TECHNICAL BULLETIN

COTTON INCORPORATED

6399 Weston Parkway, Cary, North Carolina, 27513 • Telephone (919) 678-2220

ISP 1014

LAB-TO-PLANT CORRELATION IN DYEING

This report is sponsored by the Importer Support Program and written to address the technical needs of product sourcers.

INTRODUCTION

The accurate correlation of a laboratory dyeing to a production dyeing lot is a universal concern of dyeing operations. Laboratory dyeing techniques, which are both accurate and repeatable to bulk dyeing processes, are absolutely essential for the optimization of the production output and the cost effectiveness of the modern competitive dyeing operation. For example, it has been reported that the cost of each color correction or production add can increase dyeing costs as much as 30%. Dye lots that must be stripped and redyed can cost an additional 170% compared to normal dyeings.

Not only do poor quality dyeings result in higher production costs, but they also lead to difficulties in production planning, increased pollution loads on waste treatment facilities, and prolonged delivery times. Maximization of "right-first-time" dyeings and minimization of redyeings, color additions, and off-quality problems, such as shading within the dye lot, are direct results of optimum lab-to-plant dyeing correlation. Laboratory dyeing consistency is necessary if the dyeing facility is to be successful and meet all of the dyed fabric requirements demanded by the customer. Those demands include the following:

- On shade, non-metameric dyeings.
- Acceptable fabric fastness properties.
- Level color application.
- Minimal fiber (fabric) damage during processing.
- On-time dye lot deliveries.
- Total processing costs within budget.
- Full order shipments (no partial shipments).

The importance of optimizing the techniques and procedures of the dye formula development laboratory cannot be over emphasized.

Traditionally, the poor accuracy and reproducibility of the formulas developed in the dyeing laboratory has best been illustrated by the often used dyer's practice of subtracting 10-15% from the lab recipe before proceeding to production lots. However, in the modern textile market where consistent quality and service to the customer are paramount and where profit margins are often razor thin, this type of practice is not good enough due to its inherent variability. One approach useful for improving consistency is to consider this process as a plant-to-lab correlation. In other words, every factor that might influence optimum dyeing conditions in the production process should be considered, evaluated, and simulated where possible in the lab process with no shortcuts. Each factor leading to shade variability, large or small, should be evaluated and controlled to the best possible extent.

WATER QUALITY AND AVAILABILITY

Whether in production or in shade matching, process water quality is one of the most important and often overlooked processing factors. The source of the water should be as consistent as possible. Typical sources are rivers, lakes, streams, wells, and municipal systems. All incoming process water should meet minimum specifications for purity, so as not to interfere with dyeing. Most routine analysis of process water will include tests for:

- Water hardness.
- pH and/or acidity/alkalinity.
- Turbidity and sediment.
- Color.
- Dissolved organic matter.
- Dissolved minerals such as iron, copper, etc.
- Chlorine.

Certain specific impurities unique to a particular plant location may require special testing. Additionally, the water used for laboratory dyeings should be the same as that used for dyeing production. Often plants use extremely pure water for laboratory dyeings, such as specially deionized or distilled water. Because of the large volume of water used in the production dyeing process, this practice leads directly to poor lab-to-bulk correlation.

FIBER AND YARN

The source of the fabric for laboratory dyeings should be identical to that of production lots. The particular fiber content or blend of fibers used in fabrics determine many of the specific production parameters required for successful dyeing. For example, with cotton fibers, variables such as fiber maturity, micronaire, color grade, plant variety, growth region, and crop year can result in dyeing variation. In the case of synthetic fibers, key variables include fiber variant within a given generic group, fiber finish, lubricating oils, merge number, luster, cross-section and fiber size (microdenier). Often additional dyeing challenges arise when the fabric is a fiber blend.

Another factor producing apparent dyeing variability is the type of yarn in the fabric. Different spun yarns (ring, open-end, or air jet) of the same fiber source and yarn size produce apparent shading even though the amount of dye uptake within the yarns is identical. Similar differences are observed between flat and textured filament yarns or between spun and filament yams. Additionally, the specific fabric construction often directly determines many of the practical dyeing parameters. Knits must be handled differently than wovens. Heavy weight wovens require special handling compared to light weight wovens or knits. Alternatively, stretch fabrics, such as spandex blends or certain knit constructions, can be over tensioned during processing leading to increased fabric shrinkage and/or distorted fabric appearance. Also, fabrics that are sensitive to surface abrasion often can only be successfully dyed on machines with soft flow or gentle agitation. Therefore, for these and other reasons, the choice of the production dyeing equipment and the dye formulation laboratory equipment are directly influenced by the fiber content and fabric construction.

QUALITY OF FABRIC PREPARATION

The quality of fabric preparation is always a major factor in obtaining high quality repeatable dyeings, which have the best chance of being dyed right the first time. Key factors in determining preparation quality include:

- Removal of impurities (dirt, oils, greases, waxes, sizes, etc.).
- Fabric whiteness.
- Presence or absence of optical brighteners.
- Chemical residues (especially alkalinity).
- Fabric stability and resistance to distortion.
- Uniformity and consistency of preparation.

Any variability in preparation can lead directly to production shade variability. Fabrics for laboratory dyeings should be from production lots prepared on production equipment. Any special preparation processes used for production lots should also be performed on the fabrics used for laboratory dyeings for those lots.

WEIGHT OF THE FABRIC

Any factor that affects the weight of the fabric that the laboratory dyeing recipe is based on must be taken into account. For instance, if the production dye formula is based on the greige fabric weight, then the lab dye formula should be based on greige weight, not on prepared fabric weight. Additionally, the moisture content of the fabric for lab dyeings should be the same as that of production fabrics. Scales used for weighing both laboratory and production fabrics should be routinely calibrated and serviced.

SOURCE AND SELECTION OF DYES

Dye selection for both laboratory and production dyeings is based not only on the technical requirements of shade, fixation, substantivity, and fastness, but also on the dye quality, cost, and reliability of the service provided by the dye vendor. All dyes for the production lots and the dye formula lab should be routinely tested and characterized. Some of the main factors to consider include:

- Each dye supplier should provide documented test data of each dye shipment to the plant.
- All incoming dye shipments should be tested by the plant using standard methods to verify that each dye container meets specifications.
- Powdered dyes should be evaluated for moisture content and dusting potential.
- Liquid dyes should be evaluated for concentration and potential settling during storage.
- Each dye container should be checked for color strength by transmission or reflectance techniques.

- Leveling, migration, and streaking potential as well as solubility/dispersion characteristics should be checked and recorded.
- The stability/compatibility characteristics of dyes in combination within the bath and foaming properties during the dyeing cycle should be recorded and evaluated in regard to the agitation created by the lab and production dyeing machines.
- pH and shade change sensitivity of the dye should be tested and recorded.
- Adverse effects of specific dye diluents should be noted.
- All dyes in the plant inventory should meet necessary requirements for environmental, health, and safety issues.
- Lab and production dye containers should be properly covered and resealed after each use.

SOURCE AND SELECTION OF CHEMICAL AUXILIARIES

For any dyeing facility, each incoming container of auxiliary chemical should be pre-screened and then, on a routine basis, retested for the following quality parameters:

- pH (if the auxiliary is water based), viscosity, and density.
- Color.
- Clarity.
- Odor.
- Refractive index (for clear liquids).
- Any unique specific quality indicators.

Exact specifications for acceptable quality should be established for each chemical. Testing should be done in standardized, acceptable methods.

Additionally, before purchase, dyeing auxiliaries should be evaluated as follows:

- Cost vs. performance.
- Effect on final fabric properties (hand, shade change, odor, etc.).
- Potential for harm to the environment (toxicity, corrosivity, reactivity, and/or flammability).
- Biodegradability of the chemical and/or its waste products.
- Availability of safer chemical alternatives.

WEIGHING OF DYES AND AUXILIARIES

The central point of dye recipe development is the correct weight of the dye in the lab apparatus and subsequently in the production machine. Weighing errors in either process result in poor lab-to-plant correlation. Recording scales and balances that are accurate to the required degree of precision are the minimum requirement. Small weighing errors in lab dyeings lead to large variability in production. Care should be taken when measuring the amount of chemical auxiliaries required for laboratory dyeings. Although not as easily defined, errors in the amounts of chemicals in the lab dye bath can lead to serious shade variability and poor correlation in production dyeing. Many companies have found that the purchase and proper use of electronic dispensing pipettes improves the consistency of their lab dyeings.

MIXING AND DISPENSING METHODS

Documented mixing procedures should be posted. Lab and production personnel should be thoroughly trained and routinely observed to ensure that correct procedures are followed. Supervisory personnel should evaluate the common practice of the plant in an attempt to minimize the potential for weighing errors, contamination of dye and/or chemical storage containers, and the possibility of using mislabeled products. Some useful recommendations include:

- A separate scoop for each dye or chemical container.
- Use of disposable pipette tips for lab dyeings.
- Minimization of dye and chemical inventory.
- Preventative maintenance and routine calibration procedures for all equipment and instruments.

Where feasible, automated weighing, mixing, and dispensing systems are available for the shade matching lab. Depending on the manufacturer, these units can store dye recipes and automatically calculate and dispense the required amount of formula components once the weight of the substrate is entered. These instruments have the advantage of better accuracy, improved speed compared to manual methods, less qualified staff, and overall reduced labor costs. However, some limitations of these systems are that they often require a relatively large amount of floor space, the units have high initial costs, and some dyes may not have a long shelf life once dissolved or dispersed in water. Normally, a dyeing facility will need to have a high volume of lab dyeings to justify the investment in this type of laboratory system.

LABORATORY DYEING EQUIPMENT

In the best case scenario, the lab dyeing equipment duplicates the operational parameters of the production dyeing machine. Of course, production equipment is complex and intricately designed. Laboratory equipment may not be available to simulate the exact conditions of the production machine. However, some of the key factors that should be the same between lab and plant machines include:

- Dye liquor to fabric ratio/liquor ratio.
- Dye bath pH.
- Temperature control/rate of rise.
- Fabric movement and agitation level throughout the dye bath.
- Machine induced fabric surface change.
- Wet pickup.
- Speed.

The control systems of the lab and production equipment should ensure that the dye application method (dyeing procedure) is identical. The use of microprocessor controls has greatly improved the ability to accurately control and repeat the dyeing cycle. Additional factors that should be considered when evaluating dyeing control systems are:

- Accurate time/temperature controls.
- Controlled heating/cooling rates.
- Chemical dosing capability.
- pH monitor and control.
- Washing cycle controls.
- Cloth turnover rate monitor and control.
- Dye cycle reproduction reliability.

However, in many cases, small volume lab dyeings may be more uniformly and easily controlled than the production machine. If the production equipment is not properly maintained, routinely cleaned, and correctly operated, lab-to-plant correlation will be poor regardless of the consistency and accuracy of the lab dyeings.

METHOD OF SHADE EVALUATION

The lab and production dyeings should be evaluated in an identical manner. Once swatches are dyed in the lab equipment or taken from the production machine, the fabric is dried, conditioned, and then evaluated for shade. Care should be taken not to use hot, bone dry samples as shade indicators. Many dyes are very sensitive to the heat and/or the moisture content of the fabric. It is very important that the shade sampling technique and dyed sample presentation be systematic, so that the color evaluated is representative of the true shade of the lab dyeing or production lot.

After sampling, the key choice becomes whether the sample is to be visually evaluated, instrumentally evaluated, or both. There are pros and cons depending on the product mix and the demands of the customers. Various key factors to consider include:

- Fabric surface and geometric properties.
- Solid shades vs. cross dyes.
- Shade tolerances allowed.

In the case of visual shade matching:

- Use standardized and acceptable illumination.
- Use standard, uniform backgrounds.
- All personnel involved with shade evaluation should be tested for color blindness.
- All personnel should be trained using standard repeatable techniques.

In the case of instrumental shade evaluation:

- Instruments should be selected with capabilities that coincide with the product mix.
- Limitations of the instrument should be understood.
- All personnel using the instrument must be properly trained.
- Routine calibration and service of the instrument are required.

It is a good plan to keep a dye-by-lot history of each accepted shade for both lab and production dyeings. However, the shade tolerance, as a quality parameter, can change as business conditions change. Knowledge of and experience with customers count in regards to shade acceptance.

FABRIC AFTERTREATMENTS

A common circumstance occurring with the customers of dyeing companies is that they may compare a lab dyeing that is unfinished with fabric from the finished production lot. Chemical and mechanical finishing techniques have a great potential to change the shade of the dyed lot. Customers should be made aware of the process state of lab swatches. Where possible, any chemical or mechanical finishing techniques used on the production lot should also be used on the lab dyed swatches. As a word of caution, because lab scale surface finishing equipment is not always representative of production processing or even readily available, dyeing companies often attempt to surface finish goods before lab dyeing instead of after dyeing. Unfortunately, the dyeing process normally alters the surface so that the lab dyeing will not be representative of the production dyeing. The key issue is to communicate to customers exactly what the lab dyeing actually represents.

LAB-TO-PLANT STRATEGIES

In practice, dyers often adjust lab dye formulas for production equipment based on their personal experience. This approach has the potential for poor dyeing correlation. Due to the relatively low cost of lab dyeings compared to production and the low cost of lab dyeing mistakes, some companies perform multiple lab dyeings (at least three) as an alternative. If this is the case, then average these to obtain the predicted production recipe.

Due to the inevitable processing differences between various types of lab equipment and the variety of production processes, it has been proven that dye formula correlation can be improved by employing sample scale dyeing equipment. In this approach, lab dye formulas developed on small fabric swatches are dyed on sample scale equipment, normally 5 to 100 pounds fabric capacity, which closely resembles the construction and operation of the actual plant production equipment. Once the lab formula is used on the sample scale equipment, any corrections necessary are made, and the recipe is now ready to be used with production dye lots.

CONCLUSION

The simulation of any potential dyeing circumstance encountered in the production dyeing process should be replicated in the lab dyeing process. The high cost of shade corrections in production justifies extraordinary efforts to improve lab-to-plant dyeing reproducibility. Automating lab processing can have a positive effect on dyeing accuracy and consistency. Careful selection of compatible dyes and auxiliary chemicals for the lab and production lots is crucial. Current practice should be routinely evaluated for overlooked inaccuracies and avoidable errors. Laboratory dye formulas with the aid of computer programs can be systematically adjusted to routine bulk dyeing conditions. Lab dip to sample scale to production often gives the best reliability to the predicted production recipe. Good lab-to-plant dyeing correlation is a constant work in progress due to the sensitive and complex nature of textile dyeing.

Importer Support Program

The Cotton Board and Cotton Incorporated are funded by U.S. upland cotton growers and importers of cotton and cotton products (this includes raw cotton, piece goods, and finished apparel). A percentage of the importer funds are devoted for importer specific programs organized under the Importer Support Program. Examples of projects funded from this fund include training schools, educational programs, focus groups, economic meetings, and research initiatives.

Selected technical issues have been identified by importer members as relevant to their business. This report is a condensed, less technical report of those issues intended to provide the reader with basic, yet useful information on the topic.

For more information contact:

ELIZABETH KING
VICE PRESIDENT
IMPORTER SERVICES
COTTON BOARD
PHONE: 973-378-7951
FAX: 973-378-7956
eking@cottonboard.org

DENNIS P. HORSTMAN
SENIOR DIRECTOR
ACCOUNT MANAGEMENT
COTTON INCORPORATED
PHONE: 919-678-2336
FAX: 919-678-2231
dhorstman@cottoninc.com

Visit our website at: www.cottoninc.com

COTTON INCORPORATED