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OCCUPATIONAL VAT DYEING PRACTICES IN THE KANO METROPOLIS OF NIGERIA- Part 3: Step-by-Step dyeing processes in relation to industrial practices

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ABSTRACT

In traditional indigo dyeing it takes up to 45 days to ferment (reduce) the dye but with the advent of synthetic vat blue and the development of sodium dithionite the dyeing process becomes relatively short. Additionally, there is no standard process in vat dyeing. The aim of this paper is to assess the step-by-step vat dyeing processes in Kano metropolis in relation to industrial practices. This crossectional descriptive study was conducted among 1387 dyers together with focus group discussion, observation and measurement. Data were analysed by descriptive statistics (frequency and average) using statistical package for the social sciences (SPSS) software. Results showed that the dyeing process is entirely manual and the dyers can apply the dye using different procedures with some similarities, modifications, and differences in relation to industrial practices. The dyeing venture may not live to its full potential due to shortcomings related to the quality of the dyed materials. In order to improve on the dyeing processes, it is recommended for related departments in academic institutions to collaborate with the major dyeing enterprises in terms of research/innovation and placement of students under Students Industrial Work Experience Scheme (SIWES). Furthermore, government should introduce tie-dye among entrepreneurship courses offered in tertiary institutions to enable interested students acquire chemistry background of the dyeing processes. (Remove italics)

Keywords: *vat dyeing, caustic soda, hydros, fabric, Kano metropolis*

INTRODUCTION

In the 2nd part of this 6-part series, we examined the operations of the dyers/dyeing enterprises and reported that they offer numerous services to customers from neighbourhood, other states, other countries, and cloth vendors using open plastic bowl as the dyebath, firewood as fuel, water mostly purchased from vendors. Synthetic vat dye, caustic soda, hydros, starch, sodium chloride, sodium sulphate, and cotton/cotton blend fabric are used as raw-materials and the dyehouses usually work on demand and are more engaged during festive periods. In this 3rd part, we investigated the step-by-step dyeing processes employed by the enterprises in relation to industrial practices.

Vat dyes, with very few exceptions, fall into 2 clearly defined groups namely indigoid and anthraquinoid where the former include indigo, thioindigo and their derivatives while the latter comprises derivatives of anthraquinone as well as heterocyclic quinones (Chattopadhyay, 2011). Vat dyes are also classified into 4 groups namely IK, IW, IN and IN special based on the different substantivities of the leuco vat anions and the corresponding difference in temperature, salt, caustic soda and hydros concentration necessary to give the best overall dyeing results (Aspland, 1992). Vat dyes yield coloured fibres of excellent all-round fastness particularly to light, washing and chlorine bleaching (Bozic and Kokol, 2008; Chavan, 2015; Zanoni et al., 2006). In vat dyeing the insoluble dye is first converted to the alkali soluble leuco form which exhibits substantial substantivity towards protein (wool and silk) and cellulosic fibres (cotton, flax and regenerated cellulose fibres) and then the adsorbed reduced dye is oxidized to generate the coloured insoluble form of the colourant using air or chemical oxidants (Bechtold, 2013).

Cellulose fibres, whether they are natural or regenerated, require pretreatment to remove natural or added impurities and can be carried out on loose fibres, yarns or fabrics (Hickman, 1995). The conventional pretreatment processes consist of desizing, scouring, bleaching and mercerization (Choudhury, 2011; Hauser, 2015). Desizing removes previously added size or starchy material;

scouring remove oils, fats and waxes; and bleaching uses oxidizing agents to improve the whiteness of the fabric (Harane and Adivarekar, 2016). Mercerization can be performed using a wide range of operating conditions, for instance, reaction time can be as short as minutes or as long as hours or days, with temperature ranging from ambient to 150 oC (Modenbach and Nokes, 2014) and can be done in slack state or under tension (Sameii et al., 2008). There are at least 5 procedures used in vat dyeing namely vatting (leuco dyeing), semi-pigmentation, pre-pigmentation, use of acid leuco compounds (vat-acid method), and dyeing with 'solubilized' leuco ester vat dyes (Giles, 1974). Regardless of the vat dyeing process used, once the dyebath has been dropped, after-treatments are carried out which include rinsing, oxidation, soaping, and neutralization/acidification (Aspland, 1992).

There are 3 principles that dyeing machines operate namely (i) the material moves, but the liquor is stationary (e.g. jig and winch machines for fabric dyeing), (ii) the liquor moves, but the material is stationary (e.g. hank and package dyeing of yarns and beam dyeing of fabrics), (iii) both the liquor and the material move (e.g. jet, soft flow and over flow jet dyeing machines for fabrics) (Holme, 2016; Wardman, 2018; Baumann and Fletcher, 1966). Dyeing machines have been developed on those 3 principles, additionally providing the option of batchwise, semi-continuous and fully continuous (Holme, 2016; Burkinshaw, 1990). The most important types of dyeing equipment for the batchwise application of vat dyes to woven fabrics are jigs, winches, and beam dyeing machines where the most suitable jigs are the closed types (Latham, 1995). Vat dyeing equipment has been designed either to exclude air as much as possible or to apply hydros at a critical moment, just before high energy is given to the material (Baumann and Fletcher, 1966).

Until now, little work has been done on step-by-step dyeing processes relating to occupational dyeing in the context of science and technology either in Kano metropolis or even in Abeokuta, south-western Nigeria where the dyers have been extensively studied. Kano metropolis was selected because the ancient city has attracted historical prominence in the 14th Century with its fine indigo dyed cloth (Ezeanya-Esiobu, 2019) and currently there are many secondary dyeing units in the area that are engaged in hand dyeing using synthetic vat dyes coupled with large population and abundant markets enabling huge patronage of the services offered by the dyers. The study will contribute in addressing the fundamental question: what is the step-by-step dyeing processes employed by the dyers in Kano metropolis? The study will focus on dyers using synthetic vat dyes and chemicals.

MATERIALS AND METHODS

Study Area

Kano metropolitan area is the most developing as well as urbanizing cities and commercial centre of the Northern Nigeria whose population is projected to reach 5,724,000 people by 2025 (Abdullahi et al., 2019). It occupies an area of about 600 km2 with an altitude of 488 m above sea level and lies between Lat. 10oN to 11oN and Long. 8oE to 9oE. It is boarded by Madobi and Tofa Local Government Areas to the South West, Gezawa to the East, Dawakin Kudu to the South East, and Minjibir on the North East. It has eight (8) local governments namely: Municipal, Fagge, Dala, Gwale, Tarauni, Nassarawa, Ungogo and Kumbotso (Suleiman et al., 2020).

Kano metropolis has 4 industrial estates namely Bompai, Sharada, Challawa and Tokarawa with many manufacturing industries where Bompai hosts most of the textile industries that are engaged in spinning, weaving and dyeing (Nabegu, 2016) as well as many plastic producing companies. There is also a local industry for traditional indigo dyeing in "Kofar Mata" even though most of the dyers are now using synthetic vat dyes. In addition, there are many secondary dyeing units spread across the metropolitan area which are in close proximity to residential houses. There are several markets in the area and the business landscape is characterized with the proliferation of super stores, shopping malls and other trading centres along major roads and streets which form another kind of market (Ibrahim, 2015). "Kantin Kwari" cloth market, provides a significant demand for the locally dyed materials. For the purpose of this study, the respondents are called "dyers", non-industrial dyeing units are referred to as dyehouses, and traders in 'Kantin-Kwari' and colour shops are called cloth and colour vendors respectively.

Data Collection and Analysis

The research relied on data gathered through a structured questionnaire, focus group discussions, observation, and measurement. A structured questionnaire was developed according to standard protocol for questionnaire design and testing (Geer et al., 2006) and questions were developed as a result of insight from Johnson (1999), information from Aspland (1992) and Chakraborty (2010) as well as practical experience of the corresponding author. The validity of the coverage of questions included in the questionnaire (content validity) was gained through experts in the field, colleagues as well as members of the target population. Reconnaissance visits were made in June, 2020 to locate the dyers. The developed questionnaire was pretested in a pilot study among the dyers that did not participate in the study and during the reconnaissance visits. Variability in dyers response and the understanding of question content (face validity) was evaluated and this information was used to produce a revised final version of the questionnaire, specifically questions were added where content coverage was lacking and questions were rephrased where understanding was vague. The questionnaire was prepared in English but was communicated to the dyers in their local dialect (Hausa).

This part of the series covered 7 questions in 1 section which dealt with the step by step dyeing processes (e.g. dyeing sequence employed, methods of achieving levelled dyeing/colour and shade, treatments carried out before and after dyeing etc.). The research population is the total number of occupational dyers in Kano metropolis and participating dyers were chosen as a purposive sample. A total of 1387 questionnaires were administered in 20 dyeing units (geographical locations of the dyehouses are shown in part 1 of the series) where willingness to participate in the study was confirmed through completed consent form. Dyers who are at least 18 years of age and had worked for at least 5 years in the dyehouses were eligible to participate in the study. Data was collected from August to December, 2020, with the dyers working, through self-completed questionnaire by the researcher and 2 enumerators over a duration of 25-30 minutes with each dyer being asked the same question in the same order. A monetary incentive of ₦3000 ($7.75) was provided for participation due to initial reluctance to participate because according to the dyers, the Chinese used similar approach to learn their techniques. Before initial data screening all the completed questionnaires were coded and entered in Excel software after which the data were analysed by descriptive statistics (frequency and average) using SPPS version 26.

Other data source included observation while the dyers are on the job. Additional information was obtained from focus group discussion with the researcher, assistant researcher and 7 dyers, 1 from a dyehouse in each of 7 local government areas (Nassarawa was not represented) in December, 2020 selected by purposive sampling technique. Two key informants were used in the study. Aliyu Umar, a wholesale colour vendor, whose nature of business permits him to know the major dyers in Kano metropolis as well as cloth vendors in the market, and Mallam Haruna Baffa who has valuable information being the Secretary of "Kofar Mata" dyers Association coupled with his exposure having attended numerous exhibitions of Africa by Design namely Ghana (2016 and 2019), Dubai (2017), London (2018), United States (2019) and Abuja (2020).

Focus group discussion with the dyers centred on 2 open-ended questions designed to get more insight on the activities of the dyers namely the dyeing methods employed and treatments they carry out before and after dyeing. The discussion lasted for 2 hours and was recorded using paper and pencil. Volume, weight, and temperature were measured using measuring cylinder, weighting balance and thermometer and the results were presented as average of measurements in triplicates from each of the 20 dyehouses visited. Dollar exchange rate has fluctuated considerably between 2020 till date. (exchange rate of ₦386.96 per US$ as at 30th August, 2020 was used where dollar equivalent is given in the text).

RESULTS AND DISCUSSION

Treatments carried out before dyeing

As shown in Table 1, majority of the dyers carry out partial desizing, none of them employ scouring and bleaching operations, and most carry out mercerization process. It has been observed that fabrics sold at "Kantin Kwari" cloth market are mostly finished by the manufacturers with light starch and according to the dyers soaking the material in water and squeezing after a few minutes removes most of the starch, the remaining being washed up during dyeing. This mimics rot steeping (Harane and Adivarekar, 2016) but with much shorter treatment time. This can be a disadvantage since the nature of the starch is unknown and some types are difficult to remove (Hickman, 1995) impeding dye penetration. Those that carry out mercerization do that for the purpose of producing "shadow" effect discussed in subsequent section while those that do not are of the opinion that excess caustic soda reduces the strength of the material resulting in tear and customer complain. Amubode (2009) reported a situation in Abeokuta where the use of caustic soda in preparation of vat dyebath was banned in the past due to complaints from traders and customers that the dyed material rots.

Dyeing methods

The dyers are involved in hand dyeing making use of batchwise method in an open plastic bowl and moving the fabric/garment relative to the dye liquor as shown in Figure 1. Application of colour can be achieved by exhaust dyeing (batch), continuous (padding) and printing where in exhaust dyeing the dye is transferred to the fibre surface by motion of the dye liquor or by motion of the substrate being dyed (Clark, 2011). Dyeing machines are designed to move the material or the liquor or both relative to each other (Holme, 2016; Wardman, 2018; Baumann and Fletcher, 1966). The use of open bath may be a problem because oxygen from air combats with the reduction action of hydros and that is why machines are designed to either exclude air or to apply hydros only at crucial moment during the dyeing process (Baumann and Fletcher, 1966).

Figure 2 shows that among the dyeing methods used, sequence D is more prevalent followed by sequences E, B, A, and C. Sequences A and B are referred to as leuco vat dyeing where the material to be dyed is entered into a prepared liquor that contain the fully vatted dye, caustic soda and hydros with various amounts of auxiliaries (Latham, 1995). According to the dyers, leuco vat dyeing is referred to as "Danbusununu" (in Hausa) meaning a duller dyeing in which the design of the dyed material is not that visible. Sequences C and D mimic pre-pigmentation which is a process where dispersions of vat pigments with no substantivity are circulated and uniformly distributed at the fibre surface before alkali and reducing agent are added (Aspland, 1997). In practice, the dyers prepare a dyebath containing the dye and caustic soda, circulate the material and then add hydros to initiate reduction and absorption of the dye. It can be seen that the proportions of dyers employing starching prior to full oxidation (sequences B and D) are higher irrespective of whether it is a leuco or modified pre-pigmentation process. The dyers revealed that oxidation process is always almost completed during rinsing and that starching before full oxidation is advantageous since there will be saving in time speeding up the dyeing process. This can also be a disadvantage.

According to the dyers, sequence E is called "Rinin kwalba" or "Dan Sokoto" (in Hausa). They also refer to it as "shadow" which is a word used to describe irregular shadow dyeing (Eltz and Maier, 1973). It was revealed that the "shadow" effect is more pronounced on cotton blend fabric due to selective dye absorption. The method involves treating the material with very high concentration of caustic soda (mercerization) without tension at elevated temperature for a few minutes and dyeing to a very deep shade using any of the dyeing sequences described above and without the intermittent washing and drying step after the caustic treatment (wet on wet process). Mercerization, a process named after its inventor, John Mercer, is the treatment of native cellulose fibres with concentrated caustic soda solution (Budtova and Navard, 2016). Mercerization is technically simple and uncomplicated process (Niaz and Tahir, 1989) which makes it easy for the dyers to carry out the process non-industrially. According to Jena et al (2015), up to 300 g/L of caustic soda is used for mercerization and such high concentration has been used to treat fabric in slack state (Sameii et al., 2008; Tarbuk et al., 2014). The dyers use excessive caustic soda concentration may be due to lack of accurate means of measurement and for economic reasons they cannot rinse to remove the excess sufficiently which is a requirement after mercerization. For those reasons, the dyed material may be inferior in terms of strength.

Table 1: Treatments carried out before dyeing

Treatments	Yes N=1387 (%)	No N=1387 (%)
Partial desizing	1384 (81.8)	252 (18.2)
Scouring	0 (0)	1387 (100)
Bleaching	0 (0)	1387 (100)
Mercerization	1221 (88)	166 (12)

Figure 1: Continuous movement of fabric relative to dye liquor (Remove pic) (the Figure is very important to depict how the dyeing is carried out)

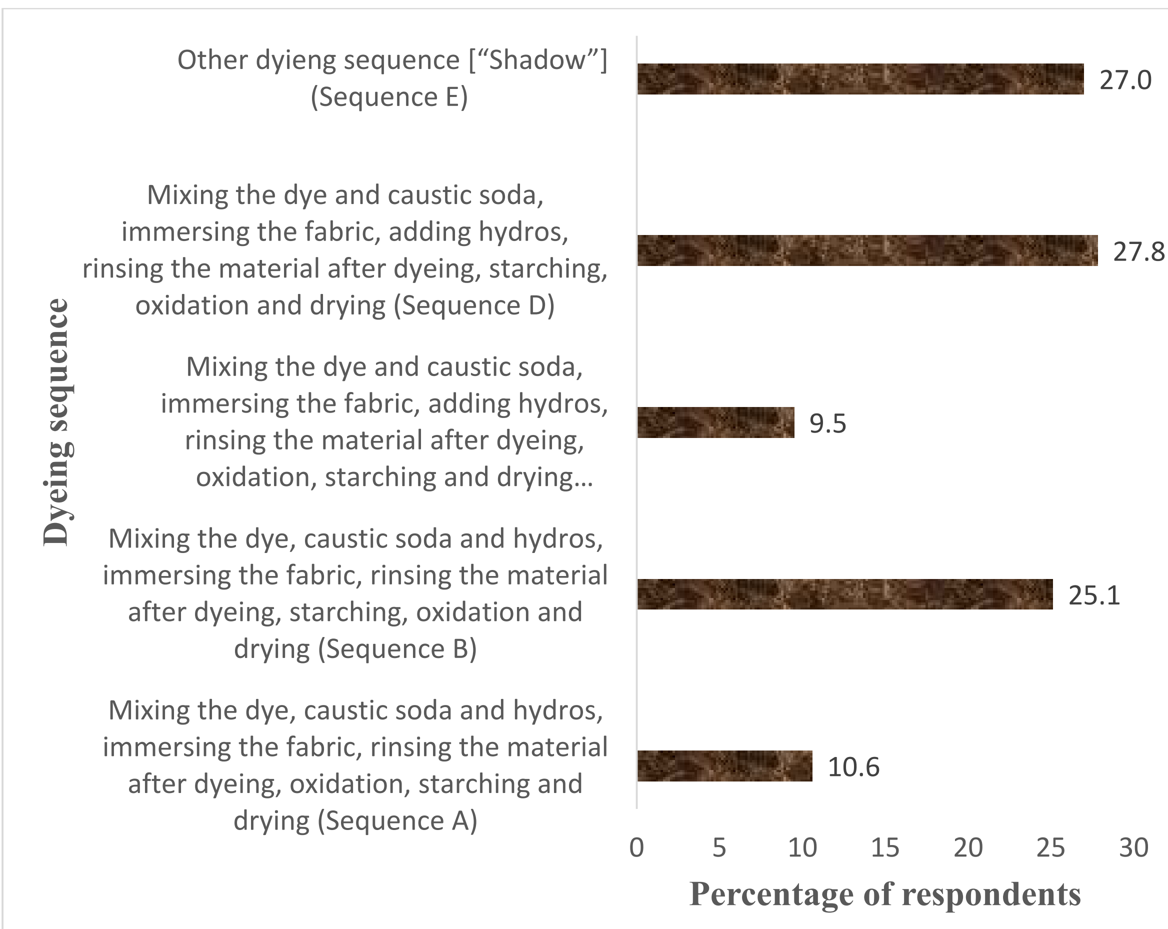

Figure 2: Dyeing methods

Caustic treatment of cotton/polyester (Haji et al., 2011; Moses and Pitchai, 2015; Borisova and Reihmane, 2013) and 100 % polyester (Ibrahim, 2003) to increase dye absorption has been reported. Oschatz (1993) carry out wet on wet dyeing of mercerized cotton with reactive dyes to increase dye absorption. Eltz and Maier (1973) developed a process for obtaining irregular shadow dyeings on polyester and cotton/polyester blend using alkali susceptible disperse dyes. According to Valko (1941), X-ray examination of cellulose dyed with 29.9 % vat dye showed that only the lines due to the pattern of mercerized cellulose can be recognized after oxidation. Similarly, it can be seen that a mercerized sample made of cotton/polyester (Figure 3B) had better appearance than an un-mercerized one (Figure 3A) dyed under similar conditions because the lines due to pattern of mercerization are highly visible. Ability to produce the "shadow" effect may be considered as a breakthrough in the dyers perspective and is also a competitive advantage.

The "shadow" effect may be due to the fact that fabric construction with different yarn characteristics and fibre properties could be used as weft to produce deliberate shade variations. According to Ashraf et al (2014), vat dyeing of fabric containing weft yarns from different sources, different types, different fineness or twist levels in the same fabric may lead to weft-way fabric streaks or barriness due to perceptible colour difference. Another probable explanation for the "shadow" effect is that at high concentration of sodium hydroxide, swelling of the outermost fibres forms a barrier, inhibiting the penetration of liquor into the yarn core and crossing points which results in poor mercerizing of the core and lack of uniformity (Wagaw and Chavan, 2012; Wakida, 2002; Montazer and Sadighi, 2006) and when such mercerized materials are dyed, there could be preferential dye absorption thus producing the so called "shadow" effect.

The dyers disclosed that customers desire materials dyed to deep shades with well pronounced fabric design patterns ("shadow") which resembles the expensive 'Senegalese' material that majority cannot afford. The dyers obtain very deep shades by using high percentage of dye on weight of fabric. Similarly, it is possible to incorporate up to 60 g of dye into 100 g of mercerized cellulose material (Valko, 1941) and up to 20 % reactive dye on weight of fabric has been applied on mercerized cellulose (Siroky et al., 2011). Additionally, changes in internal light scattering by mercerization can increase the perceived depth of shade on cotton and the process is effective for obtaining deeper shades than otherwise would be possible (Fu et al., 2013). According to the dyers, it is possible to dye cotton blend fabric but while the cellulosic portion look very deep, the non-cellulosic component usually appears lighter in shade. This may be due to high temperature requirement and the need of vat acid process for synthetics' dyeing. Studies have shown that synthetic fibres such as Polyester (Kunttou et al., 2005), nylon (Baig, 2010), acrylic and lycra (Baig, 2012), and polypropylene (Gupta et al., 2010) can be dyed to a deep shade with vat dyes using caustic soda and hydros through a leuco vat –acid method using exhaust dyeing at high temperature. The dyers may be unaware of this development and do not have the facility to generate the high energy (≥100oC) required nor could they have the technical know-how of the vat acid process.

It is important to note that the dyers also produce cheaper, low quality, dyeings by reusing spent dyebath after addition of caustic soda and hydros and they refer to this as "Kanbakare" or "Tsome" (in Hausa). Similarly, the possibility of reuse of spent dyebath has been suggested by Chakraborty (1992). Also interesting is the fact that in some instances, the dyers continuously add dye and hydros in the course of dyeing as can be seen in Figure 4 and this could compensate for hydros lost due to oxidative degradation. Similarly, Chakraborty (1992) reported that in vatting and dyeing, hydros must be compensated by supplying extra quantity to continue the reduced state throughout dyeing. Metered addition of hydros has advantages such as better levelling by slower vatting, no need of levelling agent, protection from over reduction, control of initial dyeing rate (strike), possibility of warm pre-pigmentation and good reproducibility (Shamey et al., 2005).

According to the dyers, they normally work in the early hours of the morning to minimize the effect of heat, which could otherwise be intense under the sun, and chemicals and also to avoid levelling problems associated with yellow and orange dyes. Giles (1974) described phototendering common with red, yellow, and orange dyes as a chemical attack on cellulose fibre causing severe weakening 'tendering' when the dyed fibre is exposed to light during the actual dyeing process or in use in the normal finished state. In the dark, in the presence of oxygen, the problem is restored (Aspland, 1992).

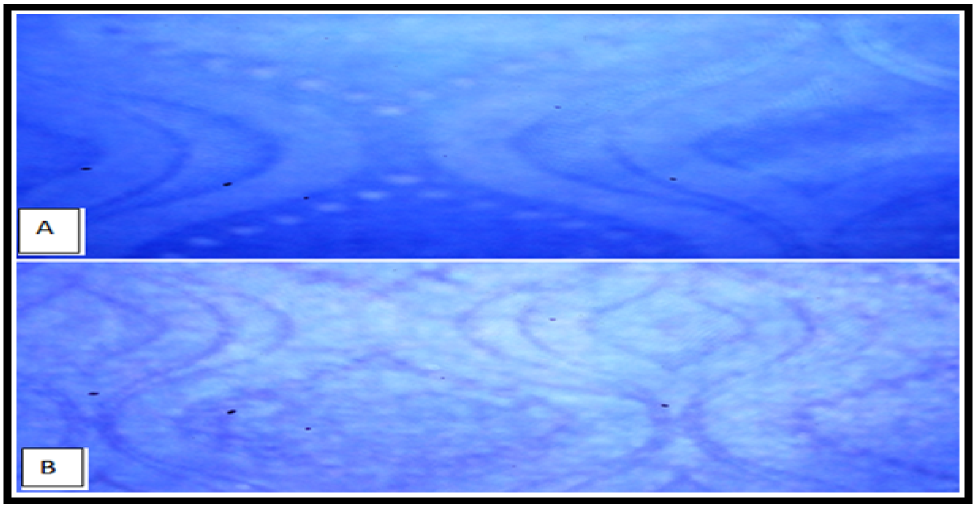

Figure 3: Dyed samples of un-mercerized (A) and mercerized (B) materials

Figure 4: Metered addition of dye and hydros in the course of dyeing (Remove picture) (those pictures are very important in a survey to show the actual processes)

Vatting and dyeing time

The vatting time employed by the dyers in not more than 2 minutes. The duration is too short because normally, vatting is carried out for about 10 minutes prior to dyeing (Aspland, 1992; Aspland, 1997; Giles, 1974). It is possible that the dyers normally start the dyeing process before the vat pigment is completely converted into soluble dye anions in order to avoid rapid strike common with vat dyes.

The dyeing time employed by most of the dyers (Figure 5) is 4-6 minutes and is majorly not more than 12 minutes. In part 2 of the series, we reported that the fabric is entered into the dyebath at an average temperature of 76±4.24 oC and as dyeing progresses, the temperature drops. Industrially, dyeing time at the maximum temperature can vary from about 45 minutes at 60 oC (Giles, 1974) to about 20 minutes at 100 oC (Aspland, 1992; Aspland, 1997). It can be assumed that the dyers take advantage of the rapid strike where 80-90 % of the dye may be exhausted within 10 minutes of dyeing (Broadbent, 2001).

Liquor ratio and Levelness of shade

Liquor ratio (LR) is the amount of water required in relation to the mass of textile expressed in a ratio. The dyers use an average of 20 l of water for dyeing 5 yards (4.57 m) of material which is in the range of 710 to 814 g (liquor ratio of ≈ 40:1). LR for various batch dyeing machines range from 5:1 to 30:1 or even more (Wardman, 2018). It has been reported that majority of local vat dyers in Ghana use a LR of 40:1 (Frimpong, 2009). Use of too large LR is disadvantageous because water causes oxidative decomposition of hydros and when in excess, due to the presence of more dissolved oxygen, the decomposition rate will be accelerated (Chakraborty, 1992).

Figure 6 shows that the dyers achieve level dyeing mostly by continuous movement of the fabric/garment in the dyebath. It is also achieved by proper control of goods to LR, steeping the fabric/garment before dyeing, and dyeing at relatively lower temperature for light shade. Other means of achieving level dyeing is the use of adequate quantities of dye/auxiliaries in the dyebath. Because the chemicals necessary for vatting process make the leuco vat dye anions in solution highly substantive, there is always the possibility of unlevelness if circulation of the dye liquor is inadequate (Aspland, 1997). Level dyeing is attained through the migration of dye by desorption from inside the fibre into the dye liquor and subsequent adsorption and diffusion in another part of the fibre, the levelling process being aided by the relative motion of fibre and the dye liquor and after appropriate time, a level, well penetrated dyeing is obtained (Holme, 2016).

Even though the dyers normally achieve a well levelled dyeing, they are unaware that the levelling properties of different group of vat dyes are not the same and therefore maximum overall result may not be achieved. For example, in general, the IK group levels very well, the IW group levels well, and the IN-group levels badly. Another factor for the levelling properties of a vat dye is the aggregation of its molecules after vatting. True solution is formed only with vat dyes of simple chemical constitution such as indigo and thioindigo while their derivatives form aggregates by agglomeration of several molecules and the more complicated the chemical structure of a vat dye, the greater is the tendency to combine and form larger aggregates creating levelling problems (Musshoff, 1975). Industrially, the problem of levelness has been addressed through the following: control of dyebath assistants, time, and temperature; application of the dye in the form of a non-substantive dispersion and reduction and oxidation of the dye in-situ; use of auxiliary compounds designed to slow down the rapid rate of exhaustion characteristics of most vat dyes; employment of the practically non-substantive hydrogen leuco compound of the vat dye with subsequent conversion into a highly substantive sodium leuco compound after distribution and adequate penetration of the goods (Fox, 1949). The latter approach is similar to the modified pre-pigmentation employed by the occupational dyers.

Colour and shade

As shown in Figure 7, the most common means of achieving desired colour and shade is by adding appropriate dye to the dyebath until the desired shade appears at the top of the dye liquor as foam while others include mixing the colour (s) and testing on the palm until the desired shade is obtained and consulting an experienced dyer. Another way of achieving desired colour and shade is keeping dyed sample and memorizing the mixture although it is rarely employed. According to the dyers, the ability to obtain an exact colour and shade from a sample provided by a customer is the most tasking in the dyeing occupation and requires several years of experience. Similarly, Saikhao et al (2018) reported that dyeing process of natural indigo vat dye requires a high level of expertise and experience to achieve the desired colour and shade.

In the 2nd part of the series, we reported that the dyers almost entirely do not measure dye/chemicals analytically and cannot control temperature precisely which makes it very difficult or almost impossible to reproduce an exact shade. Additionally, when large lot/order is to be dyed to the same shade, variation is hardly avoidable since the dyers can only dye 20 yards (18.29 m) of fabric at a time in a single dyebath. Industrially, colour matching system is used which works on the principle that colour is measurable and so is reproducible. The system allows the identification of colour since the human mind is deficient in remembering specific shades and no single person can recall the exact differences in a hue without a sample/recipe as a guide (Frimpong, 2009). For these reasons, obtaining desired colour and shade may pose problem to the occupational dyers.

Treatments carried out after dyeing

Table 2 shows that all the dyers (100 %) subject the dyed materials to air oxidation. Just a few, (0.1 %) each, employ soaping and acidification respectively because the dyers involved have chemistry background. Similarly, according to Shuvo II (2018), local artisans lack technical chemistry background required for aftertreatment. Exposure to air and rinsing will oxidize the colour but speed and economy have made it standard practice to use chemical agents such as hydrogen peroxide, sodium perborate etc. (Baumann and Fletcher, 1966). Industrially, after-treatments namely oxidation, soaping and neutralization/acidification are carried out as vat dyebath is dropped (Aspland, 1992). Soaping is the final stage in vat dyeing which involves treatment in a boiling solution of soap/other detergent and has the double purpose of removing from the fibres loosely attached surface dye thus achieving the full degree of fastness to washing and rubbing and of effecting a colour change to final shade (Summer et al., 1953; Shamey and Hussein, 2005). It is believed that during soaping, the isolated molecules of vat pigments are reoriented and associate into a different, more crystalline form enhancing the fastness properties (Aspland, 1992; Broadbent, 2001). Fastness properties of the locally dyed materials may be inferior due to the omission of the soaping stage.

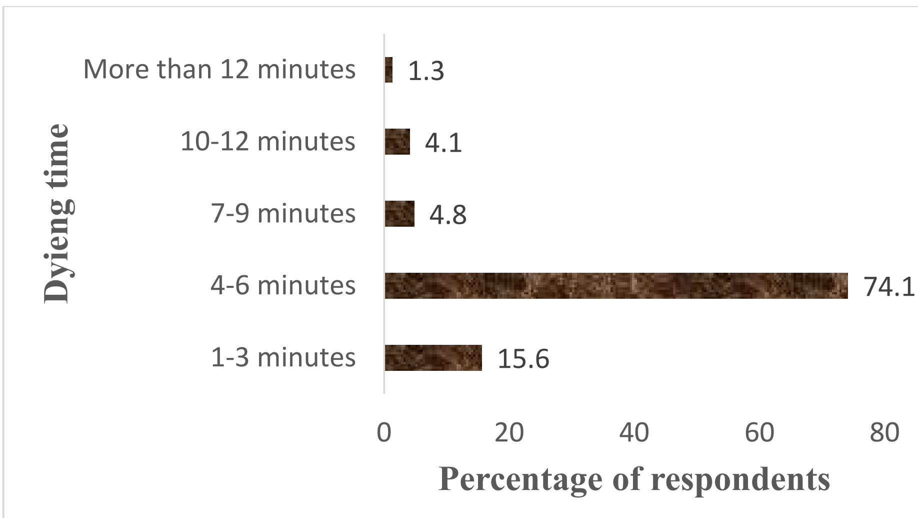

Table 5: Dyeing time

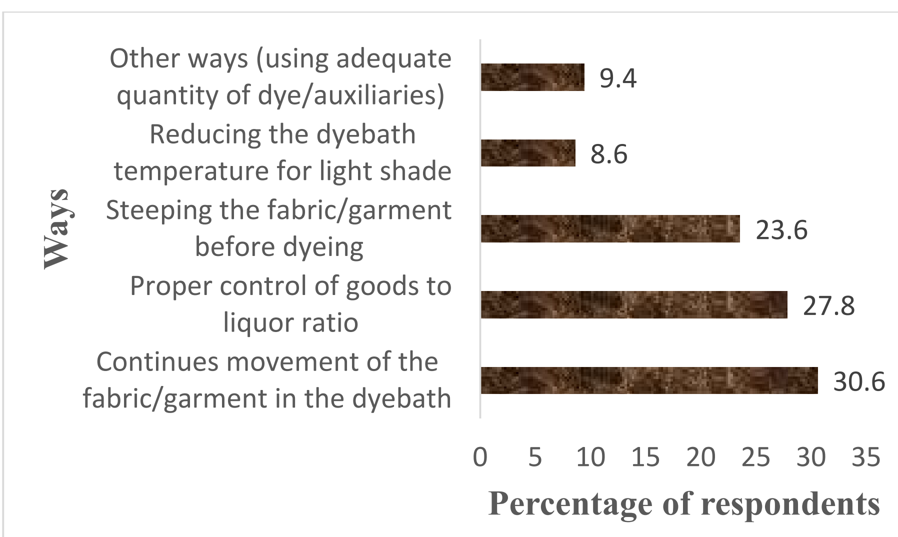

Figure 6: Ways in which the dyers achieve level dyeing

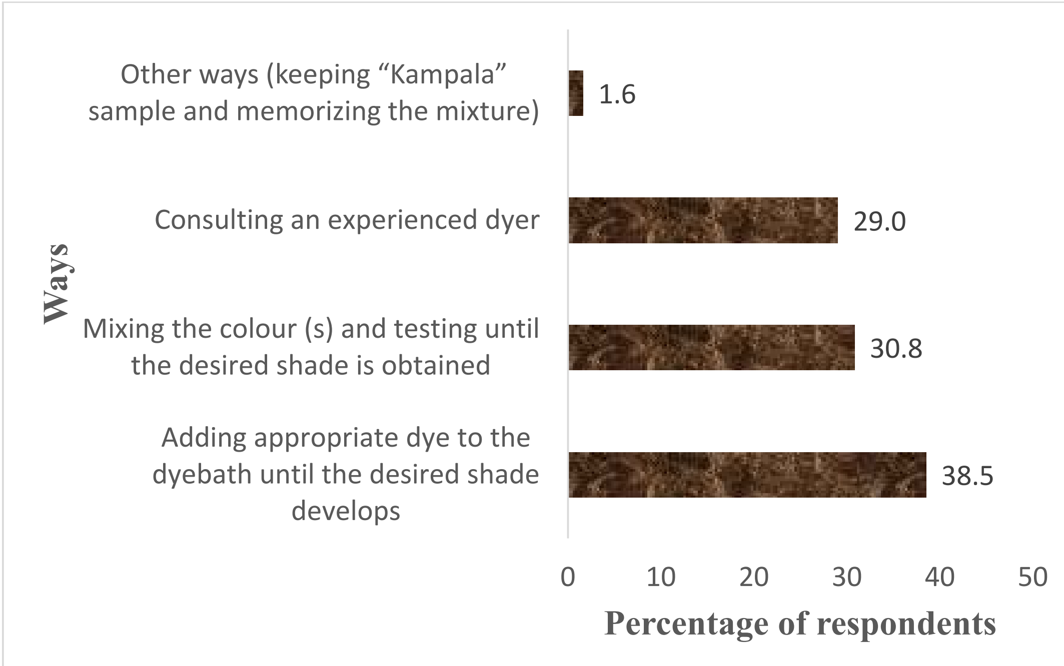

Figure 7: Ways in which the dyers achieve desired colour and shade

Table 2: treatments carried out by the dyers after dyeing

Treatments	Yes N=1387 (%)	No N=1387 (%)
Oxidation	1387 (100)	0 (0)
Soaping	2 (0.1)	1385 (99.9)
Acidification	2 (0.1)	1385 (99.9)

CONCLUSION

Results showed that the dyers were able to perfect the vat dyeing processes from years of experience which may, in some respects, be compared to industrial practices. Despite their lack of technical chemistry background, the dyers can carry out leuco vat dyeing, modification of pre-pigmentation, and mercerization followed by wet on wet 'shadow' dyeing. They can limit over-reduction of hydros by its metered addition, avoid phototendering of orange and yellow dyes by working in the early hours of the day, achieve level dyeing by moving the fabric in a stationary dyebath, and reuse spent dyebath to minimize wastage of dye and maximize profit. Additionally, the dyeing and vatting times are very short comparably which speeds up the dyeing processes. However, the dyeing processes may not give the best overall result due to potential shortcomings related to the quality of the dyed materials. Fastness of the locally dyed materials especially to light and washing may be inferior due to the lack of the soaping stage and also because the region is temperate coupled with the fact that most customers use any type of soap and detergent in laundry. Mercerized materials may become weaker with significant reduction in tensile strength basically due to excessive caustic soda used and insufficient rinsing after dyeing. The dyers being inconsistent with measurement of dye and chemicals and lacking precise temperature control may produce dyeings of poor colour yield and increase in dyeing cost for unutilized expensive vat dyes. Producing exact colour and shade may be difficult due to lack of colour matching system. In order to improve on the dyeing processes, it is recommended for related departments in academic institutions to collaborate with the major dyeing enterprises in terms of research/innovation and placement of students under Students Industrial Work Experience Scheme (SIWES). Furthermore, government should introduce tie-dye among entrepreneurship courses offered in tertiary institutions to enable interested students acquire chemistry background of the dyeing processes. The dyers on their part should only buy dyes bearing manufacturers recommendation and adhere to the instructions during application.

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