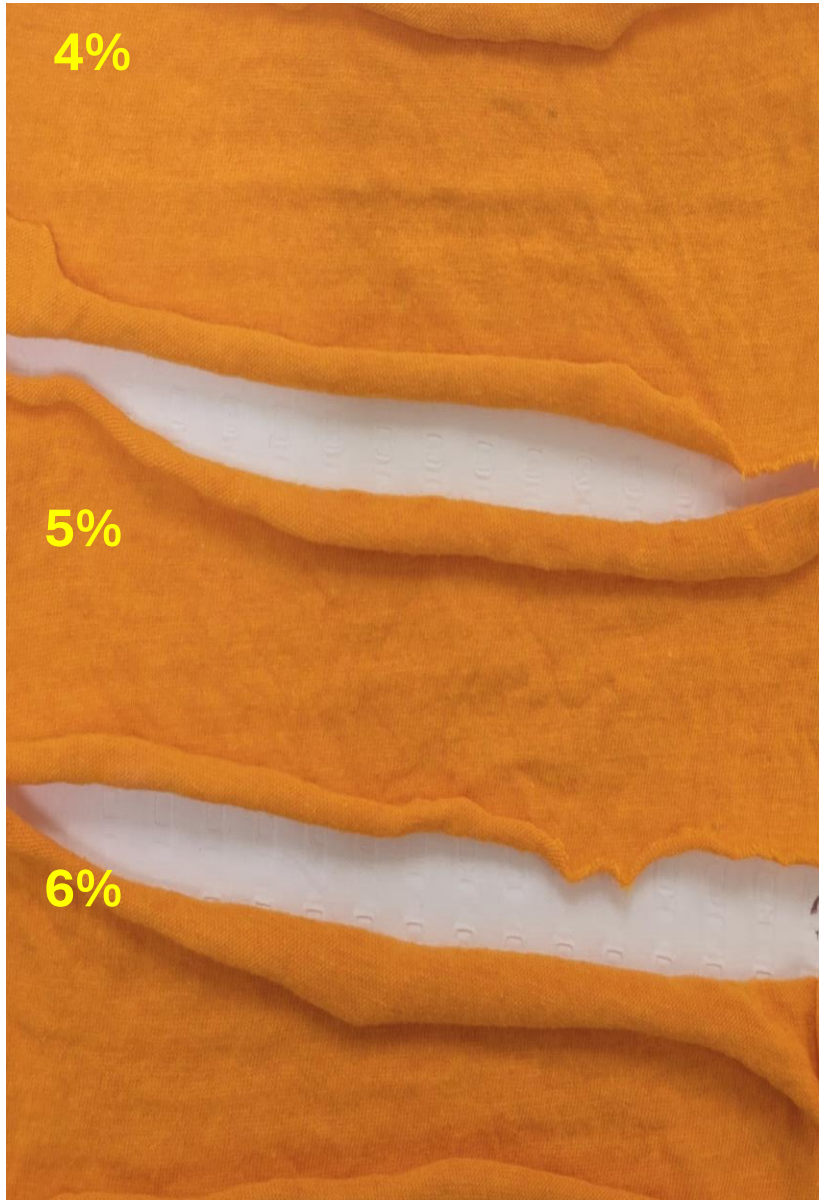


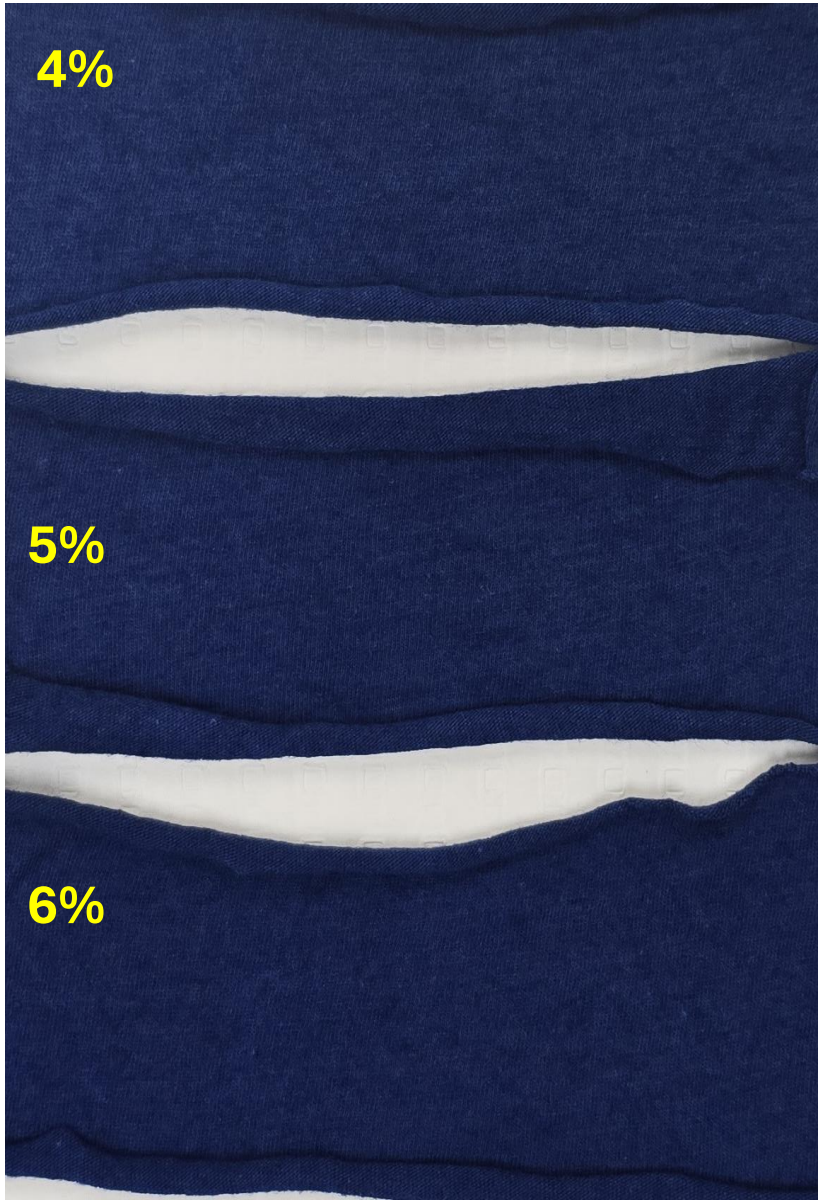
6% TR Pretreatment at 65°C can save up to **30 mins** compared to pretreatment at 85°C

Colour fastness to washing was **excellent – 4 to 4/5** at 60°C **(ISO 105-C06:2010)**

4% - 6% Red, Yellow & Blue without Thiotan R Pretreatment







Can we stop using Thiotan R Pa?

FUTURE FIBRES

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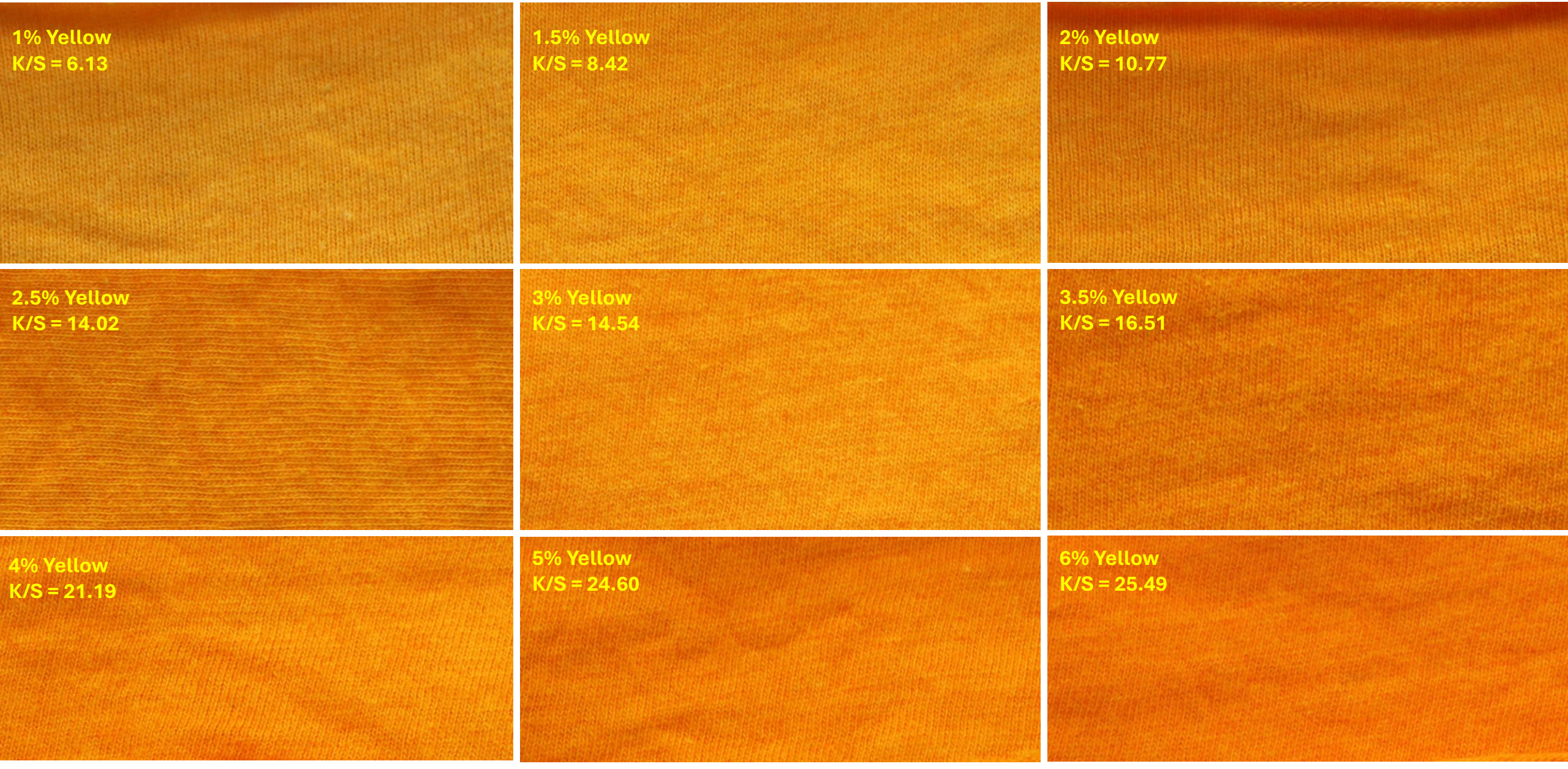

Can we stop using Thiotan R Pa?

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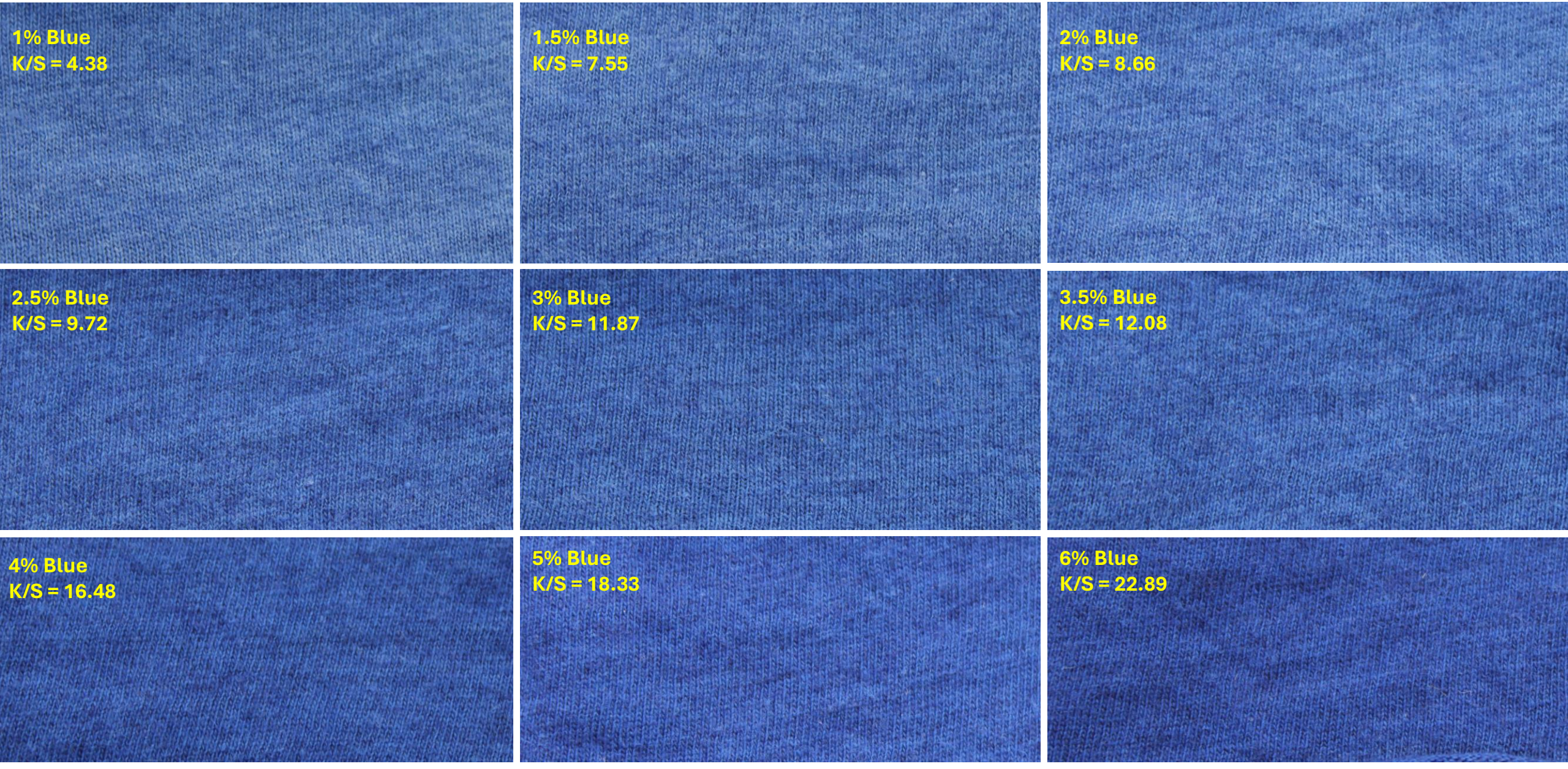
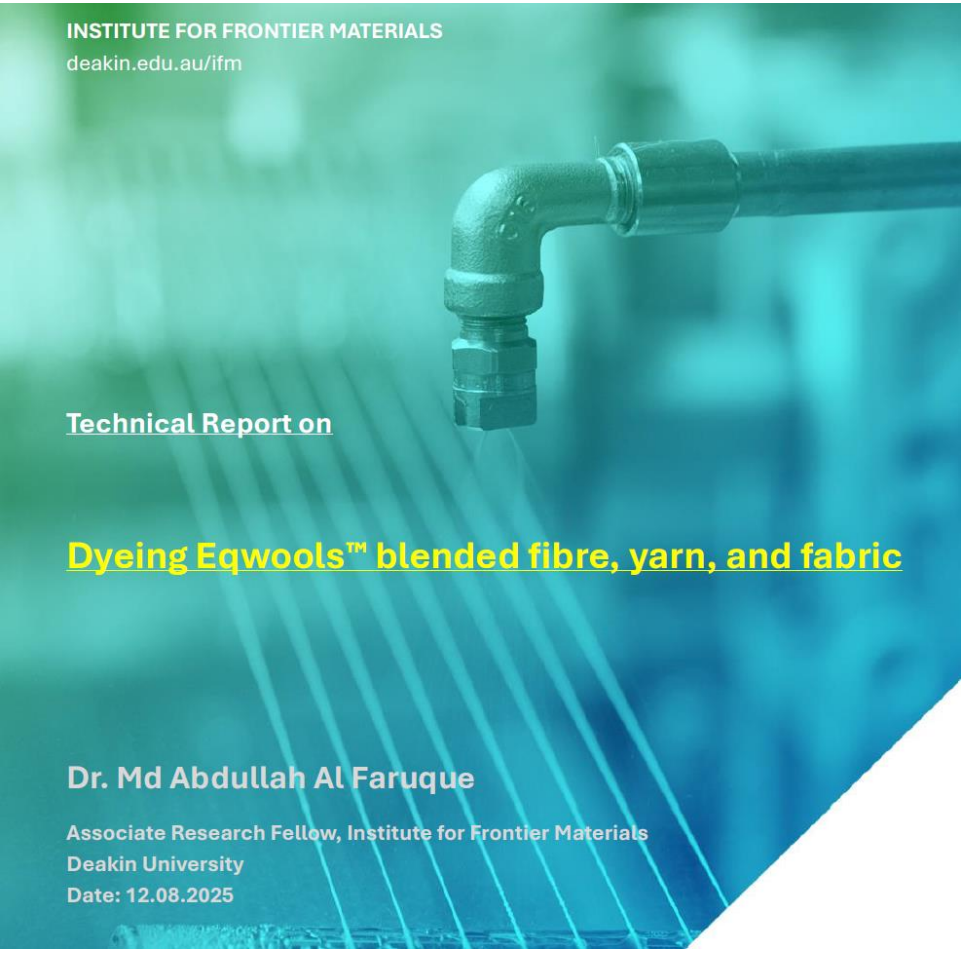


Conclusion & Final Cotton-Eqwools Dyeing Recipe...

- One bath dyeing of Cotton-Eqwools blended textiles with excellent colour fastness to washing.
- For better and even dyeing with the trichromat <2% dye conc., we need to use 6% TR pretreatment at 85°C.
- If a slight melange dyeing is acceptable, we can use 6% TR pretreatment at 65°C.



- Scouring & Bleaching process with recipe.
- Details on the Thiotan R Pa pretreatment process with recipe.
- Details on the dyeing process with recipe.
- Amount of required salt and soda depending on dye %
- Colour fastness to Washing results.
- Bleaching process for White colour (single bath and double bath)

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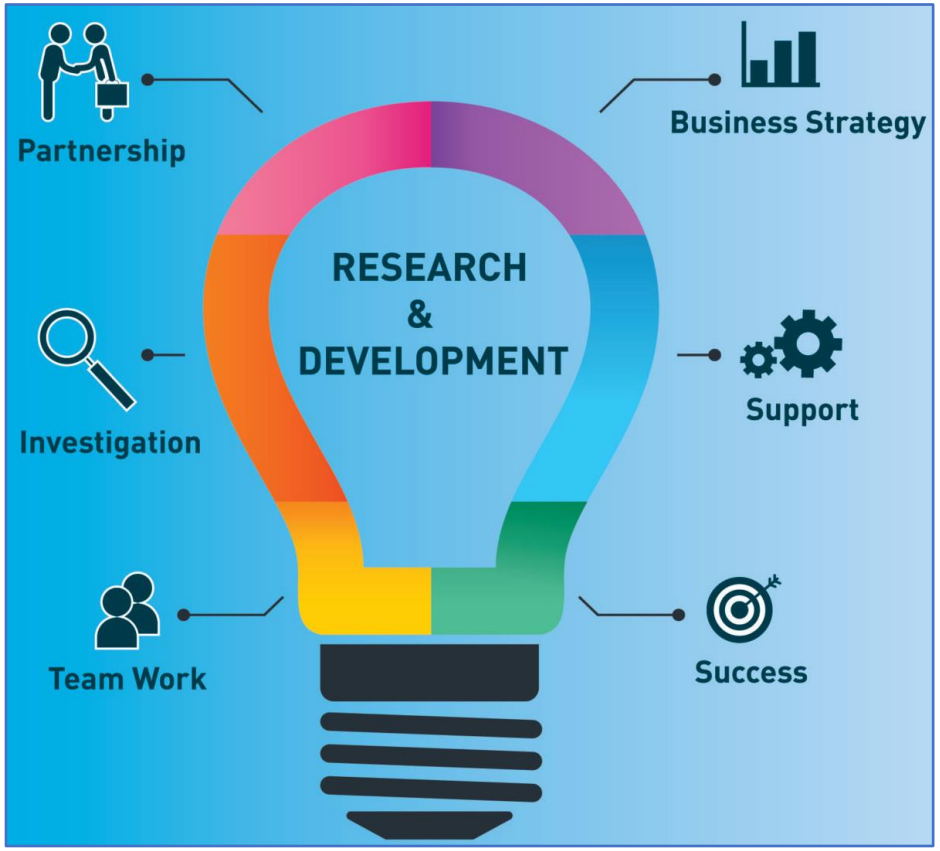
Collaboration continues...



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