INTERNATIONAL HELLENIC UNIVERSITY

Improving Productivity at Colora S.A.

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A thesis submitted for the degree of

Master of Science (MSc) in Management

December 2019

Thessaloniki – Greece

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I hereby declare that the work submitted is mine and that where I have made use of another's work, I have attributed the source(s) according to the Regulations set in the Student's Handbook.

December 2019

Thessaloniki - Greece

Abstract

This consulting project was written as part of the MSc in Management at the International Hellenic University, for the academic year of 2018-2019.

The object of this consulting project is the productivity improvement, through application and analysis of Overall Equipment Effectiveness (OEE) ratio in the laboratory of Colora S.A. For this reason, laboratory inflows and outflows were examined, for the period of October 2018 to October 2019. Research showed that although the availability component of OEE was above the world class value, performance and quality components of OEE, as well as the latter, were well below world class values. Additionally, useful data was extracted about customers and current trends and preferences, considering the company's field of operations. Finally, suggestions for improvements were made, based in Statistical Process Control (SPC) tools.

My special thanks should first be attributed to Messrs Alexandros & Ioannis Apostolidis, head of Colora S.A., for the opportunity to accomplish this dissertation and the valuable experience collected during the time spent in the company and to my supervisor, Dr. Korina Katsaliaki, who was always accessible and helpful. Together with the aforementioned people, let me not forget the head of Quality Management at Colora S.A., Mr. Apostolos Kanarakis, for the perfect collaboration and advice, throughout the whole period of the consulting project. Additionally, the friendly staff of the company's laboratory, Mr. Vasilis Vakalis, Mr. Danos Chadjianagnostou, Mr. Nick Tekelidis and Mr. Odysseas Ntompros, deserves my praise.

Above all, however, my sincere and priceless thanks belong to my family and Elena, for their continuous support, during my studies, by all means.

Keywords: Productivity, Overall Equipment Effectiveness (OEE), Dyeing, Laboratory, Fabric composition

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December 2019

Contents

Introduction

The textile industry

Not many industrial sectors are as timeless as the textile industry, which boosted its productivity and strength since the Industrial Revolution. Generally, textile industry is a field with origins dated to the prehistoric era. In the European area, a “knitless knitting” sample, as it is originally known, is timely positioned approximately back to 6500 BC.

The European Union textile and clothing industry is a leader in world markets, as its exports represent nowadays more than 30% of the total market. That can be attributed to the high specialization and quality of the final products, its quick adaptation to the market and the emerging trends and its level of scientific research, that contributes to the development of new products, such as technical textiles (Commission, n.d.). Data of 2017 indicates the above described situation (picture 1). The following graphs present the number of enterprises operating in 2017 for textile and apparel production, the labour productivity per person, the number of employees in those sections and the value of textiles and apparels produced.

Picture 1: EU textile industry in 2017 (Lu, n.d.)

Textiles and dyes

Beginning from raw materials, either natural (such as cotton, linen or wool) or synthetic (such as nylon, rayon or polyester), there is a wide variety of processing and processes, before someone will be able to handle the final product. Among various processes, which add value to the final product in either a subtractive (through the removal of natural impurities or impurities created at the production process) or an additive way (through the addition of dyestuffs or various chemicals, in order to change fabrics' colours or to improve their properties) (Ammayappan L., 2016), dyeing is specially positioned in the whole function.

Dyeing can be defined as the interaction between a dye and a fibre, as well as the movement of dye into the internal part of the fibre. Generally, a dyeing process involves absorption (transfer of dyes from the aqueous solution onto the fibre surface) and diffusion (dyes diffused into the fibre). (Shang, 2013)

From the beginning of our civilization, textile dyes were derived from natural sources, which contained colourants. Examples of those are:

- *Vegetal:* saffron (yellow-red), alizarin (red), indigo (light blue), henna (yellow-brown), turmeric (yellow)
- *Animal:* kermes (red), cochineal (red)
- *Inorganic:* chromium yellow, zinc green, manganese oxide (brown), ferrum oxide (red)

Use of natural colorants was flourishing until the end of 19^{th} century, when they were fully replaced with synthetic dyes, considering the superiority of the latter in terms of colour stability and uniformity (Eleftheriadis I., 2015).

Synthetic dyes, which were introduced at around 1860 (W. Perkin, 1856, with the invention of mauveine), offered unlimited choices in colour, shade, nuance and reproductivity issues at mass volume production levels. However, apart from the challenging perspectives aroused, many factors should be taken into account, such as the type (composition) of fabric, the dyestuff type, the method of dyeing and the temperature in which the latter takes place, the auxiliary substances used in the dyeing procedure, the ecological standards respected, waste management of dyeing and textile finishing processes etc.

Colora S.A.

The selected company, Colora S.A. is actively occupied in the textile processing sector for over 90 years, as it was established in 1926 in Thessaloniki, Greece. Its main area of interest includes textile dyeing, printing and various textile finishing processes. The company's expertise is a combination of modern practices with traditional methods and proven techniques, that have evolved over the years, by adapting to today's technological and market standards. According to the company, all employees and executives are constantly passing through the most demanding training and learning sessions, in order to catch up with the latest breakthroughs in textile printing and finishing. The customers of Colora S.A. operate globally and serve the most demanding international markets. The company is closely monitoring its customers' demands and quickly responds to satisfy all qualitative criteria and -above all- to ship orders on time.

Colora S.A. is located in Thermi and employs 126 people, as of November 2019. The company adopts a functional organizational structure. Its main departments include:

a) Production department, with the subdepartments of Warehouse, Dyeing, Printing, Finishing and the Laboratory.
b) Financial department, with the subdepartments of Personnel, Pricing/Ordering and Sales.
c) Technical Assistance department, with the Mechanical, Electrical and Construction subdepartments.
d) Trading department
e) Quality Management department

Main competitors of Colora S.A. are companies in the field of textile processing. Those include both dyehouses and textile finishing companies, as well as companies with vertical organization, from textile knitting, to dyeing/printing and/or final product processing (fabric). Northern Greece and -especially- Thessaloniki region has a long history and tradition in those fields. However, from the over 150 enterprises operating approximately 30 years ago, nowadays the relevant companies are only five, in northern Greece. Those include: i). Fieratex S.A.-Anezoulakis Bros, in Nea Santa, Kilkis, ii). Maitex S.A., in Katramio, Xanthi, iii). Viostamp-Vafeia-Finiristiria Thessalonikis S.A., in the industrial area of Thessaloniki, iv). Ermis-A. Itimoudis S.A., in Oreokastro, Thessaloniki.

Considering Colora S.A., about 60% of the total business level relates to the local (Greek) market and the remaining 40% relates to foreign markets. Current market share in the local (Greek) market is estimated around 35% to 40%, according to data given by the company.

Company's laboratory holds a special place and role in the whole organization, as it will be furtherly analysed, in the Scope of the Consulting Project, as it is the starting point of the dyeing processes accomplished, as a whole. Customers demand their samples dyed right, on time, considering that most of them operate under subcontracting (or "outsourcing" as it is more commonly known), in order to forward large-scale orders. As a result, performance (including quality and speed) is vital for the laboratory operation. Cost is not a priority for customers, at the laboratory's production scale. However, a large number of samples created for a customer and a low amount of them forwarded into production may result into a problematic situation for the laboratory and for the company, as a whole.

Total Preventive/Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE) and analysis of the results

In our case, we will analyse the laboratory department of Colora S.A. The inflows and outflows are going to be examined, in order to determine the current productivity and to propose ways of improving it, through the analysis of the Overall Equipment Effectiveness (OEE) ratio, which is the major measurement unit of Total Preventive/Productive Maintenance (TPM).

Total Preventive/Productive Maintenance (TPM) refers to a complete approach considering the equipment's maintenance, which aims to achieve perfection in the production process and maximum performance, through absence of breakdowns, absence of defects and stops or decreased production speed and a safe working environment, without accidents. S. Nakajima, the "father of TPM", who introduced this approach in 1971, supports that a company can gain a competitive advantage when manufacturing near to or in ideal condition, with zero downtimes, zero defects, in "Lean Production" philosophy (eliminating waste [= any activity that does not add value, from the customer's perspective] from the manufacturing process, due to: overproduction, transportation, over-processing, manufacturing defective products, motion, waiting or inventory and in Just-in-Time (JIT) production (Nakajima, 1988). The supporting activities (or “8 Pillars”) of TPM, include (Pereira Castro F., 2012):

1. Planned Maintenance
2. Education and Training
3. Initial Control
4. Focused Improvement
5. Autonomous Maintenance
6. Safety, Health and Environment
7. Office/ Administrative TPM
8. Quality Maintenance

OEE is the foundation of the previously described improvement strategies, TPM and Lean Manufacturing and measures the success of the TPM implementation. OEE gives us vital information considering the operations’ resource availability, the actual performance compared to the ideal one and the quality of goods produced. Additionally, OEE can serve as a measure of asset or equipment utilization (R. Singh, 2013). It is calculated as the product of Availability (=Actual Operating Time/Planned Operating Time), Performance (=Net Operating Rate * Operating Speed Rate) and Quality (=Total Number Produced - Number Scrapped / Total Number Produced).

*OEE= [(Availability) * (Performance) * (Quality)] * 100%*

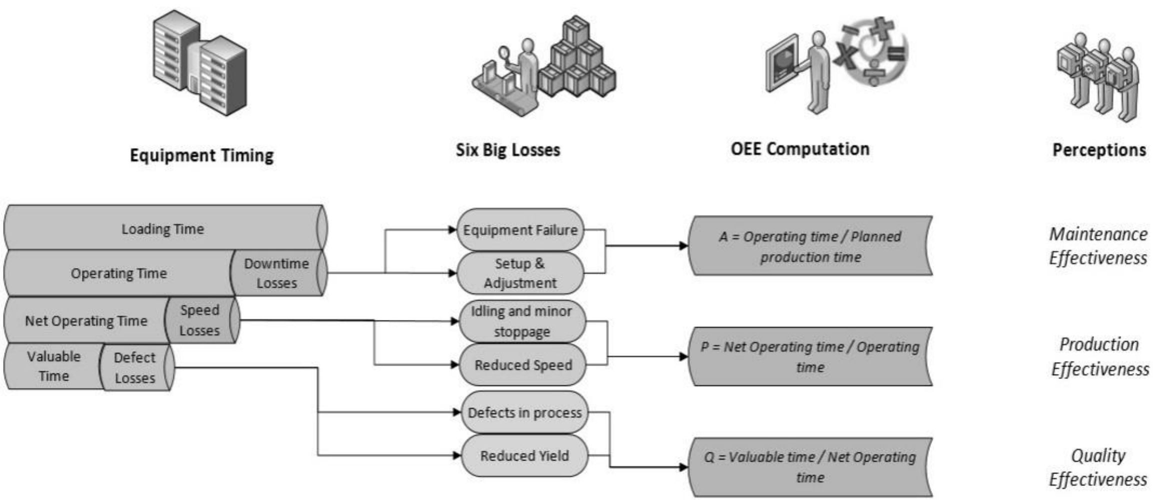
As far as the latter is concerned, “quality”, as a term, can have a lot of interesting definitions. According to Taguchi, “the quality of a manufactured product is total loss generated by that product to society, from the time it is shipped, other than any losses caused by intrinsic functions” (Taguchi G., 1988). The term “loss” refers to any possible losses caused by the variability of function and by negative side effects. Deming defines “good quality” as “a predictable degree of uniformity and dependability, with a quality standard suited to the customer” (Best M., 2005). Nowadays, the International Organization for Standardization (ISO) states that “quality refers to a degree to which a set of inherent characteristics (=features that constitute a product, a service or a combination of both and are responsible for satisfaction achievement) fulfills requirements”.

Availability factor measures the total time that a system is not operating, due to set-ups and breakdowns of machinery, necessary adjustments by the users and other possible stoppages. Generally, this parameter is influenced by setup losses and failures.

Performance factor refers to the actual operating speed or output of a system, compared to its ideal speed or output. Generally, this parameter is influenced by micro-downtime losses and speed losses.

According to Nurcahyo et al. (2018), world class TPM standard rates for the OEE components are: for the availability ratio ≥ 90%, for the performance ratio ≥ 95% and for the quality ratio ≥ 99%. If multiplied, those three ratios give an OEE score of equal to or greater from 85%. However, the initial measurement of OEE at the start of TPM initiatives, is normally less than 40% in most of the industries, as similarly in our case. Adoption of TPM programme can have impressive results, boosting OEE to over 80%, within a period of 3-4 years.

The OEE optimization should be a main objective for the company. Its application, in the context of TPM, as well as the definition and monitoring of its values, contributes substantially in management efforts of decision-making processes, in shaping its short or long-term strategies, as well as in remaining competitive and viable, in an unstable environment. According to Bamber et al. (2003), management's support and the formation of small groups are vital actions, for the successful implementation of OEE improvements. However, it is important, prior to the implementation, for the management team to have a clear understanding of stoppages' and losses' classification, as well as to ensure data accuracy, for the correct selection of improvement activities, which will further improve OEE. An evaluation mechanism of the latter is shown below (picture 2).



Picture 2: OEE evaluation mechanism (Mahmood K., 2016)

After the necessary collection of data over a specific period of time, data analysis is performed. The latter aims to specify the problematic areas and losses/inefficiency causes in the production process. For this reason, Statistical Process Control (SPC) tools are being used, such as pareto diagrams (its basic idea is that most of an "activity" is caused by relatively few of its factors), histograms, cause-and-effect diagrams, and other graphics (bar charts, pie charts for necessary comparisons etc.) and tables.

Scope of Project

The scope of this consulting project is the application and analysis of OEE ratio in the laboratory of Colora S.A. and relies on the fact that the company's laboratory stands above all departments, as the place where the dyeing recipes are created, before the textiles will be sent for mass dyeing procedures. Production at a large scale does not exist without reliable samples, approved by the customers. For this reason, it is significant to concentrate on quality, time and flexibility, in order to improve laboratory's productivity and create a greater number of samples, easier and more efficiently, with less efforts, at the same or in less time. (Cost is not always a significant issue at this department, as clients' needs are concentrated on speed, quality and accuracy of the deliverables, factors which are more important than cost, according to them.)

Structure of Project Report

The chapters of the project's report are structured as follows: first of all, the lab is being presented, considering its machinery and the flowchart of all the processes accomplished inside. Then, each part of the flowchart is further analyzed. For better understanding, we deepen more into details of some functions, which are described with a detailed separate flowchart. As a result, we can suggest some qualitative or "best practice" criteria, in the next chapter. Fabric compositions and dyestuffs come afterwards and in the next chapter we refer to breakdowns that took place in the period we investigate. After that, the results are presented. Those include the number and type of the standard and trial samples produced, production per customer, the OEE ratio and its components, etc. Finally, we suggest improvements for the processes and -generally- for productivity gain.

Data collection

Data collection was performed through the analysis of total samples (trial and standard ones) created in the laboratory, from October 2018 until October 2019 (12 months of full production, as in August the company does not operate at all). As a "standard" sample, we define the one that will be created and approved, regardless of the attempts required. "Trial" samples refer to the number of attempts (=the number of samples required), in order to get the standard (=ideal) one. The necessary data was extracted from the computer connected to the spectrophotometer, used to measure colour. Initial data (picture 3) was presented in PDF format, which was then converted to MS Excel spreadsheets. For our convenience, we separated data into specific files for each month, which contained the daily "standard" and "trial" production of samples, categorized in terms of fabric composition and type of dyestuff used. Each of those files contained also the number of standard and trial samples created monthly for each customer. For the OEE computation, we used a specific spreadsheet, where we calculated the ratio and its components (availability, performance & quality) daily, weekly and monthly. After performing the computations, we used the spreadsheets to create the graphs. Necessary information for a variety of laboratory issues were also obtained from the laboratory staff.

Full Name	Date	ΕΝΤΟΛΗ ΒΑΦΗΣ	Group2:	Pantone	ΠΕΛΑΤΗΣ	ΣΥΝΘΕΣΗ	ΒΑΦΗ
17238	4/1/2019 11:07:08 πμ			[redacted]	[redacted]	STH 100% BW	R60
17239	4/1/2019 11:11:49 πμ			00366	[redacted]	STH 100% VISCOSE	P80
17240	4/1/2019 2:09:56 μμ			00226	[redacted]	STH 100% BW	P80
17241	4/1/2019 2:52:44 μμ			00251	[redacted]	STH 100% BW (ORGANIKO)	P80
17242	4/1/2019 2:56:44 μμ			00226	[redacted]	100% BW	R60
17243	4/1/2019 2:57:08 μμ			00226	[redacted]	100% BW	P80
17244	4/1/2019 2:57:26 μμ			00226	[redacted]	100% BW	R80
17245	4/1/2019 3:08:25 μμ			00226	[redacted]	100% BW	R80
17246	4/1/2019 4:31:00 μμ			00177	[redacted]	VISC/L	P80
17247	7/1/2019 8:46:05 πμ			00888	[redacted]	STO PES/L (98/2)	130
17248	7/1/2019 4:08:18 μμ			00396	[redacted]	100% BW	R60
17249	8/1/2019 12:38:34 μμ			00270	[redacted]	STH VISC/L	R60
17250	8/1/2019 12:38:47 μμ			00270	[redacted]	STH 100% PES	130
17251	8/1/2019 4:24:31 μμ			00270	[redacted]	STH 100% VISCOSE	P80
17252	8/1/2019 4:24:42 μμ			00270	[redacted]	STH 100% PES	130
17253	8/1/2019 4:46:06 μμ			HIGH	[redacted]	VISC/L	R60
17254	8/1/2019 5:31:02 μμ			00270	[redacted]	STH 100% PES	130
17255	9/1/2019 9:58:58 πμ			HIGH	[redacted]	BW/L	P80
17256	9/1/2019 9:59:55 πμ			HIGH	[redacted]	BW/L	P80
17257	9/1/2019 10:00:13 πμ			HIGH	[redacted]	BW/L	R60
17258	9/1/2019 1:32:53 μμ			00139	[redacted]	100% NYLON	NYL
17259	9/1/2019 1:35:29 μμ			00139	[redacted]	100% NYLON	NYL
17260	9/1/2019 1:57:42 μμ			00139	[redacted]	STH PES/L	130
17261	9/1/2019 1:58:05 μμ			00139	[redacted]	STH PES/L	130
17262	9/1/2019 2:27:40 μμ			00260	[redacted]	STO 100% BW	P80
17263	10/1/2019 9:43:46 πμ			00251	[redacted]	STH BW/L	R60
17264	10/1/2019 9:50:29 πμ			00270	[redacted]	STH VISC/L	R60
17265	11/1/2019 10:28:04 πμ			51136	[redacted]	STH 100% PES	130
17266	11/1/2019 1:22:48 μμ			[redacted]	[redacted]	STO BW/L	R60
17267	11/1/2019 3:31:05 μμ			[redacted]	[redacted]	STH BW/L	R60
17268	11/1/2019 3:31:26 μμ			[redacted]	[redacted]	STH BW/L	R60
17269	11/1/2019 3:31:44 μμ			[redacted]	[redacted]	STH BW/L	P80
17270	11/1/2019 4:06:59 μμ			00295	[redacted]	100% VISCOSE	P80
17271	11/1/2019 4:10:10 μμ			00260	[redacted]	STO 100% BW	P80
17272	11/1/2019 4:10:35 μμ			00260	[redacted]	STO 100% BW	R60
17273	14/1/2019 9:32:17 πμ			00251	[redacted]	STH 100% BW	R60
17274	14/1/2019 10:02:58 πμ			00251	[redacted]	MMD/L	R80
17275	14/1/2019 12:26:04 μμ			00390	[redacted]	100% BW	R80

Picture 3: Initial data extracted

1. The Laboratory

First of all, a short description of the laboratory and its machinery will be given, in order to create a perception of the tasks accomplished. Each piece of equipment contributes either positively or negatively in the final result; it affects and it is being affected by a wide variety of factors: maintenance level, age, user's experience, temperature, time, substances used in the various processes, quality of raw materials etc.

1.1 Laboratory Machinery

The laboratory machinery consists of the following pieces:

1. Ugolini Mini Jet Flow: preparation machine (picture 4), used for washing the textile samples with soaps, acids etc, thus preparing them for the dyeing process or afterwards, for removing excess dye. (Process time: approximately 2.5 hours)

Picture 4: Ugolini preparation machine

2. Datacolor Ahiba Eco dyeing machine (picture 5): used both as a high-temperature dyer (130°C) and as a colour fastness tester. It is used for polyester fibres. (Process time: approximately 2.5 hours)

Picture 5: Datacolor dyeing machine

3. Ugolini dyeing machine (picture 6): used for secondary dyeing samples at 60°C and 80°C – usually, for “emergency” samples sent by the production department. (Process time: according to specific needs, usually 2-2.5 hours)

Picture 6: Ugolini dyeing machined

4. Original Hanau Linitest dyeing machine (I) (picture 7): used for simple dyes at 95°C. (Process time: 0.5-1.5 hours)

Picture 7: Linitest dyeing machine

5. Datacolor Ahiba dyeing machine (picture 8): used for simple dyes at 80°C. (Process time: approximately 2 hours)

Picture 8: Ahiba dyeing machine

6. Original Hanau Linitest dyeing machine (II): used for simple dyes at 95°C. (Process time: 0.5-1.5 h)

7. Ahiba Texomat dyeing machine: used for simple dyes at 60°C. (Process time: approx. 2.5 h)

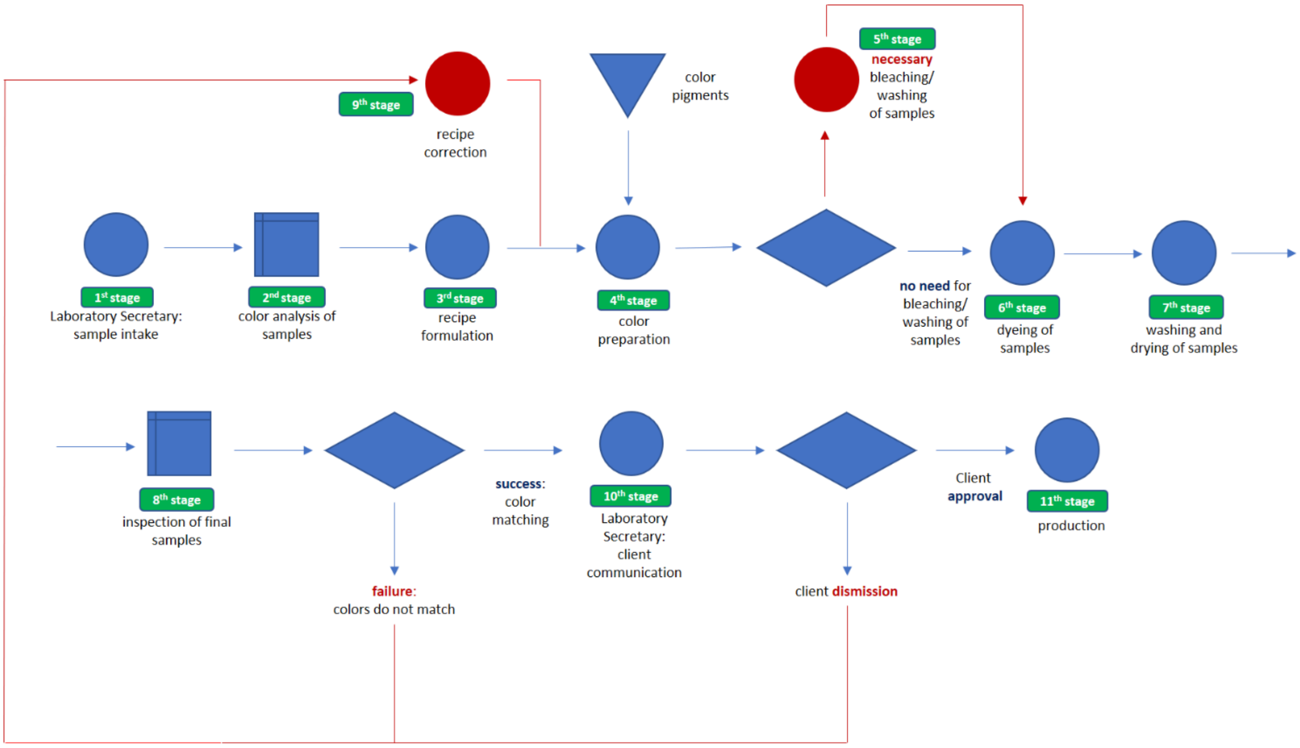
8. Tecnorama Dosorama colour dispensing machine (pictures 9 and 10): fully automated, prepares the dyeing solutions used in the dyeing process. (Process time: approx. 0.5 h for a set of 12 dyeing solutions.)

Pictures 9,10: Tecnorama colour dispensing machine

The generic laboratory's flowchart, which presents the main steps for a textile sample to be created (from sample intake, until approval of the dyed sample by the customer and forwarding it to the production department), is given below, as well as a description of each flowchart's component/stage of the process accomplished in the laboratory.

1.2 General Flowchart and Components

At this chapter, the laboratory's general flowchart is presented, as well as its components. The flowchart shows the complete process accomplished. Each step/component is further analysed below the chart (flowchart 1).

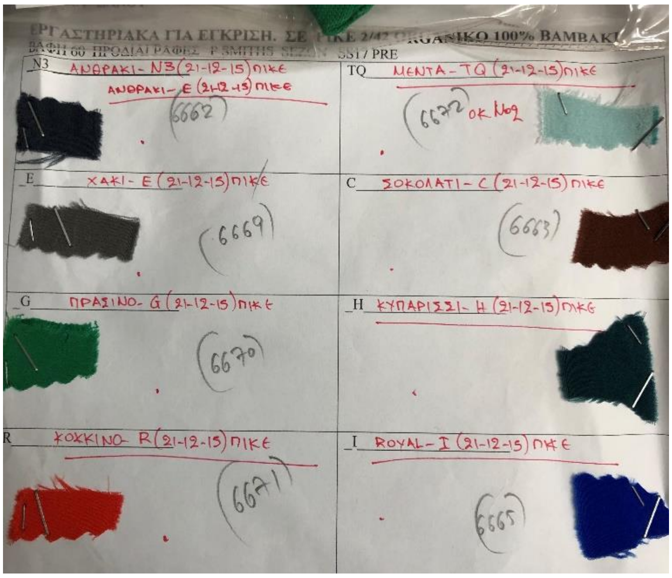


Flowchart 1: The laboratory operation

Flowchart Components:

1. *Laboratory Secretary: Sample Intake*

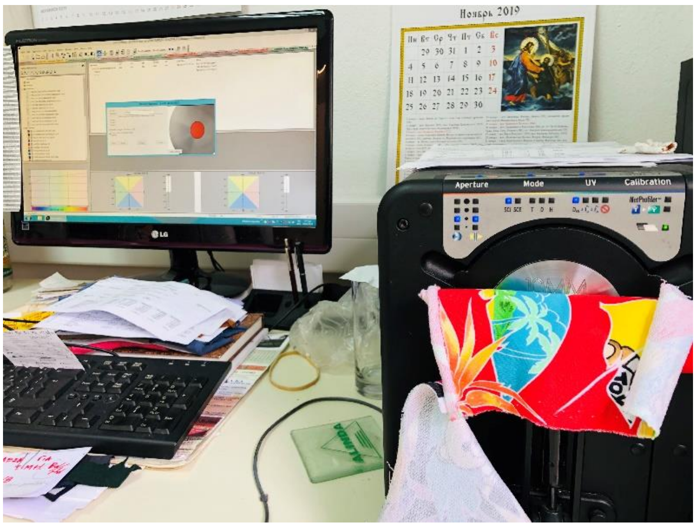
   At the beginning of the process within the company's laboratory, all incoming fabric samples (picture 11) are being collected by the lab secretary. The latter is responsible for the whole communication with the clients, both at the beginning and at the final step of the process. He is also responsible for forwarding the approved-by-the-customer samples into production.



Picture 11: Customer colour sample list

2. *Colour Analysis of Samples*

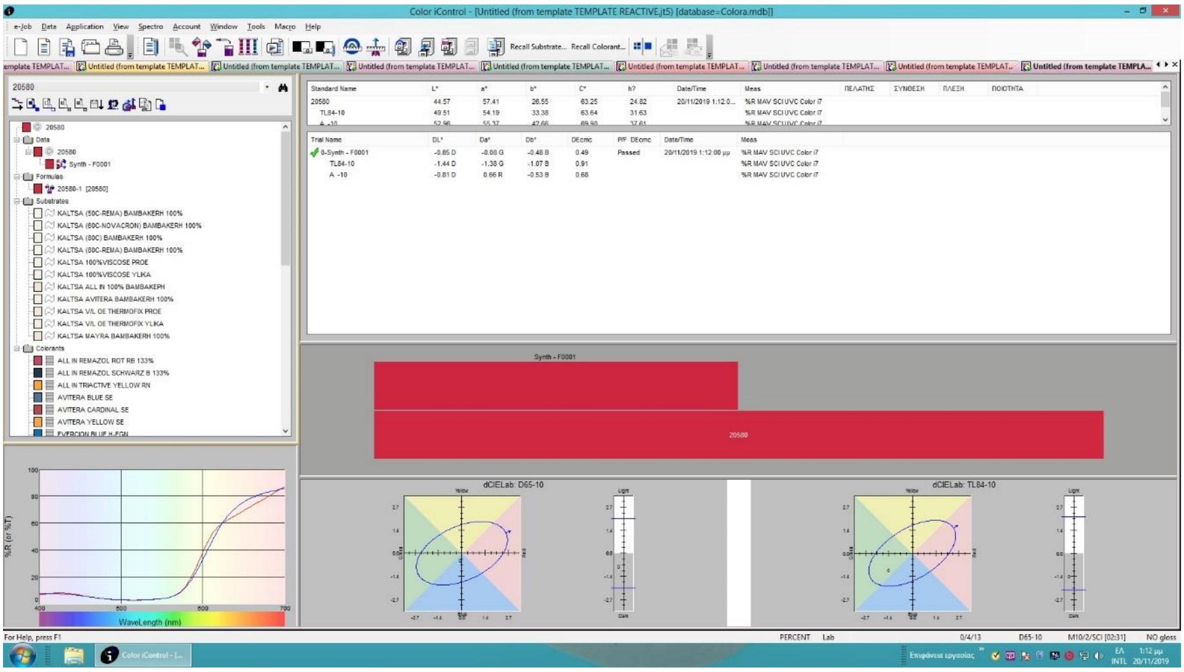
   In this stage, the samples' colours are being analysed using spectrophotometric process. To measure the colour of a medium (e.g. a textile sample, in our case), we can irradiate it with a means of light (e.g. tungsten light) and measure the amount that is transmitted or reflected respectively, as a function of wavelength. A spectrophotometer (picture 12) carries out this function and produces a graph, which is called the" spectrophotometric curve". The latter provides a "fingerprint" of that colour (Roderick McDonald-Society of Dyers and Colourists, 1987, pp. 29-31). Through the instrument's analysis, ''a'', ''b'' and ''L'' indexes are determined, which will be used in defining the number and quantity of predominant colours needed (blue, yellow and magenta) to formulate the dyeing solution.



Picture 12: X-rite spectrophotometer

3. *Recipe Formulation*

After a, b and l indexes are specified, they are corresponded to actual colour substances and the dyeing recipe is created. The quantity of colours and added substances, as well as their required weight are specified. Software's formulated recipe is shown on picture 13. This data is then forwarded to the Tecnorama machine, which is responsible for the preparation of the dyeing solution.



Picture 13: Formulated dyeing recipe

4. *Colour Preparation*

In this stage, the dyeing recipe is entered in the Tecnorama machine, which automatically prepares the dying solution for each sample, based on its robotic technology. The pigments are entered in specific bottles. The machine automatically weights individual dyeing solutions, according to the recipe. Each recipe has its own number and position on the electronic scale. As soon as the colour preparation finishes, a recipe bulletin is printed, which consists of customer details, order number and a timestamp (date and time). Additionally, it states information about dyeing process (stirring and dispensing time, water temperature, machine number, dye bath ratio, position of the dyeing glass on the scale, water volume, total volume and disclosure of colours and substances used ("auxiliaries", e.g. formic acid, NaCl, bicarbonate), as well as their theoretical and actual percentage in the dyeing solution and the required and actual weight of each substance. A deviation in the 3^{rd} decimal is accepted.

5. *Bleaching / Washing of Samples*

   Before moving to the dyeing process, textile samples may need to be bleached, in order to be dyed. Sometimes washing is necessary, mainly due to reasons such as dirt accumulated by the production process, staining by oily substances etc. Samples are usually left moist, as the dyeing process follows, which takes place in a wet environment (dyeing solution).

6. *Dyeing of samples*

   Dyeing is being proceeded in the Ugolini, Datacolor and Hanau dyeing machines. During this process, each textile sample is attached to an arm, which moves upwards and downwards in a glass tube, which contains the dyeing solution. Before the dyeing procedure, pre-weighted additional substances are manually added in the tubes (picture 14).

Picture 14: Manual preparation of additives for dyeing

7. *Washing and Drying of Samples*

   After dyeing, all samples are being washed with a special detergent in the preparation machine, for 1-3 times each, according to the dyeing procedure, for the excess dye to be removed. Then, samples are dried in the special drying oven (picture 15), for a minimum of 15 minutes, according to the kind of fabric and at temperatures of 130°C -140°C.

Picture 15: Drying of samples in oven

8. *Inspection of Final Samples*

   The laboratory chemist inspects the result after the samples are dyed. The same spectrophotometric technique is used, as in the initial colour analysis of samples.

9. *Success / Failure of Colours*

   A decision is taken, whether the dyeing process is successful or not. In case of success, communication with client follows (10^{th} stage). In the opposite case, the recipe needs to be corrected and the dyeing process to be repeated (9^{th} stage).

10. *Recipe Correction*

    In this stage, the recipe is corrected and formulated again, in order to achieve the preferred result, according to the colour. Colour preparation and dyeing process is repeated.

11. *Laboratory Secretary: Client Communication*

    In the 10^{th} stage of the process, the laboratory secretary communicates with the client, which is the final responsible to decide on the approval or dismission of the dyed samples.

12. Client Approval / Dismission

In case the client does not approve the result, due to colour mismatch or other imperfections, the dyeing process must be repeated. Thus, the process is driven to the 9^{th} stage and the recipe is corrected.

13. Production

After samples are finally approved from the client, large scale production process follows, in the analogous department.

However, in order to concentrate into each process and discover its strengths and weaknesses, we need to give a more detailed description of each individual process inside the laboratory. For better understanding, a detailed flowchart accompanies most stages, as it can be seen in the following chapter.

1.3 Detailed description of laboratory processes

- Sample Intake

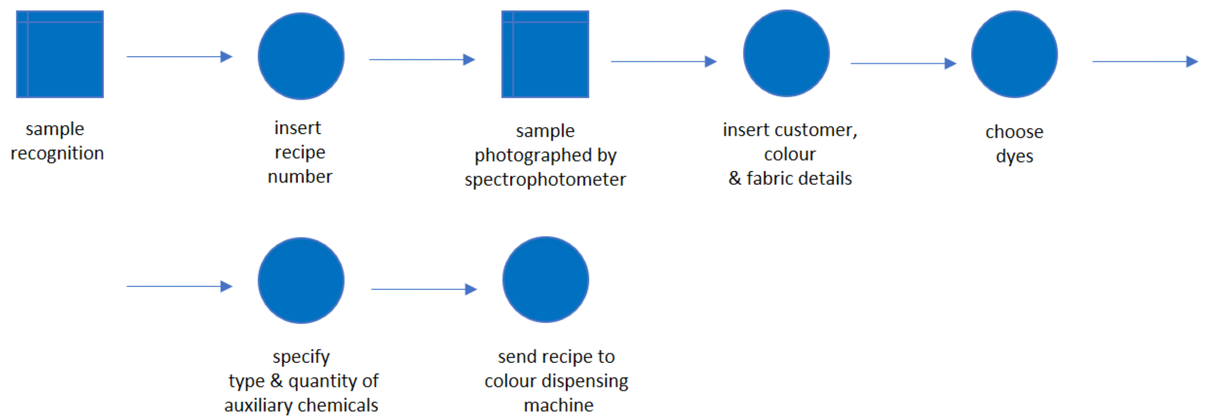
There is not a standardized form of customers' orders. Each customer uses its own one, different in terms of appearance, but approximately with the same information: name, number of orders, colours and quantity of fabric dyed. Orders which are coded with quantitative characteristics (for example, serial number) or match each colour with a specific and unique code, are much to the ease of the laboratory. A predefined order form, the same for all customers, was introduced some time ago, but it was soon abandoned by the latter, who preferred their own order forms.

- Colour Analysis of Samples and Recipe Formulation

Firstly, the fabric is recognised by the competent chemical, its category is chosen (e.g. Nylon) and the serial number of the recipe is inserted in the system. Then, the fabric sample is being photographed by the spectrophotometer and basic details are also inserted (customer, type of dye, composition of fabric, knit). The dyes are being chosen, as a result of the function of the colours that the instrument photographs. (The experience of the user is necessary, in order to specify the colours-dyes. The spectrophotometer gives basic indication of the colours, the final decision relies on the use, for example, a “blue” nuance may be produced by mixing blue, red and yellow dyes, at different percentages.) Finally, the type and quantity of auxiliary chemicals is specified, according to the type of dyeing and the percentages of the dyes used. The recipe is then forwarded to the Tecnorama colour dispensing machine.

The duration for the completion of that process varies. No more than 5 minutes are required, for the first attempt. However, that can be significantly increased, when multiple attempts are needed to match the colour ordered by the customer.

The detailed flowchart of that process is given below (flowchart 2):



Flowchart 2: Sample colour analysis & recipe formulation

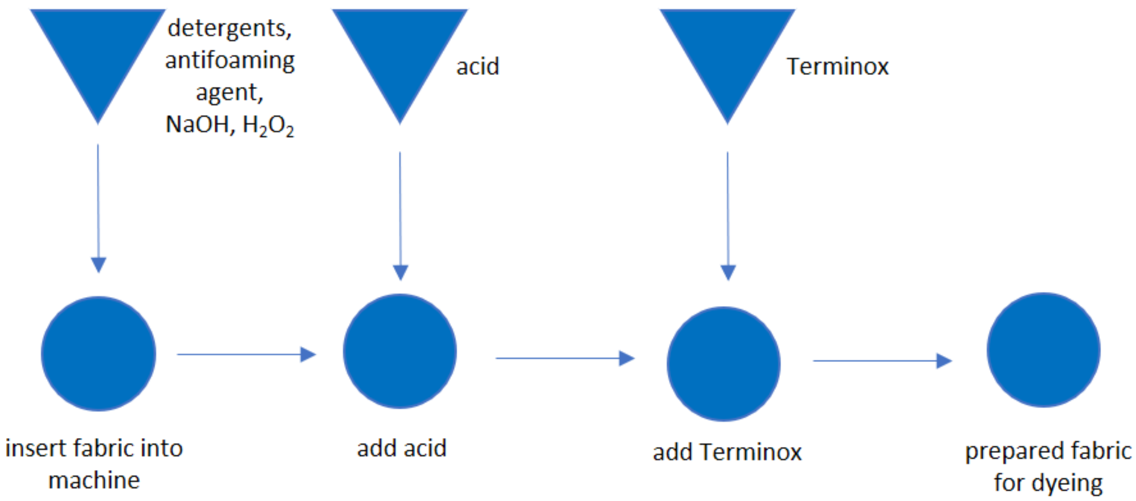
- Colour Preparation

At the previous step, all necessary recipe data have been forwarded to the dispensing machine. The staff prints, at the beginning, a list with all necessary auxiliary chemicals that need to be added externally (not by the dispensing machine). Each time, the machine can prepare 12 different recipes (as the electronic scale inside the machine has 12 positions for dyeing solutions preparation). The first recipe is being read and the required amount of dye is transferred automatically inside the glass on the scale, with a pipette. Then, the other recipes are being scanned and in case the same dye appears on another recipe, the machine transfers the dye with the same way. If the specific dye does not appear elsewhere, the machine moves to the second colour of the first recipe. The same procedure is followed, until all recipes are ready. Finally, the recipe bulletin is being printed, as previously described.

- Bleaching and Washing of Samples

At this stage, fabrics may need to go through a bleaching or washing process, before the dyeing procedure. This is done in the preparation machine. For bleaching, 3 different detergents, antifoaming agent, sodium hydroxide (NaOH) and hydrogen peroxide (H_2O_2) are entered the machine, along with the fabric, which should weight approximately 0.5 kg. The first stage lasts about 45 minutes and it is proceeded in 95°C. Then, acid is being put, for the latter to neutralize the hydroxide reaction and it is left for 10 minutes, at 80°C. Lastly, a substance called "Terminox" is used, as to neutralize the hyperoxide added and it is left for another 10 minutes, with cold water, until the whole process finishes. As a total, this process has a duration of 110-120 minutes, as the machine needs to wash off the fabric and reach desired temperature, after each step.

The detailed flowchart of that process is given below (flowchart 3):

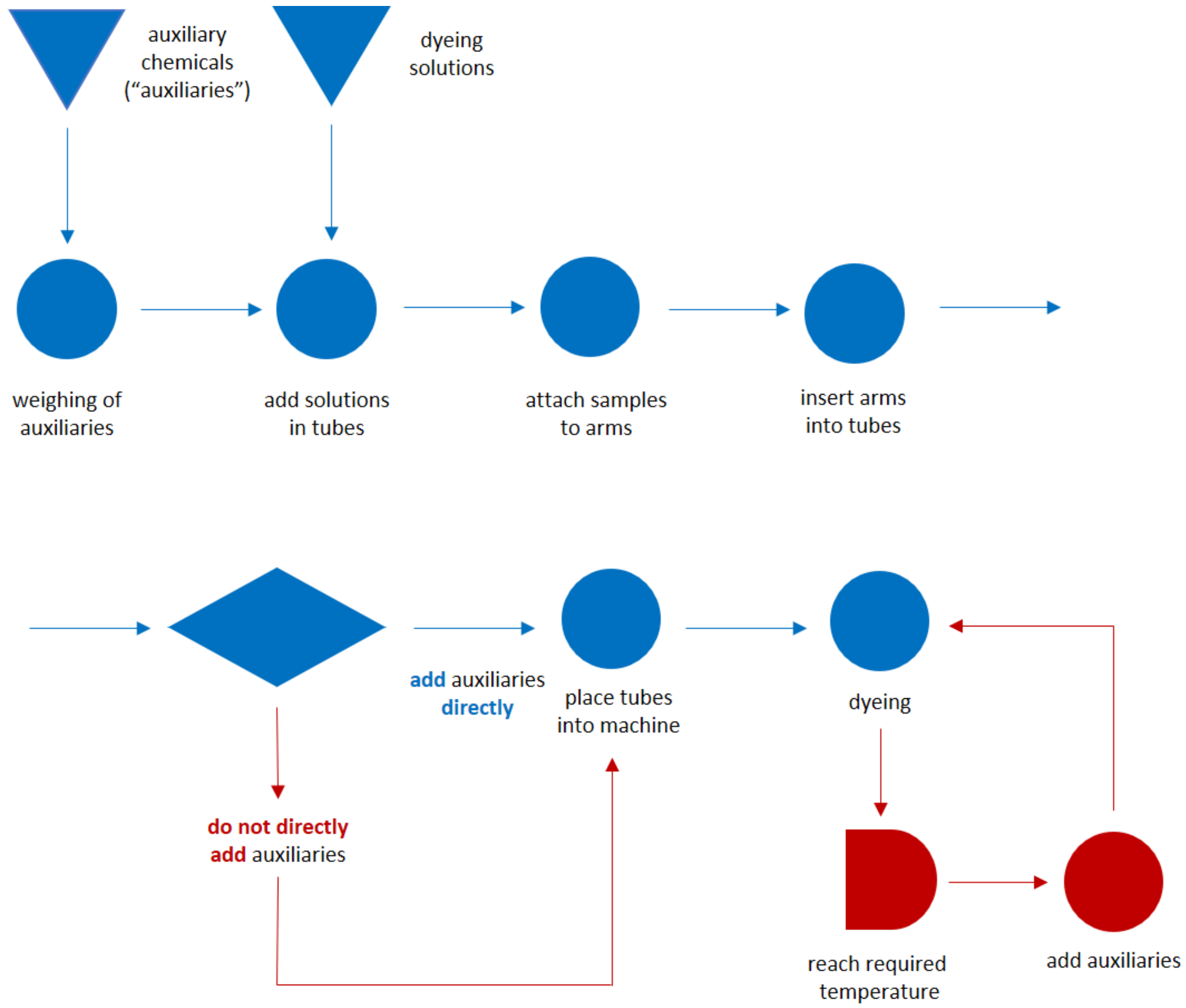


Flowchart 3: Sample bleaching and washing

- Dyeing of Samples

At the dyeing process, after the dyeing solutions have been prepared, staff weighs the auxiliary chemicals needed for each sample. Each dyeing machine (e.g. Ahiba) has a set of tubes, usually 12. The chemical attaches each fabric sample to a fork-shaped arm and adds the dyeing solution. Auxiliary chemicals are being added at the beginning or when the required temperature is reached (e.g. 80°C). The set of tubes is finally attached to the dyeing machine and the process starts. The duration of the process varies between 1 and 2.5 hours, according to the type of fabric, dyeing process followed and temperature used, for each dyeing machine (duration for each is stated above).

The detailed flowchart of that process is given below (flowchart 4):

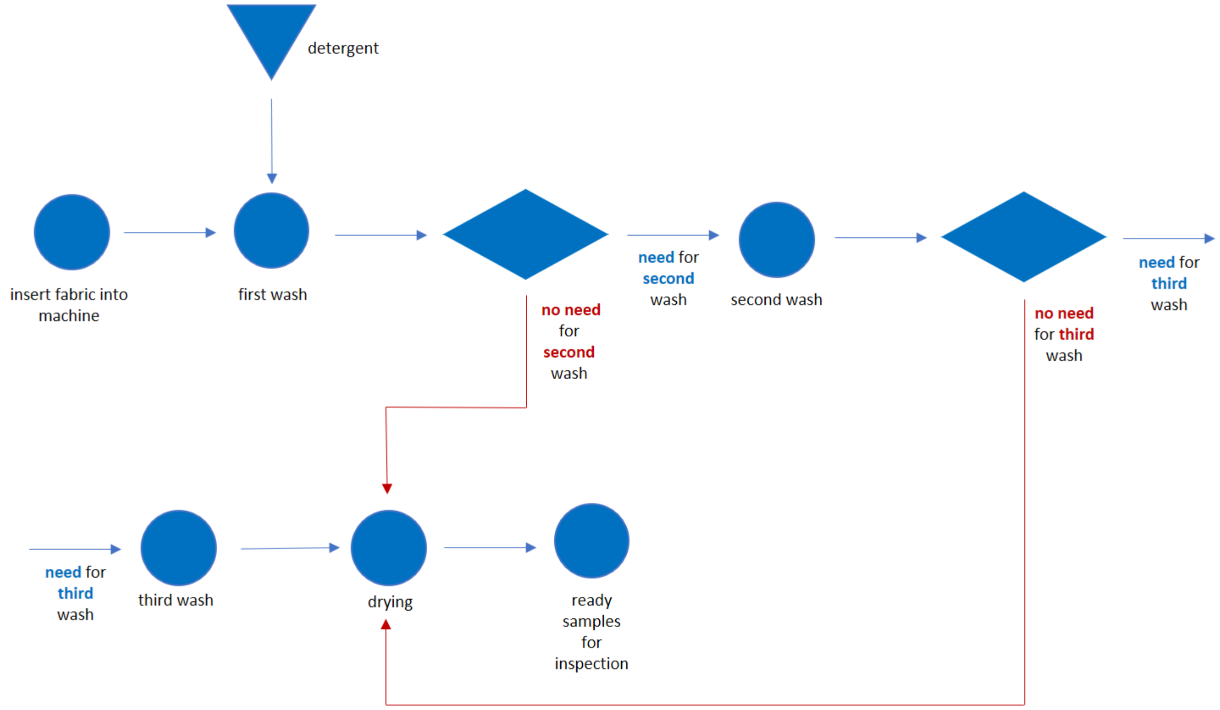


Flowchart 4: Dyeing of samples

- Washing and Drying

After the dyeing procedure, samples need to be washed, to remove excess dye and to be dried, in order to for the final inspection to de done. According to the percentage of dyes in the dyeing solutions, 1,2 or 3 washes may be needed, at 95°C. Each wash lasts about 15 minutes (10 minutes for the washing process plus 5 minutes for the machine to reach the desired temperature). The machine has 13 positions for samples. The maximum duration, for 3 washes, is about 50 minutes, as the machine quickly reaches the desired temperature. After washing, samples are dried in a special oven at 130°C-140°C, for about 15 minutes.

The detailed flowchart of that process is given below (flowchart 5):



Flowchart 5: Washing and drying of samples

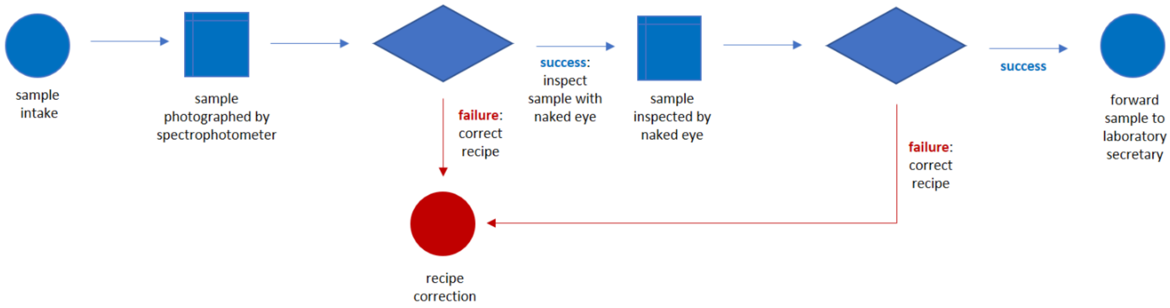
- Inspection of Final Samples

The samples are checked both by eye, as well as in the spectrophotometer. A combination of both ways is necessary, for the colours to be matched successfully. The instrument should give a result of ΔE≤1, to accept the result. ΔE refers to the colour difference, as given by the CIELAB equation:

$$\Delta E = \sqrt{(\Delta L *)^2 + (\Delta \alpha *)^2 + (\Delta b *)^2},$$

where: L refers to the lightness of colour, α refers to the position between magenta and green colour and b refers to the position between yellow and blue. (Roderick McDonald-Society of Dyers and Colourists, 1987, pp. 106-107). If ΔE is lower than 1 and the visual result with naked eye is also satisfying, then the sample is accepted. Otherwise, the recipe is corrected, and the dyeing process is repeated.

The detailed flowchart of that process is given below (flowchart 6):



Flowchart 6: Inspection of final samples

1.4 Qualitative Success Criteria

1. *Sample Intake*

Concerning the colour samples, it is strongly preferred the colours to be presented with a serial number from the customer. This helps to simplify the intake process, both by avoiding misunderstandings, as well as for time-saving reasons (Customers vary in size; small industries, with limited computerization and absence of systems such as ERP, can ask from staff to search for the textile rolls dyed at a specific date and use them as a colour reference for the new order, thus creating a time-consuming situation). Ideally, the customer who includes a serial number for each colour sample can refer to each recipe as "unique", from the beginning of the sample creation process. (e.g. 10 colors= 10 recipes= 10 different serial numbers). Otherwise, the laboratory staff should include their own serial number from the spectrophotometric process as a reference number, in order to label each colour. It is common fact not to understand even the nuance by the description (e.g. "orchid" refers to fuchsia, "sorbet" is a pink nuance, etc.).

A good example of a colour sample list is presented below (picture 16):

(company) **Date:**
Order number:

Textile Composition: *(e.g. 50% organic cotton-50% modal 160 gr.)*

Colour code:	**Colour name:**	**Cust. colour:**	**Colour sample:**
PR-17378	“Sky blue”	light blue	☐
PR-17379	“Yellow”	yellow	☐
PR-17380	...	...	...

Textile Specifications: *(preparation, type of dyeing process etc.)*

Picture 16: “Best practice” example of colour sample list

2. *Colour Analysis and Recipe Formulation*

As previously mentioned, colour analysis of fabric samples is accomplished by spectrophotometric means. The instrument’s user requires the fabric samples to be of enough size, in order to be measured. The instrument accepts heads of different diameter. Most of the times, the Ø 10mm head is used. Each sample is measured twice, by carefully folding the textile, in order to have a neutral background of the knitting. For clearer results, fabrics should be measured also at a different fibre orientation. In case the sample cannot be measured, due to textile thinness, naked eye is used to estimate the approximate colours. Then, predefined dyes are chosen from a list (usually, 3 dyes per recipe) and the machine forms the recipe. Finally, auxiliaries are being chosen and the recipe is sent to the colour preparation machine. The recipe formulation process takes about 5 minutes, in case no problems or difficulties occur.

3. *Colour Preparation*

Due to the full automatization of that process, the time required is usually 25 to 30 minutes for the machine to prepare a dozen of recipes, consisted of 3 colours each. The colour dispensing machine replaces the dyeing solutions every 3 or 7 days, according to each specification. Usually, higher concentration solutions have a longer preservation time. Expiration dates are stored in the machine software, which informs the user accordingly.

4. *Bleaching and Washing of Samples*

About 98% of all fabrics dyed, requires bleaching, before they are forwarded to the dyeing process. After this process is completed, fabric is dried in the drying machine and put into storage, for future use. Sometimes, fabrics may not be white enough after bleaching, so the process must be repeated. The bleaching result is estimated mostly by naked eye. However, spectrophotometry could also be used for that reason, in order to estimate the level of whiteness achieved (for more "scientifically-specified" results). If the result is not satisfying enough, the fabric may be flawed, or the machine cannot implement well the bleaching substances used (failure of machine's water pump). As previously mentioned, this stage lasts about 110-120 minutes. In case the fabric is to be stored after this process, it is being dried for about 1-2 h, at a temperature that eliminates any remained moisture.

5. *Dyeing of Samples*

For successful dyeing, samples should be bleached enough. Staff should be careful enough, in order to weigh exactly the amount of auxiliaries needed. For the Ahiba dyeing machines, glass tubes may be prone to breaking, as they have accumulated salt residues; as a result, their replacement is suggested. For the polyester dyeing machine, samples should weigh no more than 5 gr, as the tubes are too narrow to successfully dye a 10gr sample (it can be folded inside the tubes). The same applies for the Hanau Linitest machines; the user should place the sample folded twice inside the tube and not simply drop it.

6. *Washing and Drying*

During the washing process, staff should be careful of each washing position to keep enough water inside, as due to wrong estimations and high washing temperatures, water may be depleted. In that case, fabric gets burnt. The same can happen during drying, as the process is not standardized (neither the drying temperature, nor the time needed). For better and quicker drying, only half of the drying apparatus capacity is being used. The latter could be avoided, by using another machine, with more standardized characteristics. For washing of samples, apart from the previously mentioned soaps, an “official detergent”, which does not contain over-bleachers, is also used when some testing is necessary to be done (e.g. in case of polyester fabrics, when another sample of fabric, with different fibre composition is attached to the main one, in order to estimate discolouring of the latter).

2. Classification of dyes

Nowadays, the most common dyes are being categorised in the following four groups:

1. *Disperse dyes (for polyester fibres):* colloidal dyes with low water solubility and affinity for one or more types of hydrophobic fibre (Shore, 1990, p. 20) . Usually, they are added in the form of (aqueous) dispersion in the dyeing bath. Dyeing of the fabric is accomplished through direct colloidal absorption or, sometimes, through dye sublimation from high temperatures. As a result, when the dye penetrates the fibre, it gets concentrated in a solid colloidal phase and gets absorbed by the latter.

2. *Reactive dyes (at 60°C or 80°C):* they form covalent bonds with the fibres' molecules that they colour and -thus- they constitute an integral part of the substrate after dyeing, by contributing to its uniformity and homogeneity. They have excellent shade reproducibility and great properties of dye spreading. They are characterized by excellent wet processing durability; however, they are priced higher than direct dyes.

3. *Direct dyes:* easy to apply dyes, with a wide colour spectrum at a relatively low cost. They are being categorized based on their needs in an electrolyte (e.g. salt), which is being added in the bath as an auxiliary material. They are unable of restraining the dye on the fibre substratum after washing, due to the rinsing of the contained salt in the bath, which gives stability. Nowadays, these dyes tend to be replaced by the reactive ones.

4. *Acid (or "Nylon") dyes (for polyamide fibres at 95°C):* in this type, chemical reactions take place during dyeing. As a result, an insoluble molecule of colorant is being created on the fabric. They are characterized of low colour fastness during wet processes (e.g. washing).

Below, a summary table (table 1) of dye classification is presented, along with the main characteristics of each category.

Table 1: Main dyes and their characteristics (Snowden-Swan, 1995)

CATEGORY		CHARACTERISTICS	SUITABLE FIBRE TYPE	DYE FASTENING (%)
1.	**Disperse**	• Insoluble in water • Low molecular weights	• Polyester • Cellulose acetate • Other synthetic fibres	80-92
2.	**Reactive**	• Water soluble • Creation of covalent bond with fibre	• Cotton • Cellulose substrates • Wool • Silk • Nylon	60-90
3.	**Direct**	• Water soluble • Low resistance in wet processing	• Cotton • Cellulose substrates • Wool • Silk	70-95
4.	**Acid**	• Water soluble	• Wool • Nylon • Silk	80-93

In our case, we categorize the different dyes used as:

a. *R60*: “Remazol” * reactive dye at 60°C
b. *R80*: “Remazol” * reactive dye at 80°C
c. *P80*: “Procion” * reactive dye at 80°C
d. *130*: disperse dye at 130°C
e. *NYL*: acid dye at 95°C

(*“Remazol” and “Procion” are commercial dye names of DyStar Group)

3. Classification of fabric composition

The production process followed in the textile industry, and -particularly- in the dyeing and finishing industry, depends on both the type of raw material and the desired final characteristics of the fabric.

Processed fabrics consist of various raw materials, which may be natural, synthetic or blended. Accordingly, fabrics are characterized as natural, synthetic or mixed.

Natural raw materials are either of vegetable or animal origin and the products received are separated into cellulose and protein, respectively. Raw materials of vegetable origin usually include cotton and linen, while wool, silk, cashmere and others are of animal origin.

Synthetic raw materials include acrylic, polyester, nylon (the first fibre synthesized entirely from petrochemicals, introduced by DuPont Company in 1936) and other. Mixed fabrics come from blends of natural and/or synthetic materials. Indicatively, those fabrics may include polyester/cotton (PES/BW), polyester/linen (PES / LINEN), cotton/viscose (BW/VISC) etc. The fabric composition may vary, from 100% pure raw material up to all kinds of raw material ratios for mixed fabrics. Synthetic fibers are combined together with natural ones, in order to produce textiles with mixed properties, the best from both categories. For example, cotton-polyester blends are stronger than pure cotton ones, wrinkle- and tear-resistant, with reduced shrinking and drying time. The composition of the fabric and the final desired result determine which dyeing and finishing methodology should be followed each time.

In our case, the different fabric compositions used are categorized as following, into five groups, which -in our opinion- represent the main compositions used nowadays:

a. *BW*: cotton fabrics, plain or organic, with a percentage of Lycra contained from 0% up to 10%.
b. *VISC*: viscose fabrics, with a percentage of Lycra contained from 0% up to 10%.
c. *PES*: polyester fabrics, with a percentage of Lycra contained from 0% up to 10%.
d. *NYL*: nylon fabrics, with a percentage of Lycra contained from 0% up to 10%.

e. *OTHER*: mixed fabrics, either natural or synthetic, from natural or synthetic blends. Additionally, fabrics from the above described categories, with more than 10% content in Lycra, are included. Fabrics made from natural raw materials, apart from cotton, are also included in this category (e.g. wool or linen), due to their low incidence in dyeing recipes.

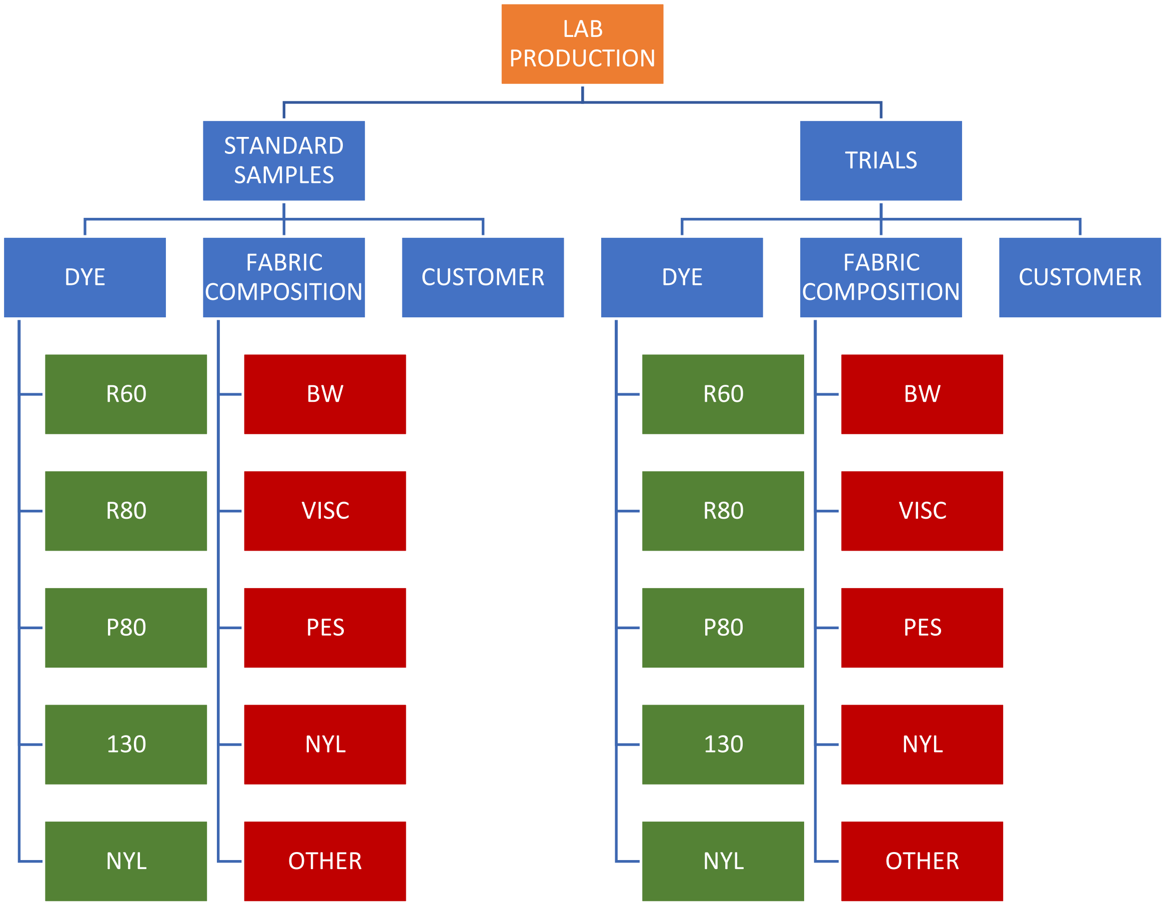
The following table (table 2) summarizes the various compositions indicated on the recipes into the previously described five groups.

Table 2: Main fabric compositions

CATEGORY		COMPOSITIONS INCLUDED
1.	**BW**	100% BW, BW/L (up to 10% Lycra), 100% organic BW
2.	**VISC**	100% VISCOSE, VISC/L (up to 10% Lycra), 100% MODAL, MMD (micromodal)/L, RAYON, TENCEL, LYOCELL
3.	**PES**	100% PES, PES/L (up to 10% Lycra)
4.	**NYL**	100% TACTEL, TACTEL/L (up to 10% Lycra), POLYAMIDE, MERYL
5.	**OTHER**	*(numbers inside parentheses refer to percentages of each composition)* PES/BW (65/35), BW/PES (65/35), MODAL/WOOL (80/20), PES/VISC (65/35), BW/MOD (50/50),100% LINEN, MODAL/BW (60/40), 100% WOOL, BW/MOD/L (47/47/6), BW/CASHMERE (85/15), VISC/WOOL, VISC/LINEN, BW/VISC, VISC/PES, BW/NYL, PES/NYL etc.

4. Synopsis of the analysis performed

To sum up, below is a graph (graph 1) of the analysis of extracted data, which will be furtherly accomplished, considering the samples (standard & trials) produced in the laboratory on daily, monthly and annually basis:



Graph 1: Organised data for analysis

5. Breakdowns/Failures

In calculating Overall Equipment Effectiveness (OEE) ratio and -specifically- its "Availability" component, we should take into consideration the Time to Repair (TTR) ratio, which refers to the elapsed time from the moment that production stopped, due to a failure, until the moment the production process started again and includes the time for necessary repairs to be accomplished. The laboratory operates daily during weekdays, from 6 AM to 6 PM. So, the necessary calculations are made to the assumption that the daily operation/production hours are 12, or 12*60=720 minutes. Based on previous calculations by experienced staff members, we consider the production of 120 samples in an 8-hour-shift, or equally, in 8*60=480 minutes, as "ideal".

The failures occurred during the period that is being examined (October 2018-October 2019), in terms of each piece of machinery/equipment, are the following:

1. Original Hanau Linitest dyeing machine: malfunction of electric switch for cooling water, unable to raise temperature, switch replaced (6 hours or 360 minutes delay), 6th of February 2019
2. Datacolor Ahiba: same as above (2 hours or 120 minutes delay), 20th of February 2019
3. Ugolini Mini Jet Flow: non-functional water outflow, in-lab repair (2 hours or 120 minutes delay), 12th of April 2019
4. Tecnorama Dosorama colour dispensing machine: no preparation of programmed dyeing recipes due to sensor malfunction, sensor replaced (1-hour delay for each manual preparation * approximately 10 times = approximately 10 hours or 600 minutes delay), 20th of May 2019
5. Datacolor Ahiba: motor speed reducer failure, sent for repair (36 hours (3days*12 hours) or 3*720 minutes delay), 27th, 28th and 29th of May 2019
6. Datacolor Ahiba: failure of one out of two electrical resistances, replaced both (12 hours or 720 minutes delay), 18th of June 2019
7. Datacolor Ahiba (II): motor speed reducer failure, replaced the same day (3 hours or 180 minutes delay) 26th of September 2019

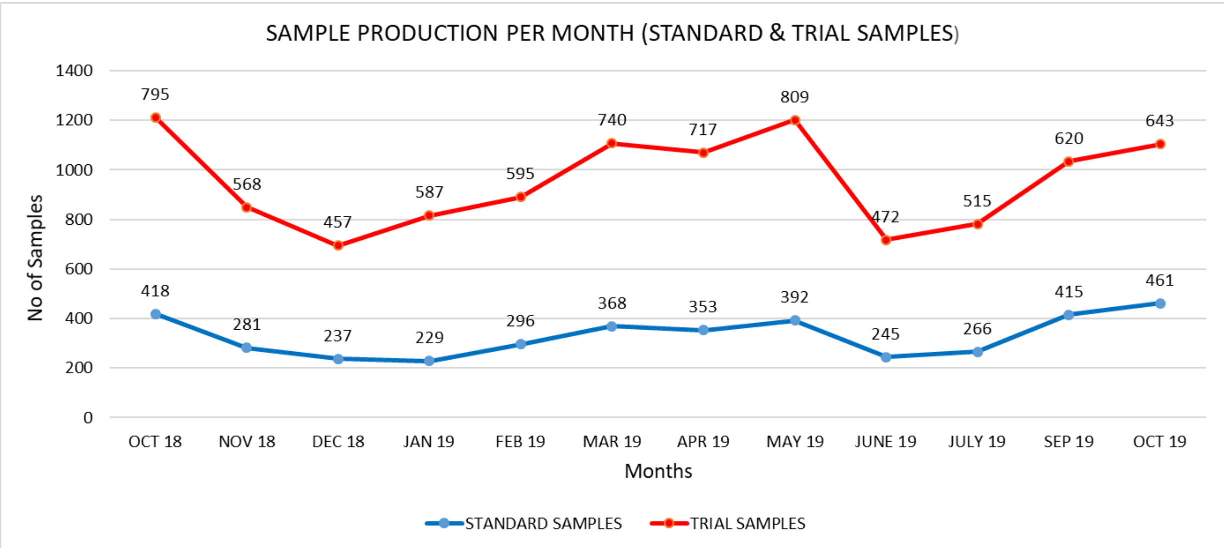
6. Results

6.1 Sample production per month (standard samples, trial samples)

Beginning with the monthly results for standard and trial sample production (table 3), we observe that the vast number of standard samples was produced in October 2019 and of trials in May 2019. Oppositely, the least standard samples were produced in January 2019 and the least trials in December 2018. In graph 2, the number of samples is presented as a timeline.

Table 3: Sample production per month

	OCT 2018	NOV 2018	DEC 2018	JAN 2019	FEB 2019	MAR 2019	APR 2019	MAY 2019	JUN 2019	JUL 2019	SEP 2019	OCT 2019
STANDARD SAMPLES	418	281	237	229	296	368	353	392	245	266	415	461
TRIAL SAMPLES	795	568	457	587	595	740	717	809	472	515	620	643

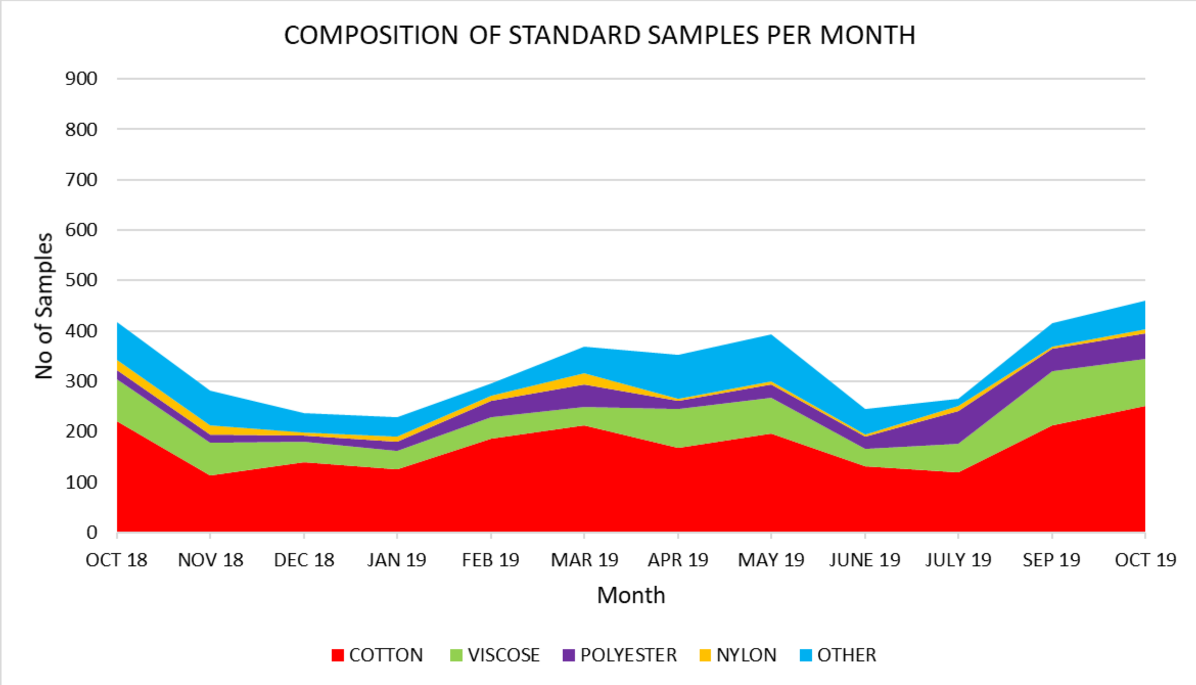


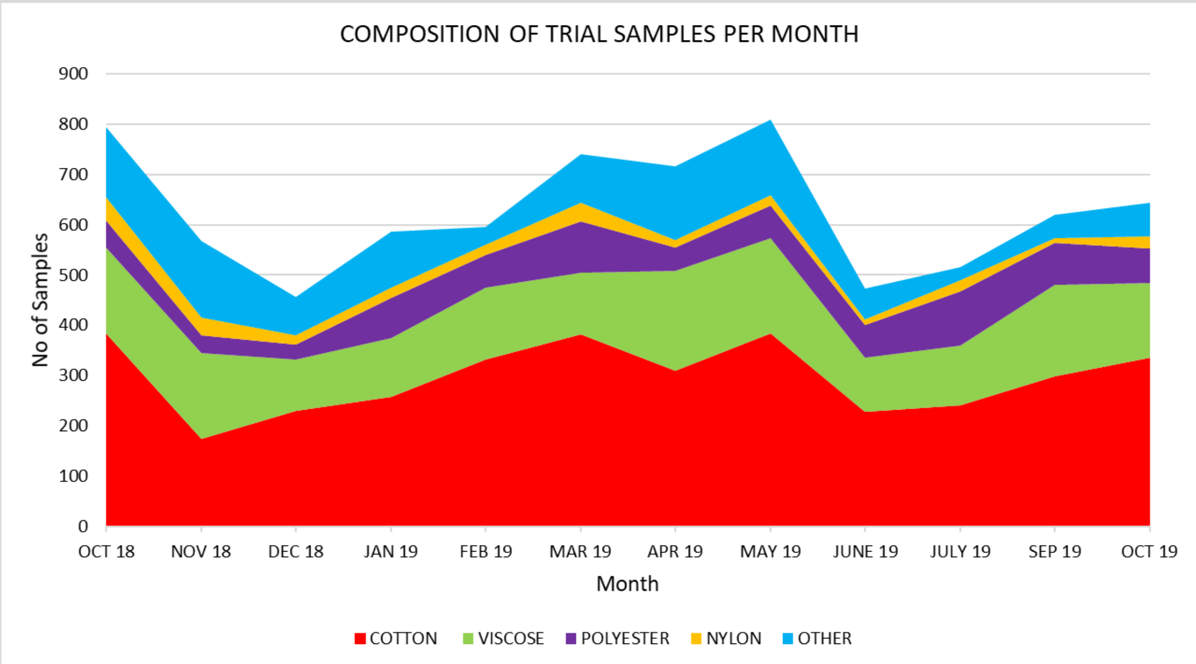
Graph 2: Sample production per month

In the following table (table 4), the monthly number of standard and trial samples is presented, as of their composition and the type of dye used. Pink cells in the table represent the minimum value in each row, whereas green cells indicate the maximum. The table is accompanied by area graphs 3 and 4, which show us the development of the dominant compositions and dyes in time (months).

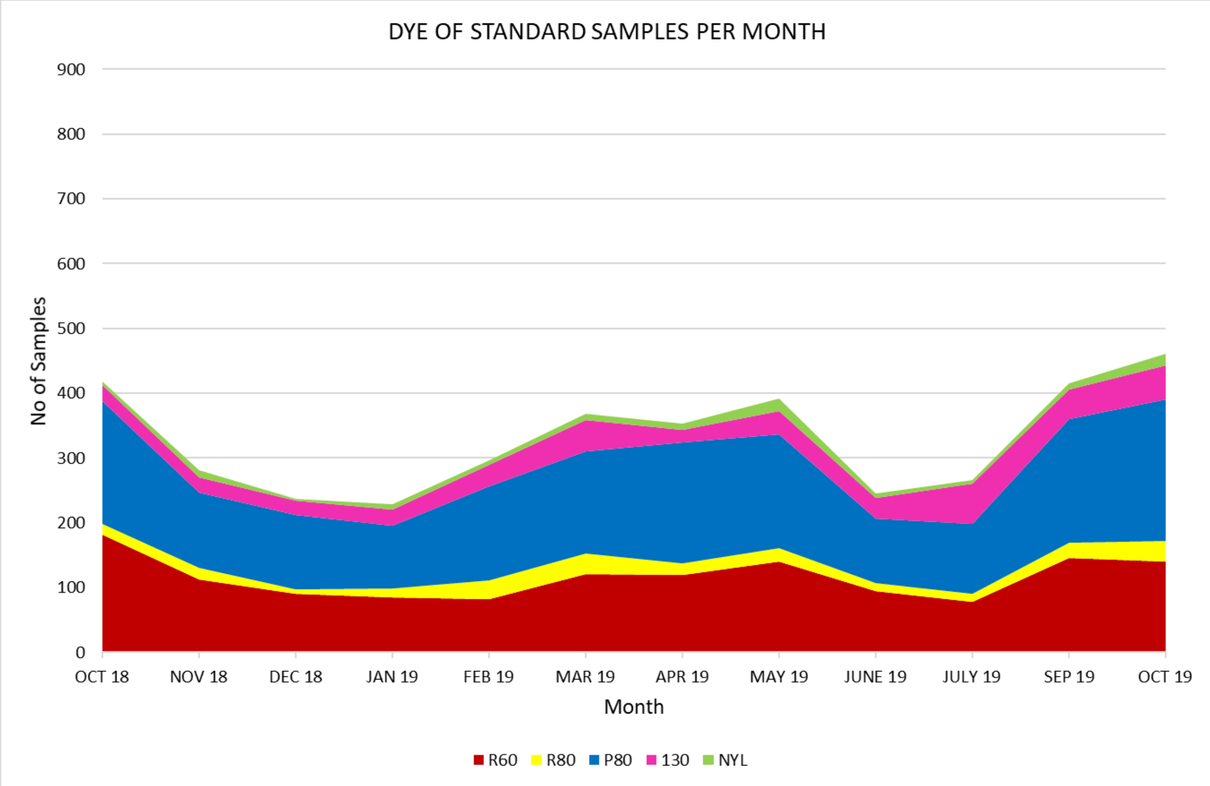
Table 4: Composition and dyes used for per month sample production

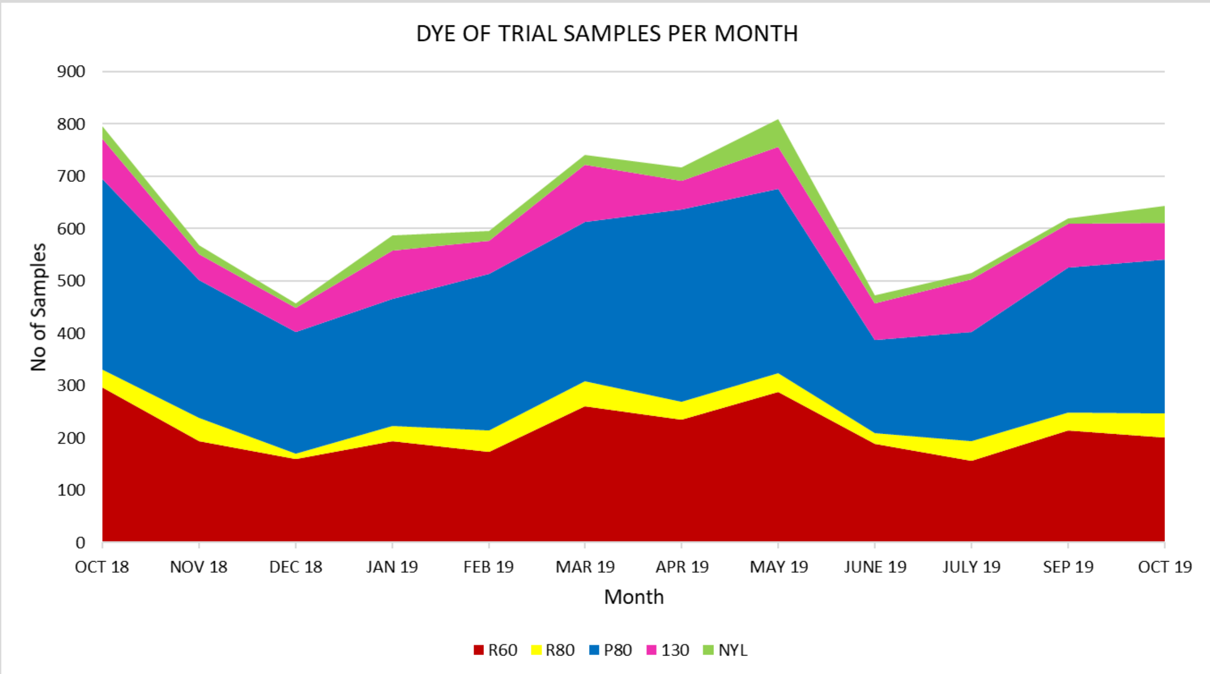
			OCT 2018	NOV 2018	DEC 2018	JAN 2019	FEB 2019	MAR 2019	APR 2019	MAY 2019	JUN 2019	JUL 2019	SEP 2019	OCT 2019
STANDARD SAMPLES	COMPOSITION	COTTON	221	113	139	126	185	213	167	196	131	118	213	250
		VISCOSE	82	65	41	35	44	36	77	72	34	58	106	95
		POLYESTER	19	16	12	19	32	44	17	25	25	64	45	51
		NYLON	20	18	7	11	11	23	5	6	4	10	5	7
		OTHER	76	69	38	38	24	52	87	93	51	16	46	58
	DYE	R60	182	112	90	85	82	121	119	140	94	78	146	140
		R80	16	19	7	14	29	31	19	21	13	12	23	32
		P80	189	115	115	97	146	158	186	175	99	108	191	218
		130	25	24	22	24	32	49	20	36	33	63	46	53
		NYL	6	11	3	9	7	9	9	20	6	5	9	18
TRIAL SAMPLES	COMPOSITION	COTTON	383	174	230	257	332	382	310	383	227	240	298	335
		VISCOSE	171	171	101	117	143	122	198	190	109	120	182	149
		POLYESTER	54	35	31	80	64	102	47	66	64	107	83	69
		NYLON	46	36	18	21	21	38	15	20	12	23	11	24
		OTHER	141	152	77	112	35	96	147	150	60	25	46	66
	DYE	R60	297	193	160	193	174	261	234	287	188	156	214	297
		R80	34	46	10	29	40	47	35	36	21	37	34	34
		P80	364	262	232	244	299	304	368	352	178	209	277	364
		130	77	50	46	92	64	110	55	82	70	102	84	77
		NYL	23	17	9	29	18	18	25	52	15	11	11	23





Graph 3: Composition of standard and trial samples per month





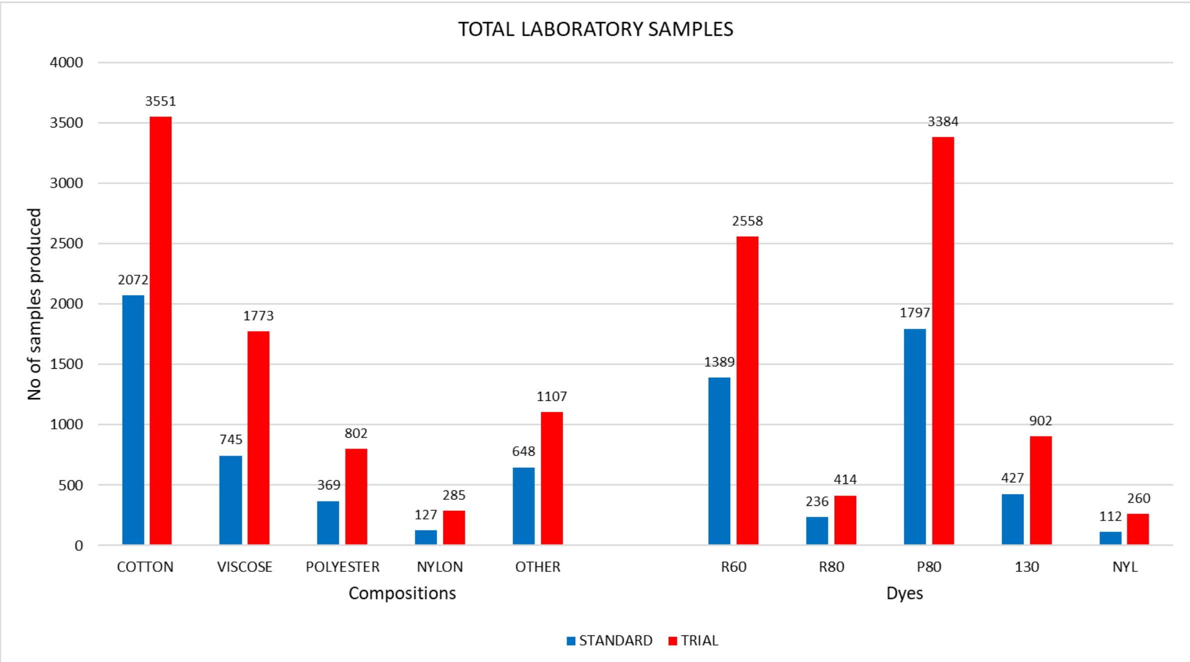
Graph 4: Dye of standard and trial samples per month

6.2 Total sample production (standard samples, trial samples)

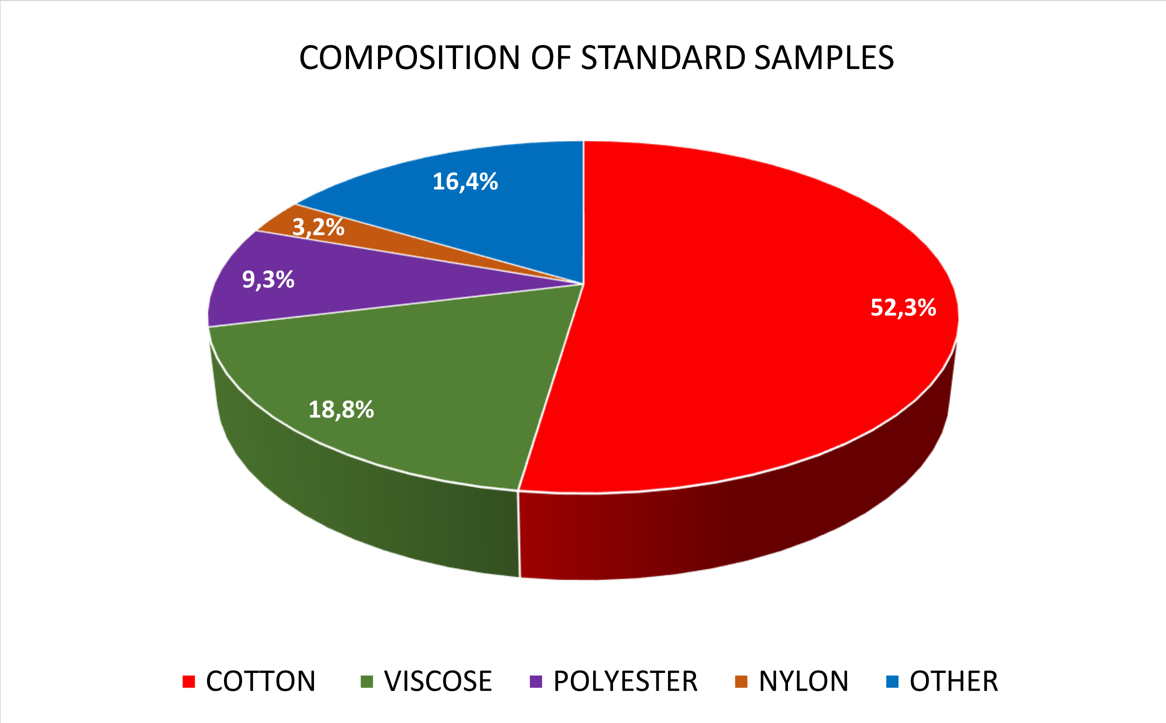
At this stage, the total sample production of the laboratory is going to be examined. As it can be easily observed in table 5, most of the samples (over 50% of total standards and approximately 50% of total trials) were made from cotton and the least were nylon ones. As far as the dye is concerned, “nylon” acid dye was the rarest, whereas “Procion” reactive dye (80°C) was the most commonly used. In graph 5, the above results are presented in the form of bars and in graphs 6 and 7, in the form of a pie.

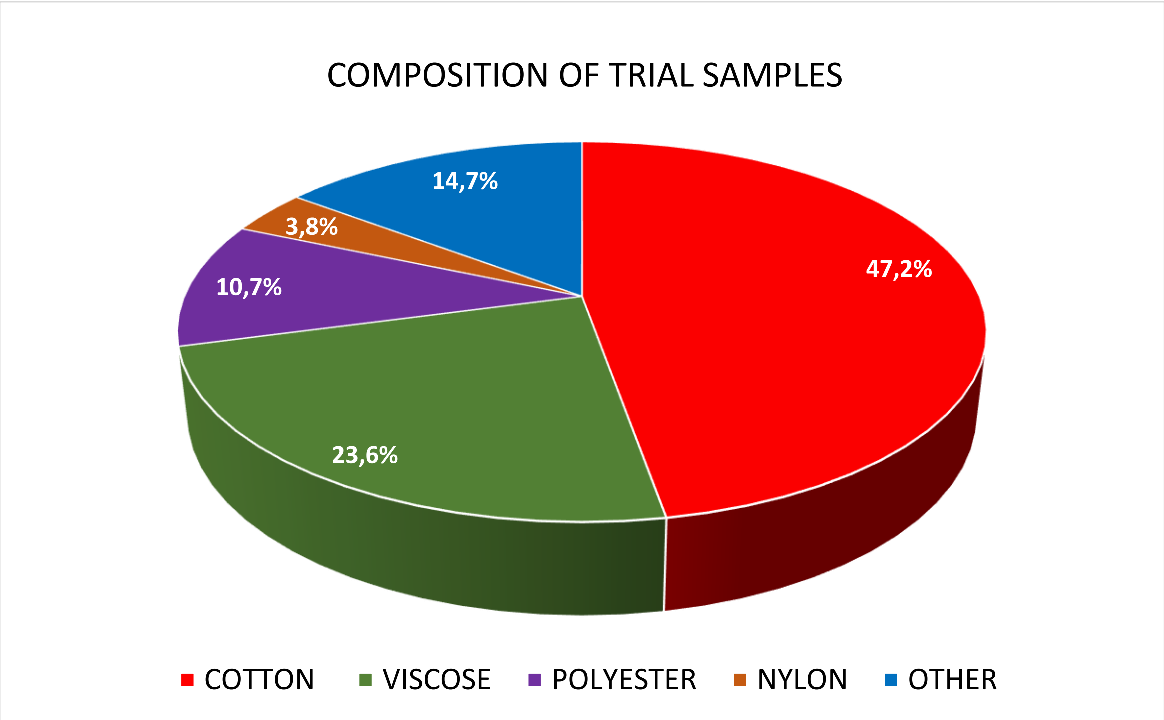
Table 5: Compositions and dyes used for total sample production

		STANDARD SAMPLES	% OF STANDARD	TRIAL SAMPLES	% OF TRIAL
COMPOSITION	COTTON	2072	52,31	3551	47,23
	VISCOSE	745	18,81	1773	23,58
	POLYESTER	369	9,32	802	10,67
	NYLON	127	3,21	285	3,79
	OTHER	648	16,36	1107	14,72
DYE	R60	1389	35,07	2558	34,03
	R80	236	5,96	414	5,51
	P80	1797	45,37	3384	45,01
	130	427	10,78	902	12,00
	NYL	112	2,83	260	3,46

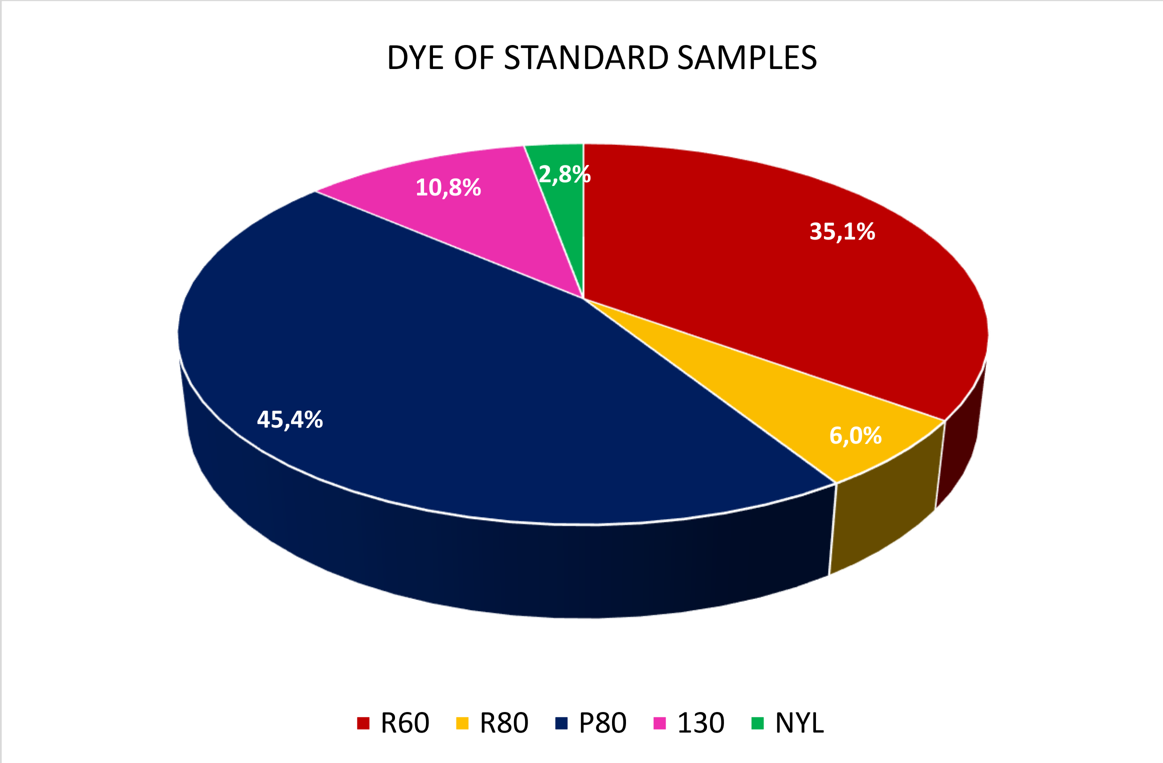


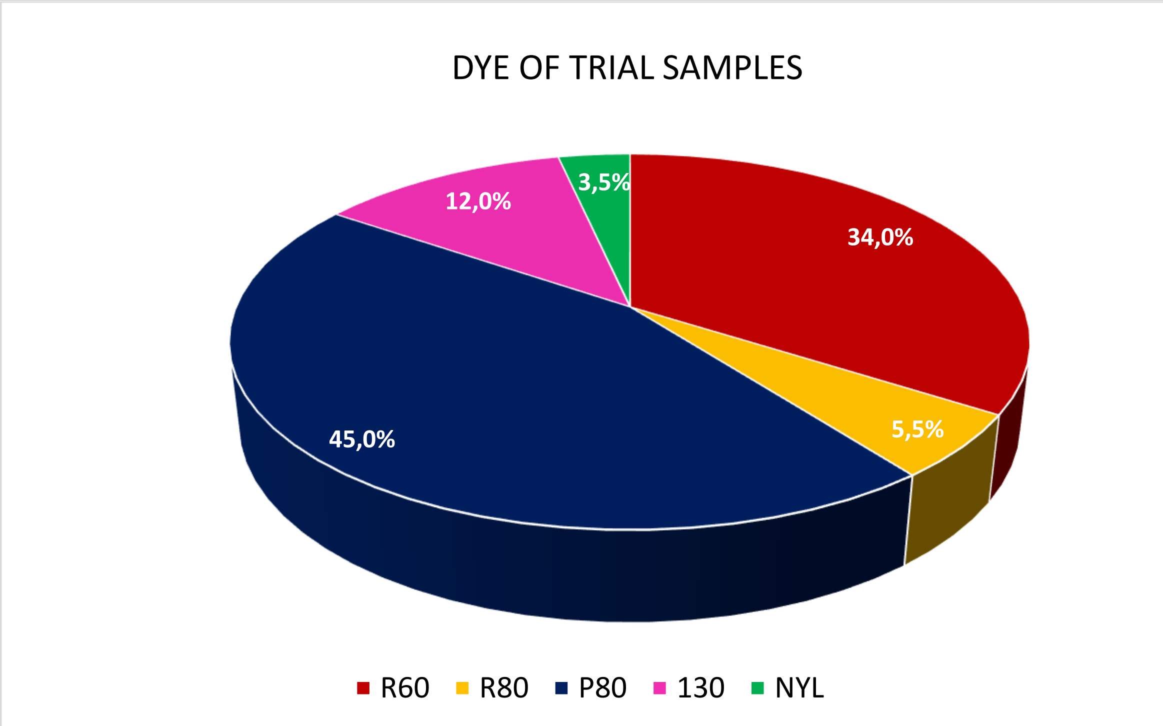
Graph 5: Total laboratory production per composition and dye used





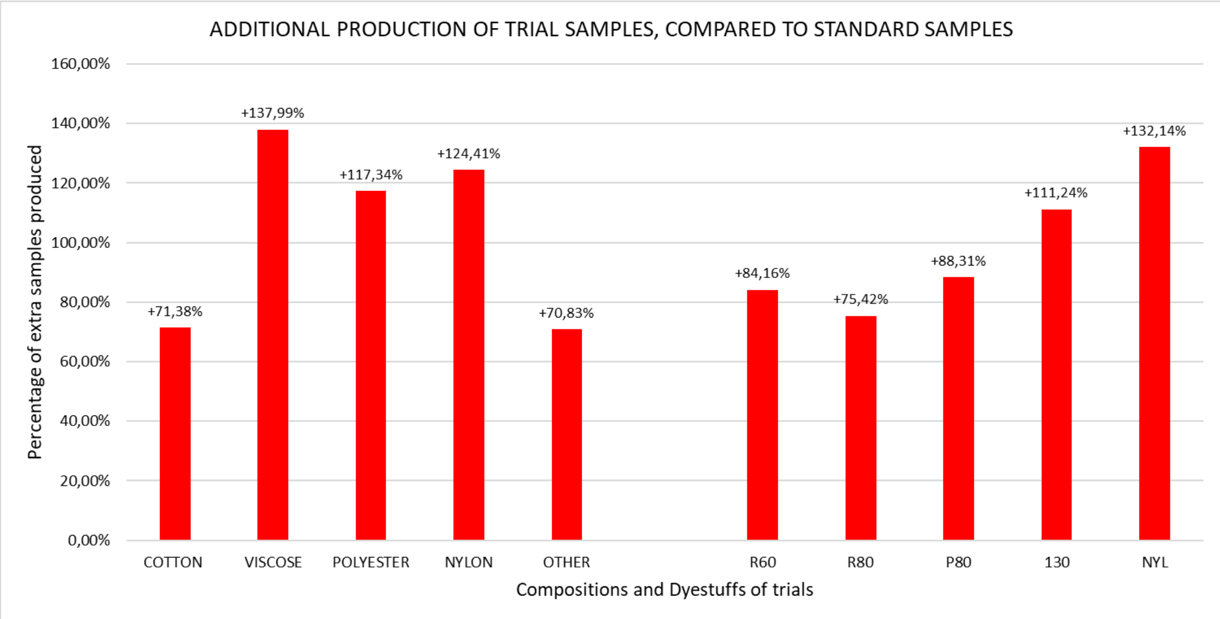
Graph 6: Composition of standard and trial samples





Graph 7: Dye of standard and trial samples

In the following graph (graph 8), the additional production for the trials, compared to the standards, is presented. For example, in order to produce 100 standard cotton samples, we needed to produce 171 trial ones (≈+71% over the standard samples, as shown on the graph). With this, we can conclude about the most "problematic" composition, which is viscose (+138%), thus having the largest number of trials, compared to standard ones and the hardest-to-achieve dyeing procedure, which occurs with nylon dyes (+132%). High absorbance of viscose, compared to other compositions such as cotton, is the reason for the difficult-to-achieve result and the large amount of trials needed. The same applies with nylon dyes, as nylon has a lot of types (polyamide, tactel, meryl), each with different colour absorbances.

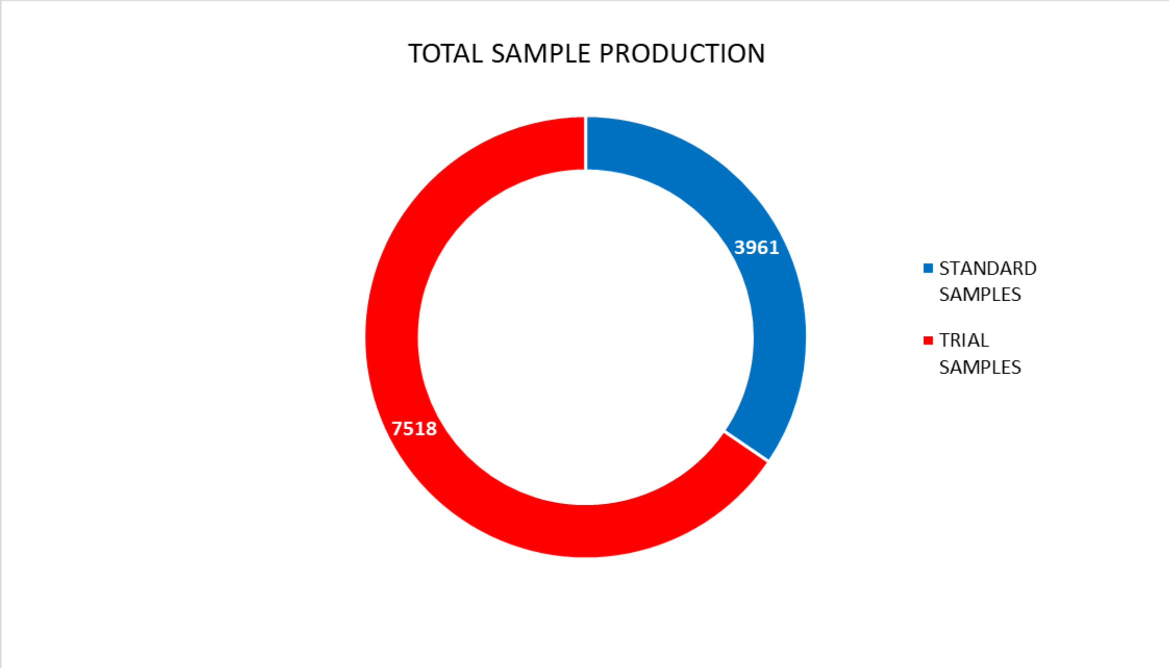


Graph 8: Additional production of trial samples

Total sample production, for the period under scrutiny was determined in 11479 units, divided into 7518 trial samples and 3961 standard ones (table 6 and graph 9). As a result, we can conclude that the average laboratory's outcome is approximately "one out of three" good samples. This, however, may have fluctuations, when fabric composition and dyestuff used are considered.

Table 6: Total sample production

TYPE OF SAMPLE	UNITS
STANDARD SAMPLES	3961
TRIAL SAMPLES	7518
TOTAL SAMPLES	11479

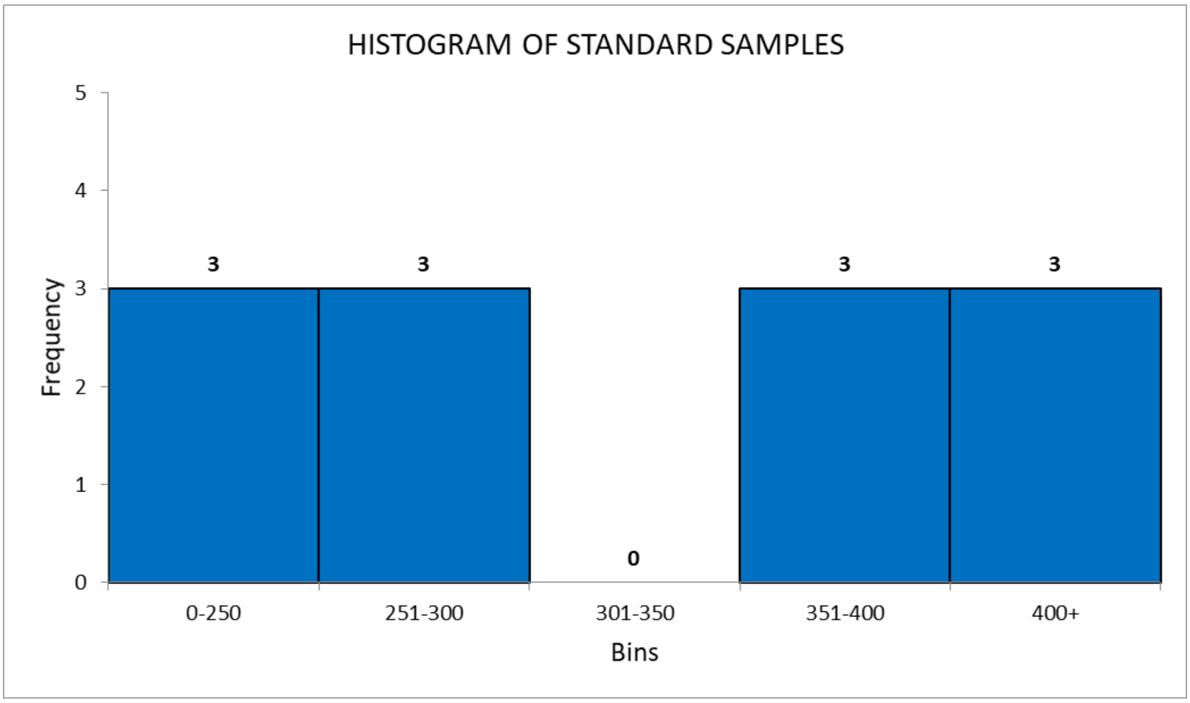


Graph 9: Total sample production

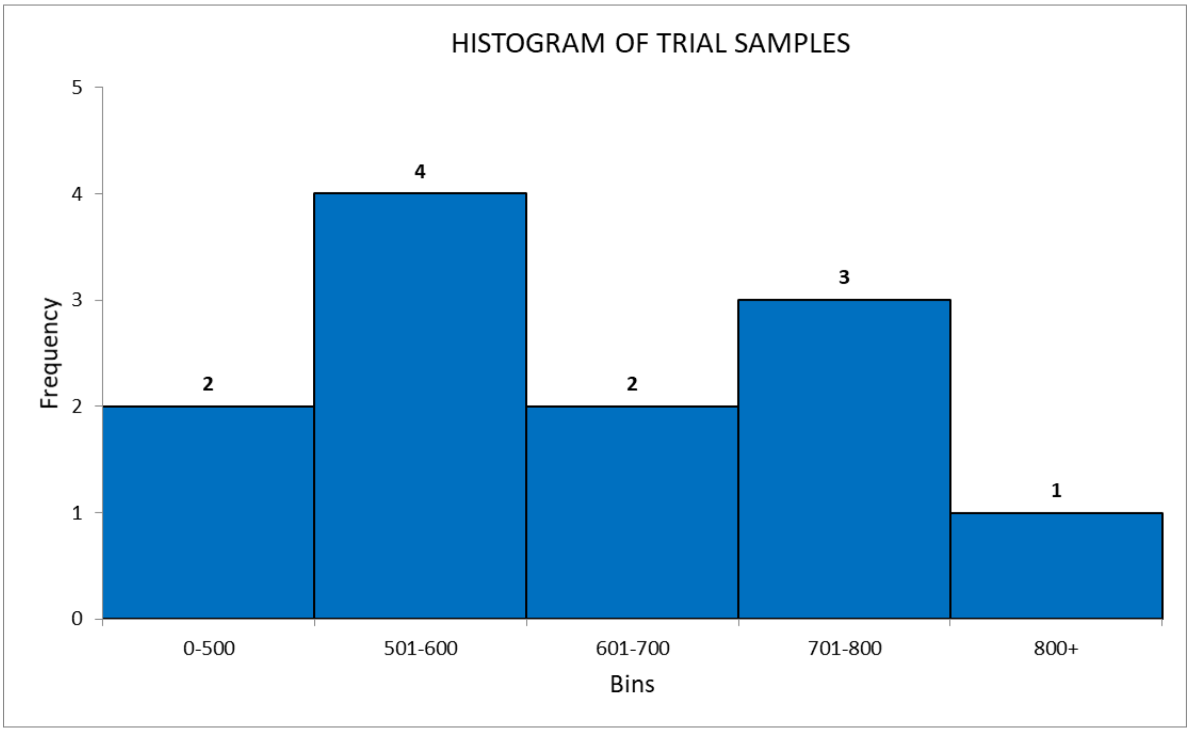
The following histograms (graphs 10 & 11), as well as table 7 indicating the bins estimated for the histograms, prove that most of the months had a production of trial samples from 501 to 600 units. For the standard samples, no such conclusion can be extracted.

Table 7: Bins of histograms

STANDARD SAMPLES		***TRIAL SAMPLES***	
BINS	**FREQUENCY**	**BINS**	**FREQUENCY**
0-250	3	**0-500**	2
251-300	3	**501-600**	4
301-350	0	**601-700**	2
351-400	3	**701-800**	3
400+	3	**800+**	1



Graph 10: Histogram of standard samples

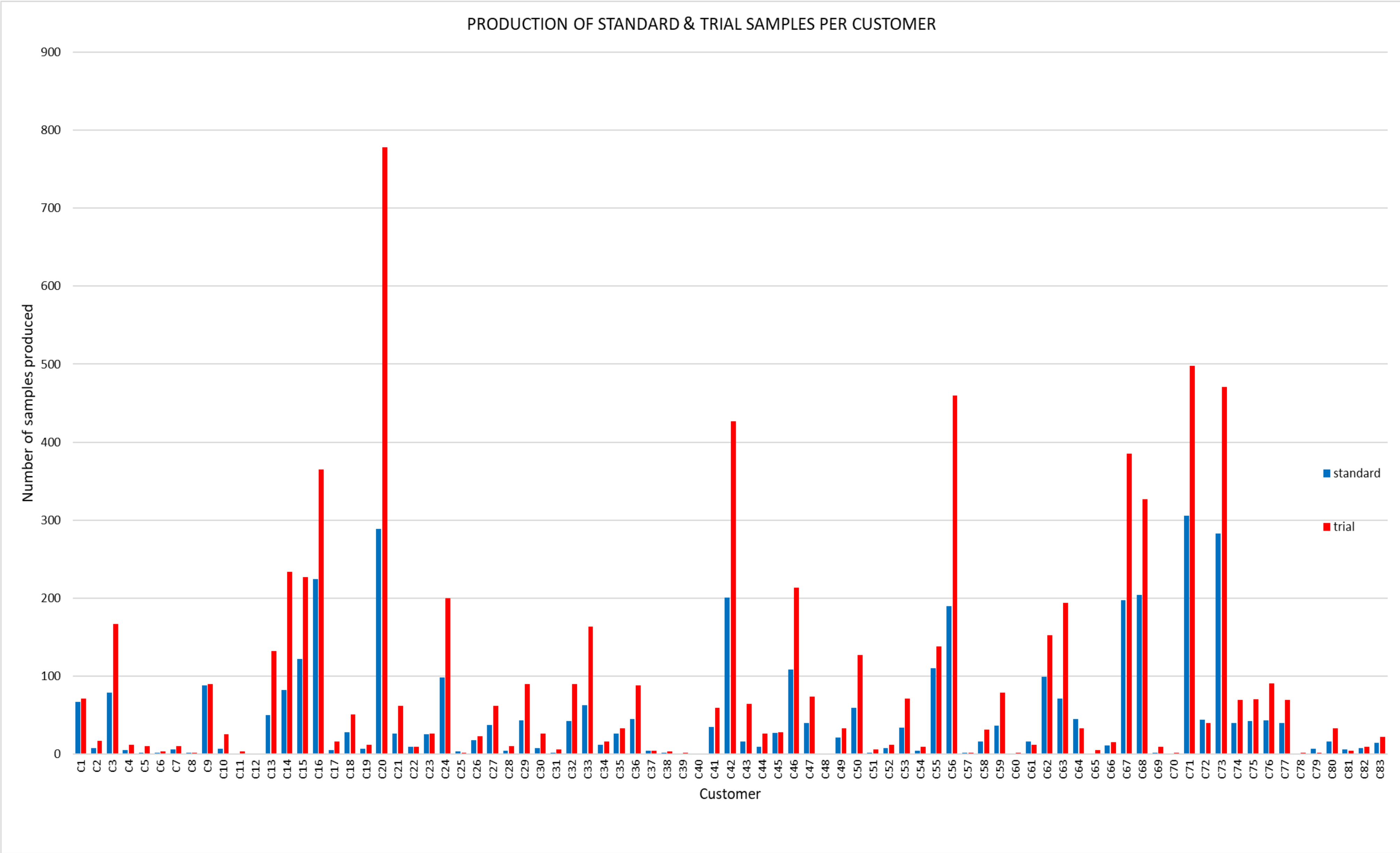


Graph 11: Histogram of trial samples

6.3 Sample production per customer

Apart from the number and type of samples produced, it its vital for the company to determine the "best" customers, in terms of volume. In the following graph (graph

12) and table 8, the total production per customer, for the period of October 2018-October 2019, is presented. Please note that for ethical reasons, the customers' names have been replaced by a number for each one (the original names will be provided to the company).



PRODUCTION OF STANDARD & TRIAL SAMPLES PER CUSTOMER
Number of samples produced
0
100
200
300
400
500
600
700
800
900
Customer
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21 C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36 C37 C38 C39 C40 C41 C42 C43 C44 C45 C46 C47 C48 C49 C50 C51 C52 C53 C54 C55 C56 C57 C58 C59 C60 C61 C62 C63 C64 C65 C66 C67 C68 C69 C70 C71 C72 C73 C74 C75 C76 C77 C78 C79 C80 C81 C82 C83
standard
trial

Table 8: Sample production per customer

CUSTOMER	STANDARD SAMPLES	TRIAL SAMPLES	TRIAL/STANDARD RATIO
C1	67	71	1,06
C2	8	17	2,13
C3	79	167	2,11
C4	5	12	2,40
C5	2	10	5,00
C6	2	3	1,50
C7	6	10	1,67
C8	2	2	1,00
C9	88	90	1,02
C10	7	25	3,57
C11	1	3	3,00
C12	1	1	1,00
C13	50	132	2,64
C14	82	234	2,85
C15	122	227	1,86
C16	224	365	1,63
C17	5	16	3,20
C18	28	51	1,82
C19	7	12	1,71
C20	289	778	2,69
C21	26	62	2,38
C22	9	9	1,00
C23	25	26	1,04
C24	98	200	2,04
C25	3	2	0,67
C26	18	23	1,28
C27	37	62	1,68
C28	4	10	2,50
C29	43	90	2,09
C30	8	26	3,25
C31	2	6	3,00
C32	42	90	2,14
C33	63	163	2,59
C34	12	16	1,33
C35	26	33	1,27
C36	45	88	1,96
C37	4	4	1,00
C38	2	3	1,50
C39	1	2	2,00
C40	1	1	1,00
C41	35	59	1,69
C42	201	427	2,12

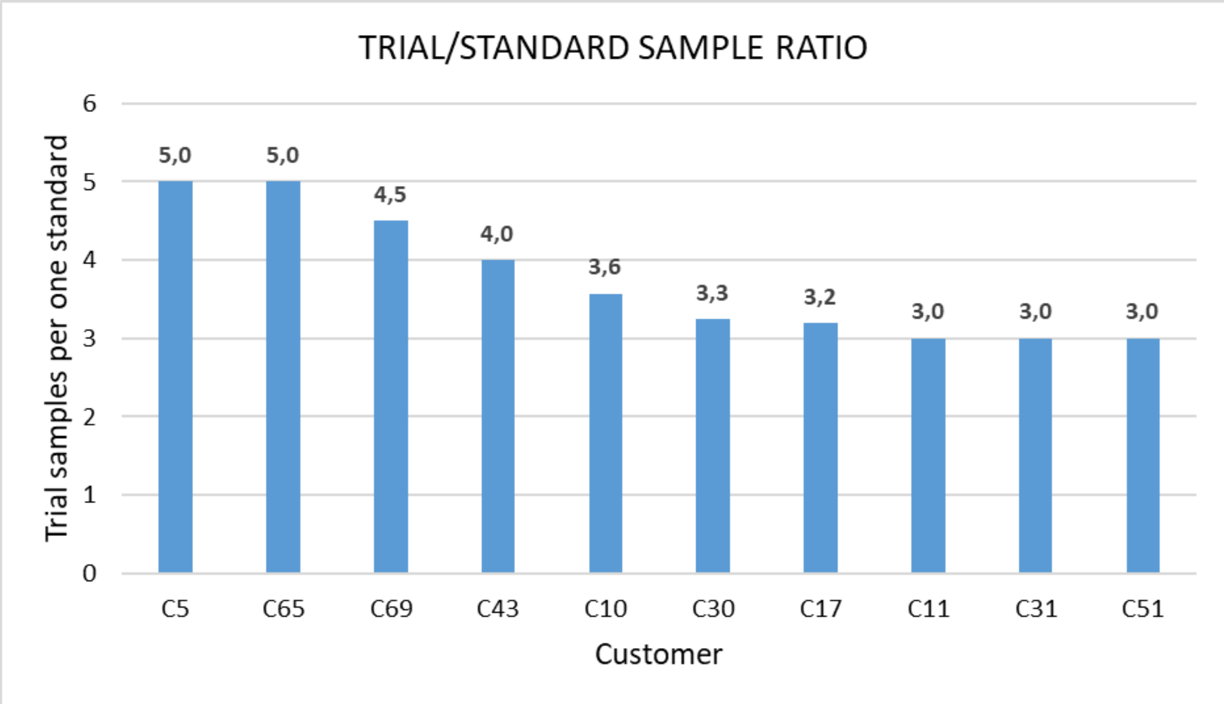
CUSTOMER	STANDARD SAMPLES	TRIAL SAMPLES	TRIAL/STANDARD RATIO
C43	16	64	4,00
C44	9	26	2,89
C45	27	28	1,04
C46	108	213	1,97
C47	40	74	1,85
C48	1	1	1,00
C49	21	33	1,57
C50	59	127	2,15
C51	2	6	3,00
C52	8	12	1,50
C53	34	71	2,09
C54	4	9	2,25
C55	110	138	1,25
C56	190	460	2,42
C57	2	2	1,00
C58	16	31	1,94
C59	36	79	2,19
C60	1	2	2,00
C61	16	12	0,75
C62	99	152	1,54
C63	71	194	2,73
C64	45	33	0,73
C65	1	5	5,00
C66	11	15	1,36
C67	197	385	1,95
C68	204	327	1,60
C69	2	9	4,50
C70	1	2	2,00
C71	306	498	1,63
C72	44	40	0,91
C73	283	471	1,66
C74	40	69	1,73
C75	42	70	1,67
C76	43	91	2,12
C77	40	69	1,73
C78	1	2	2,00
C79	7	2	0,29
C80	16	33	2,06
C81	6	4	0,67
C82	8	9	1,13
C83	14	22	1,57

However, one aspect that should also be observed is the ratio of trial to standard samples, for each customer. The higher the ratio, the more difficult to produce the desired samples. This is a sign for the company to concentrate more on that customers and further search for the reasons of that difficulty. For example, samples of a customer may be of a specific composition or require a specific dyeing. If those requests are low in number during the year, in limited quantity or the customer does not forward their samples into production in the company, it may be unprofitable or financially detrimental for the company to produce a lot of trials for a small amount of standard samples, especially if even less samples are forwarded into actual production.

In the following table 9 and graph 13, a list of 10 customers with the highest trial/standard samples ratio is presented (=how much trial samples per standard one we need to produce).

Table 9: Customers with the highest trial/standard sample ratio

CUSTOMER	STANDARD SAMPLES	TRIAL SAMPLES	TRIAL/STD RATIO
C5	2	10	5
C65	1	5	5
C69	2	9	4.5
C43	16	64	4
C10	7	25	3.6
C30	8	26	3.3
C17	5	16	3.2
C11	1	3	3
C31	2	6	3
C51	2	6	3



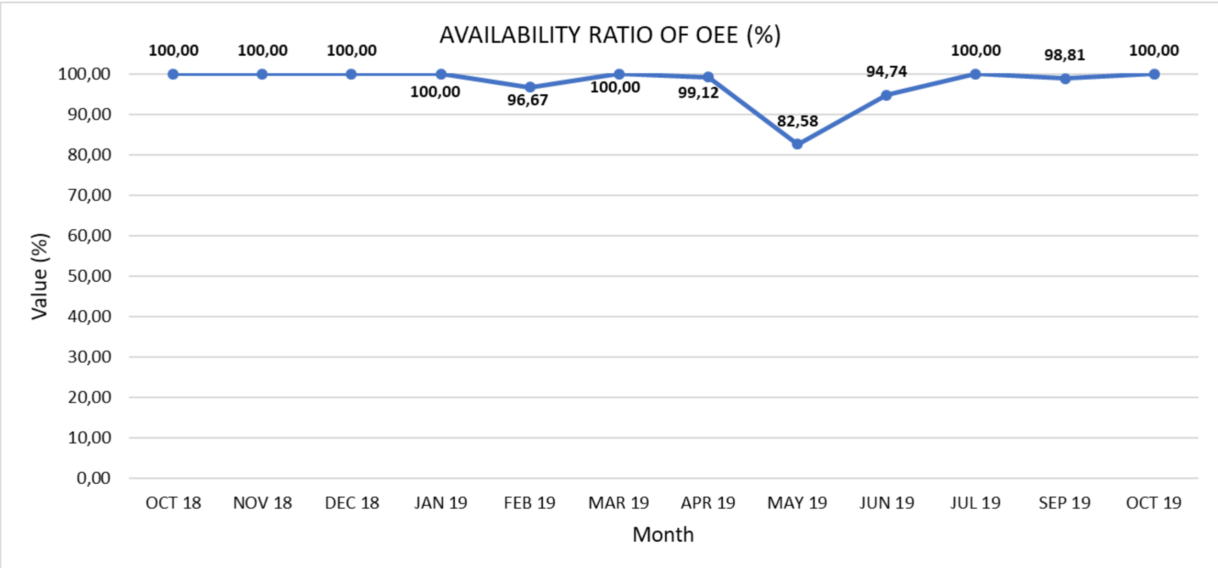
Graph 13: Customers with the highest trial/standard sample ratio

6.4 Overall equipment effectiveness (OEE) & components

The last category of calculations includes those of the OEE ratio and its components, availability, performance and quality. Values of each were calculated in spreadsheets, formulas for the OEE components are given in the appendix. In the following table (table 10), monthly results of the aforementioned elements are given. Green-coloured cells represent the highest value, whereas pink-coloured cells lowest value. Then, timeline graphs are also presented, in order for the evolution of OEE and its components to be observed through time (graphs 14-17).

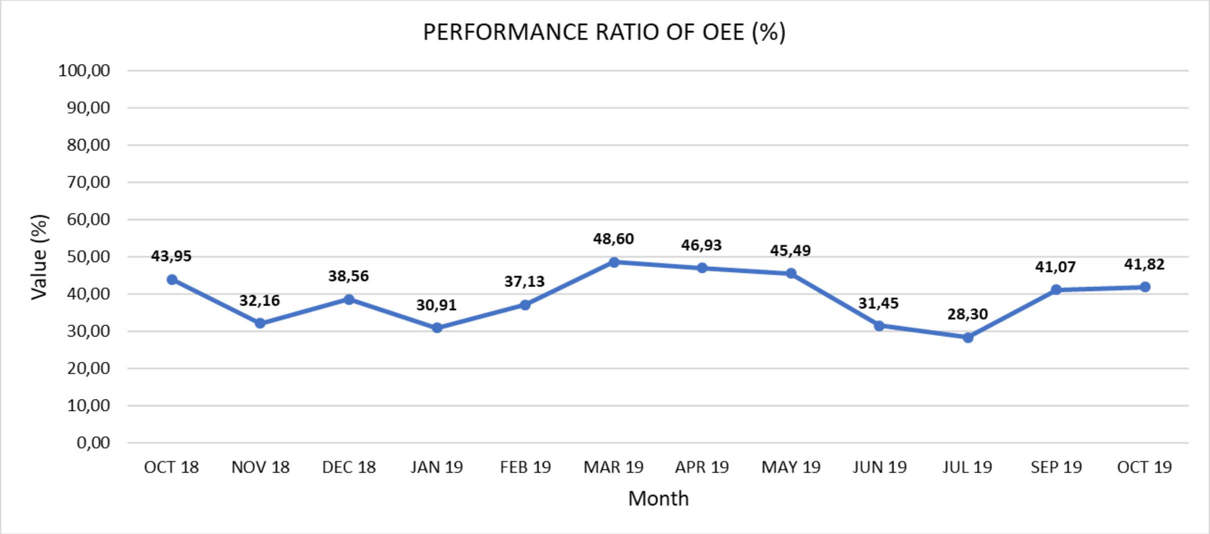
Table 10: OEE & components (monthly calculation)

MONTH	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
OCT 18	100,00	43,95	35,10	15,14
NOV 18	100,00	32,16	33,34	10,64
DEC 18	100,00	38,56	34,22	13,17
JAN 19	100,00	30,91	27,72	8,67
FEB 19	96,67	37,13	33,99	11,75
MAR 19	100,00	48,60	33,11	16,14
APR 19	99,12	46,93	36,90	15,31
MAY 19	82,58	45,49	32,43	11,90
JUN 19	94,74	31,45	35,11	10,00
JUL 19	100,00	28,30	34,92	9,64
SEP 19	98,81	41,07	41,46	16,28
OCT 19	100,00	41,82	43,90	17,46



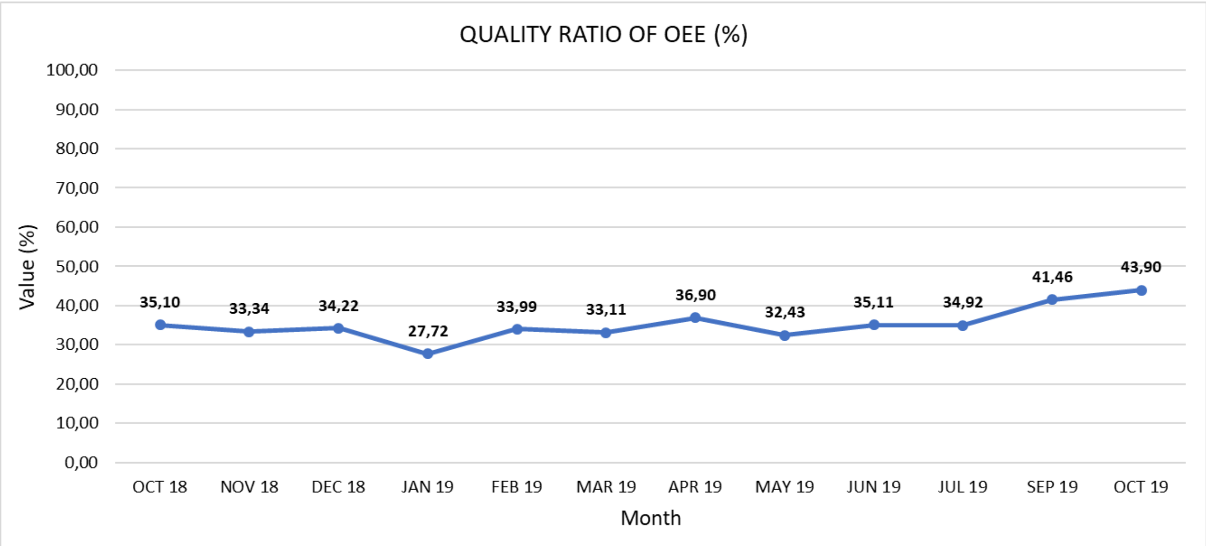
Graph 14: Availability ratio (monthly calculation)

Availability of the laboratory, which mainly relies on the machinery, has minor fluctuations, due to the relatively low frequency of machinery failures and breakdowns. On average, availability has a score of 98%, well above the world standard of ≥90%.



Graph 15: Performance ratio (monthly calculation)

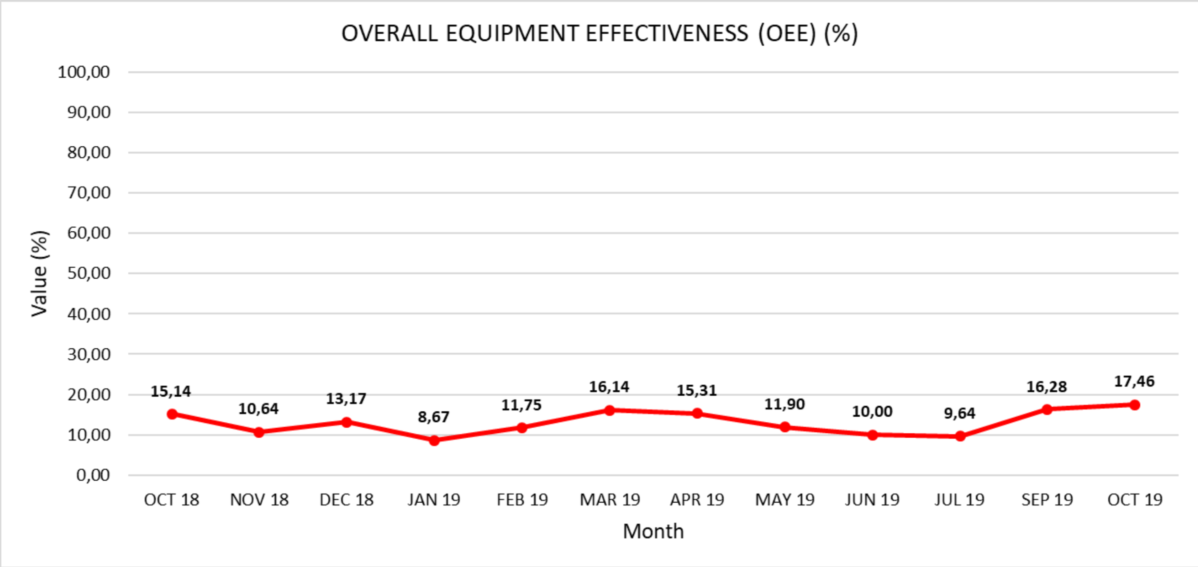
As far as performance is considered, monthly results, as well as the average value for the whole examination period (39%) are well below the world standard of 95% and can attributed to the low number of samples created, during the 720 minutes of daily laboratory operation. (Previous research defined an “ideal” lab production of 120 samples in 720 minutes).



Graph 16: Quality Ratio (monthly calculation)

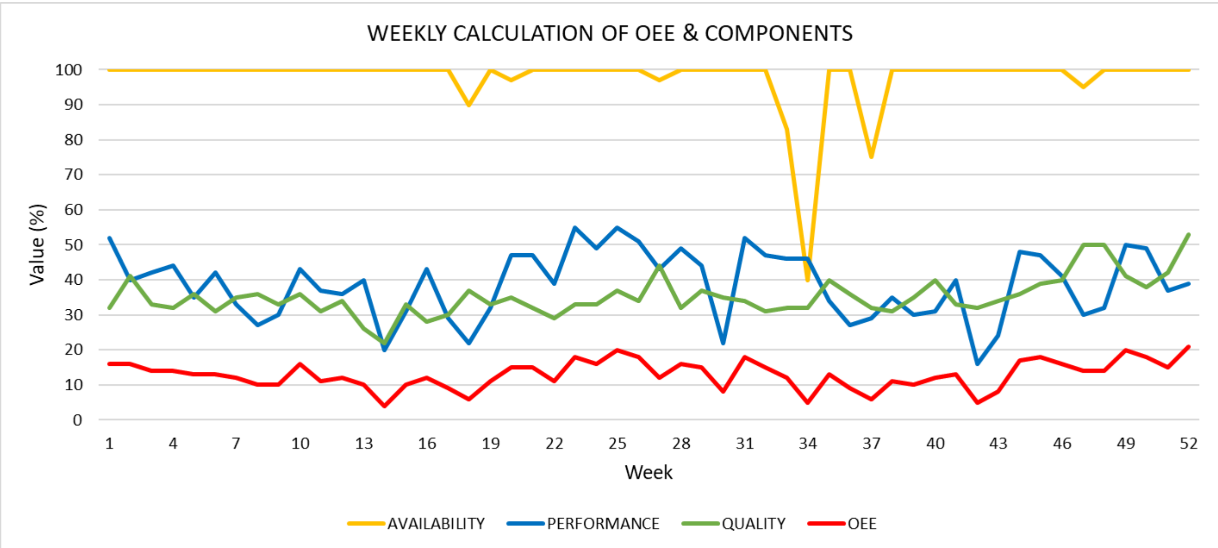
As for quality, its values are also worryingly lower than those of the world class standard (99%). This is due to the high number of trials produced, compared to the standard samples (2 out of 3 samples are trials and they count as “defective” ones).

As a result of the above calculated components, OEE ratio (graph 17) has an average value of 13% for the whole period, when the world class standard is 85%.

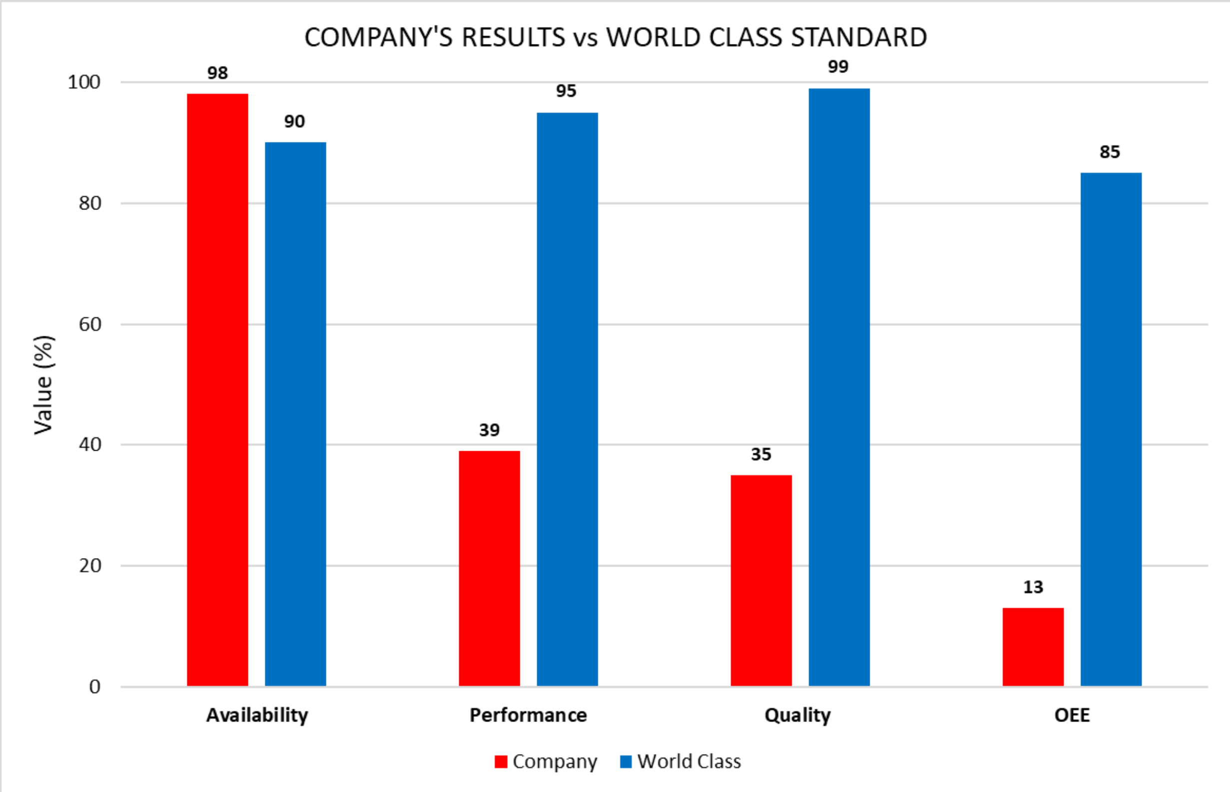


Graph 17: OEE (monthly calculation)

For better visualisation, below is the graph (graph 18) of the weekly calculation of OEE ratio and its components. In graph 19, a synopsis of the average company values, compared with those of the world class, is being shown.



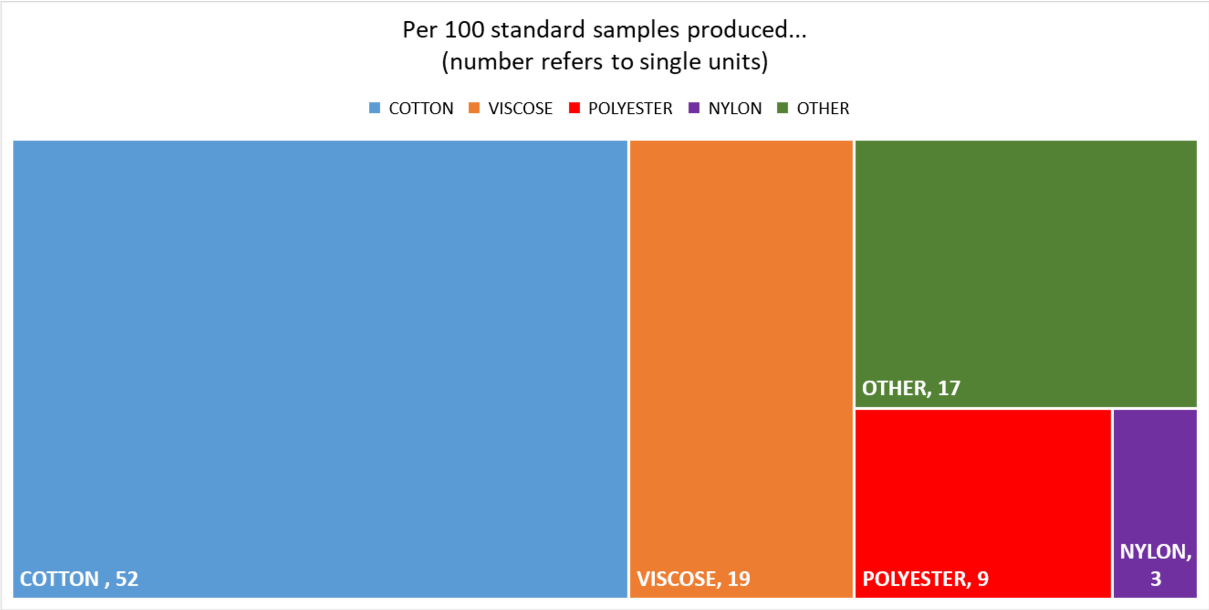
Graph 18: Weekly calculation of OEE & components



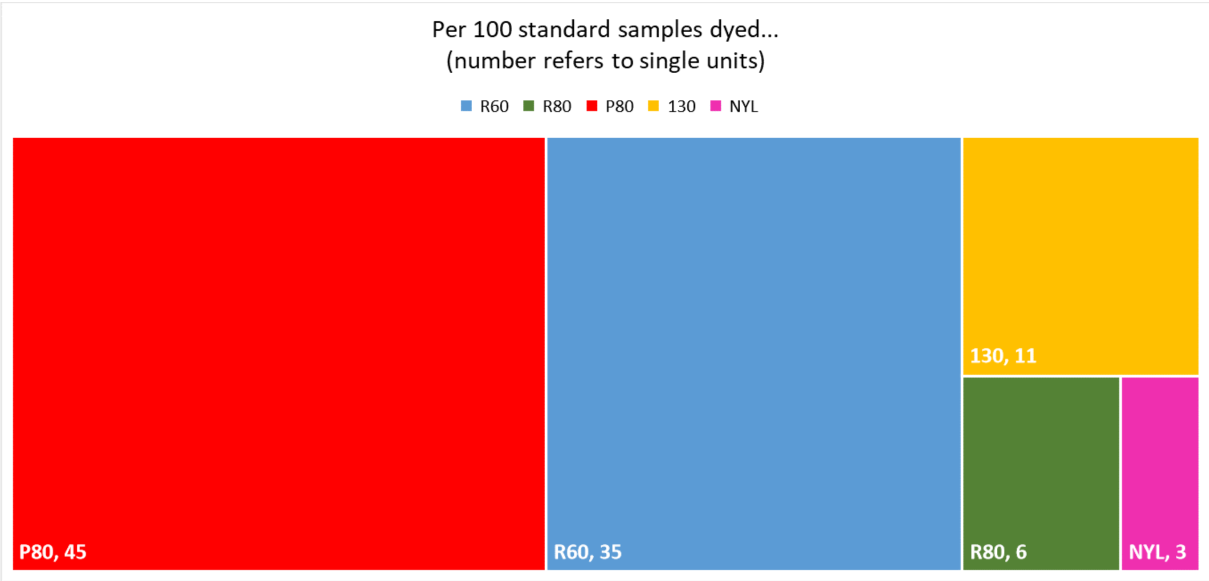
Graph 19: Company’s results of OEE and components VS the world class standards

6.5 Customer preferences – trends

By analysing the composition and dye type of standard samples produced, we can extract valuable conclusions about the customer preferences and the current trends (or seasonality of certain textiles during the year) in the textile and dyeing industry. For example, it would be useless to acquire a new piece of machinery in order to dye nylon samples, as this is the least common composition (3 out of 100, in our case). In the following tree map diagrams (graphs 20 & 21), compositions and dyes per 100 standard samples produced are presented.



Graph 20: Composition per 100 standard samples produced



Graph 21: Type of dye per 100 standard samples produced

7. Suggestions

In the previous chapter, results of OEE and its components were presented. Whereas the availability ratio had an impressive value of 98%, performance and quality were well below the world class standard values. In this chapter, we will attempt to give suggestions for process and productivity improvements, which will furtherly improve the aforementioned components of OEE.

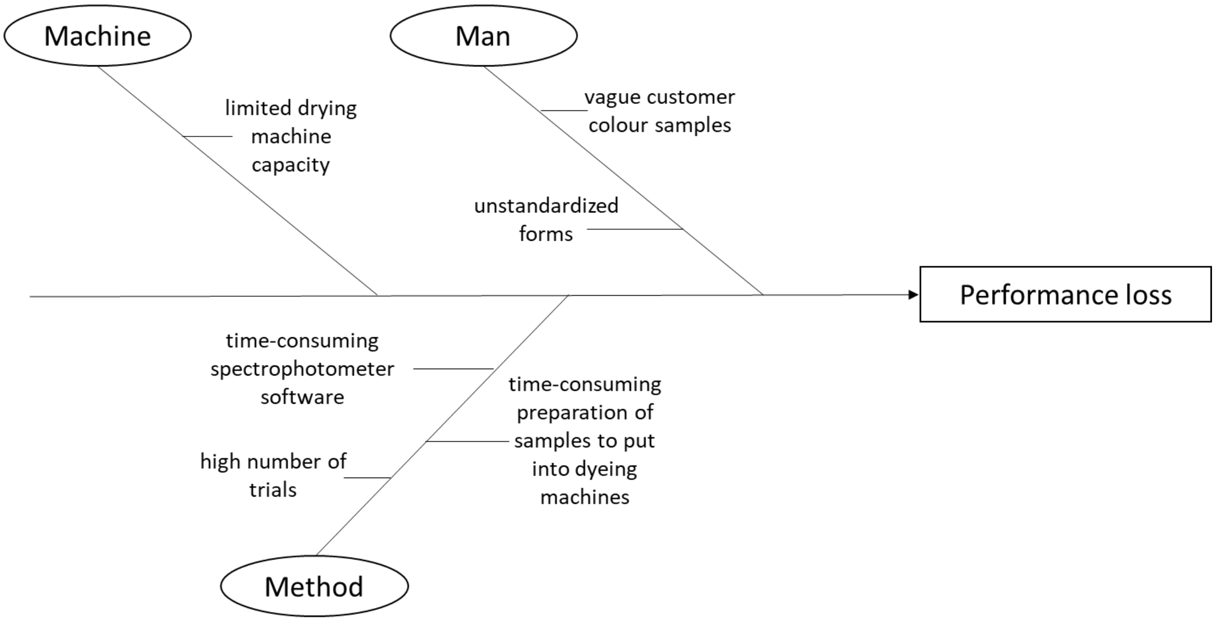
7.1 Availability improvement

As previously discussed, availability component of OEE relies on the absence of breakdowns and stoppages of production, due to unavailability of equipment. Company's result is above the world class standard. However, some useful suggestions could be:

- Adopt preventive maintenance (=perform maintenance and regular checks of critical machinery parts, based on a maintenance schedule) and TPM principles (as previously described in the Introduction).
- Keep a fully organized failure diary, with dates, duration of each failure, necessary service performed to overcome breakdowns, parts replaced and cost related to the tasks accomplished.
- Focus on recent and/or most common failures and try to maintain a stock of the more commonly replaced parts, for time-saving reasons.

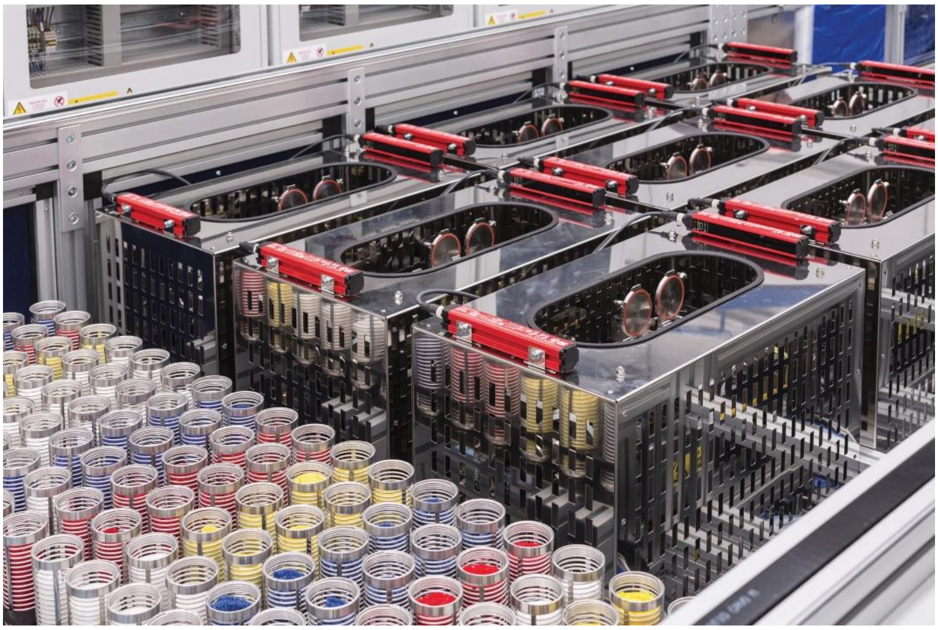
7.2 Performance improvement

Performance is related to the productivity at a defined amount of time, compared to an" ideal" amount produced in a specific time period. Considering company's low score (39%) and the cause-and-effect diagram (graph 22) below, we can propose the following suggestions:



Graph 22: Cause-and-effect diagram for performance loss

- Laboratory should stop using the fainted, old colour chart and switch to the digital Pantone colour database. The company should acquire the latter, in order to save time, enhance the user-friendliness for the staff who need to use such equipment and -gradually- improve standardization.
- The dyed samples' archive (both digital and physical) includes over 20,000 different recipes. This is a valuable "asset" and laboratory's staff should trust it and rely on it, in order to eliminate the number of trials per sample produced, at least at the beginning of a new recipe, when the spectrophotometric parameters are close and a close enough match already exists. Digital approach to colour identification and management implies cost and time saving and quality increase. Speed and efficiency are key for delighted and loyal customer base.
- Laboratory staff should create a standardised colour sample form (as described in Chapter 1.4) and force customers to use it every time. Customers should also stop sending vague colour samples, in small sizes, which are impossible to be measured precisely and not to waste time.
- Time-consuming preparation of samples may be eliminated, by acquiring the "Shakerama" dyeing module (picture 11) for the Tecnorama Dosorama colour dispensing machine

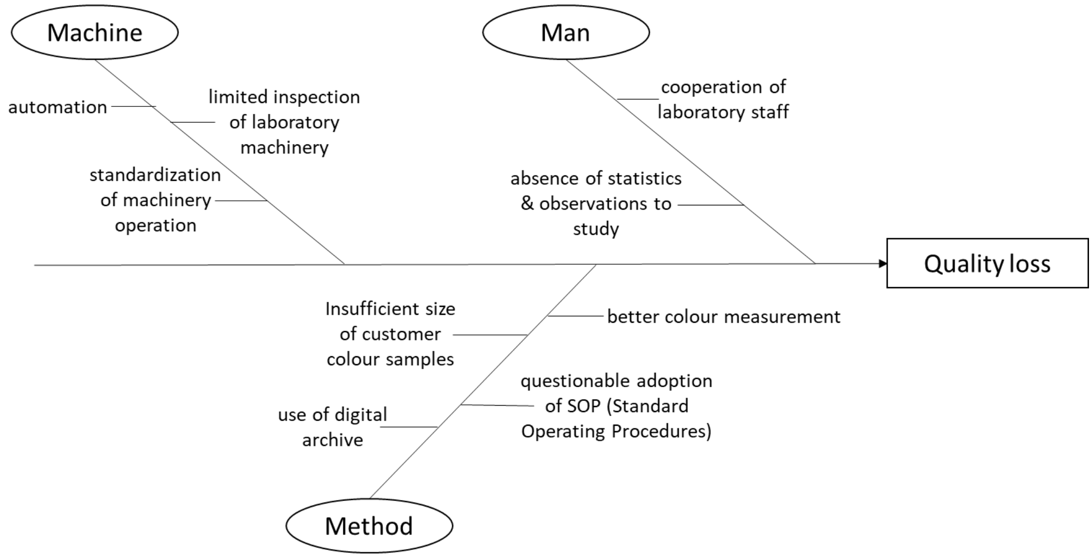


Picture 17: “Shakerama” dyeing module

- Acquaintance of a more “specific” drying machine for the process performed in laboratory, with higher capacity.
- Software of the spectrophotometer is quite complicated and time-consuming, when simple tasks are to be performed, such as to save a recipe. Updates of the existing program or an upgraded version of the latter should be searched
- Reduction of number of trial samples, together with quality improvement, as it will be furtherly described, will also be a step into performance improvement.

7.3 Quality improvement

The quality component of OEE relies on the production of acceptable samples versus unacceptable ones. Company’s result of 35% is explained by the large number of trial samples, compared to the standard ones. Reasons for the latter can be extracted from the following cause-and-effect diagram (graph 23).



Graph 23: Cause-and-effect diagram for quality loss

- Laboratory machinery should be frequently inspected, in order to maintain the quality of the operation and prevent failures that could have been avoided. Instruments, such as the spectrophotometer, should be calibrated every year, in accordance with the standards set by the manufacturer.
- Machinery operation should be standardized, as only the same, repetitive actions are able to ensure stability in the operation quality.
- Automation of processes, such as the preparation of samples, by acquiring the dyeing module, as previously described, will also benefit the quality aspect.
- Laboratory staff should also cooperate, in order for all to have a clear view of the tasks performed, as well as for them to have the opportunity to propose quality and process improvement actions to upper management levels. The creation and monitor of statistics, such as those generated in the current consulting project is also important.
- Considering the methods followed, it is of great importance to improve them from the beginning of the laboratory process. For example, it is vital to ask for and accept only sufficiently sized colour samples from customers, as well as providing them with standardized forms, for sample intake. Measurement of colour should be accomplished using Standard Operating Procedures set by the customers, by the companies providing equipment or by organizations such as ISO. Digital colour management is also important for quick comparison of samples to target standards.

In conclusion, Overall Equipment Effectiveness is a simple, but strong ratio. Apart from the benefits described above, it can also serve as a check tool for decision making processes. The importance of OEE does not basically rely on achieving optimum result, but on getting a measure that reveals the areas for improvement (Jonsson, 1999). Or, as H. Mintzberg, in his book "The Structuring of Organizations" (1979), states: "Performance control systems can serve 2 purposes: to measure and to motivate".

As far as the scope of the consulting project is concerned, it has been successfully accomplished. Data analysis generated valuable results, which revealed the current situation in the OEE and its components. Future research may be focused in expanding OEE application in the production department or in the whole company. Another concept would be to apply other measurement ratios of TPM, or other maintenance systems, apart from TPM.

All things considered, concentrating on Total Quality Management and developing of such a culture, standardization of procedures, adoption of improved methods in the customer-company collaboration and precise collection of data with analysis of OEE and its components, is sure to have a positive result in the laboratory of Colora S.A., as well as in maintaining its special position in the company, among other departments and highlighting its production capabilities which have positioned it above the existing market competition.

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Appendix

Formulas for calculating Availability, Performance, Quality and OEE

1. Availability = $\frac{Loading\ Time - TTR}{Loading\ Time}$ * 100%
    - Loading Time = total time available for production (minutes)
    - TTR = Time to Repair (minutes)

2. Performance = $\frac{\frac{Total\ Productivity}{Loading\ Time}}{\frac{120\ Units}{720\ Minutes}}$ * 100%
    - Total Productivity = sum of standard & trial samples produced (units)
    - 120 Units/720 Minutes = "ideal" production

3. Quality = $\frac{Total\ Productivity - Defective\ Units}{Total\ Productivity}$ * 100%
    - Defective Units = trial samples

4. OEE = (Availability) * (Performance) * (Quality)

OEE calculation (weekly basis)

WEEK	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
1	100	52	32	**16**
2	100	40	41	**16**
3	100	42	33	**14**
4	100	44	32	**14**
5	100	35	36	**13**
6	100	42	31	**13**
7	100	33	35	**12**
8	100	27	36	**10**
9	100	30	33	**10**
10	100	43	36	**16**
11	100	37	31	**11**
12	100	36	34	**12**
13	100	40	26	**10**
14	100	20	22	**4**
15	100	31	33	**10**
16	100	43	28	**12**
17	100	29	30	**9**
18	90	22	37	**6**
19	100	32	33	**11**
20	97	47	35	**15**
21	100	47	32	**15**
22	100	39	29	**11**
23	100	55	33	**18**
24	100	49	33	**16**
25	100	55	37	**20**
26	100	51	34	**18**
27	97	43	44	**12**
28	100	49	32	**16**
29	100	44	37	**15**
30	100	22	35	**8**
31	100	52	34	**18**
32	100	47	31	**15**
33	83	46	32	**12**
34	40	46	32	**5**
35	100	34	40	**13**
36	100	27	36	**9**
37	75	29	32	**6**

WEEK	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
38	100	35	31	**11**
39	100	30	35	**10**
40	100	31	40	**12**
41	100	40	33	**13**
42	100	16	32	**5**
43	100	24	34	**8**
44	100	48	36	**17**
45	100	47	39	**18**
46	100	41	40	**16**
47	95	30	50	**14**
48	100	32	50	**14**
49	100	50	41	**20**
50	100	49	38	**18**
51	100	37	42	**15**
52	100	39	53	**21**

OEE calculation (daily basis)

DATE	HOURS	MINS	TOTAL PROD.	DEFECTIVE	TTR	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
1/10	12	720	54	37	0	100,00	45,00	31,48	**14,17**
2/10	12	720	90	65	0	100,00	75,00	27,78	**20,83**
3/10	12	720	56	37	0	100,00	46,67	33,93	**15,83**
4/10	12	720	77	50	0	100,00	64,17	35,06	**22,50**
5/10	12	720	32	22	0	100,00	26,67	31,25	**8,33**
8/10	12	720	34	19	0	100,00	28,33	44,12	**12,50**
9/10	12	720	50	30	0	100,00	41,67	40,00	**16,67**
10/10	12	720	56	33	0	100,00	46,67	41,07	**19,17**
11/10	12	720	29	16	0	100,00	24,17	44,83	**10,83**
12/10	12	720	69	45	0	100,00	57,50	34,78	**20,00**
15/10	12	720	56	37	0	100,00	46,67	33,93	**15,83**
16/10	12	720	73	52	0	100,00	60,83	28,77	**17,50**
17/10	12	720	39	29	0	100,00	32,50	25,64	**8,33**
18/10	12	720	25	15	0	100,00	20,83	40,00	**8,33**
19/10	12	720	57	36	0	100,00	47,50	36,84	**17,50**
22/10	12	720	81	54	0	100,00	67,50	33,33	**22,50**
23/10	12	720	57	40	0	100,00	47,50	29,82	**14,17**
24/10	12	720	35	26	0	100,00	29,17	25,71	**7,50**
25/10	12	720	43	29	0	100,00	35,83	32,56	**11,67**
26/10	12	720	50	31	0	100,00	41,67	38,00	**15,83**
29/10	12	720	20	12	0	100,00	16,67	40,00	**6,67**
30/10	12	720	55	31	0	100,00	45,83	43,64	**20,00**
31/10	12	720	75	49	0	100,00	62,50	34,67	**21,67**
1/11	12	720	22	15	0	100,00	18,33	31,82	**5,83**
2/11	12	720	38	26	0	100,00	31,67	31,58	**10,00**
5/11	12	720	23	13	0	100,00	19,17	43,48	**8,33**
6/11	12	720	89	54	0	100,00	74,17	39,33	**29,17**
7/11	12	720	59	46	0	100,00	49,17	22,03	**10,83**
8/11	12	720	16	12	0	100,00	13,33	25,00	**3,33**
9/11	12	720	63	48	0	100,00	52,50	23,81	**12,50**
12/11	12	720	62	34	0	100,00	51,67	45,16	**23,33**
13/11	12	720	48	35	0	100,00	40,00	27,08	**10,83**
14/11	12	720	20	12	0	100,00	16,67	40,00	**6,67**
15/11	12	720	29	21	0	100,00	24,17	27,59	**6,67**
16/11	12	720	39	26	0	100,00	32,50	33,33	**10,83**
19/11	12	720	13	9	0	100,00	10,83	30,77	**3,33**
20/11	12	720	26	17	0	100,00	21,67	34,62	**7,50**
21/11	12	720	53	35	0	100,00	44,17	33,96	**15,00**
22/11	12	720	34	21	0	100,00	28,33	38,24	**10,83**
23/11	12	720	35	20	0	100,00	29,17	42,86	**12,50**
26/11	12	720	88	63	0	100,00	73,33	28,41	**20,83**
27/11	12	720	30	20	0	100,00	25,00	33,33	**8,33**
28/11	12	720	32	21	0	100,00	26,67	34,38	**9,17**

DATE	HOURS	MINS	TOTAL PROD.	DEFECTIVE	TTR	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
29/11	12	720	15	11	0	100,00	12,50	26,67	**3,33**
30/11	12	720	15	9	0	100,00	12,50	40,00	**5,00**
3/12	12	720	66	44	0	100,00	55,00	33,33	**18,33**
4/12	12	720	49	31	0	100,00	40,83	36,73	**15,00**
5/12	12	720	47	26	0	100,00	39,17	44,68	**17,50**
6/12	12	720	34	22	0	100,00	28,33	35,29	**10,00**
7/12	12	720	59	35	0	100,00	49,17	40,68	**20,00**
10/12	12	720	27	18	0	100,00	22,50	33,33	**7,50**
11/12	12	720	51	37	0	100,00	42,50	27,45	**11,67**
12/12	12	720	29	20	0	100,00	24,17	31,03	**7,50**
13/12	12	720	51	32	0	100,00	42,50	37,25	**15,83**
14/12	12	720	64	48	0	100,00	53,33	25,00	**13,33**
17/12	12	720	50	36	0	100,00	41,67	28,00	**11,67**
18/12	12	720	42	22	0	100,00	35,00	47,62	**16,67**
19/12	12	720	38	25	0	100,00	31,67	34,21	**10,83**
20/12	12	720	62	43	0	100,00	51,67	30,65	**15,83**
21/12	12	720	25	18	0	100,00	20,83	28,00	**5,83**
2/1	12	720	38	28	0	100,00	31,67	26,32	**8,33**
3/1	12	720	38	27	0	100,00	31,67	28,95	**9,17**
4/1	12	720	69	54	0	100,00	57,50	21,74	**12,50**
7/1	12	720	10	8	0	100,00	8,33	20,00	**1,67**
8/1	12	720	34	28	0	100,00	28,33	17,65	**5,00**
9/1	12	720	29	21	0	100,00	24,17	27,59	**6,67**
10/1	12	720	11	9	0	100,00	9,17	18,18	**1,67**
11/1	12	720	33	25	0	100,00	27,50	24,24	**6,67**
14/1	12	720	46	30	0	100,00	38,33	34,78	**13,33**
15/1	12	720	9	7	0	100,00	7,50	22,22	**1,67**
16/1	12	720	48	30	0	100,00	40,00	37,50	**15,00**
17/1	12	720	60	43	0	100,00	50,00	28,33	**14,17**
18/1	12	720	21	12	0	100,00	17,50	42,86	**7,50**
21/1	12	720	46	30	0	100,00	38,33	34,78	**13,33**
22/1	12	720	23	17	0	100,00	19,17	26,09	**5,00**
23/1	12	720	84	64	0	100,00	70,00	23,81	**16,67**
24/1	12	720	40	28	0	100,00	33,33	30,00	**10,00**
25/1	12	720	63	46	0	100,00	52,50	26,98	**14,17**
28/1	12	720	36	26	0	100,00	30,00	27,78	**8,33**
29/1	12	720	39	26	0	100,00	32,50	33,33	**10,83**
30/1	12	720	17	12	0	100,00	14,17	29,41	**4,17**
31/1	12	720	22	16	0	100,00	18,33	27,27	**5,00**
1/2	12	720	60	41	0	100,00	50,00	31,67	**15,83**
4/2	12	720	36	24	0	100,00	30,00	33,33	**10,00**
5/2	12	720	24	17	0	100,00	20,00	29,17	**5,83**
6/2	12	720	50	31	360	50,00	41,67	38,00	**7,92**
7/2	12	720	17	11	0	100,00	14,17	35,29	**5,00**

DATE	HOURS	MINS	TOTAL PROD.	DEFECTIVE	TTR	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
8/2	12	720	4	2	0	100,00	3,33	50,00	**1,67**
11/2	12	720	44	28	0	100,00	36,67	36,36	**13,33**
12/2	12	720	35	25	0	100,00	29,17	28,57	**8,33**
13/2	12	720	79	50	0	100,00	65,83	36,71	**24,17**
14/2	12	720	8	5	0	100,00	6,67	37,50	**2,50**
15/2	12	720	23	17	0	100,00	19,17	26,09	**5,00**
18/2	12	720	43	29	0	100,00	35,83	32,56	**11,67**
19/2	12	720	52	29	0	100,00	43,33	44,23	**19,17**
20/2	12	720	92	65	120	83,33	76,67	29,35	**18,75**
21/2	12	720	60	39	0	100,00	50,00	35,00	**17,50**
22/2	12	720	34	22	0	100,00	28,33	35,29	**10,00**
25/2	12	720	57	39	0	100,00	47,50	31,58	**15,00**
26/2	12	720	51	39	0	100,00	42,50	23,53	**10,00**
27/2	12	720	64	43	0	100,00	53,33	32,81	**17,50**
28/2	12	720	58	39	0	100,00	48,33	32,76	**15,83**
1/3	12	720	54	33	0	100,00	45,00	38,89	**17,50**
4/3	12	720	22	16	0	100,00	18,33	27,27	**5,00**
5/3	12	720	75	54	0	100,00	62,50	28,00	**17,50**
6/3	12	720	63	45	0	100,00	52,50	28,57	**15,00**
7/3	12	720	19	13	0	100,00	15,83	31,58	**5,00**
8/3	12	720	56	40	0	100,00	46,67	28,57	**13,33**
12/3	12	720	63	41	0	100,00	52,50	34,92	**18,33**
13/3	12	720	77	55	0	100,00	64,17	28,57	**18,33**
14/3	12	720	54	38	0	100,00	45,00	29,63	**13,33**
15/3	12	720	70	43	0	100,00	58,33	38,57	**22,50**
18/3	12	720	60	42	0	100,00	50,00	30,00	**15,00**
19/3	12	720	64	46	0	100,00	53,33	28,13	**15,00**
20/3	12	720	72	46	0	100,00	60,00	36,11	**21,67**
21/3	12	720	53	33	0	100,00	44,17	37,74	**16,67**
22/3	12	720	42	28	0	100,00	35,00	33,33	**11,67**
26/3	12	720	94	61	0	100,00	78,33	35,11	**27,50**
27/3	12	720	45	27	0	100,00	37,50	40,00	**15,00**
28/3	12	720	66	44	0	100,00	55,00	33,33	**18,33**
29/3	12	720	59	35	0	100,00	49,17	40,68	**20,00**
1/4	12	720	86	56	0	100,00	71,67	34,88	**25,00**
2/4	12	720	34	24	0	100,00	28,33	29,41	**8,33**
3/4	12	720	59	39	0	100,00	49,17	33,90	**16,67**
4/4	12	720	71	45	0	100,00	59,17	36,62	**21,67**
5/4	12	720	57	36	0	100,00	47,50	36,84	**17,50**
8/4	12	720	73	51	0	100,00	60,83	30,14	**18,33**
9/4	12	720	52	39	0	100,00	43,33	25,00	**10,83**
10/4	12	720	70	52	0	100,00	58,33	25,71	**15,00**
11/4	12	720	1	0	0	100,00	0,83	100,00	**0,83**
12/4	12	720	61	37	120	83,33	50,83	39,34	**16,67**

DATE	HOURS	MINS	TOTAL PROD.	DEFECTIVE	TTR	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
15/4	12	720	42	28	0	100,00	35,00	33,33	**11,67**
16/4	12	720	40	25	0	100,00	33,33	37,50	**12,50**
17/4	12	720	47	37	0	100,00	39,17	21,28	**8,33**
18/4	12	720	89	54	0	100,00	74,17	39,33	**29,17**
19/4	12	720	77	55	0	100,00	64,17	28,57	**18,33**
22/4	12	720	62	39	0	100,00	51,67	37,10	**19,17**
23/4	12	720	16	8	0	100,00	13,33	50,00	**6,67**
24/4	12	720	72	52	0	100,00	60,00	27,78	**16,67**
25/4	12	720	61	40	0	100,00	50,83	34,43	**17,50**
2/5	12	720	28	19	0	100,00	23,33	32,14	**7,50**
3/5	12	720	24	15	0	100,00	20,00	37,50	**7,50**
6/5	12	720	45	31	0	100,00	37,50	31,11	**11,67**
7/5	12	720	76	48	0	100,00	63,33	36,84	**23,33**
8/5	12	720	75	53	0	100,00	62,50	29,33	**18,33**
9/5	12	720	38	25	0	100,00	31,67	34,21	**10,83**
10/5	12	720	79	50	0	100,00	65,83	36,71	**24,17**
13/5	12	720	53	36	0	100,00	44,17	32,08	**14,17**
14/5	12	720	59	41	0	100,00	49,17	30,51	**15,00**
15/5	12	720	33	23	0	100,00	27,50	30,30	**8,33**
16/5	12	720	64	45	0	100,00	53,33	29,69	**15,83**
17/5	12	720	75	52	0	100,00	62,50	30,67	**19,17**
20/5	12	720	62	43	600	16,67	51,67	30,65	**2,64**
21/5	12	720	56	40	0	100,00	46,67	28,57	**13,33**
22/5	12	720	43	29	0	100,00	35,83	32,56	**11,67**
23/5	12	720	62	39	0	100,00	51,67	37,10	**19,17**
24/5	12	720	55	37	0	100,00	45,83	32,73	**15,00**
27/5	12	720	68	44	720	0,00	56,67	35,29	**0,00**
28/5	12	720	24	17	720	0,00	20,00	29,17	**0,00**
29/5	12	720	89	58	720	0,00	74,17	34,83	**0,00**
30/5	12	720	40	29	0	100,00	33,33	27,50	**9,17**
31/5	12	720	53	35	0	100,00	44,17	33,96	**15,00**
3/6	12	720	61	46	0	100,00	50,83	24,59	**12,50**
4/6	12	720	23	11	0	100,00	19,17	52,17	**10,00**
5/6	12	720	23	14	0	100,00	19,17	39,13	**7,50**
6/6	12	720	48	24	0	100,00	40,00	50,00	**20,00**
7/6	12	720	50	32	0	100,00	41,67	36,00	**15,00**
10/6	12	720	35	24	0	100,00	29,17	31,43	**9,17**
11/6	12	720	23	15	0	100,00	19,17	34,78	**6,67**
12/6	12	720	58	42	0	100,00	48,33	27,59	**13,33**
13/6	12	720	37	22	0	100,00	30,83	40,54	**12,50**
14/6	12	720	9	5	0	100,00	7,50	44,44	**3,33**
18/6	12	720	46	29	720	0,00	38,33	36,96	**0,00**
19/6	12	720	19	13	0	100,00	15,83	31,58	**5,00**
20/6	12	720	13	9	0	100,00	10,83	30,77	**3,33**

DATE	HOURS	MINS	TOTAL PROD.	DEFECTIVE	TTR	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
21/6	12	720	60	42	0	100,00	50,00	30,00	**15,00**
24/6	12	720	76	52	0	100,00	63,33	31,58	**20,00**
25/6	12	720	47	31	0	100,00	39,17	34,04	**13,33**
26/6	12	720	26	18	0	100,00	21,67	30,77	**6,67**
27/6	12	720	56	38	0	100,00	46,67	32,14	**15,00**
28/6	12	720	7	5	0	100,00	5,83	28,57	**1,67**
1/7	12	720	19	12	0	100,00	15,83	36,84	**5,83**
2/7	12	720	21	14	0	100,00	17,50	33,33	**5,83**
3/7	12	720	46	33	0	100,00	38,33	28,26	**10,83**
4/7	12	720	27	15	0	100,00	22,50	44,44	**10,00**
5/7	12	720	65	45	0	100,00	54,17	30,77	**16,67**
8/7	12	720	58	40	0	100,00	48,33	31,03	**15,00**
9/7	12	720	19	8	0	100,00	15,83	57,89	**9,17**
10/7	12	720	3	2	0	100,00	2,50	33,33	**0,83**
11/7	12	720	53	34	0	100,00	44,17	35,85	**15,83**
12/7	12	720	50	30	0	100,00	41,67	40,00	**16,67**
15/7	12	720	78	52	0	100,00	65,00	33,33	**21,67**
16/7	12	720	26	16	0	100,00	21,67	38,46	**8,33**
17/7	12	720	28	18	0	100,00	23,33	35,71	**8,33**
18/7	12	720	68	47	0	100,00	56,67	30,88	**17,50**
19/7	12	720	38	27	0	100,00	31,67	28,95	**9,17**
22/7	12	720	23	15	0	100,00	19,17	34,78	**6,67**
23/7	12	720	32	22	0	100,00	26,67	31,25	**8,33**
24/7	12	720	24	17	0	100,00	20,00	29,17	**5,83**
25/7	12	720	12	8	0	100,00	10,00	33,33	**3,33**
26/7	12	720	6	4	0	100,00	5,00	33,33	**1,67**
29/7	12	720	34	21	0	100,00	28,33	38,24	**10,83**
30/7	12	720	31	22	0	100,00	25,83	29,03	**7,50**
31/7	12	720	20	13	0	100,00	16,67	35,00	**5,83**
2/9	12	720	87	58	0	100,00	72,50	33,33	**24,17**
3/9	12	720	36	19	0	100,00	30,00	47,22	**14,17**
4/9	12	720	65	46	0	100,00	54,17	29,23	**15,83**
5/9	12	720	15	10	0	100,00	12,50	33,33	**4,17**
6/9	12	720	85	54	0	100,00	70,83	36,47	**25,83**
9/9	12	720	26	18	0	100,00	21,67	30,77	**6,67**
10/9	12	720	72	40	0	100,00	60,00	44,44	**26,67**
11/9	12	720	93	58	0	100,00	77,50	37,63	**29,17**
12/9	12	720	52	36	0	100,00	43,33	30,77	**13,33**
13/9	12	720	36	18	0	100,00	30,00	50,00	**15,00**
16/9	12	720	61	38	0	100,00	50,83	37,70	**19,17**
17/9	12	720	49	32	0	100,00	40,83	34,69	**14,17**
18/9	12	720	60	38	0	100,00	50,00	36,67	**18,33**
19/9	12	720	36	16	0	100,00	30,00	55,56	**16,67**
20/9	12	720	37	24	0	100,00	30,83	35,14	**10,83**

DATE	HOURS	MINS	TOTAL PROD.	DEFECTIVE	TTR	AVAILABILITY (%)	PERFORMANCE (%)	QUALITY (%)	OEE (%)
23/9	12	720	29	19	0	100,00	24,17	34,48	**8,33**
24/9	12	720	55	34	0	100,00	45,83	38,18	**17,50**
25/9	12	720	23	10	0	100,00	19,17	56,52	**10,83**
26/9	12	720	37	18	180	75,00	30,83	51,35	**11,88**
27/9	12	720	38	12	0	100,00	31,67	68,42	**21,67**
30/9	12	720	43	22	0	100,00	35,83	48,84	**17,50**
1/10	12	720	24	9	0	100,00	20,00	62,50	**12,50**
2/10	12	720	27	11	0	100,00	22,50	59,26	**13,33**
3/10	12	720	13	7	0	100,00	10,83	46,15	**5,00**
4/10	12	720	85	57	0	100,00	70,83	32,94	**23,33**
7/10	12	720	16	9	0	100,00	13,33	43,75	**5,83**
8/10	12	720	86	56	0	100,00	71,67	34,88	**25,00**
9/10	12	720	89	52	0	100,00	74,17	41,57	**30,83**
10/10	12	720	48	29	0	100,00	40,00	39,58	**15,83**
11/10	12	720	60	32	0	100,00	50,00	46,67	**23,33**
14/10	12	720	66	38	0	100,00	55,00	42,42	**23,33**
15/10	12	720	45	26	0	100,00	37,50	42,22	**15,83**
16/10	12	720	86	59	0	100,00	71,67	31,40	**22,50**
17/10	12	720	57	36	0	100,00	47,50	36,84	**17,50**
18/10	12	720	39	25	0	100,00	32,50	35,90	**11,67**
21/10	12	720	36	18	0	100,00	30,00	50,00	**15,00**
22/10	12	720	48	28	0	100,00	40,00	41,67	**16,67**
23/10	12	720	55	34	0	100,00	45,83	38,18	**17,50**
24/10	12	720	26	15	0	100,00	21,67	42,31	**9,17**
25/10	12	720	56	34	0	100,00	46,67	39,29	**18,33**
29/10	12	720	37	16	0	100,00	30,83	56,76	**17,50**
30/10	12	720	35	17	0	100,00	29,17	51,43	**15,00**
31/10	12	720	70	35	0	100,00	58,33	50,00	**29,17**