INFLUENCE OF SURFACTANTS ON FABRIC BEHAVIOUR

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INFLUENCE OF SURFACTANTS ON FABRIC BEHAVIOUR

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BY

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CERTIFICATE

This is to certify that the thesis entitled "INFLUENCE OF SURFACTANTS ON FABRIC BEHAVIOUR" submitted by Miss SHREELA B. MATTI, for the degree of MASTER OF HOME SCIENCE in TEXTILE AND APPAREL DESIGNING to the University of Agricultural Sciences, Dharwad is a record of bonafide research work carried out by her during the period of her study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar titles.

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JUNE, 2016

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In every one's life, the day arises when one has to shape the feelings in words. Sometimes, the words become unable to express the feelings of the mind, because, the feelings of the heart are beyond the reach of the words.

Any tedious task is made tight and smooth by god's grace. When I came to complete this manuscript, so many memories have rushed through my mind, which are full of gratitude to those who encouraged and helped me at various stages of this research.

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CONTENTS

LIST OF TABLES

Contd…..

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

The history of clothing is nothing but the evolution of civilization. By the development of science and technology, people began to use cloth in the form of garments. The development of clothing depended on the invention of fibre, which is the basic raw material of making fabric. Cotton rules the kingdom of fibres hence, called as king of fibres. Today, cotton is the most versatile fibre all over the world because of its friendly applications.

Cotton is a soft, fluffy staple fibre that grows in a boll, or protective capsule, around the seeds of cotton plants of the genus *Gossypium* in the family of *Malvaceae*. The greatest diversity of wild cotton species is found in Mexico, Australia and Africa. Cotton was independently domesticated in the Old and New Worlds. The word *cotton* comes from the Arabic word *qutun* or *kutun* used to describe any fine textile. Archaeologists found cotton fabric 5,000 years old at Mohenjo Daro, an ancient town in the Indus River Valley of West Pakistan.

The current estimates (2010) for world production are about 25 million tones or 110 million bales annually, accounting for 2.5 % of the world's arable land. China is the world's largest producer of cotton, but most of it is used domestically. The United States has been the largest exporter for many years. In the United States, cotton is usually measured in bales, which measure approximately 0.48 cubic meters (17 cubic feet) and weigh 226.8 kilograms (103.09 pounds).

The fiber is most often spun into yarn and used for making soft, pliable and breathable textiles. Although cultivated since antiquity, it was the invention of the cotton gin that lowered the cost of production that led to its widespread use. The Indian Textile Industry consumes a diverse range of fibres and yarn, but is predominantly cotton based. Cotton accounts for more than 75 % of the total fibre consumption in the spinning mills and more than 54 % of the total fibre consumption in the textile sector. From all types of apparel, including astronauts’ in-flight space suits, to sheets and towels, and tarpaulins and tents, cotton in today’s fast-moving world is still nature’s wonder fibre.

Cotton textiles represent more than half of the global textile market and the demand is expected to continue. This dominance mainly due to its natural comfort and simple process of its dyeing and finishing compared to synthetic fibre, because of excellent absorbency ability (Mohamed and Ahlem, 2014).

Clothing is an expression of a person, his personality and way of living. Clean clothes in good repair are necessary for a person to present a well groomed, well organized appearance. Clothes that receive the right kind of care look better and increase the wearing ability of materials.

The problems of stains on garments during use are as old as the use of textiles. Stains can be removed from all fabrics more easily when are fresh than when old. The choice of the method as well as the specific reagent to be used in stain removal are of utmost importance but sometime it may cause fading or loss of ground colour, luster, shrinkage of fabric or may even destroy the fabric itself (Gogoi and Kalita, 2000).

Stain removal for modern fabrics is complex. It requires special tools and skills. The same stain on two different fabrics may behave quite differently, depending on fibre content, dye, finish characteristics as well construction of the fabric. No single procedure or basic method of treatment exists for removal of the hundreds of different types of stains that occur on variety of fabrics while wearing apparel and use of house hold items.

Cotton fabric attracts dirt, dust, and soil by both dry and wet soiling mechanism as it has good absorptive and easy proneness to moisture absorption. Thus, the cotton, either dyed or undyed tends to attract these particles and therefore it becomes necessary to find out suitable type of surfactant for effective washing of cotton fabric without harming its major textile related properties.

Stains that come across in usual practices are plenty and may grouped as oily, greasy and mineral in composition. The oily, greasy and mineral stains set a very remarkable stain on both cotton and other synthetic fabrics, as some of these stains contain dye pigments. Hence, a great deal of care has to be taken to remove these stains from the clothes. Most common mineral stains are nail polish, hair dye, mud, fountain ink, ball point ink and so on.

Soaps and detergents are used as surfactants to remove these stains in usual practice. Most of the detergent powders contain sodium perborate which is effective in removing the stains. Usually four to seven percent of sodium perborate is added to a detergent (Naik and Kammar, 1998).

Surfactants, the surface active agents, are amphiphilic organic compounds with a strong tendency to adsorb at surfaces and interfaces. These consist of a hydrophobic tail and a hydrophilic head group. The hydrophobic tail can be branched or linear; aliphatic, alkylaryl; short or long (typically between 8 and 18 carbon atoms in a straight alkyl chain) chain. The hydrophilic head group may be ionic or nonionic. Thus, the chemical structure of surfactants can vary widely.

Surfactant is a blend of surface active agents. These are the compounds that lower the surface tension between two liquids or between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifier, foaming agent and dispersant. There are three main types of surfactants used in laundry detergents: *anionic*, *nonionic* and *cationic*.

Today, there are number of surfactants available in the market such as powder, chips, cake, bar and liquid for consumers to use in day-to-day life. Chemicals present in these surfactants affect the surface appearance of the fabric viz., pilling, weight, thickness, shrinkage, colour fastness, yarn slippage etc. Colour fastness of dyed fabric is the most prominent observation noticed during laundering where bleeding of colour is not only because of washing, but fading is also due to hot pressing (ironing), exposure to sunlight, crocking, and perspiration.

It is common for more than one surfactant to be used in a laundry detergent. This is because the actions of the surfactants can reinforce each other, giving rise to a greater cleaning ability from the combination than would be expected from a mixture of the two surfactants working independently.

Today, the detergents contain at least the components *viz*; anionic surfactants such as sodium alkylbenzenesulphonate, nonionic surfactants such as ethoxylated fatty alcohol and soap. Powdered detergents contain other components such as builders, bleaching agents and electrolytes. The surfactants used in the detergent formulations, whether in powder or liquid form, are obtained from petroleum by-products (Carrion, 2015).

In general, laundry detergents contain water softeners, surfactants, bleach, enzymes, brighteners, fragrances, and many other agents. The formulation is strongly affected by the temperature of the cleaning water and varies from country to country.

Most detergents contain enzymes to help remove food stains: amylase for starch; protease for protein; and lipase for fats. Many detergents also contain the cellulase enzyme that is designed to remove the fuzzy surface fibers and pills (fuzz balls) from the surface of cellulosic fiber and fabric blends. Detergent companies claim this removal of lint-forming fiber ends helps restore the surface colour of the fabric.

A detergent (including soaps) contains active agents that wets the fabric, emulsifies oily matter, solubalizes stain and keeps the soil in suspension. The active agent molecule is composed of two groups, an oil loving part and a tail with an affinity for water. These two combine together to help in the cleansing process by solubilising the dirt in water.

Detergents now are concentrated so that less is needed per wash load than in the past. “Ultra” is a term used to describe very concentrated detergents. Detergents that contain bleach or fabric softener may not be as effective on stain removal and/or softening as regular detergent which also contain some amount of additives. However, detergents form stubborn foam and require too many rinses for complete removal of residual suds.

Today’s consumer is conscious not only of style and comfort, but also of care and durability. He demands a quality product and controls the market. Studies show that consumers make many purchase choices based on colour. Therefore, to retain the original colour of the fabric is one of the most important concerns.

Colourfastness is defined by the American Association of Textile Chemists and Colourists (AATCC) as “the resistance of a material to change in any of its colour characteristics, to transfer its colourant(s) to adjacent materials, or both, as a result of the exposure of the material to any environment that might be encountered during the processing, testing, storage or use of the material.” In other words, it is a fabric’s ability to retain its colour throughout its intended life cycle (*https://textlnfo.wordpress.com*).

Cotton textiles are dyed with an extensive number of dye classes, including reactive, azoic, direct, indigo, pigment, sulphur and vat dyes. Vat dye is fine suspension of water insoluble pigment, which adheres to the cotton by undergoing an intermediate chemical state in which the dye become water-soluble and develops affinity for the fiber. Typically, vat dyes exhibit very good colour fastness properties.

Colour fastness properties are also influenced by consumer practices. These include laundry detergent selection and wash procedures. Some fabrics may fade a little when home laundered with standard detergent, but fabrics laundered with detergents containing activated bleach can show significant losses in colour strength as determined by the sensitivity of the dye to those detergents.

The detergents generally reduce the colour change associated with home laundering by decreasing the fuzziness on the fabric surface. Wash procedures influence ability of a fabric to retain its colour. Consumer practices such as washing clothes inverted, reducing the wash load size, adding softener to the final rinse and reducing the tumble dry time all collectivity minimize colour loss.

However, cotton will reach the consumers either in the form of fabrics or readymade garment. The maintenance of cotton fabric is also an important aspect, which could be done with the usage of proper soaps and detergents that not only remove dirt and grime from the fabric but also act as conductive to maintain good health (Deshwal *et. al.,* 2008). But it has adverse effect on physical properties of cotton fabric. Keeping in view the importance of surfactants, the present study on 'Influence of surfactants on fabric behaviour' is taken up with following objectives:

- To elicit the information on the most popularly selling surfactants in the local market
- To assess the efficiency of surfactants on stain removal
- To assess the effect of surfactants on colour strength of dyed fabric
- To study the impact of surfactants on structural, performance and durability properties of dyed fabric

2. REVIEW OF LITERATURE

This chapter presents the relevant research articles pertaining to the present study on "Influence of surfactants on fabric behaviour" and the review is presented under the following headings:

2.1 Stain removal

2.2 Colour fastness of dyed fabrics

2.3 Properties of cotton fabric

2.1 Stain removal

Stains that one come across in usual practices are plenty of which many of them fall in the category of oily, greasy and mineral in their composition. For e.g.: curry, mud, ink, rust so on. The oily, greasy and mineral stains set a very remarkable mark on cotton fabric, as some of these stain contain dye pigments in them. Hence, a great of care has to be taken to remove these stains from the clothes (Naik and Kumar, 1998).

Naik and Kammar (1998) conducted the study on "Impact of cleansing agents on mineral, oily and greasy stains". Here an attempt was made to study the efficiency of cleansing agents in removal of oil, greasy and mineral stains on cotton and polyester materials. Stains and cleansing agents were selected based on the survey results. The samples after laundering were evaluated to assess the colour change using grading scale and the results revealed that among the selected soaps and detergents 501, MYS,WHL,NIR, all yellows were found to be more effective on both cotton and polyester materials. Among the white agents ASY was highly efficient followed by AMS and SEL.

Gogoi and Kalita (2000) conducted the study on "Effect of various treatments on the removal of stain, (part-I)". In the experiment, plain woven mercerized cotton fabric and three stains namely blood, medicine and ink (ball pen) were selected. Stains aged for one week were selected for the study, since old stains are difficult to remove. The methodology consisted of dip method for stain removal and assessment of selected physical properties. The study concluded that stain removal with various stain removers has pronounced effect on physical properties of cotton fabric. Based on these physical properties, blood stain treated with salt water, medicine stain treated with methanol and ink stain treated with borax showed better results for removing the stains.

Preeti *et al.* (2001) conducted the study on "Effect of stain removing reagents on the colour of the cotton fabrics". The study was undertaken to get information of the commonly used colours for garments of rural masses. The cotton fabric of red and blue colour was stained with different stains. Selected stain removing reagents were applied to see the effect of reagents on colour of cotton fabrics and it was concluded that there was heavy change in colour of fabrics (red and blue) after treated with bleaches like jevelle water and sodium perborate but noticeable change in case of sun bleach.

In the study, alpha-amylase was immobilized on silica nanoparticles and immobilized alpha-amylase used in formulation of detergent powder for enhancing removal of starch soils. Detergent products contain very components which may affect the free enzyme activity and stability. Also various factors such as temperature, pH and humidity reduced enzyme activity and cleaning efficiency. Therefore the effect of enzyme immobilization on the removal of starch based soil was investigated on cotton fabrics as the model soil. The effect of temperature and humidity on stability of free and immobilized enzyme was compared. It was found that the immobilized enzyme increased cleaning efficiency soil removal on cotton fabrics, whereas free enzyme imposed a small effect on the enzymatic activity towards the same soil substrates. In addition, stability of immobilized enzyme against factors toward temperature humidity was much more than free enzyme. This study was carried out by Soleimani *et al.* (2012) conducted the study on "Alpha - Amylase immobilization on the silica nanoparticles for cleaning performance towards starch soils in laundry detergents".

Jetendra *et al.* (2012) conducted the study on "Characterization and application of a detergent-stable alkaline alpha-amylase from Bacillus subtilis strain AS-S01a". A strain AS-S01a, capable of producing high-titer alkaline alpha -amylase was isolated from a soil sample of Assam (India) and was taxonomically identified as Bacillus subtilis strain AS-S01a. Optimized alpha-amylase yield by response surface method (RSM) was obtained as 799.0 U with a specific activity 201.0 U/mg in a process control bioreactor. A 21.0 kDa alkaline alpha-amylase purified from this strain showed optimum activity at 55°C and pH 9.0, and it produced high molecular weight oligosaccharide including small amount of glucose from starch as the end product. The *K*m and *V*m values for this enzyme towards starch were determined as 1.9 mg/ml and 198.21micron mol/min/mg, respectively. The purified alpha-amylase retained its activity in presence of oxidant, surfactants, EDTA and various commercial laundry detergents, thus advocating its suitability for various industrial applications.

Kannappan and Santhi (2014) worked on "Ultrasonic studies on dye stain removal by surfactants". The ultrasonic velocities and densities has been measured for three surfactants, viz sodium lauryl sulphate, cetyl trimethyl ammonium bromide and triton X-100with methyl orange in aqueous solutions in the absence of and in the presence of lipase at different time intervals at 308K and at pH 5.5. The dye concentration has been maintained constant ($5.0*10^{-6}$m) and the concentration of the surfactant maintained to critical micelle concentration. Acoustical parameters such as adiabatic compressibility, inter-molecular free length and acoustic impedance has been computed. The ultrasonic studies reveal that lipase can enhance the detergent action of surfactant.

The study on "Methodological study on the removal of solid oil and fat stains from cotton fabrics using abrasion" was conducted by "Prieto and Bakalis" (2014). In this, fabric abrasion has been studied for the first time in a systematic and controlled manner using a tribometer. The efficiency of cotton–cotton abrasion, to simulate the rubbing of clothes, was studied in the absence of detergents using models of liquid and solid oils (hexadecane, octadecane, and undecanoic acid) and real fats (lard and buttermilk fat). In model oils, abrasion is not very effective at any temperature, whereas in typical fats abrasion significantly improves cleaning in a wide range of temperatures. The different behavior is caused by the temperature-dependent solid fat content of lard and butter. All the fats tested can never be completely removed with water alone; detergents will be necessary.

2.2 Colour fastness of dyed fabrics

Colourfastness is defined by the American Association of Textile Chemists and Colourists as "the resistance of a material to change in any of its colour characteristics, to transfer its colourant(s) to adjacent materials, or both, as a result of the exposure of the material to any environment that might be encountered during the processing, testing, storage, or use of the material." In other words, it is a fabric's ability to retain its color throughout its intended life cycle. There are many types of colourfastness properties that must be considered to provide the consumer with an acceptable product (*https://textlnfo.wordpress.com).*

'Efficacy of selective surfactants/detergents as washing agents on soiled white and dyed cotton fabrics was the research conducted by Samanta *et al.* (2004). Four types of surfactants viz., alkyl benzene sulphonate (A), sodium lauryl sulphate (B), glycerol monostearate (C) and distearyl dimethyl ammonium chloride (D) were selected and the result revealed that, the critical micelle concentration (CMC) value and the corresponding degree of soil removal at CMC level were 1.9 % and 90.8 % for surfactant A, 1.5 % and 90.6 % for surfactant B, 2% and 92%for surfactant C and 1 % and 39.4 % for surfactant D. On multiple wash, the surfactants C and D did not show good performance at lower concentrations (0.5 -1 %), while the surfactant B was found to be better than others.

Alam *et al.* (2008) conducted the study on "Dyeing of cotton fabrics with reactive dyes and their physico-chemical properties". Highlighted the effect of dye concentration, electrolyte concentration, dyeing time and dyeing temperature on dyeing performance of cotton fabric dyed with reactive dyes, viz. Reactive Red 6B and Reactive Yellow RL. It was revealed that the dye absorption increased with the increase in the electrolyte concentration, dyeing time and dyeing temperature but decreases with the increase in dye concentration. Considering the effects of various external influences on the dyed cotton fabric, it was concluded that the Reactive yellow RL imparted better physico-chemical properties than Reactive red 6B.

Was-Gubala and Grzesiak, (2009) worked on "The kinetics of colour change in textiles and fibres treated with detergent solutionsPart II — Spectrophotometric measurements". The aim of this study was to assess colour variations that occur in several types of textiles and their constituent fibres, resulting from the long-term influence of various laundry detergents. A 14-day experiment was conducted using blue, red and grey/black cotton, wool, acrylic and polyester textiles. The spectrophotometric measurement of colour changes in fabric samples and test solutions, as well as the microspectrophotometric analysis of colour changes in single fibres were described. The spectrophotometric analysis confirmed that the most significant differences in textile and fibre colour–regardless of the type of detergent used–were achieved with the natural fibres: wool and cotton. The type of dye used and the finishing process applied to a textile have a bearing on the process as well: in the visible range, blue wool underwent a greater change than red wool.

The ‘Effect of nonionic surfactants on the dyeing process of cellulose fibres with C.I. reactive blue 217’was carried out by Kazimierz and Bemska, (2010). This investigation addressed the role of nonionic surfactants on the sorption of C.I. Reactive Blue 217 by cellulose fibres, focusing on the influence of the surfactant concentration and type on the spectroscopic properties of this dye. It was found that surfactants in dyeing baths change the spectroscopic properties of dye solutions, resulting in the decomposition of aggregates and agglomerates to form a surfactant-dye complex. The surfactants in bath counteract the aggregating action of sodium chloride. The performed studies concerned the sorption kinetics of dye from dyeing baths containing various surfactants and their influence on the exhaustion coefficients of the dye. It was also found that nonionic surfactants retard the sorption processes of dye from the dyeing bath, improving dyeing quality.

Nihat, *et al*. (2010) carried out study on “Effect of the particle size of fluorocarbon-based finishing agents on fastness and color properties of 100 % cotton knitted fabrics”. This study examines the effect of the particle size of fluorocarbon-based water-oil-soil-repellent finishing agents on color fastness and colorimetric properties by experimental analyses. Therefore, two finishing agents with different particle sizes were applied to red-dyed and blue-dyed knitted fabric samples of single jersey and rib-structured knits, produced from 100 % cotton yarns. The results show that smaller particle size causes less color change for all washings (0, 1 and 5), both of the dyes and the fabric structures (single jersey and rib). Also, it is observed that smaller particle size positively affects the rub fastness results.

Santhi and Moses (2010) performed on “Study of different reducing agents for effective vat dyeing on cotton fabric”. The test sample was cent percent cotton poplin fabric, having specifications viz., ends/ inch 132, picks/ inch 70, warp count 37s and weft count 41s. Effect of treatment with zinc (2.0 % owm), ferrous sulphate (2.0 % owm), zinc + hydrose (1.0 % + 1.05 owm) and ferrous sulphate + hydrose (1.0 % + 1.05 owm) reducing agents on dyeing properties of cotton fabric dyed with vat dye was studied and the results were compared with those of the treatment with conventional hydrose (2.0% owm) in terms of reduction potential, depth of shade and SEM analysis. The appreciable results are observed for the combination ferrous sulphate + hydrose as reducing agent showed 99.17 % colour strength with uniform dyeing and good reduction potential.

“Dyeability of cationised cotton and nylon 6 fabrics using acid dyes” was performed by El-Molla *et. al*., (2011). Cationisation off cotton and nylon 6 fabrics has been done using Solfix E, Tino fix ECO, Acramine berfix k and cetyl trimethyl ammonium bromide to impart cationic sites on fabric surface for improving their substantivity to acid dyes. Pre-cationisation of cotton and nylon 6 fabrics improves the depth of the colour as well as fastness properties. In all the cases, the overall colour fastness of cationic cotton dyed with acid dyes is found to be comparable to the colour fastness of the nylon 6 dyed with same acid dyes.

The effect of spectrophotometer geometry on the result of colour measurement is investigated in this paper for textile samples with different types of texture. In addition, the effect of texture on the measured colours was compared for two geometries; d/8 and 45/0. A comparison was applied between 45/0 and d/8 geometries in which the color change via the texture variation was discussed.

To do that a pair comparison T-Test was performed. The P-value of 0.032 was obtained with 0.95 confidence level, which shows that the color change by the texture difference is statistically dependent on the spectrophotometer geometry with 0.95 confidence level. This research was studied by Saeideh, (2011) on “The effect of spectrophotometer geometry on the measured colour for textile samples with different textures.

Necla *et al*. (2012) carried out the research on “Improvement fastnesses and colour strength of pigment printed textile fabric”. This paper focused on the improvement of fastnesses and colour strength of pigment printed textile fabrics. To improve fastness and colour strength of the polyester fabrics, atmospheric plasma treatment was used. The effects of atmospheric plasma treatments were evaluate by XPS, SEM and AFM. When the properties of atmospheric plasma treated samples were compared to those of untreated sample, higher K/S values were obtained. Also, the fastness of treated samples increased between ½ and 1 point.

Hemen *et al.* (2014) conducted the study on ‘Surface activation of polyester fabric using ammonia dielectric barrier discharge and improvement in colour depth’. The effect of atmospheric pressure ammonia dielectric barrier discharge on the surface of the polyester fabric has been studied using contact angle goniometer, ATR-FTIR spectroscopy and SEM. It was observed that the surface of plasma treated polyester was more hydrophilic due to incorporation of nitrogenous polar functional groups and shows different conformational composition and crystallinity. The ATR-FTIR results clearly indicate the conversion of trans-ethylene glycol residue to gauche one after plasma treatment and thus reduction in crystallinity. Plasma treatment has shown synergetic effect on dye uptake. Natural dyeing of plasma treated polyester with ‘*Rubia cordifolia’* has shown 65 % improvement in colour depth in comparison to untreated polyester fabric.

A comparative study of the colour, abrasion and colour fastness properties of plain knitted fabrics made from 100% modal viscose fibres in different fibre finenesses such as microfibre and conventional fibre, their 50/50 blends with cotton fibre and 100 % cotton fibre was presented by Ahu *et al*. (2014) in ‘Colour, abrasion and some colour fastness properties of reactive dyed plain knitted fabrics made from modal viscose fibres’ research paper. Abrasion behaviours of the fabrics were assessed by measuring the weight loss and colour values after four different abrasion cycles. All the results were compared with respect to both the fibre fineness and blend proportion of cotton fibre in the fabrics. The L* and K/S values of the fabrics after abrasion reveal a similar tendency to that of the fabrics before abrasion. Before and after abrasion cycles, the fabrics with microfiber revealed lower K/S and C* values and higher L* values than those with conventional fibre. With an increase in the cotton amount the K/S values of the fabrics decrease and the L* values of the fabrics increase.

2.3 Properties of cotton fabric

Fabric properties are determined by the fibre content, yarn and fabric construction and any chemical and mechanical treatment applied to the yarn or fabric. These need to be assessed within the context of the requirements of the specific end-use for which the fabric is destined within the broad categories of clothing (apparel) textiles, home textiles and industrial (technical) textiles. With respect to clothing aspects relating to the fabric aesthetics or appearance generally dominate, while in case of industrial textiles, technical and performance related properties predominate.

Gulrajani *et al.* (1998) conducted the study on “Kawabata evaluation of enzyme-treated cotton knitted fabric”. In this, industrial trial of the enzymatic treatment of 20s combed and 20s carded knitted cotton fabric with cellulose enzyme Denified was carried out under optimized conditions and the various low-stress mechanical properties of the treated fabrics have been assessed in the Kawabata system. The results showed an improvement in the surface smoothness and a decrease in the bending and shear rigidities. The improvement in handle is reflected by the decrease in tensile and compressional energies.

Kalita (1998) conducted the study on “Effect of dry cleaning and laundering on silk fabrics”. The investigation has been made to compare the effect of dry cleaning and laundering on physical properties of white silk and colour silk and the results revealed that the white and coloured silk could withstand up to 15 time dry cleaning and washing. Not much drastic change has been found in all tested samples. Among the physical properties, silk fabric, which was dry cleaned exhibit best results compared to laundering.

Sarkar *et al.* (1999) conducted the study on “Use of surface active agent in cooking and reeling of muga cocoon and its effect on properties of fibre and yarn”. The best commercial crops of muga cocoon were selected for the study and the properties of silk fibre and yarn tests were conducted such as breaking load and elongation percentage and the study concluded that the use of surface active agent along with Na_2CO_3 in cooking and reeling of muga cocoon was highly satisfactory. Surface active agent along with alkali helped in easy removal of sericin from silk fibre without damaging the fibre and there by easy tracing of it from the cocoon.

Khambra and Chanchal, (2000) conducted the study on “Effects of laundering on properties of jute/ acrylic knitted fabrics”. Here, jute-acrylic blended yarn of 20:80 proportions was prepared on ring-spun mechanism of 20s count. The plain knit fabric was knitted for making the sweaters. These sweaters were subjected to 10 laundering cycles using 2 % soap solution by following the ATTCC standards. The dimensional and mechanical properties of new and washed fabrics were determined and evaluated using standards test procedures and it concluded that, with the shedding down of the jute the fabric had good areal density, air permeability, porosity and drape coefficient. Therefore the acceptance increased after five washing, where as the acceptance for the sweaters declined after 10 washing because of more pilling on the surface of fabric which deteriorates the surface of the blended fabric.

“Effect on laundering on the Aesthetic properties of cotton/polynosic blended fabrics. Cotton/polynosic (62c/38p) blended material was taken Bombay dyeing, colour of the material was light yellow, soap (pH of the solution 8.5) and detergent (pH-7.5) was taken. The tests were conducted after washing and the result revealed by Sarkar (2000) that crease recovery angle was more in detergent washed samples. Thickness increased after repeated washings and significant to soap and moderate pilling occurred after washing and more bleeding of water.

Sarkar and Munshi (2001) conducted the study on “Effect of soap and detergent on the strength of the cotton/polynosic blended fabric”. For the study, cotton/polynosic (62C/38P) blended material, soap (pH- 8.5) and detergent (pH- 7.5) were taken. The blended fabric was subjected for 50 washes with soap and synthetic detergent maintaining a standard condition. After laundering, tests were carried out. Results of test were reported as statistically significant at 5 % level. Paired “t” test was applied. It was observed that compared to detergent washed sample tearing strength decreased remarkably with soap washed samples. Breaking strength was more for detergent washed sample though it was non-significant.

“Evaluation of comfort properties and dyeing characteristics of fabrics made out of compact yarns” was carried out by Chellamani *et al.* (2008). In this study, the plain and twill weave fabrics were woven using compact as well as conventional ring spun yarn. Dyeing was carried out using reactive dye after appropriate pre-treatments and the study concluded that the tensile strength of compact yarn fabrics is higher as compared to ring yarns by about 10 %, ring yarn fabrics exhibited better crease recovery and this is attributed to the relatively lower packing of fibres in those yarns and there is no significant difference in colour strength values between compact and ring spun yarn fabrics.

Deshwal *et al.* (2008) conducted the study on “Effects of soaps and detergents on cotton fabric”. Two soaps and two detergents were selected, as per the survey results of hundred rural housewives of four villages. The results revealed that the cotton fabric laundered with soaps showed significant increase in the fabric count over control sample than detergent. Further it was concluded that shrinkage parameters were adversely affected by detergents than soaps.

Hasani (2010) conducted the study on “Effect of different processing stages on mechanical and surface properties of cotton knitted fabrics”. Here the influence of different processing stages on the low stress mechanical and surface properties of cotton knitted fabrics was studied. The KES-FB system was used for the measurements of low stress tensile, shear, bending and compression and surface properties. The results showed remarkable changes in mechanical and surface properties of knitted fabrics after processing stages, such as bleaching, dyeing and softening.

Hussain *et al.* (2010) conducted the study on “Prediction of tensile strength of polyester/cotton blended woven fabrics”. The study was undertaken to develop statistical models for the prediction of tensile strength of 52:48 polyester/cotton blended woven fabrics using empirical data based on a carefully manufactured range of woven fabrics under controlled conditions using a systematic selection of yarns. The study concluded that the polyester/cotton blended woven fabrics were very strong ability and accuracy of the prediction model.

Faiza Ebrahim *et al.* (2011) conducted the study on “Effect of Surface Active Agents on Cellulosic Fabric Properties”. The effects of four different types of surfactants on Cellulosic Fabric Properties were studied. The non-ionic surfactant improve surface and mechanical properties by approximately 15 % while in the presence of amphoteric, anionic and cationic surfactants decreased by13, 18, and 50 %, respectively. The mechanical properties, such as tensile strength, thickness and crease recovery (angle) of the cellulosic fabrics were measured. In the presence of non-ionic surfactant, the tensile strength loss for cellulose treated fabric was increased by 17 %. The loss of tensile strength did not change using cationic surfactant while in the presence of amphoteric and anionic surfactants, the strength loss decreased rather insignificantly.

Rana *et al.* (2011) conducted the study on "Effect of laundering on flammability characteristics of FR treated cotton fabric". The sample selected in this study was 100 % pure white mercerized cotton fabric, with GSM 220g, flame retardant chemicals zirconium dioxide and two binders' viz., polyvinyl alcohol and silicon liquid nitrile. The results revealed that, laundering affected burning characteristics of cotton fabric finished with flame retardancy. It was found that, the cotton sample treated with 15 per cent zirconium dioxide and 5 per cent PVA binder exhibited better flame retardancy compared sample treated with 12 per cent zirconium dioxide and 5 per cent SNL binder. The study conclude that, as the number of treatments/ dips increased, time taken to ignite was increased and as washing cycle increased the time taken was reduced.

Jiang *et al.* (2013) conducted the study on "Influence of surfactants on shear-thicking behavior in concentrated polymer dispersions". Concentrated dispersions consisting of 310 nm poly (styrene–ethylacrylate) nanospheres and ethylene glycol, which exhibited pronounced shear-thickening behavior, were prepared in this work. The influence of surfactants on their shear-thickening behavior was investigated, which indicated that the surfactants affected the shear-thickening behavior by changing the surface force and interparticle force. Various surfactants, such as cationic, anionic, nonionic, and zwitterionic surfactants were added to the shear-thickening fluid (STF) and their rheological properties were measured. The results indicated that all kinds of surfactants could enhance shear-thickening behavior by changing their electrostatic, steric or lubrication interaction, especially for nonionic surfactant Triton X-100 (TX100) and cationic surfactant etyltrimethyl ammonium bromide (CTAB). TX100 led to the maximum viscosity up to 1,650 Pa s and CTAB enhanced the maximum viscosity up to 1,000 Pa s when the introduced surfactants were only 2 and 0.3 %, both values were nearly five times larger than the neat STFs.

Nair *et al.* (2013) conducted the study on "Studies on friction in cotton textiles: Part II- A study on the relationship between physical properties and frictional characteristics of chemically treated cotton fabrics". The study aimed at investigating the role of various fabrics attributes on fabric friction and the effect of chemical modifications/treatments were given to the fabric on the frictional behaviour of fabrics. The results revealed that the relative movement of one fabric over the other results in varied frictional behaviour depending upon their dimensional direction. Chemical modifications was done on the fabric alter the surface characteristics of the fabric and accordingly influence the fabric's frictional behaviour. From the results of friction between fabrics it can be concluded that it is more difficult to move two similar surfaces over each other than dissimilar ones.

Kulloli and Naik (2014) conducted the study on "Designing eco-friendly fabrics from naturally colour linted cotton". Two genotypes of naturally brown coloured cotton yarns viz., Dharwad desi colour cotton – 1 (DDCC-1) and Dharwad brown hirsutum -250 (DBH-250) were woven on handloom with white cotton and filature silks (Muga and Tasar) to produce user and ecological friendly fabrics. Japanese Kawabata evaluation system assessed these union fabrics for their performance. The results revealed that union fabrics showed higher tensile strength, bending, shear, compressional and surface property values indicating the fabrics having low bending rigidity and fabric density, greater flexural rigidity, coarse and rough to handle than their corresponding control samples.

Gulzar and Chris (2015) conducted the study on “Kawabata evaluation of PLA – knitted fabric washed with various laundering formulations”. PLA – knitted fabric was scoured in the presence of sodium carbonate and a non-ionic detergent through an exhaust technique. The scoured fabric was washed in the presence of tailor-made formulations. PLA fabric was laundered up to 50 cycles and then evaluated in terms of mechanical properties and surface morphology. The results revealed that the tensile properties of PLA yarns were little affected by the detergent treatment. Some holes and cracks were also observed on the surface of fibres and might contribute to the strength loss and increased surface friction.

3. MATERIAL AND METHODS

The present investigation on 'Influence of surfactants on fabric behavior' is carried out in Dharwad city to find out the different types of cleansing agents available in local market and the impact of selected cleansing agents on stains and structural, performance and durable properties as well as colour fastness of the dyed cotton fabrics.

The methodology adopted to carry out the present study is classified into two sections, *viz.,*

3.1 Survey method

3.2 Experimental procedure

The detailed classification of methodology involved in this study is presented under the following headings:

3.1 Survey: The present study includes two surveys *i.e.,* and

Survey - I

Survey - II

3.1.1 Selection of sample

3.1.2 Criteria set for selection of sample

3.1.3 Tools used for data collection

3.1.4 Pilot study

3.1.5 Variables included for the study

3.1.6 Classification of the independent variables

3.2 Experimental procedure:

3.2.1 Selection of test samples

3.2.1.1 Selection of fabric

3.2.1.2 Selection of stains and detergents

3.2.1.3 Selection of colours and dye

3.2.2 Application and washing of stains

3.2.3 Evaluation of colour strength of stains and dyed samples

3.2.4 Laundering

3.2.5 Evaluation of quality parameters of dyed cotton fabrics

3.2.5.1 Structural properties

3.2.5.1.1 Cloth count (threads per inch)

3.2.5.1.2 Cloth thickness (mm)

3.2.5.1.3 Cloth weight (GSM)

3.2.5.1.4 Cloth dimensional stability (%)

3.2.5.2 Performance properties

3.2.5.2.1 Cloth bending length (cm)

3.2.5.2.2 Cloth crease recovery (degree)

3.2.5.3 Durable properties

3.2.5.3.1 Cloth abrasion resistance (cycles)

3.2.5.3.2 Cloth tensile strength (kgf) and elongation (%)

3.3 Statistical tools used

3.4 Hypothesis set for the study

3.1 Survey method

In the present study, two surveys were carried out to elicit the information from the selected sample group. These results will be the base for further experimental procedure.

3.1.1 Selection of sample

Survey I was carried out to elicit the information regarding the availability of different types of cleansing agents (surfactants) in the local market of Dharwad city. The sample size comprised of fifty shop owners selected randomly.

Survey II was carried out to collect the information regarding the common stains experienced by the working men and women. To elicit this information, 30 each working men and women were selected randomly.

3.1.2 Criteria set for selection of samples

3.1.2.1 Criteria set for selection of sample in survey I

a) The grocery shops have good collection of cleansing agents

b) There will be good promotion of cleansing agents

3.1.2.2 Criteria set for selection of sample in survey II

a) The respondents acquainted with different types of stains

b) The respondents aware about the ads on stains

3.1.3 Tools used for data collection

Survey was the tool adopted to collect the relevant information from the grocery shop owners, working men and working women.

In survey I, a self structured interview schedule was developed to elicit the information regarding the forms and types of cleansing agents available in the shops, promotion technique adopted by the shop owners and consumers demand for various surfactants.

T V ads: In most of the visual aids, Tide (T) and Wheel (W) detergents have shown more times followed by Surfexcel (SE), Rin (R), Areal (A), Ghadi (G), Nirma (N) and so on.

In survey II, a self structured questionnaire was formulated for gathering information about type of clothes used by the respondents, fibre content, occurrence common stains, surfactants used and mode of stain removal.

3.1.4 Pilot study

Two pilot studies were carried out separately for survey I and survey II. In survey I, a pilot study was carried out to pre-test the self structured interview schedule and administrated on 10 shop owners from Dharwad city. In survey II, to pre-test the self structured interview schedule and it was administrated on a total of 10, five each working men and working women. The sample selected for pre-tests was not included in actual data collection. On the results of pilot study, the questions in the interview schedules were modified by substituting and eliminating the suitable and irrelevant items required respectively.

3.1.5 Variables included for the study

The following independent and dependent variables were included for both surveys.

Independent variables

- Age
- Education
- Annual income

Dependent variables

- Common stains and cleansing agents
- Laundering

3.1.6 Classification of the independent variables

3.1.6.1 Age of the respondent (years)

The age of the respondents was classified into the following three groups on the basis of ± 0.425 standard deviation.

Table 1. Age group of the respondents

Categories	Age groups (years)		
	Younger	Middle age	Elderly
Shop owners	< 37 years	37 – 47 years	> 47 years
Working men	< 37 years	37 – 47 years	> 47 years
Working women	< 32 years	32 – 42 years	> 42 years

3.1.6.2 Education of the respondents

Based on the education level, the respondents were classified in to seven categories as, primary, secondary, higher secondary, PUC, Graduate, Post Graduate and illiterates for both survey I and survey II.

3.1.6.3 Annual income

The shop owner, working men and working women were grouped into three categories as per their annual income based on mean $\pm$ 0.425 standard deviation.

Table 2. Annual income of the respondents

Categories	Annual income (Rs)		
	Low	Middle	High
Shop owners	< 52,696	52,696 – 68,794	> 68,764
Working men	< 38,395	38,395 – 60,732	> 60,732
Working women	< 34364	34364 – 54245	> 54245

3.2 Experimental procedure

The experimental procedure involved selection of test samples, stains and surfactants; dye and colour; application of stains and its removal; laundering of dyed fabric; and assessment of quality parameters on subsequent washes. The detailed procedure of each entity is presented below.

3.2.1 Selection of test samples

This selection involves selection of textile substrate, stains, surfactants, dyes and their colours on the basis of survey results I and II.

3.2.1.1 Selection of fabric

The test sample selected for the present study was bleached cotton fabric.

3.2.1.2 Selection of stains and surfactants

Based on the survey results I, three popular surfactants sold rather purchased by the consumers and four commonly occurring stains experienced by working men and women were selected for further study (survey II).

The selected three surfactants were in powder form and coded to avoid discrepancy among the brands. All these three surfactants though basically are of white colour, one of the three surfactants exhibited an admixture of blue and orange granules whereas second showed greenish blue granules and the last one was pure white. Keeping these physical colour combinations and their pH values, surfactants were coded as below:

Pure White	- PW (09.50 pH)
Pure white with greenish granules	- WG (10.60 pH)
Pure white with blue and orange granules	- WBO (09.70 pH)

3.2.1.3 Selection of dye, hue and dyeing

The most popular dye commonly used on cotton to dye the fabric, vat dye that has good light and wash fastness was selected. Further four dark hues which fade on exposure to light and bleed on washing were chosen, of which one being the neutral colour, the black. Both dye and hues were selected purposively.

Dyeing: Each five meters of cotton cloth, the test sample was dyed in each hue of vat dye, commercially. Further was taken for staining, assessment of stain removal, washing and evaluation of quality parameters including colour fastness.

3.2.2 Staining the test samples and stain removal

Three selected common stains were applied on the white cotton fabric. The stained samples were kept for a week to make them artificially old and were washed with three selected detergents up to three washes. Each stain on each test sample was treated with each surfactant, washed, rinsed and shade dried. This procedure is repeated for another two times with a gap of 24 hours.

3.2.3 Evaluation of colour strength of stains and dyed samples

Colour strength of stains on white samples were evaluated before and after washing by using spectrophotometer.

Spectrophotometer, measures the spectral reflectance and spectral transmittance of the samples through the visible spectrum relative to a particular reference. The Viewing Angle and the illuminating condition, considerably influence the perceived colour. The geometry of a colour measurement instrument is therefore, an important factor in its design.

Colour strength (K/S) of the stain fabrics

Colour is a sensation which occurs when light enters the eyes. Colour of any substance decides the ultimate appearance of the article. The shade of the stain after washing was measured and recorded as colour strength (K/S), L*, a*, b* value.

K/S value

K/S value defines a relationship between spectral reflectance (R in %) of sample and its absorption (K) and scattering (S) characteristics. Higher the K/S values, greater the colour yield and colour uptake.

CIELAB (or CIE L* a* b*)

Colour space in which value L* a* and b* are plotted at right angles to one another to form a three dimensional coordinate system. Equal distance in the space approximately represents equal colour differences. Value L* represents lightness/darkness, value a* represents the redness/greenness while b* is indicative of yellowness or blueness of the samples.

∆ E (Colour difference)

The colour differences of the dyed cotton fabrics before and after washing were measured using the Premier Colour scan Software. The colour difference generally calculated as the square root of the combined squares of the chromaticity differences (a*, b* and lightness difference L*).

3.2.4 Laundering

Laundering is another aspect of the study to find out the quality parameters of the dyed cotton fabrics. The dyed cotton fabrics were subjected for a total of 15 washes and the quality parameters were assessed after every 5^{th} wash. The surfactant which was in demand by the consumer and sold maximum, was selected to wash the test samples.

- ❖ Method of washing : Hand wash
- ❖ Method of drying : Shade drying
- ❖ Number of rinsing : 3 times
- ❖ Concentration of surfactant : 5gpl

3.2.5 Assessment of quality parameters of dyed cotton fabrics

3.2.5.1 Structural properties

When deciding on a fabric it is imperative to consider certain fabric properties to infer on its end use. The geometry of the fabric is nothing but its structure and in a woven fabric ends and picks per unit area, cloth thickness and GSM are the three features invariably decide on the cloth configuration. These parameters do forma base for the performance, durability and comfort properties of a woven fabric. Hence, an effort was made to find out the impact of surfactant on the structural properties of dyed test sample.

3.2.5.1.1 Cloth count (Ne)

Cloth count in woven textile material is the number of ends and picks per unit area, while the fabric is free from wrinkle and held under no tension. Counts of the specimen / sample were determined with the help of pick glass by BS method 2862: 1957 (Booth, 1996).

The number of warp and weft yarns in one square inch of the fabric was counted randomly at selected places across the width and along the length of the test specimen by using magnifying counting device. Ten readings were recorded and mean values of ends and picks / inch were calculated.

Number of readings : 10 each warp way and weft way (1 inch)

Method used : Direct counting of threads per unit area

Instrument used : Magnifying lenses (pick glass)

3.2.5.1.2 Cloth thickness (mm)

The specimens were tested as directed in ASTM test method D-1777-1975. The dyed fabric is placed on the anvil of the test apparatus and pressure foot is brought into contact with the opposite side of the material and the thickness is recorded in mm.

Thickness is the distance between the upper and lower surface of the material measured under a specified pressure, expressed in mm. The specimens were tested as directed in BS test method 2544:1954 (Booth, 1996). The specimen chosen were free from folds, crushing or distortion, wrinkles. Specimen was placed on the anvil of the test apparatus and brings the pressure foot in to the contact with the opposite side of the material and record the thickness in mm.

Shape of the anvil : Round

Area of the anvil : 1cm Diameter

Number of specimen tested : 10

Instrument used : Sherley's thickness tester

3.2.5.1.3 Cloth weight per unit area (GSM)

Fabric weight is expressed as mass per unit area in g/sq.mt. A sample of 5 X 5cm was cut and weighed on electronic weighing balance to determine the weight per square meter (g) (Booth, 1996). Further, warp and weft threads were separated and weighed to calculate respective percentages. The percentage composition of warp and weft was calculated as follows.

Weight of 5 x 5 cm sample = a (g)

Weight of warp yarn = b (g)

Weight of weft yarn = c (g)

$$\text{Percent of warp} = \frac{100 \times b}{a}$$

$$\text{Percent of weft} = \frac{100 \times c}{a}$$

Number of specimens tested : 10

Instrument used : Electronic weighing balance

3.2.5.1.4 Cloth dimensional Stability (%)

Cloth dimensional stability is measured in terms of shrinkage percentage. The fabric sample of 20x20cm was taken and initial length of 15cm was marked both in warp and weft direction. The test samples were soaked in the soap solution of 1gpl at room temperature for 30 min, rinsed thoroughly in cold water and dried under shade. The dried samples were pressed gently without stretching. The final distance was measured and change in dimension was expressed in % using formula

$$S = \frac{Lo - La}{Lo} \times 100$$

Where,

Lo – Initial length

La – Final length

Size of specimen : 15 x 15

Number of readings : 5 each warp and weft ways

3.2.5.2 Performance properties

Performance is the ability of a textile product to serve to its end use. It determines the behaviour characteristics of fibres and their suitability in specific end use conditions. Strong demands on good performance properties such as strength / modulus, durability and dimensional stability and on functions such as flame-retardancy, hydrophilicity, hydrophobicity, biocompatibility, smart and responsive textiles, sensors, etc.

3.2.5.2.1 Cloth crease recovery (degree)

Crease recovery is nothing but allowance of the fabric to recover from the crease. The test samples were tested as directed in IS method: 4681-1968 by using shirely's crease recovery tester. Samples were cut both warp and weft way from the fabric with a template, 2 inch long by 1 inch wide. It was creased by folding in to half and placed under a weight of 2 kg for 5 minutes. The weight was removed and the specimen transferred to the fabric clamp on the instrument using forceps and was allowed to recover from the crease for 5minutes. As it recovered the dial of the instrument was rotated to keep the free edge of the specimen in line with the knife edge. At the end of the time period as it was allowed for recovery, usually 1 minute the recovery angle in degrees was read on the engraved scale. Readings were recorded for both warp and weft way separately (Booth, 1996).

3.2.5.2.2 Cloth stiffness (cm)

Fabric stiffness is the resistance of the fabric to bending. Bending length is the length of the fabric that bends under its own weight to a definite extent. It equals half the length of rectangular stripe of fabric that bends under its own weight to an angle of 41.5^{o}. The test samples were tested as directed in BS test method: 3356-1961.

A rectangular strip of fabric, 6 inch x 1 inch was mounted on a horizontal platform in such a way that it over hangs, like a cantilever, and bends downwards. Test specimen was cut with help of template and then both template and test specimens were placed on the platform with the fabric underneath. Both were pushed forward slowly. The strip of the fabric was started to a droop over the edge of the platform and the movement of the templates and the fabric was continued until the tip of the specimen viewed in the mirror cuts both index lines. The bending length was read off from the scale mark opposite a zero line engraved on the side of the platform. Ten readings were recorded by using shirley's stiffness tester (Booth, 1996).

3.2.5.3 Durable properties

A measurement of the length of time of a textile product will meet expectation of performance for its end use. Durability properties relating to resistance to wear and destruction in use. (*http://www.ask.com/web-question/what-is-the-definition-of-durability*).

3.2.5.3.1 Cloth tensile strength (kgf) and Elongation (%)

Tensile strength is the ability of the material to resist or rupture induced by external force. It is expressed as force/ unit cross sectional area of the specimen at the time of maximum load. The specimens were tested as directed in ASTM test method: 12616-1989. The method employed to determine the breaking load and elongation of the material by using the 'strip test' in UniStretch 250 tensile tester.

The specimen was gripped between two clamps of the tensile testing machine in such a manner that the same fabric was gripped by both the clamps and a continual increasing load was applied longitudinally to the specimen by moving one of the clamps until the specimen ruptured. Values of breaking load of the test specimen were recorded from the indicator of the machine (ISI hand book of Textile Testing).

Elongation (%)

Elongation is the increase in length of the specimen from its initial length expressed in units of length. The distance that material will extend under a given force is proportional to its original length. Hence elongation is coated as strain or per centage extension. The elongation percentage was assessed for the fabrics dyed with different colours.

3.2.5.3.2 Cloth abrasion resistance (cycles)

Abrasion is rubbing away of the component fibres and yarns on the surface of the fabric (Booth, 1996). Abrasion resistance was carried out using the instrument ‘Martindale Abrasion tester’ which works in multi directional way.

Fabric specimens were cut according to the size of the templates. Weight and thickness was measured using electronic balance and shirley’s thickness tester. Weight of 9Kpa was placed on the mounted sample and abraded using ‘0’ number polish/ emery paper. The specimen was abraded untill the breakage of 4-5 threads in warp and weft way. Number of cycles, weight loss and thickness of test specimen was recorded. Five such readings were recorded.

3.3 Statistical tools used

Appropriate statistical methods were adopted to analyze the data and infer on the results of the findings. The data was analyzed by using the following statistical methods wherever applicable:

- Frequency and percentages were calculated for all the variables
- One way ANOVA was used to find out the effect of surfactants on stains and physical properties of the test samples
- Regression was used to find out the effect of independent variables *viz*., cloth count, cloth thickness and cloth weight on dependent variables *viz*., cloth tensile strength and elongation and cloth abrasion test samples

3.4 Hypothesis set for the study

- The selected surfactants remove the stain in first wash
- The selected surfactants affected the hue of the dyed fabric
- The washing affected the performance and durable properties of the dyed fabrics

4. EXPERIMENTAL RESULTS

The results of the present study on 'Influence of surfactants on fabric behaviour' are presented under the following headings:

4.1 Survey results

4.1.1 Survey I Information on availability of surfactants in the local grocery shops

4.1.1.1 Demographic information of the respondents

4.1.1.2 Forms of surfactants (cleansing agents) available

4.1.1.3 Type of surfactants (cleansing agents) available

4.1.1.4 The popular promotion technique adopted by the shop owners

4.1.1.5 Type of surfactants (cleansing agents) purchased by the consumer

4.1.1.6 Form of surfactants (cleansing agents) most preferred by the consumer

4.1.1.7 Salable packages of surfactants (cleansing agents)

4.1.2 Survey II Common stains experienced by the working men and women

4.1.2.1 Demographic information of the respondents

4.1.2.2 Dresses used by the respondents at home and for function

4.1.2.3 Fibre content of the dress materials

4.1.2.4 Common stains and stains hard to remove: Experience of the respondents

4.1.2.5 Occurrence of stains

4.1.2.6 Solvents/reagents used to remove the stains

4.1.2.7 Detergents effective in removing the stains

4.1.2.8 Detergents used for different types of fabrics

4.1.2.9 Effect of surfactants on colour fading: Respondents opinion

4.2 Experimental results

4.2.1 Effect of surfactants on stains

4.2.1.1 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'WG' surfactant

4.2.1.2 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'PW' surfactant

4.2.1.3 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'WBO' surfactant

4.1 Survey results

4.1.1 Survey I Information on availability of surfactants in the local grocery shops

In survey I, the local grocery shop owners were personally interviewed to gather information about their demographics, form and type of cleansing agents available in the shop, type and form of cleansing agents purchased by consumers, promotion techniques adopted by the shop owners.

4.1.1.1 Demographic information of the respondents

The demographic information of the respondents encompassed age, education and the annual income.

Table 3 and Fig. 1 gives a clear picture about the general information of the shop owners

a) Age:

The age of the shop owners was categorized into younger, middle and old age groups. It is evident from this Table that 38.00 per cent of the respondents belonged to middle age group followed by younger (34.00 %) and old age (28.00 %).

b) Education of the respondents

As far as education of the respondents was considered, 54.00 per cent of them had education up to higher secondary level, almost 1/4th of them had studied up to PUC level, 18.00 per cent upto secondary level and only 02.00 per cent were Graduates. It is interesting to know that none were illiterates.

c) Annual income of the respondents

It is found from this Table that 40.00 per cent of the respondents belonged to low income group (Rs. < 6,32,352) followed by high income group (36.00 %, Rs. > 8,25,528) whereas about ¼th of them belonged to middle income group (24.00 %, Rs. 6,32,352 - 8,25,528).

Specific information about the surfactants

Under specific information the researcher collected first hand information about forms and type of surfactants available in the selected grocery shops; popular promotion techniques adopted by shop owners, most selling and most preferred surfactants by the consumers.

4.1.1.2 Forms of surfactants (cleansing agents) available in the shops

Table 4 shows the details about the forms of surfactants available in the selected shops and it is event that all the shops have cleansing agents in powder and cake form whereas about 75.00 per cent of the shops had liquid detergents too, with powder and cakes.

4.1.1.3 Type of surfactants (cleansing agents) available in the shop

The type of surfactants (cleansing agents) available in the selected 50 shops is presented in Table 5. This table shows that many surfactants are available in powder form (09.00) followed by cake (07.00) and liquid (02.00) and all are branded. Among the cleansing powders Nm, Sx, Td and Wl were available in all the selected shops, whereas R and A in 96.00 per cent and 92.00 per cent of the shops; on the contrary less than 50 per cent of the shops had Hk and Gd.

As far as liquid agents were considered, about 50.00 per cent of the shops found to have only two branded detergents (R and Sx).

It is learnt from Table 5 that cakes in Yellow, Green and Blue colours were available in the shops. However, many of the cakes were found to be in Blue colour, followed by Green and Yellow.

4.1.1.4 The popular promotion technique adopted by the shop owners

Sales promotion technique is a media, adopted by company/shop owners to attract the consumers, earn better returns and popularity. Table 6 shows the details about the techniques adopted by company/shop owners to promote the surfactants. The shop owners expressed that the style/form of packing was always found to be the best media to sell the product; whereas advertisement and window display (each 50 %) were found to good promotional techniques, sometimes; but bills and pamphlets were never considered to be a media for sales promotion.

Table 3. Demographic information of the respondents

N=50

Sl.No.	Demographic variables	No. of respondents
(a)	Age of the respondents (Years)	
1.	Younger age (<37)	17 (34.00)
2.	Middle age (37 – 47)	19 (38.00)
3.	Old age (> 47)	14 (28.00)
(b)	Education of the respondents	
1.	Primary (1st–4th standard)	Nil
2.	Secondary (5th –8th standard)	09 (18.00)
3.	Higher secondary (9th-10th standard)	27 (54.00)
4.	PUC	13 (26.00)
5.	Graduate	01 (02.00)
6.	Post Graduate	Nil
7.	Illiterate	Nil
(c)	Annual income of the respondents (Rs)	
1.	Low income (Rs < 6,32,352/-)	20 (40.00)
2.	Middle income (Rs 6,32,352/- to Rs 8,25,528/-)	12 (24.00)
3.	High income (Rs > 8,25,528/-)	18 (36.00)

Figures in parenthesis indicate percentages

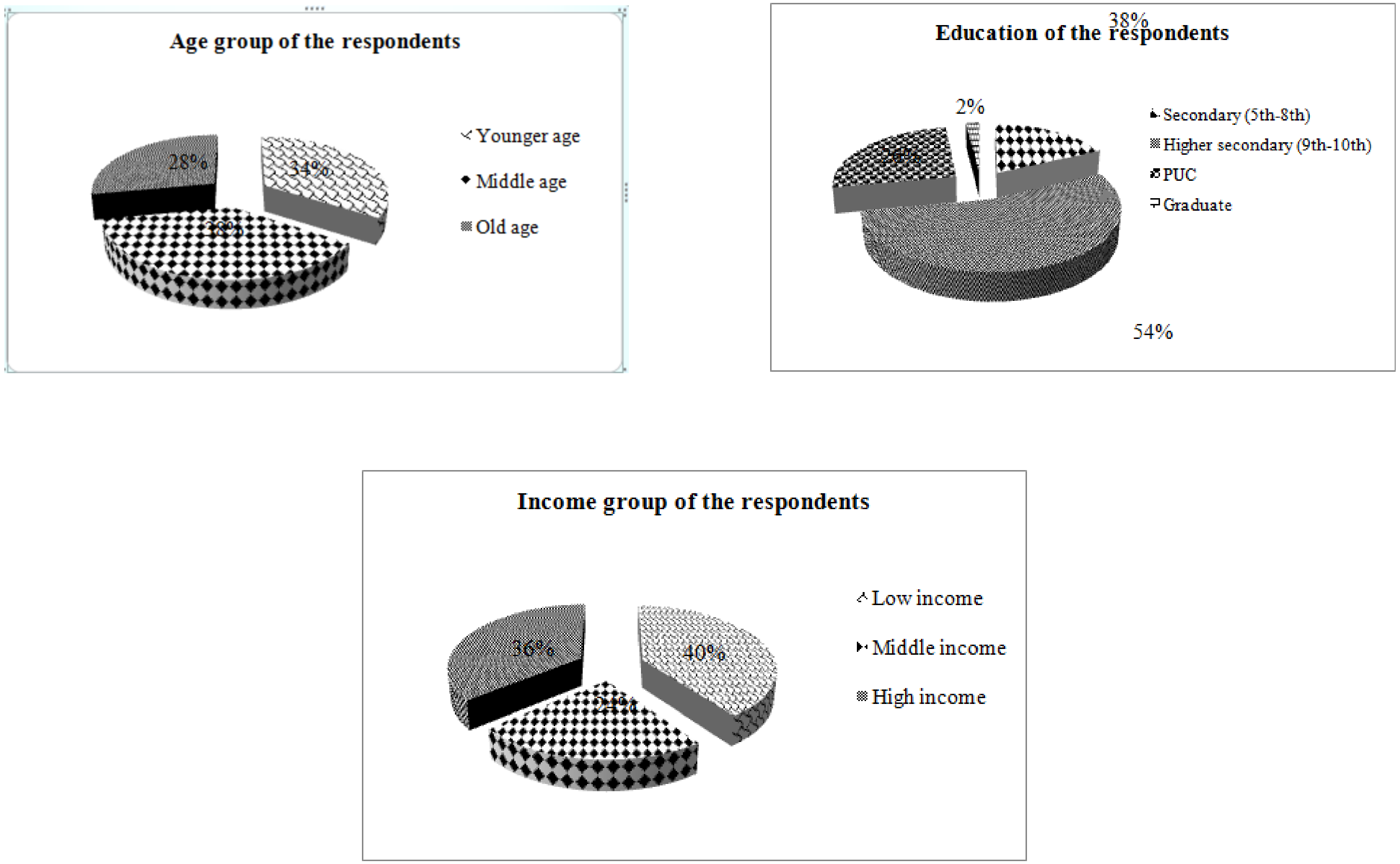

Fig. 1. Demographic information of the respondents

Table 4. Forms of surfactants (cleansing agents) available in the shops

N=50

Sl. No.	Forms of surfactants	No. of respondents
1.	Powder	50 (100.00)
2.	Cakes	50 (100.00)
3.	Liquid	38 (76.00)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 5. Type of surfactants (cleansing agents) available in the shop

N=50

Sl. No.	Surfactants	No. of respondents
A	Powder	
1.	A	46 (92.00)
2.	Fa	36 (72.00)
3.	Gd	23 (46.00)
4.	Hk	24 (48.00)
5.	Nm	50 (100.00)
6.	R	48 (96.00)
7.	Sx	50 (100.00)
8.	Td	50 (100.00)
9.	Wl	50 (100.00)
B	Cakes	
i.	Yellow	
1.	Nm	50 (100.00)
ii.	Green	
1.	Gd	22 (44.00)
2.	Wl	50 (100.00)
iii.	Blue	
1.	Fa	42 (84.00)
2.	R	49 (98.00)
3.	Sx	50 (100.00)
4.	Td	50 (100.00)
C	Liquid	
1.	R	26 (52.00)
2.	Sx	27 (54.00)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 6 The popular promotion technique adopted by the shop owners

N=50

Sl. No.	Promotion technique	No. of respondents		
		Always	Sometimes	Never
1.	T.V Advertisements	-	25 (50.00)	25 (50.00)
2.	Bills/ Pamphlets	-	-	50 (100.00)
3.	Window display	03 (06.00)	25 (50.00)	22 (44.00)
4.	Packaging style	50 (100.00)	-	-

Figures in parenthesis indicate percentages
Multiple responses possible

4.1.1.5 Type of surfactant (cleansing agents) purchased by the consumer

Whatever be the sales promotion media, it is true that all consumers purchase one or the other surfactants to wash the clothes. The consumer purchasing behaviour is presented in Table 7 and it is found that of the 9 powders, majority of the consumer always purchased Wl (100.00 %), Nm (96.00 %) and Td (86.00 %) followed by R (52.00 %) and Sx (54.00 %). About 40.00 to 45.00 per cent of them purchased Fa, Hk, R and Sx.

It is evident that 50.00 per cent of the consumers never purchased Gd and Hk, as far as powder is considered. On the contrary it is learnt that more than 50.00 per cent of the consumers never purchased liquid detergents and about $^{1}/_{3}{}^{rd}$ of them purchased sometimes.

Meanwhile, it was revealed by the shop owners that the cakes, irrespective of the colours and sizes were purchased by the consumers. Greater percent of the consumers purchased Wl (100.00 %) followed by Td and Nm (each 82.00 %) and R (50.00%) always; whereas Fa & Sx (each 46.00%) and R (42.00 %) were bought sometimes; and Gd was never by 50.00 per cent of the consumers.

4.1.1.6 Form of surfactant (cleansing agents) preferred by the consumer

The form of cleansing agents most preferred by the consumers is presented in Table 8 and is found that cent percent of the consumers preferred cakes and powder (94.00 %), always. It is interesting to learn that, 52.00 per cent never purchased liquid cleansing agents and 46.00 per cent did prefer but sometimes only. In other word, the least preferred form of surfactant was liquid.

4.1.1.7 Salable packages of surfactant (cleansing agents)

The package of definite weights/ liter is one of the criteria that influence purchasing behaviour of the consumers. Keeping this in view, efforts were made to find out the available package for consumers preference and the results are presented in Table 9. It is found from this Table that cakes are available in small, medium and large size; however, majority of them are available in medium size (100.00 %) followed by small (90.00 %).

The powders are available in ¼ kg, ½ kg, 1kg and 2kg weights either in box or polyethylene bags. It is found that all most all the surfactants are available in ¼ kg pack (96.00 %) and very meager in 2 kg (18.00 %). It is also evident that some of the powders do sell the surfactants in boxes of ½ kg (28.00 %) and 1kg (30.00 %) as well small sachets.

Meanwhile the liquid detergent is available in either ½ liter or 1 liter (each 50.00 %) or ¼ liter (46.00 %) packages.

4.1.2 Survey II Common stains experienced by the working men and women

A stain is decolouration that can be clearly distinguished from the colour of the ground fabric, surface or medium, it is found upon. These are caused due to chemical or physical interaction of two dissimilar materials. It is a spot not easily removed, but needs either suitable surfactant or reagent.

Table 7 Type of surfactants (cleansing agents)purchased by the consumers

N=50

Sl. No.	Surfactants	No. of respondents		
A	Powder	Always	Sometimes	Never
1.	A	09 (18.00)	35 (70.00)	06 (12.00)
2.	Fa	19 (38.00)	20 (40.00)	11 (22.00)
3.	Gd	13 (26.00)	10 (20.00)	27 (54.00)
4.	Hk	03 (06.00)	22 (44.00)	25 (50.00)
5.	Nm	48 (96.00)	02 (04.00)	-
6.	R	26 (52.00)	23 (46.00)	01 (02.00)
7.	Sx	27 (54.00)	22 (44.00)	01 (02.00)
8.	Td	43 (86.00)	06 (12.00)	01 (02.00)
9.	Wl	50 (100.00)	-	-
B	Cakes			
i.	Blue			
1.	Fa	14 (28.00)	23 (46.00)	13 (26.00)
2.	R	27 (54.00)	21 (42.00)	02 (04.00)
3.	Sx	14 (28.00)	23 (46.00)	13 (26.00)
4.	Td	41 (82.00)	09 (18.00)	-
ii.	Green			
1.	Wl	50 (100.00)	-	-
2.	Gd	12 (24.00)	13 (26.00)	25 (50.00)
iv.	Yellow			
1.	Nm	41 (82.00)	09 (18.00)	-
C	Liquids			
1.	R	09 (18.00)	15 (30.00)	26 (52.00)
2.	Sx	05 (10.00)	18 (36.00)	27 (54.00)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 8 Forms of surfactants (cleansing agents) preferred by the consumer

Sl. No.	Surfactants	No. of respondents		
		Always	Sometimes	Never
1.	Powder	47 (94.00)	03 (06.00)	-
2.	Cake	50 (100.00)	-	-
3.	Liquid	01 (02.00)	23 (46.00)	26 (52.00)

Figures in parenthesis indicate percentages

4.1.2.1 Demographic information of the respondents

The demographic information included age, education, occupation and annual income of the respondents, and the results are presented in the Table-10.

a) Age:

From Table-10, it is clear that, majority of the working men belonged to middle age (43.33 %) followed by younger age (40.00 %) and old age (16.66 %) where as all most $^{1}/_{3}{}^{rd}$ of the working women belonged to younger age (36.66 %) followed by old age (33.33 %) and middle age (30.00 %).

b) Education:

It is found from this Table that very meager per cent of men (6.66 %) and women (3.33 %) were illiterates. However, majority of the working men had education up to PUC (26.66 %) followed by higher secondary (20.00 %) and secondary (10.00 %) level on the contrary, majority of working women were found to be degree holders (36.66 %) as well as post graduate (36.66 %) where as only 10.00 per cent of them had education up to PUC, followed by secondary (6.66 %).

c) Occupation of the respondents

The occupation of working men and women were categorized into three groups viz., government, private and agriculture. According to the results, majority among the men were working with government (53.33 %) where as women with private (46.66 %) organizations. On the other hand, men working in private firms were only 26.66 per cent. It is interesting to note that 20.00 per cent and 26.66 per cent of both men and women respectively engaged in agriculture activities.

d) Annual income of the respondents:

It is found from Table 10 that 50 per cent of men and women belonged to high income group (Rs. > 7,28,784/- men and Rs. > 6,50,940/- women) followed by middle income (each 26.66 %, Rs. 4,60,740/- to 7,28,784/- men and Rs. 4,12,360/- to 6,50,940/- women). However, only 23.33% of both men and women belonged to low income group (Rs. < 4, 60,740/- and Rs. < 4, 12,360 /-) respectively.

II Specific Information:

The specific information about working men and women encompassed type of dresses used at home and for function, fibre content of the dresses, common stains and stains hard to remove as experienced by the respondents, occasion when usually the dresses catch the stains, solvents and type of detergents used to remove the stains, as well as laundering the fabric, effect of surfactants on colour fading of the fabrics and other related information.

4.1.2.2 Dresses used by the respondents at home and for function

Dressing pattern of every individual is governed by several factors viz., culture; family background, education, occupation, income of the family and as well as depends on individual’s taste, interest, choice and needs. Here, the clothes of men and women were categorized home wears and functional wears.

Table 9. Salable packages of surfactants (cleansing agents)

Sl. No.	Surfactants	No. of respondents			
1.	Powder	¼ kg	½ kg	1kg	2kg
a.	Box	-	14 (28.00)	15 (30.00)	-
b.	Polyethylene bag	48 (96.00)	50 (100.00)	50 (100.00)	09 (18.00)
2.	Cake	Small	Medium	Large	
	Package	45 (90.00)	50 (100.00)	04 (08.00)	
3.	Liquid	¼ litre	½ litre	1 litre	
	Package	23 (46.00)	25 (50.00)	25 (50.00)	

Figures in parenthesis indicate percentages
Multiple responses possible

Table 10 Demographic information of the respondents

N = 60

Sl. No.	Demographic variables	Working men (n_1=30)		Working women (n_2=30)	
(a)	Age of the respondents (Years)				
1	Younger age	(<37)	12 (40.00)	(<32)	11 (36.66)
2	Middle age	(37-47)	13 (43.33)	(32-42)	09 (30.00)
3	Old age	(>47)	05 (16.66)	(>42)	10 (33.33)
(b)	Education of the respondents				
1	Primary (1st – 4th standard)		Nil		Nil
2	Secondary (5th –8th standard)		03 (10.00)		02 (06.66)
3	Higher secondary (9th -10th standard)		06 (20.00)		02 (06.66)
4	PUC		08 (26.66)		03 (10.00)
5	Graduate		06 (20.00)		11 (36.66)
6	Post Graduate		05 (16.66)		11 (36.66)
7	Illiterate		02 (06.66)		01 (03.33)
(c)	Occupation of the respondents				
1	Government		16 (53.33)		14 (46.66)
2	Private		08 (26.66)		08 (26.66)
3	Agriculture		06 (20.00)		08 (26.66)
(d)	Annual income of the respondents (Rs.)				
1	Low income	(Rs < 4,60,740/-)	07 (23.33)	(Rs < 4,12,368/-)	07 (23.33)
2	Middle income	(Rs 4,60,740/- to 7,28,784/-)	08 (26.66)	(Rs 4,12,368/- to Rs 6,50,940/-)	08 (26.66)
3	High income	(Rs > 7,28,784/-)	15 (50.00)	(> 6,50,940)	15 (50.00)

Figures in parenthesis indicate percentages

According to the results of Table 11 (a), 50 per cent of the working men used track pant and T-shirt at home followed by formal pant and T-shirt (26.66 %) and pajama-kurta (23.33 %), whereas, majority of them preferred formal pant and shirt (76.66 %) followed by jeans and T-shirt (23.33 %) during functions [Table 11(a)].

Table 11 (a) and (b) depict about the dresses worn by working women at home and during functions, majority of the women preferred to wear night gown(63.33%) followed by sari (43.33 %) and salwar kameez (40.00 %). Very meager per cent (03.33 %) of women worn skirt, shirt pant and leggings at home. On the contrary, sari was the most preferred (83.33 %) attire for functions followed by salwar kameez (43.33 %). It is interesting to note that only 06.66 per cent of the women wore ghagra choli during functions.

4.1.2.3 Fibre content of the dress materials

Table 12 depicts about the fibre content of the dresses used by both working men and women. Irrespective of the respondents, the first preference goes to cotton (90.00 % working men and 73.33 % working women) followed by P/C blends of almost 50.00 per cent of respondents. However, least preference was given for polyester by both categories of respondents. Meanwhile, 1/3rd of the working women did have dresses made of silk.

4.1.2.4 Common stains and stains hard to remove: Experience of the respondents

It is already learn that, stain, is a spot on the fabric caused due to many reasons, requires to be removed since it distracts the appearance of the entire garment. The stains are of several in origin and usually occur / happen when people at work or while having food. Some of the common stains which are experienced by the working men and women are presented in Table 13.

The most commonly occurring stains as experienced by working men were oil (63.33 %), mud (50.00 %) and bhaji (30.00 %) whereas, working women experienced grease and mud (each 43.33 %), ink (36.66%) and bhaji and oil (each 30.00 %).

Though these stains are commonly experienced by the respondents, it was expressed that oil stain is very hard to remove (women- 66.66 % and men- 33.33 %), bhaji (50.00 %, women) and grease (26.66 % women and 23.33 % men). However, the respondents of both the categories expressed that it is not hard to remove some of the stains viz., tea-coffee, rust and mud.

4.1.2.5 Occasions when fabric gets stained

The information about occasions when fabric or costume gets stained is presented in Table-14. It is true that, most of the stains occur only when people are at work or while having food. This concept is supported by the expressions made by the respondents i.e., the dresses of majority of working men and women used to got stained while at work (76.66 % and 83.33 %, respectively) followed by eating (20.00 % and 33.33 %, respectively); while meager per cent of the respondents found their garments stained while driving, cleaning or during rainy season.

II. Specific Information:

Table 11. Type of dresses used by the respondents at home and for functions

Table 11a Dresses at home

N = 60

Sl.No	Dresses at home	Working men (n_1=30)	Dresses at home	Working women (n_2=30)
1	Track pant & T-shirt	15 (50.00)	Night gown	19 (63.33)
2	Formal Pant & T-shirt	08 (26.66)	Salwaar kameez	12 (40.00)
3	Pyjama & Kurta/ traditional wear	07 (23.33)	Sari	13 (43.33)
4		-	Skirt, shirt, pant, leggings, traditional wear	01 (03.33)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 11b Dresses for function

Sl.No	During functions	Working men	During functions	Working women
1	Pant & shirt	23 (76.66)	Sari	25 (83.33)
2	Jeans & T-shirt	07 (23.33)	Salwar kameez	13 (43.33)
3	Traditional	-	Ghagra choli	02 (06.66)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 12 Fibre content of the dresses

N = 60

Sl. No.	Fibre content of dresses	Working men (n_1=30)	Working women (n_2=30)
1	Cotton	27 (90.00)	22 (73.33)
2	Polyester	11 (36.66)	6 (20.00)
3	Polycot	14 (46.66)	16 (53.33)
4	Silk	-	9 (30.00)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 13. Common stains and stains hard to remove as experienced by the respondents

N = 60

Sl. No	Classification of stains	Name of the stains	Occurrence		Stains hard to remove	
			Working men (n_1=30)	Working women (n_2=30)	Working men (n_1=30)	Working women (n_2=30)
a.	Proteins	1. Bhaji	09 (30.00)	09 (30.00)	03 (10.00)	15 (50.00)
		2. Pickle	06 (20.00)	04 (13.33)	06 (20.00)	04 (13.33)
		3. Curry	04 (13.33)	05 (16.66)	02 (06.66)	15 (50.00)
		4. Tea/coffee	07 (23.33)	10 (33.33)	-	-
		5. Turmeric	03 (10.00)	-	-	07 (23.33)
b.	Oil and Grease	1. Grease	03 (10.00)	13 (43.33)	16 (23.33)	08 (26.66)
		2. Oil	19 (63.33)	09 (30.00)	09 (30.00)	17 (56.66)
c.	Minerals	1. Ink	09 (30.00)	11 (36.66)	06 (20.00)	06 (20.00)
		2. Mud	15 (50.00)	13 (43.33)	05 (16.66)	05 (16.66)
		3. Rust	04 (13.33)	-	01 (03.33)	02 (06.66)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 14 Occassions when fabric gets stained

N = 60

Sl. No.	Occurrence of Stains	Working men (n_1=30)	Working women (n_2=30)
1	At work	23 (76.66)	25 (83.33)
2	Eating	06 (20.00)	10 (33.33)
3	Driving / Cleaning	03 (10.00)	04 (13.33)
4	Rainy season	01 (03.33)	-

Figures in parenthesis indicate percentages
Multiple responses possible

4.1.2.6 Solvents/reagents used to remove the stains

The reagents used to remove the common stains by the respondents are presented in Table-15. From this table it is clear that, more than 80.00 per cent of the respondents used either soaps or detergents to remove the hard stains (96.66 % working women and 83.33 % men) followed by simple plain water.

4.1.2.7 Detergents effective in removing stains

Survey results indicated that the working men and women used 7 different types of detergents to wash their clothes. These detergents were coded and indicated in Table 16, instead of brand names. One of the catchy latter in the brand name is given as 'code'.

The various surfactants (detergents/Soaps) used to remove the stains is presented in Table 16. It is clear from this table that majority of the respondents found 'Sx' to be very effective (63.33 % men and 56.66 % women) followed by the detergent 'T' (40.00 % women and 26.66 % men) and the detergent 'R' (36.66 %, women). However, working men indicated that the detergents 'N' and 'V' were not at all effective, hence rated as zero and this opinion was supported by the working women, too.

4.1.2.8 Detergents used for different types of fabrics

Table 17 indicates about the views of working men and women about different detergents used for varieties of fabrics. The higher per cent of working men and women opined that 'Sx' is very effective in cleansing cotton, polyester and P/C blended fabrics (each 53.33 %, men and each 46.66 %, women). The working men and women found detergent 'R' to be effective on cotton (40.00 %) and 'T' for polyester (36.66 %) and both 'R' and 'T' for P/C blend. Meanwhile, working men expressed that 'W' is effective for P/C blends (33.33 %), polyester (26.66 %) and the detergents 'R' and 'W' for cotton (each 23.33 %). It was interesting to know that 'E' and 'V' were found to be not useful by working men hence, were not purchased. Similarly, working women also expressed that 'E' and 'W' were not effective except silk (23.33 %). In other words, the table clearly depicts that every detergent does not have same level of impact on dresses with different fibre contents.

4.1.2.9 Effect of surfactants on colour fading: Respondents opinion

Table 18 gives information about the colours that faded on application of detergents. Of the 60 samples, 30.00 per cent of working women and 26.66 per cent of working men could not give their opinion about impact of detergents on colour fading. Of the remaining sample, 30.00 per cent working men and 26.66 per cent working women indicated that the fabrics when washed with 'N' and 'W' led to bleeding of the colour, that ultimately faded the fabric. Meanwhile, 'A' and 'Sx' were found to be very effective since did not affect the colour when washed, as indicated by working women.

4.2.1 Effect of surfactants on stains

4.2.1.1 Colour strength and colour co-ordinate values of stains on white cotton samples subjected to multiple washes with 'WG' surfactant

Table 15. Solvents / reagents used to remove the stain

N = 60

Sl.No.	Methods	Working men (n_1=30)	Working women (n_2=30)
1	Plain water	02 (06.66)	08 (26.66)
2	Plain warm water	-	-
3	Soaps / detergents	29 (96.66)	25 (83.33)
4	Chemical reagents	-	-

Figures in parenthesis indicate percentages
Multiple responses possible

Table 16 Detergents effective in removing the stains

N = 60

Sl. No.	Detergents (Code)	Working men (n_1=30)	Working women (n_2=30)
1	A	04 (13.33)	07 (23.33)
2	Nm	-	03 (10.00)
3	R	08 (26.66)	11 (36.66)
4	Sx	19 (63.33)	17 (56.66)
5	Td	08 (26.66)	12 (40.00)
6	V	-	04 (13.33)
7	Wl	09 (23.33)	09 (30.00)

Figures in parenthesis indicate percentages
Multiple responses possible

Table 17. Detergents useful for different types of fabrics

N = 60

Sl. No	Detergents (Code)	Types of fabrics							
		Working men (n_1=30)				Working women (n_2=30)			
		Cotton	Polyester	P/C	Silk	Cotton	Polyester	P/C	Silk
1	A	01 (03.33)	-	-	-	02 (06.66)	01 (03.33)	01 (03.33)	-
2	E	-	-	-	-	-	-	-	07 (23.33)
3	N	02 (06.66)	01 (03.33)	01 (03.33)	-	03 (10.00)	03 (10.00)	03 (10.00)	-
4	R	07 (23.33)	06 (20.00)	07 (23.33)	-	12 (40.00)	10 (33.33)	10 (33.33)	02 (06.66)
5	Sx	16 (53.33)	16 (53.33)	16 (53.33)	02 (06.66)	14 (46.66)	14 (46.66)	14 (46.66)	-
6	T	02 (06.66)	05 (16.66)	02 (06.66)	02 (06.66)	10 (33.33)	11 (36.66)	10 (33.33)	-
7	V	-	-	-	-	08 (26.66)	08 (26.66)	09 (30.00)	-
8	W	07 (23.33)	08 (26.66)	10 (33.33)	02 (06.66)	01 (03.33)	-	-	-

Figures in parenthesis indicate percentages
Multiple responses possible

Table 18. Colour fading on application of detergents

N = 60

Sl. No.	Detergents	Working men (n_1=30)	Working women (n_2=30)
1	A	03 (10.00)	-
2	Nm	09 (30.00)	09 (30.00)
3	R	03 (10.00)	01 (03.33)
4	Sx	04 (13.33)	-
5	Td	02 (06.66)	03 (10.00)
6	Wl	01 (03.33)	08 (26.66)
7	Do not know	08 (26.66)	09 (30.00)

Figures in parenthesis indicate percentages

Table 19 and Fig. 2 records the colour strength and colour co-ordinate values of stained samples subjected to multiple washes with ‘WG’ surfactant.

It is apparent from this Table that the highest K/S value was observed with mud (88.52) followed by curry (46.30), pickle (43.68) and least was grease (25.04), at control. However, on washing the colour strength of all four stains decreased. Meanwhile, the increase in colour strength (K/S) of all the four stains expressed in percentage after first wash indicated a great deal of reduction in the tint of the stain. It is observed that after every first wash there is reduction in K/S value. A remarkable reduction was observed with mud (45.56 % and 50.51 %), curry (41.84 % and 49.91 %), grease (34.45 % and 43.58 %) and pickle (32.83 % and 42.03 %) after first and second wash, respectively.

The L* (lightness and darkness) value was found to be higher with grease (64.17) followed by curry (63.59), pickle (62.16) and mud (40.93), at control. However, there is increase in lightness and darkness (L*) value of all the four stains on subsequent washes which indicates that the stains have become lighter in colour. Meanwhile, the increase in lightness and darkness (L*) expressed in percentage after subsequent washes indicated reduction in darkness of the stain. A descending order of reduction in lightness is observed with curry (11.82 %), mud (11.10 %), pickle (07.84 %) and grease (06.26 %) stain after first wash and a similar trend is noticed after 2nd and 3rd wash.

The redness and greenness (a*) value of control was found to be highest in pickle stain (18.56) followed by mud (15.24), curry (09.02) and grease (04.20). A trend of decrease was observed after each wash which indicated that the stains have turned to be greener (-a*) in colour, which reveals that there is reduction in the redness (+a*) of the stains. A great reduction in redness is observed among curry (-03.42 %), pickle (-03.50 %), mud (-03.89 %) and grease (-08.59 %) stains after first wash i.e., the standard colour of ‘curry’ was remarkably reduced after first wash.

The yellowness and blueness (b*) of control sample was found to be higher in curry (49.52) followed by pickle (46.39), grease (30.19) and mud (21.19). However, there is decrease in b* value of all the four stains on subsequent washes which indicated that the stains have become bluer in colour than yellower. On the contrary, a reduction was observed with pickle (-31.69 % and -40.23 %), grease (-32.76 % and -40.26 %), curry (-39.99 % and -47.08 %) and mud (-44.02 % and -47.50 %) stains after first and second washes respectively. Higher the negative value (-b*) bluer the sample ie, i.e., lighter the stain is.

However, the colour strength (K/S), L* a* b* values of all the four stains were found to be significant at 5 per cent level of significance.

4.2.1.2 Colour strength and colour co-ordinate values of stains on white cotton samples subjected to multiple washes with ‘PW’ surfactant

Table 20 and Fig. 3 highlights the colour strength (K/S) and colour co-ordinate values of stained samples subjected to multiple washes with ‘PW’ surfactant.

Table 19. Colour strength (K/S) and colour co-ordinate values of stains on white cotton fabric subjected to multiple washes with 'WG' surfactant

Surfactant	Stains	Control				1st Wash				2nd Wash				3rd Wash			
		K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*
WG	Grease	25.04	64.17	04.20	30.91	11.26* (34.45)	69.85* (06.26)	0.43* (-08.59)	16.75* (-32.76)	05.34* (43.58)	76.90* (13.31)	-0.88* (-10.09)	09.26* (-40.26)	03.72* (49.36)	79.30* (15.71)	-01.06* (-10.91)	03.78* (-45.73)
	Pickle	43.68	62.16	18.56	46.39	09.83* (32.83)	71.44* (07.84)	05.52* (-03.50)	17.82* (-31.69)	05.43* (42.03)	76.34* (12.47)	04.65* (-04.37)	09.77* (-40.23)	05.21* (42.43)	76.07* (12.75)	03.37* (-05.65)	09.28* (-40.74)
	Mud	88.52	40.93	15.24	21.19	05.55* (45.56)	74.70* (11.10)	05.13* (-03.89)	05.50* (-44.02)	03.53* (50.15)	78.27* (14.67)	03.68* (-05.34)	02.01* (-47.50)	03.51* (52.81)	78.76* (15.16)	02.97* (-06.05)	-0.85* (-50.37)
	Curry	46.30	63.59	09.02	49.52	05.66* (41.84)	75.42* (11.82)	05.60* (-3.42)	09.53* (-39.99)	03.97* (49.91)	77.89* (14.29)	0.92* (-8.35)	02.43* (-47.08)	02.70* (54.53)	80.75* (17.15)	0.67* (-08.61)	-01.60* (-51.12)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

(K/S) Colour strength
(±L*) Lightness and Darkness
(±a*) Redness and Greenness
(±b*) Yellowness and Blueness

ANOVA TABLE

	Sample	K/S			L*			a*			b*		
		SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %
WG	Curry	0.094	01.44	0.126	0.013	0.040	0.018	0.070	03.86	0.093	0.012	0.187	0.016
	Grease	0.007	0.139	0.009	07.00	22.68	09.38	0.007	02.35	0.009	0.006	0.099	0.009
	Pickle	0.008	0.116	0.011	0.007	0.022	0.009	0.007	0.197	0.009	0.007	0.079	0.009
	Mud	0.014	0.130	0.019	0.009	0.030	0.012	0.011	0.372	0.015	0.059	01.89	0.079

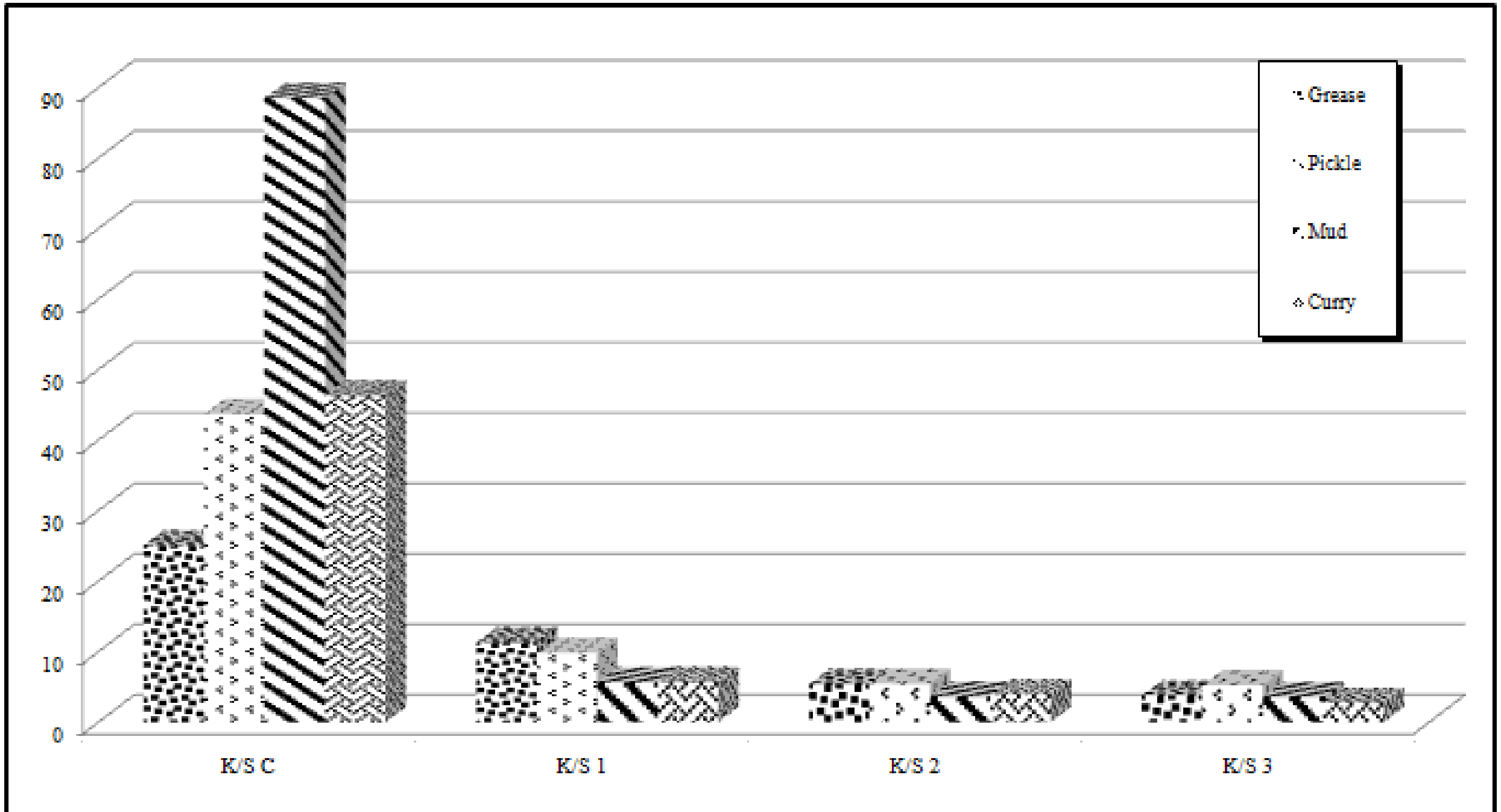

Fig. 2. Colour strength (K/S) values of stains on white cotton fabric subjected to multiple washes with 'WG' surfactant

Fig. 2. Colour strength (K/S) values of stains on white cotton fabric subjected to multiple washes with 'WG' surfactant

Table 20. Colour strength (K/S) and colour co-ordinate values of stains on white cotton fabric subjected to multiple washes with 'PW' surfactant

Surfactant	Stains	Control				1st Wash				2nd Wash				3rd Wash			
		K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*
PW	Grease	25.04	64.17	4.20	30.91	10.67* (33.03)	71.30* (07.70)	00.48* (-08.54)	18.55* (-30.96)	06.24* (40.82)	75.75* (12.18)	-0.58* (-09.61)	11.76* (-37.75)	03.24* (48.06)	81.27* (17.67)	-00.96* (-10.01)	05.95* (-43.56)
	Pickle	43.68	62.16	18.56	46.39	09.93* (30.07)	72.44* (08.84)	04.64* (-04.38)	21.11* (-28.40)	06.41* (35.65)	76.26* (12.67)	04.41* (-04.61)	16.51* (-33.01)	03.39* (45.75)	80.43* (16.84)	02.54* (-06.48)	07.47* (-42.04)
	Mud	88.52	40.93	15.24	21.19	04.85* (45.38)	77.23* (13.63)	05.49* (-03.53)	06.92* (-42.59)	04.54* (46.86)	78.33* (14.72)	05.52* (-03.72)	06.09* (-43.42)	02.89* (53.14)	80.09* (16.49)	03.50* (-05.52)	-00.69* (-50.21)
	Curry	46.30	63.59	09.02	49.52	05.88* (39.44)	75.63* (12.03)	06.58* (-02.44)	12.03* (-37.48)	02.66* (54.55)	81.02* (17.42)	00.65* (-08.59)	-01.45* (-50.97)	01.68* (57.14)	84.37* (20.77)	00.43* (-08.77)	-03.05* (-52.57)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

(K/S) Colour strength
(±L*) Lightness and Darkness
(±a*) Redness and Greenness
(±b*) Yellowness and Blueness

ANOVA TABLE

	Sample	K/S			L*			a*			b*		
		SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %
PW	Curry	0.005	0.087	0.007	0.006	0.019	0.008	0.006	0.330	0.008	0.001	0.079	0.006
	Grease	0.011	0.236	0.016	0.010	0.031	0.014	0.008	02.50	0.011	0.007	0.098	0.009
	Pickle	0.008	0.115	0.010	0.008	0.027	0.011	0.007	01.44	0.009	0.005	0.057	0.007
	Mud	0.006	0.059	0.009	0.006	0.021	0.009	0.005	0.164	0.007	0.003	0.103	0.005

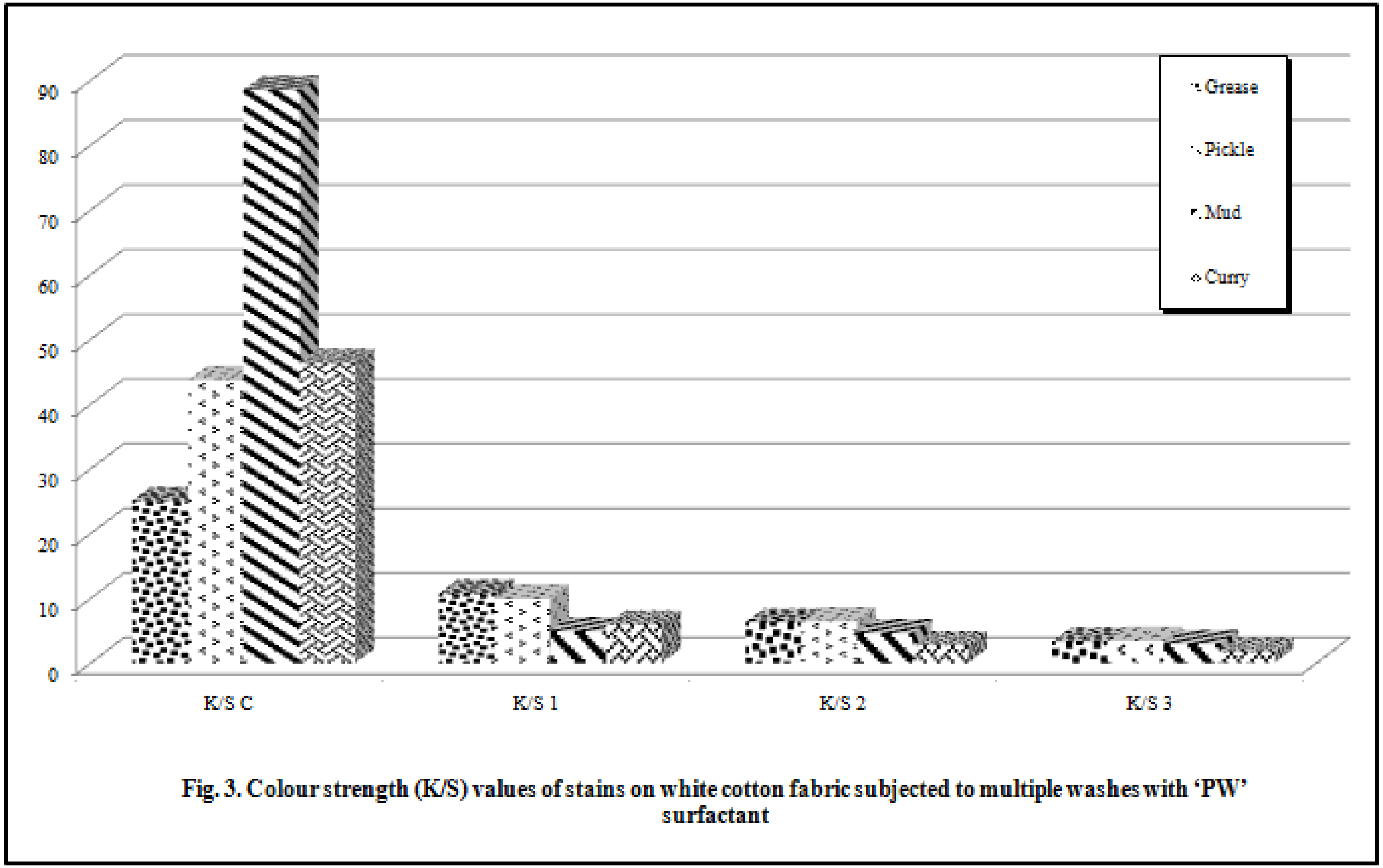

Fig. 3. Colour strength (K/S) values of stains on white cotton fabric subjected to multiple washes with 'PW' surfactant

The results revealed from this Table that the highest colour strength value was observed with mud (88.52) followed by curry (46.30), pickle (43.68) and grease (25.04), at control, similar to the values of Table 19. In other words, there is decrease in colour strength (K/S) values of all the four stains on subsequent washes. On the contrary, the increase in colour strength (K/S) of all the four samples expressed in percentage indicated a reduction in the colour of the stains. It is observed that after first and second wash, there is decrease in colour strength (K/S) value of mud (45.38 % and 46.86 %), curry (39.44 % and 54.55 %), grease (33.03 % and 40.82 %) and pickle (30.07 % and 35.65 %) stains, respectively.

The lightness and darkness (L*) value of control sample was found to be higher with grease (64.17) followed by curry (63.59), pickle (62.16) and mud (40.93). However, there is increase in lightness and darkness (L*) value of all the stains on subsequent washes which indicates that the stains have become lighter in colour (L*). Meanwhile, the change in lightness and darkness (±L*) is expressed in percentage after first, second and third washes. The percentage increase in L* value indicates fading of the stain. The descending order of percentage reduction in L* value was found to be mud (13.63 %), curry (12.03 %), pickle (08.84 %) and grease (07.70 %) stains after first wash. However, a great reduction in L* was focused to be with curry (84.37), pickle (80.43), grease (81.27) and mud (80.09) after 3rd wash.

The redness and greenness (a*) value was found to be higher in pickle (18.56) followed by mud (15.24), curry (09.02) and grease (04.20), at control when washed with 'Sx' surfactant. However, a trend of decrease in redness and greenness (a*) was observed and depicted that the stains have become greener in colour. Moreover, the decrease in redness and greenness (a*) expressed in percentage after the first wash indicated a reduction in redness of the stain. However, the descending order of reduction was observed with curry (-02.44 %), mud (-03.53 %), pickle (-04.38 %) and grease (-08.54%) stains.

Further, it is observed that the yellowness and blueness (b*) value of control sample was found to be higher in curry (49.52) followed by pickle (46.39), grease (30.19) and mud (21.19). On subsequent washes, there is decrease in b* value of all the four stains where the stains have become bluer in colour than yellower. In other words the decrease in yellowness and blueness (b*) when expressed in percentage on subsequent washes revealed that there existed a reduction in yellowness of the stain. Reduction in yellowness value indicates increase in the value of blueness which means the stain has become lighter in colour. Though, the descending order of reduction in yellowness of mud (-42.59 %), curry (-37.48 %), grease (-30.96 %) and pickle (-28.40 %) after first wash; the higher blueness was achieved by curry (-52.57 %) followed by mud (-50.21 %), grease (-43.56 %) and pickle (-42.04 %) after third wash and these values are found significant at 5 per cent level of significance.

4.2.1.3 Colour strength and colour co-ordinate values of stains on white cotton samples subjected to multiple washes with 'WBO' surfactant

A glance at Table 21 and Fig. 4 highlights the colour co-ordinate and colour strength (K/S) values of stained samples subjected to multiple washes with 'WBO' surfactant.

Table 21: Colour strength (K/S) and colour co-ordinate values of stains on white cotton fabric subjected to multiple washes with 'WBO' surfactant

Surfactant	Stains	Control				1st Wash				2nd Wash				3rd Wash			
		K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*
Surf Excel	Grease	25.04	64.17	4.20	30.91	09.55*	71.09*	00.01*	15.61*	05.38*	76.78*	-00.27*	09.21*	02.91*	80.82*	-01.07*	00.71*
						(36.00)	(08.10)	(-09.01)	(-33.90)	(43.59)	(13.18)	(-10.10)	(-40.30)	(52.58)	(17.22)	(-10.30)	(-48.80)
	Pickle	43.68	62.16	18.56	46.39	10.26*	71.62*	05.93*	19.33*	06.43*	74.37*	05.51*	10.84*	03.76*	79.21*	02.17*	06.50*
						(31.39)	(08.02)	(-03.09)	(-30.18)	(40.30)	(10.77)	(-03.51)	(-38.67)	(46.27)	(15.61)	(-06.85)	(-43.02)
	Mud	88.52	40.93	15.24	21.19	06.22*	74.07*	06.29*	08.35*	03.17*	79.30*	03.76*	-00.02*	02.64*	80.65*	02.96*	-02.67*
						(42.56)	(10.47)	(-02.73)	(-41.16)	(52.24)	(15.71)	(-05.26)	(-49.54)	(55.24)	(17.05)	(-06.06)	(-52.19)
	Curry	46.30	63.59	09.02	49.52	05.28*	76.10*	04.00*	08.99*	02.48*	81.08*	01.13*	00.99*	02.42*	82.12*	00.83*	-04.06*
						(42.70)	(12.50)	(-05.02)	(-40.52)	(52.58)	(17.48)	(-08.19)	(-48.53)	(56.91)	(18.52)	(-09.29)	(-53.58)

Figures in parenthesis indicate percentage   * - Significant at 5 % level of significance

(K/S) Colour strength
(±L*) Lightness and Darkness
(±a*) Redness and Greenness
(±b*) Yellowness and Blueness

ANOVA TABLE

Surfactant	Sample	K/S			L*			a*			b*		
		SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %
WBO	Curry	0.006	0.100	0.008	0.005	0.017	0.007	0.005	0.324	0.007	0.006	0.107	0.008
	Grease	0.004	0.098	0.006	0.005	0.016	0.007	0.005	01.58	0.006	0.004	0.073	0.006
	Pickle	0.004	0.065	0.006	0.005	0.015	0.006	0.004	0.130	0.006	0.025	0.277	0.034
	Mud	0.004	0.037	0.005	0.005	0.018	0.007	0.005	0.176	0.007	0.004	0.149	0.005

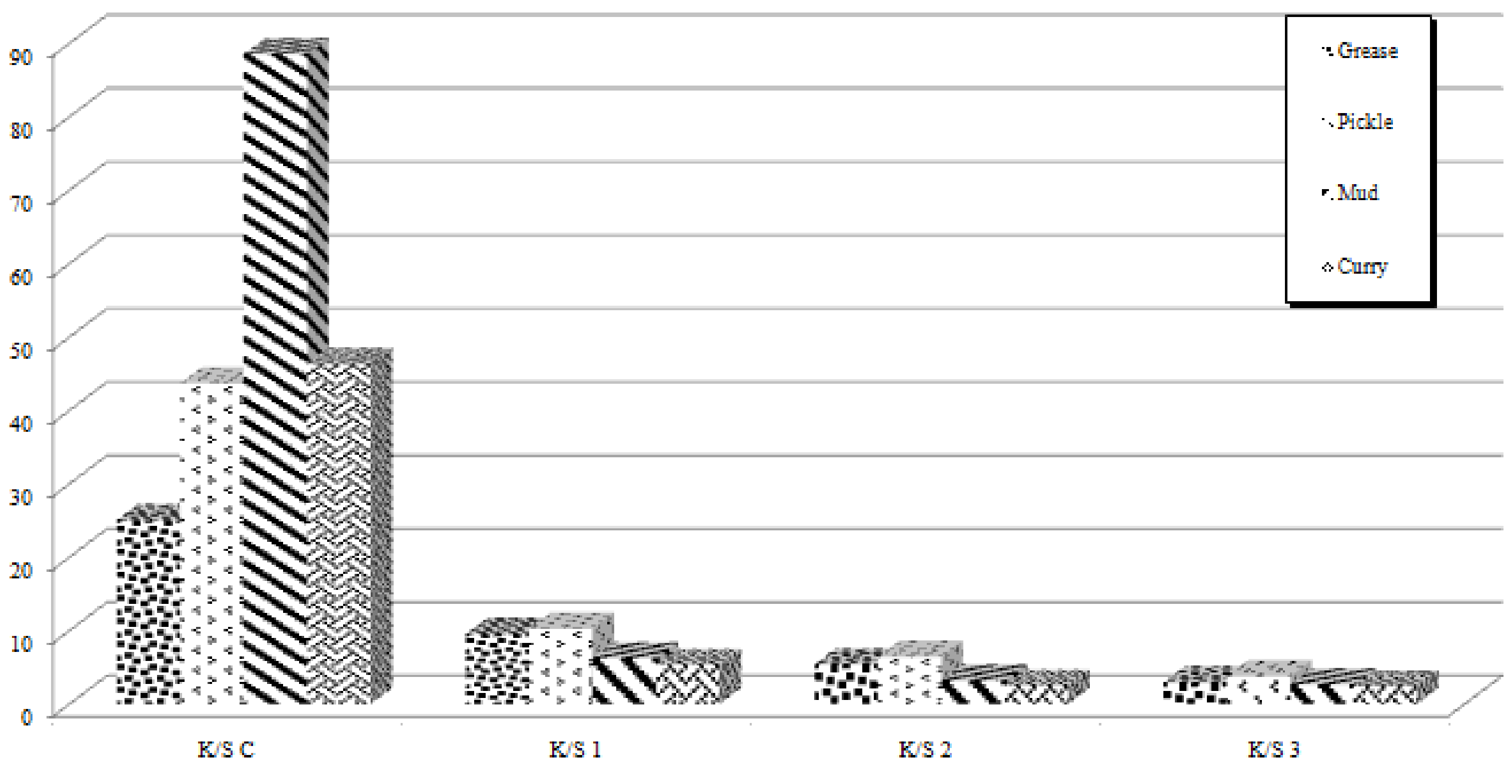

Fig. 4. Colour strength (K/S) values of stains on white cotton fabric subjected to multiple washes with 'WBO' surfactant

Fig. 4. Colour strength (K/S) values of stains on white cotton fabric subjected to multiple washes with 'WBO' surfactant

It is evident from this Table that the colour strength (K/S) at control was found to be highest with mud (88.52) followed by curry (46.30), pickle (43.68) and grease (25.04). In line with Table 20 and 21, A trend of decrease in colour strength values of all the four stains was noticed on subsequent washes. However, the percentage increase in colour strength (K/S) after every first wash indicates reduction in tint of the stain. It is observed after first and second wash that there is remarkable decrease in colour strength (K/S) value of curry (42.70 % and 52.58 %), mud (42.56 % and 52.24 %), grease (36.00 % and 43.59 %) and pickle (31.39 % and 40.30 %), respectively. And the same trend was observed even after the 3rd wash.

The descending order of L* (lightness and darkness) value of control sample was found to be higher with grease (64.17) followed by curry (63.59), pickle (62.16) and mud (40.93) stains. But on subsequent washes there is increase in L* (lightness and darkness) value which depicts that the stains have become lighter in colour. Meanwhile, the percentage increase in lightness and darkness (L*) on subsequent washes clearly indicated that a reduction in darkness of the stain i.e., the stains have become lighter in colour. However, a descending trend of reduction in lightness was observed with (17.48 % and 18.52 %), mud (15.71 % and 17.05 %), grease (13.18 % and 17.22 %) and pickle (10.77 % and 15.61 %) stains after second and third wash, respectively.

The highest redness (+a*) and greenness (-a*) value of control sample was found in pickle (18.56) followed by mud (15.24), curry (09.02) and grease (04.20). On subsequent washes, it was observed that the stains have gradually become greener in colour than redder, which indicates on attainment of lighter shade. Meanwhile, the decrease in redness correspondingly enhances the greenness, observed after each wash. The trend of decrease in redness (a*) value, after first wash was with mud (-02.73 %) followed by pickle (-03.09 %), curry (-05.02 %) and grease (-09.01 %) stains and this trend remained same even after 3rd wash.

At control, the higher yellowness (+b*) and blueness (-b*) values were found in curry (49.52) followed by pickle (46.39), grease (30.91) and mud (21.19). But on subsequent washes the yellowness decreased and turned to blueness (b*) which clearly depicts that the stains have become bluer in colour, a lighter colour. Meanwhile, the decrease in yellowness expressed in percentage directly indicates increase in blueness. Meanwhile, the trend of reduction observed after first and second wash was pickle (-30.18 % and -38.67 %), grease (-33.90 % and -40.30 %), curry (-40.52 % and -48.53 %) and mud (-41.16 % and -49.54 %) stains, respectively; was slightly changed after 3rd wash where blueness (-b*) value was attained by curry was higher (-53.58) followed by mud (-52.19), grease (-48.80) and pickle (-43.02) and it was found significant at 5 per cent level of significance.

4.2.2 Structural properties of dyed cotton samples

4.2.2.1 Cloth count of dyed cotton samples

Cloth count indicates the configuration of ends and picks per unit area that also refers to cloth geometry. Table 22 depicts about threads per unit area of dyed fabric after subsequent washes. The ends and picks of all dyed fabrics is 92 and 46, respectively at control but found increase in ends per unit area by two threads after 5th wash in all the test samples, except red. But there was no increase in the cloth count after 10^{th} and 15^{th} washes. Similarly, a trend of increase in the picks per unit area observed after 5^{th} wash, whereas no change in subsequent washes. However, the ends are almost double the number of picks and these results were found to be significant at 5 per cent level of significance.

4.2.2.2 Cloth thickness (mm) of dyed cotton samples

Cloth thickness is the difference between upper and lower layers of the fabric measured in mm. It is evident from Table 23 that all the four dyed samples have uniform thickness (each 0.33mm) and there is slight increase from 0.34 mm to 0.36 mm, after 5^{th} wash. Further, it is evident that there is no change in the cloth thickness after 10^{th} and 15^{th} washes. However, the increase in cloth thickness after subsequent washes is found to be significant at 5 per cent level of significance.

4.2.2.3 Cloth weight (GSM) of dyed cotton samples

It is evident from Table 24 that there is change in the GSM of test samples on washing. The GSM at control is almost same varying between 93 GSM to 94 GSM, among the test samples. However, the weight of the warp yarn is contributed to all most 65 per cent and weft yarn to 35 per cent, in a square meter. There is slight increase in the GSM of the test samples after 5^{th} wash by just 1 to 1.5 GSM and thereafter there is no much variation on repeated washes. It is observed that after 15^{th} wash the test samples gained a GSM of 01.69 per cent to 02.13 per cent, irrespective of the samples. Meanwhile, the configuration of ends and picks (02.17 %) remained unchanged after washing. A significant difference in GSM was seen between control and washed samples at 5 per cent level of significance.

4.2.2.4 Cloth dimensional stability (%) of dyed cotton samples

It is evident from Table 25 that all the four test samples exhibited some percent of shrinkage on washing, when compared to control values. However, the warpway shrinkage (0.73 %) was higher than weftway (0.66 %) after 5^{th} wash. But after 10^{th} and 15^{th} washes, the shrinkage in warpway and weftway was very minimal, i.e., warpway 00.13 per cent and weftway 00.06 per cent and there was significant difference observed in dimensional stability between control and treated samples, which is at 5 per cent level of significance.

4.2.3 Performance properties of dyed cotton samples

4.2.3.1 Cloth crease recovery angle (degree) of dyed cotton samples

Table 26 provides value of cloth crease recovery of the dyed cotton fabrics. The recovery is higher in weft direction (81^0) compared to recovery of warpway samples (79^0) at control. However, a trend of increase is observed after 5^{th}, 10^{th} and 15^{th} washes. The increase in warpway recovery angle from control is 01.26 per cent, 02.52 per cent and 05.04 per cent and that of weft way recovery is 01.23 per cent, 03.69 per cent and 04.92 per cent, after 5^{th}, 10^{th} and 15^{th} washes, respectively.

However, the statistical results presented in Table 26 indicated that there was significant difference in the crease recovery angle and the values are significant at 5 per cent level of significance.

Table 22. Cloth count (threads per unit) of dyed cotton samples

Sl. No	Samples	Cloth count / inch							
		Control		Washes					
				5^{th}		10th		15^{th}	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	Black	92	46	94* (02.17)	46* (0.00)	94* (02.17)	46* (0.00)	94* (02.17)	48* (04.34)
2	Blue	92	46	94* (02.17)	48* (04.34)	94* (02.17)	48* (04.34)	94* (02.17)	48* (04.34)
3	Green	92	46	94* (02.17)	46* (0.00)	94* (02.17)	46* (0.00)	94* (02.17)	48* (04.34)
4	Red	92	46	92* (0.00)	48* (04.34)	94* (02.17)	48* (04.34)	94* (02.17)	48* (04.34)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm $\pm$		CV %		CD 5 %	
		Warp	Weft	Warp	Weft	Warp	Weft
1	Black	0.299	0.287	0.271	0.260	1.00	01.96
2	Blue	0.308	0.193	0.279	0.175	01.04	01.30
3	Green	0.375	0.342	0.340	0.310	01.35	02.47
4	Red	0.171	0.214	0.155	0.194	06.39	01.44

Table 23. Cloth thickness (mm) of dyed cotton samples

Cloth thickness (mm)					
Sl. No.	Samples	Control	Washes		
			5th	10th	15th
1	Black	0.33	0.34* (03.03)	0.36* (09.09)	0.35* (06.06)
2	Blue	0.33	0.35* (06.06)	0.36* (09.09)	0.36* (09.09)
3	Green	0.33	0.36* (09.09)	0.36* (09.09)	0.36* (09.09)
4	Red	0.32	0.35* (09.37)	0.35* (09.37)	0.35* (09.37)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm ±	CV %	CD 5 %
1	Black	0.003	2.821	0.002
2	Blue	0.003	2.738	0.002
3	Green	0.003	2.764	0.002
4	Red	0.003	3.079	0.003

Table 24. Cloth weight per unit area (GSM) of dyed cotton samples

Sl. No	Samples	Cloth weight per unit area (GSM)											
		Control			Washes								
					5th			10th			15th		
		GSM	Warp (%)	Weft (%)	GSM	Warp (%)	Weft (%)	GSM	Warp (%)	Weft (%)	GSM	Warp (%)	Weft (%)
1.	Black	94.00*	65.94	34.06	95.20* (01.27)	65.99	34.01	95.60* (01.70)	66.05	33.95	96.40* (02.55)	66.00	34.00
2.	Blue	92.80*	62.30	37.70	94.40* (01.72)	62.89	37.11	94.50* (01.83)	62.91	37.09	94.80* (02.15)	62.89	37.11
3.	Green	93.60*	64.66	35.34	95.60* (02.13)	64.82	35.18	94.80* (01.28)	64.85	35.15	95.60* (02.13)	64.81	35.19
4.	Red	94.40*	64.77	35.23	95.60* (01.27)	64.80	35.20	96.40* (02.11)	64.90	35.10	96.00* (01.69)	64.87	35.13

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl. No.	Samples	SEm ±			CV %			CD 5 %		
		5*5	Warp	5*5	Warp	Weft	Weft	5*5	Warp	Weft
1	Black	0.003	0.004	0.005	0.006	0.009	0.006	03.70	07.17	18.64
2	Blue	0.001	0.002	0.001	0.003	0.002	0.002	01.22	03.52	05.65
3	Green	0.001	0.004	0.002	0.005	0.004	0.003	01.71	06.11	09.73
4	Red	0.001	0.001	0.002	0.001	0.001	0.001	01.61	01.98	03.46

Table 25. Cloth dimensional stability (%) of dyed cotton samples

Sl.No	Samples	Control		Washes					
				5th		10th		15th	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1.	Black	15	15	14.89* (0.73)	14.97* (0.20)	14.98* (0.13)	14.97* (0.20)	14.98* (0.13)	14.99* (0.06)
2.	Blue	15	15	14.89* (0.73)	14.90* (0.66)	14.98* (0.13)	14.97* (0.20)	14.98* (0.13)	14.99* (0.06)
3.	Green	15	15	14.89* (0.73)	14.97* (0.20)	14.98* (0.13)	14.98* (0.13)	14.98* (0.13)	14.99* (0.06)
4.	Red	15	15	14.97* (0.20)	14.90* (0.66)	14.90* (0.60)	15.00* (0.00)	14.98* (0.13)	15.00* (0.00)

Dimensional stability (%)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm $\pm$		CV %		CD 5 %	
		Warp	Weft	Warp	Weft	Warp	Weft
1	Black	0.033	0.023	0.044	0.031	0.501	0.350
2	Blue	0.030	0.025	0.041	0.034	0.465	0.381
3	Green	0.037	0.029	0.050	0.039	0.568	0.436
4	Red	0.029	0.030	0.039	0.041	0.442	0.462

Table 26. Cloth crease recovery angle (degree) of the dyed cotton samples

Sl. No	Samples	Cloth crease recovery angle (Degree)							
		Control		Washes					
				5th		10th		15th	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1.	Black	79	81	80* (01.26)	82* (01.23)	81* (02.53)	84* (03.70)	83* (05.06)	85* (04.93)
2.	Blue	79	81	80* (01.26)	82* (01.23)	81* (02.53)	84* (03.70)	83* (05.06)	85* (04.93)
3.	Green	78	82	80* (02.56)	83* (01.21)	82* (05.12)	84* (02.43)	83* (06.41)	85* (03.65)
4.	Red	79	81	81* (02.53)	82* (01.23)	82* (03.79)	84* (03.70)	83* (05.06)	85* (04.93)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm ±		CV %		CD 5 %	
		Warp	Weft	Warp	Weft	Warp	Weft
1	Black	0.946	0.771	1.268	1.034	2.770	2.055
2	Blue	0.663	0.927	0.889	1.243	1.967	2.481
3	Green	1.220	1.410	1.636	1.891	3.726	3.636
4	Red	0.916	1.646	1.228	2.207	2.703	4.384

4.2.3.2 Cloth bending length (cm) of dyed cotton samples

The impact of washing on bending angle of four selected sample is presented in Table 27. In general it is found that on subsequent washings the bending length of the test samples gradually reduced compared to control and is in line with the corresponding warpway and weftway values. The warpway bending length was comparatively lower than weftway value. The reduction in bending length was almost same (04.00 % in warpway and 05.00 % in weftway) among the black, blue, green and red samples, after 5th wash and there after much variation was not observed. However, there was significant difference observed between control and treated samples at 5 per cent level of significance.

4.2.4 Durable properties of dyed cotton samples

4.2.4.1 Cloth tensile strength (kgf) and elongation (%) of dyed cotton samples

The tensile strength is the fundamental ability to resist stain or rupture induced by tension. The tensile strength of the fabric depends upon the fibre content and its inherent properties like type of yarn, yarn number, crimp in the yarn, TPI, threads per inch and compactness of the weave.

Table 28(a) and Fig. 5 depicts that the tensile strength of control sample was higher. However, the warp way strength was higher than its corresponding weft way strength. The descending order of warpway tensile strength was from 0.55 per cent to 04.95 per cent and 01.00 per cent to 09.00 per cent after 5th and 10th wash respectively. In weftway, the breaking load has decreased 03.00 per cent to 06.00 per cent after 5th wash but after 10th and 15th wash it has reduced to 03.00 per cent to 11.00 per cent and 05.00 per cent to 22.00 per cent, respectively.

The breaking load and elongation (%) are directly proportional and supportive. It is evident from Table 28(b) and Fig. 6 that there was reduction in elongation percentage compared to control sample. However, the warpway elongation was higher than weftway elongation. There was slight reduction observed in warpway (0.72 % to 10.76 %) after 5th and 10th wash, respectively. But after 15th wash there was much reduction (up to 27.5 %) in warpway elongation compared to 5th and 10th wash. After 5th and 10th wash the elongation was reduced (02.01 % to 08.63 %) in weftway compared to control but slight decrease was noticed after 10th and 15th wash (02.19 % to 09.29 % and 10.00 % to 20.00 %), respectively.

The decrease in tensile strength (breaking load) and elongation (%) were found to be significant at 5 per cent level of significance.

4.2.4.2 Influence of cloth count, cloth thickness and cloth GSM on tensile strength (kgf) of dyed cotton samples

Table 29(a) and 29(b) reveals the influence of cloth count, cloth thickness and GSM on warpway tensile strength of dyed samples.

Table 27. Cloth bending length (cm) of dyed cotton samples

Sl.No.	Samples	Cloth bending length (cm)							
		Control		Washes					
				5th		10th		15th	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1.	Black	2.5	2.0	2.4* (04.00)	1.9* (05.00)	2.3* (08.00)	1.8* (10.00)	2.2* (12.00)	1.6* (20.00)
2.	Blue	2.4	2.0	2.3* (04.16)	1.9* (05.00)	2.2* (08.33)	1.8* (10.00)	2.2* (08.33)	1.7* (15.00)
3.	Green	2.4	1.8	2.4* (0.00)	1.8* (0.00)	2.3* (04.16)	1.8* (0.00)	2.2* (08.33)	1.7* (05.56)
4.	Red	2.4	2.0	2.4* (0.00)	1.9* (05.00)	2.4* (0.00)	1.8* (10.00)	2.3* (04.16)	1.7* (15.00)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm ±		CV %		CD 5 %	
		Warp	Weft	Warp	Weft	Warp	Weft
1	Black	0.035	0.031	0.032	0.028	4.641	5.478
2	Blue	0.032	0.038	0.029	0.035	4.551	6.800
3	Green	0.037	0.025	0.033	0.022	5.038	4.701
4	Red	0.042	0.032	0.038	0.029	5.295	5.581

Table 28. Cloth tensile strength (kgf) of dyed cotton samples

28(a). Cloth breaking load (kgf)

Sl.No	Samples	Control		Cloth breaking load (kgf) Washes					
				5th		10th		15th	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1.	Black	21.60	09.22	21.48* (0.55)	08.88* (03.68)	21.36* (01.11)	08.78* (04.77)	19.79* (08.37)	08.72* (05.42)
2.	Blue	22.18	09.24	21.08* (04.95)	08.68* (06.06)	20.16* (09.10)	08.22* (11.03)	20.14* (09.19)	07.76* (16.01)
3.	Green	21.62	09.14	21.14* (02.22)	08.86* (03.06)	20.40* (05.64)	08.84* (03.28)	19.58* (09.43)	07.14* (21.88)
4.	Red	21.70	09.10	21.04* (03.04)	08.76* (03.73)	20.16* (07.09)	08.12* (10.76)	19.98* (07.92)	08.06* (11.42)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm ±		CV %		CD 5 %	
		Warp	Weft	Warp	Weft	Warp	Weft
1	Black	0.428	0.444	0.573	0.595	4.619	11.162
2	Blue	0.521	0.481	0.698	0.645	5.505	12.708
3	Green	0.465	0.368	0.623	0.493	5.031	9.692
4	Red	0.347	0.425	0.465	0.570	3.794	11.175

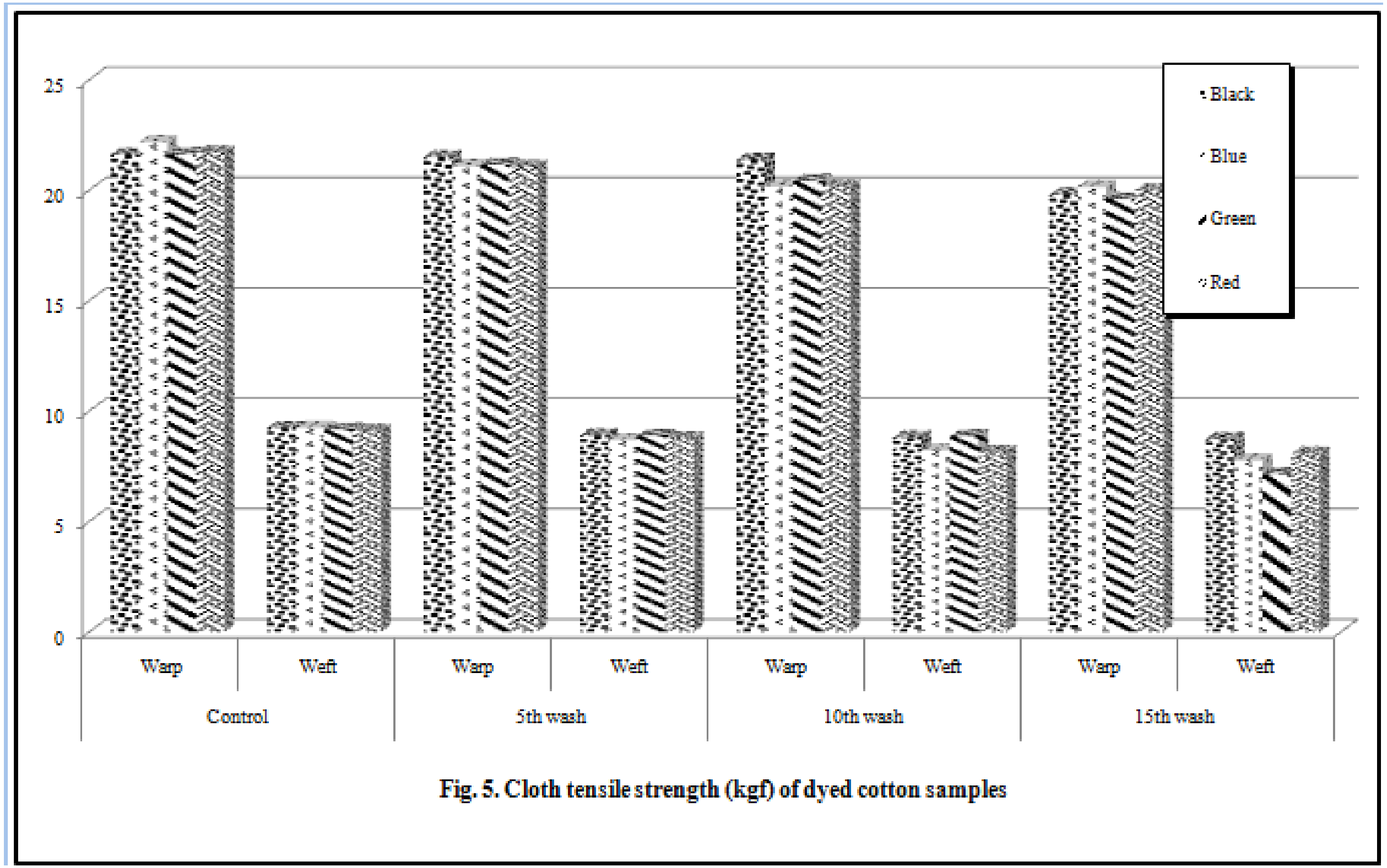

Fig. 5. Cloth tensile strength (kgf) of dyed cotton samples

Table 28(b). Cloth elongation (%) of dyed cotton samples

Sl.No	Samples	Cloth elongation (%)							
		Control		Washes					
				5th		10th		15th	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1.	Black	06.85	06.02	06.80* (0.72)	05.50* (08.63)	06.70* (02.18)	05.49* (08.80)	04.96* (27.59)	05.39* (10.46)
2.	Blue	07.34	05.27	07.12* (02.99)	04.96* (05.88)	06.55* (10.76)	04.78* (09.29)	06.03* (17..84)	04.65* (11.76)
3.	Green	07.31	05.47	07.02* (03.96)	05.36* (02.01)	06.52* (10.80)	05.35* (02.19)	05.87* (19.69)	04.81* (12.06)
4.	Red	07.05	05.66	06.89* (02.26)	05.48* (03.18)	06.75* (04.25)	05.27* (06.89)	06.21* (11.91)	04.51* (20.31)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm ±		CV %		CD 5 %	
		Warp	Weft	Warp	Weft	Warp	Weft
1	Black	0.111	0.182	0.148	0.244	3.766	7.626
2	Blue	0.128	0.175	0.172	0.235	4.216	7.972
3	Green	0.167	0.175	0.224	0.235	5.608	7.742
4	Red	0.130	0.193	0.175	0.260	4.289	8.293

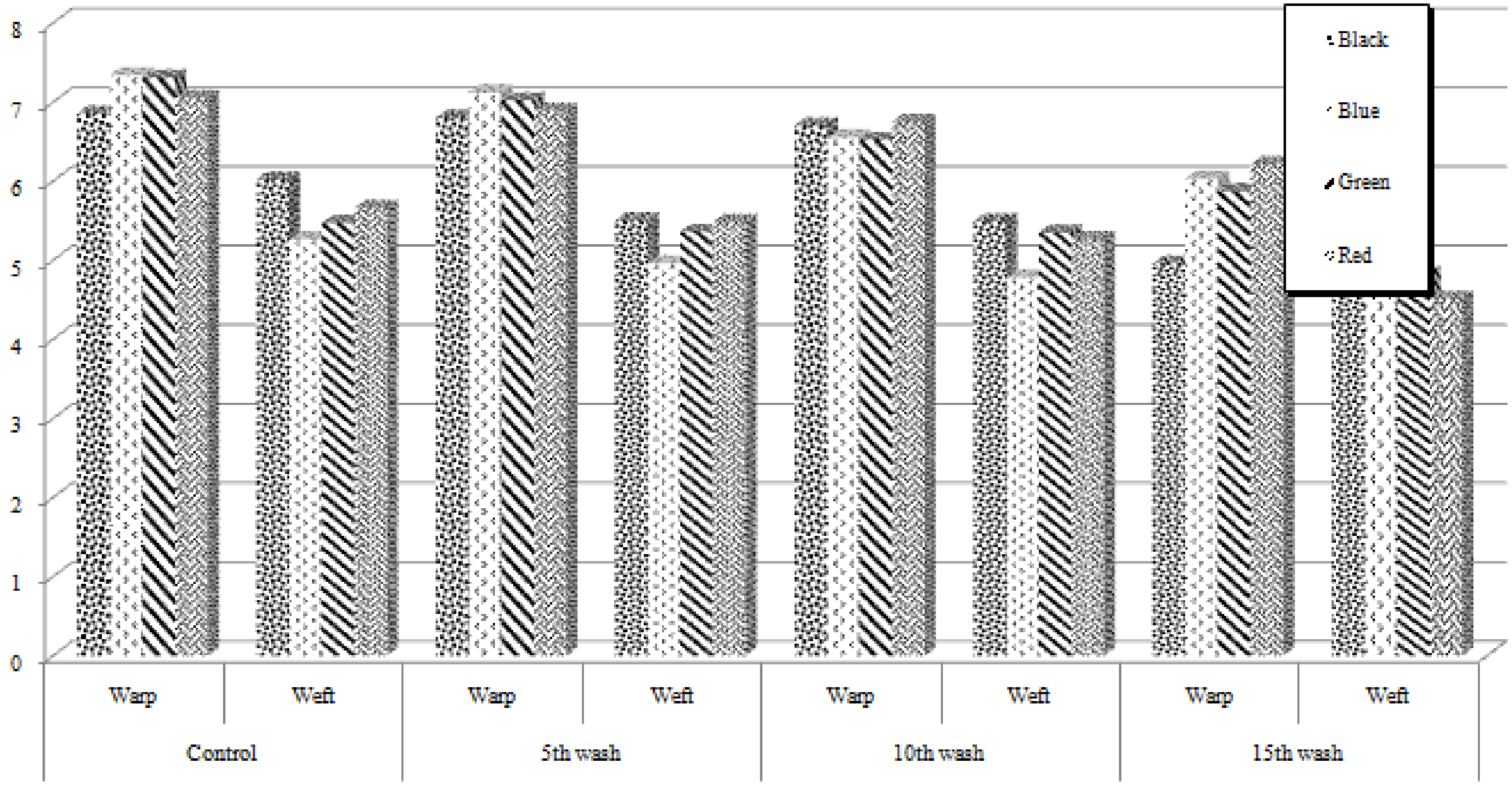

Fig. 6. Cloth elongation (%) of dyed cotton samples

Fig. 6. Cloth elongation (%) of dyed cotton samples

Table 29(a). Influence of cloth count, cloth thickness and GSM on warpway tensile strength (kgf) of dyed cotton samples

Sample	Warpway tensile strength (kgf)												
		Control			5^{th} wash			10^{th} wash			15^{th} wash		
	Variables	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat
Black	X_1	0.17	0.24	0.70^{NS}	-0.17	0.19	-0.89^{NS}	-0.09	0.08	-01.10^{NS}	-0.75	01.05	-0.71^{NS}
	X_2	-0.19	0.11	-01.73^{NS}	0.10	0.30	0.35^{NS}	-0.12	0.13	-0.87^{NS}	0.19	01.30	0.14^{NS}
	X_3	-05.66	21.08	-0.26^{NS}	-13.45	15.44	-0.87^{NS}	-03.06	09.26	-0.33^{NS}	-51.31	90.19	-0.56^{NS}
	X_4	-52.48	09.90	-05.29^{NS}	-152.21	134.89	-01.12^{NS}	-122.77	42.22	-02.90**	249.89	246.65	03.01**
	R^2	0.86			0.34			0.72			0.38		
Blue	X_1	0.32	0.51	0.64^{NS}	-0.09	0.20	-0.47^{NS}	-0.24	0.20	-01.18^{NS}	-0.31	0.48	-0.26^{NS}
	X_2	01.23	0.63	01.94^{NS}	0.96	0.96	01.00^{NS}	-0.34	0.30	-01.12^{NS}	-0.33	0.57	-0.59^{NS}
	X_3	48.63	74.79	0.65^{NS}	-17.45	23.02	-0.75^{NS}	03.70	21.79	0.16^{NS}	03.01	76.35	0.03^{NS}
	X_4	156.00	111.65	01.39^{NS}	61.80	173.44	0.35^{NS}	-221.16	43.33	-05.10**	-731.14	237.77	-03.07**
	R^2	0.51			0.21			0.86			0.82		
Green	X_1	-01.54	0.71	-02.14^{NS}	0.13	0.16	0.77^{NS}	0.30	0.79	0.37^{NS}	-0.19	0.34	-0.57^{NS}
	X_2	-0.05	0.63	-0.08^{NS}	-0.03	0.25	-0.13^{NS}	0.03	0.60	0.06^{NS}	0.02	0.24	0.11^{NS}
	X_3	130.20	38.97	00.34^{NS}	01.60	14.71	0.10^{NS}	-15.02	51.12	-0.29^{NS}	18.55	34.18	0.54^{NS}
	X_4	-77.67	72.28	-01.07^{NS}	180.41	68.49	02.63^{NS}	25.16	126.56	0.19^{NS}	-555.89	125.79	-04.41**
	R^2	0.72			0.69			0.03			0.83		
Red	X_1	0.02	0.72	0.04^{NS}	0.04	0.64	0.07^{NS}	0.43	0.76	0.57^{NS}	0.80	0.23	0.37^{NS}
	X_2	-0.24	0.56	-0.44^{NS}	0.37	0.54	0.69^{NS}	0.37	0.50	0.72^{NS}	-0.57	0.27	-02.06^{NS}
	X_3	-48.94	61.20	-0.79^{NS}	-02.22	17.77	-0.12^{NS}	-42.64	35.54	-01.19^{NS}	-57.28	36.55	-01.56^{NS}
	X_4	-12.07	324.28	-0.03^{NS}	46.54	122.73	0.37^{NS}	-59.47	205.21	-0.28^{NS}	-316.96	93.76	-03.38**
	R^2	0.13			0.13			0.42			0.80		

X1= Cloth count warp
X2= Cloth count weft
X3= Cloth thickness
X4= Cloth GSM

NS – Non significant
** - Highly significant at 1 % level of significance

It is evident from this Table 29(a) that the cloth count and cloth thickness did not influence the corresponding warpway tensile strength significantly. On the contrary, the influence of GSM of black and blue test samples on the corresponding warpway tensile strength was found to be significant at 1 % level of significance after 10^{th} and 15^{th} washes. Similarly, the influence of GSM of green and red test samples was also significant at 1 % level of significance after 15^{th} wash, which clearly indicates that the GSM of the test samples has direct and positive impact on the warpway tensile strength. However, it is imperative to state that the cloth count and cloth thickness have impact on GSM, that intern has affected the warpway tensile strength.

The R^2 value of black and blue test samples were found to be 0.72 and 0.86 respectively after 10^{th} wash i.e., the influence is 72.00 and 86.00 per cent respectively; and that of black, blue, green and red samples were found to be 0.38, 0.82, 0.83 and 0.80 respectively, which indicates that the percentage influence of GSM on the tensile strength of black fabric was minimum (38.00 %) compared to others.

From Table 29 (b), it is found that the influence of cloth count, cloth thickness and GSM on weftway tensile was non significant at control, after 5^{th} and 10^{th} wash. But the GSM has negatively influenced the weftway tensile strength of black and red test samples; and positively the blue sample where the value is significant at 5 % level of significance. The R^2 value of black, blue and red test samples was 0.79, 0.63 and 0.85 respectively.

4.2.4.3 Influence of cloth count, cloth thickness and cloth GSM on elongation (%) of dyed cotton samples

Table 30(a) and (b) depict the influence of cloth count, cloth thickness and GSM on warpway elongation (%) of dyed fabrics.

It is evident from Table 30(a) that there was influence of GSM on warpway elongation of black sample and cloth thickness of green sample at control and is found to be significant at 5 % levels of significance, respectively. Further the cloth thickness influenced the warpway elongation of blue sample after 5^{th} wash and is significant at 5 % level of significance. After 15^{th} wash, the cloth thickness of blue sample and GSM of green sample influenced the warpway elongation negatively and the values are significant at 5% level of significance.

The R^2 value of black and green samples were found to be 0.71 and 0.76 (control), blue to be 0.76 after 5^{th} wash, blue and green samples to be 0.82 and 0.64 after 15^{th} wash.

Table 30(b) indicates the influence of cloth count, cloth thickness and GSM on weftway elongation (%) of four dyed cotton samples. It is found that the ends per inch influenced the weftway elongation (%) of green fabric at control and is significant at 1 % level of significance. Similarly, the cloth count (warpway) influenced the elongation (%) of red sample after 5^{th} wash and 15^{th} wash and is significant at 1 % level of significance. Meanwhile the GSM of red sample did influence the percentage elongation after 5^{th} and 15^{th} washes and is significant at 5 % and 1% level of significance, respectively; however, the latter showed negative influence.

Table 29(b). Influence of cloth count, cloth thickness and GSM on weftway tensile strength (kgf) of dyed cotton samples

Sample	Weftway tensile strength (kgf)												
	Control				5th wash			10th wash			15th wash		
	Variables	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat
Black	X_1	-0.48	0.44	-1.08 NS	0.17	0.30	0.57 NS	-0.79	0.39	-2.03 NS	-0.46	0.35	-1.31 NS
	X_2	0.052	0.20	0.26 NS	-0.19	0.46	-0.42 NS	-0.15	0.63	-0.24 NS	0.87	0.43	2.01 NS
	X_3	-8.76	37.82	-0.23 NS	41.05	24.03	1.70 NS	7.09	42.01	0.16 NS	-16.69	30.02	-0.55 NS
	X_4	-11.07	17.76	-0.62 NS	-258.12	209.88	-1.22 NS	-410.57	191.60	-2.14 NS	-232.71	82.11	-2.83*
	R^2		0.35			0.38			0.60			0.79	
Blue	X_1	0.11	0.34	0.33 NS	-0.03	0.26	-0.15 NS	-0.16	0.90	-0.17 NS	0.06	0.36	0.18 NS
	X_2	-0.38	0.43	-0.88 NS	1.71	1.23	1.38 NS	-0.52	1.36	-0.38 NS	-0.32	0.42	-0.76 NS
	X_3	9.28	50.87	0.18 NS	-21.39	29.64	-0.72 NS	36.39	96.64	0.37 NS	-40.36	56.53	-0.71 NS
	X_4	57.37	75.95	0.75 NS	159.67	223.26	0.71 NS	-231.01	192.20	-1.20 NS	444.37	176.04	2.52*
	R^2		0.39			0.30			0.30			0.63	
Green	X_1	-1.31	0.31	-0.25 NS	-0.08	0.34	-0.25 NS	-0.34	0.82	-0.41 NS	-0.33	0.34	-0.99 NS
	X_2	-0.47	0.27	-1.70 NS	0.46	0.52	0.87 NS	-0.12	0.61	-0.20 NS	0.11	0.24	0.47 NS
	X_3	-19.72	17.09	-1.15 NS	12.40	29.91	0.41 NS	15.63	52.73	0.29 NS	28.04	33.66	0.83 NS
	X_4	-13.3	31.69	-0.42 NS	-37.71	139.17	-0.27 NS	-17.11	130.55	-0.13 NS	-266.54	123.89	-2.15 NS
	R^2		0.87			0.22			0.52			0.49	
Red	X_1	-1.002	0.37	-0.19 NS	1.41	0.31	2.56 NS	0.18	0.19	0.97 NS	1.31	0.35	2.17 NS
	X_2	0.41	0.28	1.42 NS	0.75	0.26	2.25 NS	-0.08	0.12	-0.65 NS	-0.67	0.41	-1.62 NS
	X_3	-65.49	31.39	-2.08 NS	-26.99	8.52	-1.16 NS	3.08	8.94	0.34 NS	-67.91	55.08	-1.23 NS
	X_4	-506.15	166.32	-2.04 NS	179.87	58.86	2.05 NS	19.38	51.62	0.37 NS	-725.52	141.30	-2.43*
	R^2		0.13			0.87			0.34			0.85	

X1= Cloth count warp
X2= Cloth count weft
X3= Cloth thickness
X4= Cloth GSM

NS – Non significant
* - Significant at 5 % level of significance

Table 30(a). Influence of cloth count, cloth thickness and GSM on warpway elongation (%) of dyed cotton samples

Sample	Warpway elongation (%)												
		Control			5th wash			10th wash			15th wash		
	Variables	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat
Black	X_1	-0.06	0.07	-0.93NS	0.02	0.05	0.04NS	0.21	0.09	2.26NS	-0.14	0.22	-0.62NS
	X_2	-0.02	0.03	-0.07NS	0.01	0.09	0.17NS	-0.12	0.15	-0.80NS	0.12	0.28	0.42NS
	X_3	0.61	6.04	0.10NS	-8.09	4.70	-1.72NS	-4.57	10.41	-0.43NS	-11.14	19.61	-0.56NS
	X_4	-7.79	2.83	-02.74*	12.22	41.08	0.29NS	-21.05	47.48	-2.44*	25.17	53.65	02.46*
	R^2	0.71			0.38			0.63			0.28		
Blue	X_1	0.06	0.08	0.72NS	-0.09	0.05	-1.68NS	-0.21	0.16	-1.24NS	-0.02	0.08	-0.35NS
	X_2	0.11	0.10	1.10NS	-0.43	0.27	-1.59NS	0.03	0.25	0.13NS	-0.07	0.09	-0.77NS
	X_3	14.33	12.49	1.14NS	15.65	6.48	02.41*	-1.28	18.02	-0.07NS	-31.50	12.81	-02.45*
	X_4	8.41	18.65	0.45NS	-30.54	48.83	-0.62NS	20.11	35.84	2.56*	-68.83	39.91	-01.72NS
	R^2	0.38			0.76			0.34			0.82		
Green	X_1	-0.37	0.16	-2.21NS	0.07	0.03	2.07NS	0.10	0.26	0.38NS	-0.16	0.28	-0.57NS
	X_2	0.01	0.14	0.09NS	-0.04	0.05	-0.75NS	0.09	0.19	0.45NS	0.01	0.19	0.06NS
	X_3	33.11	9.10	03.63**	-2.15	3.16	-0.68NS	-5.61	16.92	-0.33NS	15.45	27.74	0.55NS
	X_4	-28.63	16.87	-1.69NS	-22.25	14.70	-1.51NS	28.52	41.89	0.68NS	-284.98	102.10	-02.79*
	R^2	0.76			0.61			0.12			0.64		
Red	X_1	0.01	0.36	0.03NS	0.23	0.18	1.29NS	0.43	0.76	0.57NS	-0.07	0.12	-0.60NS
	X_2	-0.11	0.28	-0.42NS	0.21	0.15	1.40NS	0.37	0.50	0.72NS	0.01	0.14	0.12NS
	X_3	-21.85	30.63	-0.71NS	-5.07	5.06	-1.00NS	-42.64	35.54	-1.19NS	01.87	19.52	0.09NS
	X_4	11.84	162.31	0.07NS	27.51	34.95	0.78NS	-59.47	205.21	-0.28NS	-61.71	50.08	-01.23NS
	R^2	0.10			0.40			0.34			0.46		

X1= Cloth count warp
X2= Cloth count weft
X3= Cloth thickness
X4= Cloth GSM

NS – Non significant
* - Significant at 5 % level of significance
** - Highly significant at 1 % level of significance

Table 30(b). Influence of cloth count, cloth thickness and GSM on weftway elongation (%) of dyed cotton samples

Sample	Weftway elongation (%)												
		Control			5th wash			10th wash			15th wash		
	Variables	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat
Black	X_1	-0.28	0.27	-1.04^{NS}	-8.40	0.11	-0.07^{NS}	-0.28	0.10	-2.58*	-0.11	0.20	-0.53^{NS}
	X_2	0.04	0.12	0.35^{NS}	-0.06	0.17	-0.33^{NS}	0.02	0.16	0.17^{NS}	0.14	0.25	0.56^{NS}
	X_3	-7.71	23.26	-0.33^{NS}	20.34	9.12	2.22^{NS}	2.56	10.92	0.23^{NS}	-10.10	17.85	-0.56^{NS}
	X_4	-0.40	10.92	-0.03^{NS}	-2.19	79.71	-0.027^{NS}	-203.23	49.79	-4.08**	-88.17	48.83	-2.80*
	R^2	0.25			0.50			0.80			0.62		
Blue	X_1	0.04	0.13	0.36^{NS}	0.005	0.11	0.04^{NS}	0.14	0.22	0.66^{NS}	0.03	0.19	0.20^{NS}
	X_2	-0.05	0.16	-0.33^{NS}	0.89	0.53	1.67^{NS}	0.11	0.33	0.33^{NS}	-0.13	0.22	-0.61^{NS}
	X_3	-0.005	19.53	-0.002^{NS}	-13.10	12.79	-1.02^{NS}	-6.68	23.53	-0.28^{NS}	-24.55	29.75	-0.82^{NS}
	X_4	19.19	29.16	0.65^{NS}	77.17	96.38	0.80^{NS}	86.90	46.80	1.85^{NS}	157.94	92.64	2.41*
	R^2	0.22			0.42			0.51			0.43		
Green	X_1	-0.71	0.20	-03.46**	-0.10	0.10	-0.96^{NS}	-0.33	0.37	-0.88^{NS}	-0.13	0.21	-0.62^{NS}
	X_2	-0.19	0.18	-1.10^{NS}	0.17	0.16	1.08^{NS}	-0.05	0.28	-0.20^{NS}	0.03	0.15	0.20^{NS}
	X_3	-3.09	11.10	-0.27^{NS}	7.77	9.26	0.83^{NS}	1.91	24.33	0.07^{NS}	11.75	21.00	0.55^{NS}
	X_4	2.04	20.59	0.09^{NS}	-4.19	43.09	-0.09^{NS}	-2.68	60.25	-0.04^{NS}	-168.15	77.28	-2.17^{NS}
	R^2	0.77			0.34			0.15			0.50		
Red	X_1	-0.38	0.19	-1.97^{NS}	0.67	0.15	2.48*	-0.03	0.07	-0.53^{NS}	0.54	0.21	2.57*
	X_2	0.13	0.14	0.91^{NS}	0.47	0.12	1.29^{NS}	0.03	0.04	0.77^{NS}	-0.25	0.24	-1.04^{NS}
	X_3	-27.09	16.30	-1.66^{NS}	-12.86	4.12	-2.11^{NS}	-6.06	3.29	-1.84^{NS}	-25.91	32.53	-0.79^{NS}
	X_4	-190.59	86.40	-2.20^{NS}	124.94	28.50	2.38*	19.71	19.00	1.03^{NS}	-338.04	83.44	-4.05**
	R^2	0.82			0.89			0.60			0.77		

X1= Cloth count warp
X2= Cloth count weft
X3= Cloth thickness
X4= Cloth GSM

NS – Non significant
* - Significant at 5 % level of significance
** - Highly significant at 1 % level of significance

The R^2 value of green sample was found to be 0.77 at control, red sample to be 0.89 after 5th, black sample to be 0.80 after 10th and red sample to be 0.77 after 15th washes.

4.2.4.2 Cloth abrasion resistance (cycles) of dyed cotton samples

Table 31 reveals about the cloth abrasion resistance of the selected fabric samples. The control sample showed higher resistance to abrasion. As the number of washing increased reduction was found in abrasion resistance of all four dyed samples. However, after 10th wash there was great reduction in number of abrasion cycles was observed (54 % to 58 %) compared to 5th wash and these results are found to be significant at 5 per cent level of significance.

4.2.4.5 Influence of cloth count, cloth thickness and cloth GSM on abrasion resistance (cycles) of dyed cotton samples

Table 32 reveals the influence of cloth count, cloth thickness and GSM on cloth abrasion resistance (cycles) of dyed samples.

From this Table it was found that the influence of cloth count, cloth thickness and GSM was found to be non significant at control, after 5th and 10th washes. Whereas, after 15th wash the influence of picks per inch (cloth count weft) found to be significant at 5 % level of significance and the corresponding R^2 value of sample was 0.58.

4.2.4.3 Colour strength and colour co-ordinate values of stains on cotton fabric subjected to multiple washes

It is inferred from Table 33 and Fig. 7 that among the four dyed samples the highest colour strength (K/S) value was observed with black (639.70) followed by blue (375.87), green (253.44) and red (250.00), at control. After every 5th wash the colour strength (K/S) of all dyed samples decreased. However, the increase in percentage colour strength (K/S) expressed that there existed a reduction in the shade of the dye. Consequently, the percentage decreased in colour strength (K/S) was observed with blue (08.35 %), green (05.00 %), red (03.29%) and black (03.19 %) after 15th wash.

The lightness (+L*) and darkness (-L*) value of I dyed sample at control was found to be higher with red (34.94) followed by green (24.42), blue (15.68) and black (11.28) samples. However, there is increase in lightness value of all the dyed samples on subsequent washes which indicates that the dyed samples have gradually become lighter in colour. Meanwhile, the increase in percentage lightness and darkness (L*) after every 5th wash indicated a reduction in darkness, making the dyed samples lighter in hue and the descending trend of reduction observed was blue (05.05 %), black (01.63 %), red (01.20 %) and green (00.71 %) after fifth wash. Similarly a great deal of lightness observed after 15th wash and the descending trend reads as blue (08.16 %), green (04.49 %),red (02.75 %) and black (02.74 %).

Among the control samples highest redness (+a*) and greenness (-a*) value was found in red (51.12) followed by blue (02.05), black (-0.74) and green (-17.88). Among the dyed samples a trend of decrease was observed after every 5th wash which depicted that the dyed samples have attained tinge of greener colour. Meanwhile, the percentage values of redness and greenness (a*) after every 5th wash indicated a reduction in redness of the stain. The descending order of reduction in a* value was green (-02.71 %), blue (-01.27 %), black (-0.93 %) and red (-00.96 %) after 15th wash.

Table 31. Cloth abrasion resistance (cycles) of dyed cotton samples

Cloth abrasion resistance (cycles)					
Sl.No.	Samples	Control	Washes		
			5^{th}	10^{th}	15^{th}
1.	Black	133	125* (06.01)	56* (57.89)	46* (65.41)
2.	Blue	129	114* (11..62)	59* (54.26)	39* (69.76)
3.	Green	131	123* (06.10)	54* (58.77)	40* (69.46)
4.	Red	129	109* (15.50)	56* (56.58)	55* (57.36)

Figures in parenthesis indicate percentage * - Significant at 5 % level of significance

ANOVA TABLE

Sl.No.	Samples	SEm $\pm$	CV %	CD 5 %
1	Black	5.532	12.894	8.523
2	Blue	5.818	13.690	8.964
3	Green	3.985	9.175	6.140
4	Red	4.463	10.238	6.876

Table 32. Influence of cloth count, cloth thickness and GSM on cloth abrasion resistance (cycles) of dyed cotton samples

Sample	Cloth abrasion resistance (cycles)												
		Control			5^{th} wash			10^{th} wash			15^{th} wash		
	Variables	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat	Coefficient	Standard error	t Stat
Black	X_1	-12.28	8.91	-1.37^{NS}	0.81	3.19	0.25^{NS}	0.82	2.73	0.30^{NS}	4.04	6.05	0.66^{NS}
	X_2	0.63	4.03	0.15^{NS}	-3.11	4.93	-0.63^{NS}	-9.02	4.40	-2.04^{NS}	8.04	7.47	1.07^{NS}
	X_3	175.15	762.02	0.22^{NS}	-21.36	252.54	0.084^{NS}	-324.31	293.61	-1.10^{NS}	98.67	517.31	0.19^{NS}
	X_4	338.80	357.92	0.94^{NS}	151.90	205.57	0.068^{NS}	-679.73	338.89	-0.50^{NS}	-242.13	414.78	-0.87^{NS}
	R^2	0.34			0.18			0.58			0.31		
Blue	X_1	2.63	8.72	0.30^{NS}	3.00	2.51	1.19^{NS}	2.29	4.35	0.52^{NS}	2.45	3.18	0.76^{NS}
	X_2	-1.25	10.82	-0.11^{NS}	-7.00	11.86	-0.59^{NS}	-6.63	6.57	-1.00^{NS}	9.12	3.73	02.44*
	X_3	-103.48	274.79	-0.08^{NS}	237.50	283.91	0.83^{NS}	-161.18	465.44	-0.34^{NS}	187.78	498.55	0.37^{NS}
	X_4	-291.07	903.10	-1.15^{NS}	543.54	238.23	0.72^{NS}	307.15	925.65	0.33^{NS}	-155.3	152.52	0.74^{NS}
	R^2	0.25			0.41			0.42			0.58		
Green	X_1	-2.30	7.10	-0.32^{NS}	0.22	2.52	0.087^{NS}	-3.59	5.54	-0.64^{NS}	2.55	5.29	0.48^{NS}
	X_2	0.30	6.25	0.04^{NS}	3.76	3.86	0.97^{NS}	-1.78	4.17	-0.42^{NS}	-5.77	3.75	-1.53^{NS}
	X_3	382.84	384.99	0.99^{NS}	-40.27	219.48	-0.18^{NS}	287.88	355.59	0.80^{NS}	533.27	523.21	1.01^{NS}
	X_4	-487.29	713.98	-0.68^{NS}	-255.78	121.30	-0.25^{NS}	-436.24	880.37	-0.49^{NS}	-884.03	925.55	-0.45^{NS}
	R^2	0.22			0.24			0.18			0.37		
Red	X_1	-0.37	6.07	-0.061^{NS}	11.42	9.70	1.17^{NS}	7.34	6.19	1.18^{NS}	0.08	2.95	0.02^{NS}
	X_2	3.02	4.70	0.64^{NS}	8.53	8.21	1.03^{NS}	-3.57	4.13	-0.86^{NS}	-3.70	3.44	-1.07^{NS}
	X_3	613.67	512.98	1.19^{NS}	-128.21	266.09	-0.48^{NS}	-80.39	288.50	-0.27^{NS}	-120.75	453.92	-0.26^{NS}
	X_4	-660.86	717.85	-0.61^{NS}	-253.09	837.67	-0.13^{NS}	-433.92	665.67	-1.46^{NS}	-807.75	964.37	-0.69^{NS}
	R^2	0.23			0.28			0.33			0.28		

X1= Cloth count warp
X2= Cloth count weft
X3= Cloth thickness
X4= Cloth GSM

NS – Non significant
* - Significant at 5 % level of significance

Table 33. Colour strength (K/S) and colour co-ordinate values of dyed cotton fabric subjected to multiple washes

Sample	Control				No. of washings											
					5^{th}				10^{th}				15^{th}			
	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*
Black	639.70	11.28	-0.74	-01.52	538.89* (01.74)	12.86* (01.63)	-0.89* (-0.15)	-02.13* (-0.60)	537.94* (01.92)	12.92* (01.69)	-01.63* (-0.88)	-03.23* (-01.70)	447.16* (03.19)	14.56* (02.74)	-01.68* (-0.93)	-04.10* (-02.57)
Blue	375.87	15.68	02.05	-13.99	237.75* (05.35)	20.74* (05.05)	01.40* (-0.64)	-15.63* (-01.63)	208.80* (06.85)	22.26* (06.57)	01.25* (-0.97)	-15.67* (-01.67)	181.77* (08.35)	23.84* (08.16)	01.08* (-1.27)	-15.70 * (-01.71)
Green	253.44	24.42	-17.88	02.61	246.84* (01.65)	25.14* (0.71)	-19.37* (-01.48)	01.47* (-0.14)	204.11* (03.68)	27.44* (03.02)	-19.60* (-02.02)	01.00* (-0.61)	178.69* (05.00)	28.92* (04.49)	-19.91* (-02.71)	0.25* (-01.35)
Red	250.00	34.94	51.12	29.16	232.42* (01.83)	36.14* (01.20)	50.76* (01.31)	28.73* (0.43)	206.86* (02.40)	36.75* (01.81)	50.63* (0.83)	27.40* (-01.32)	188.89* (03.29)	37.00* (2.75)	49.80* (0.96)	27.20* (-01.52)

Figures in parenthesis indicates percentage * - Significant at 5 % level of significance

(K/S) Colour strength
(±L*) Lightness and Darkness
(±a*) Redness and Greenness
(±b*) Yellowness and Blueness

ANOVA TABLE

Sample	K/S			L*			a*			b*		
	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %	SEm ±	CV %	CD 5 %
Black	0.029	0.012	0.040	0.005	0.087	0.007	0.003	-0.676	0.005	0.018	-1.538	0.025
Blue	0.005	0.004	0.007	0.004	0.047	0.005	0.004	0.724	0.006	0.004	-0.066	0.005
Green	0.005	0.005	0.007	0.005	0.050	0.007	0.005	-0.063	0.007	0.005	0.949	0.007
Red	0.006	0.006	0.008	0.005	0.033	0.007	0.006	0.027	0.008	0.006	0.048	0.008

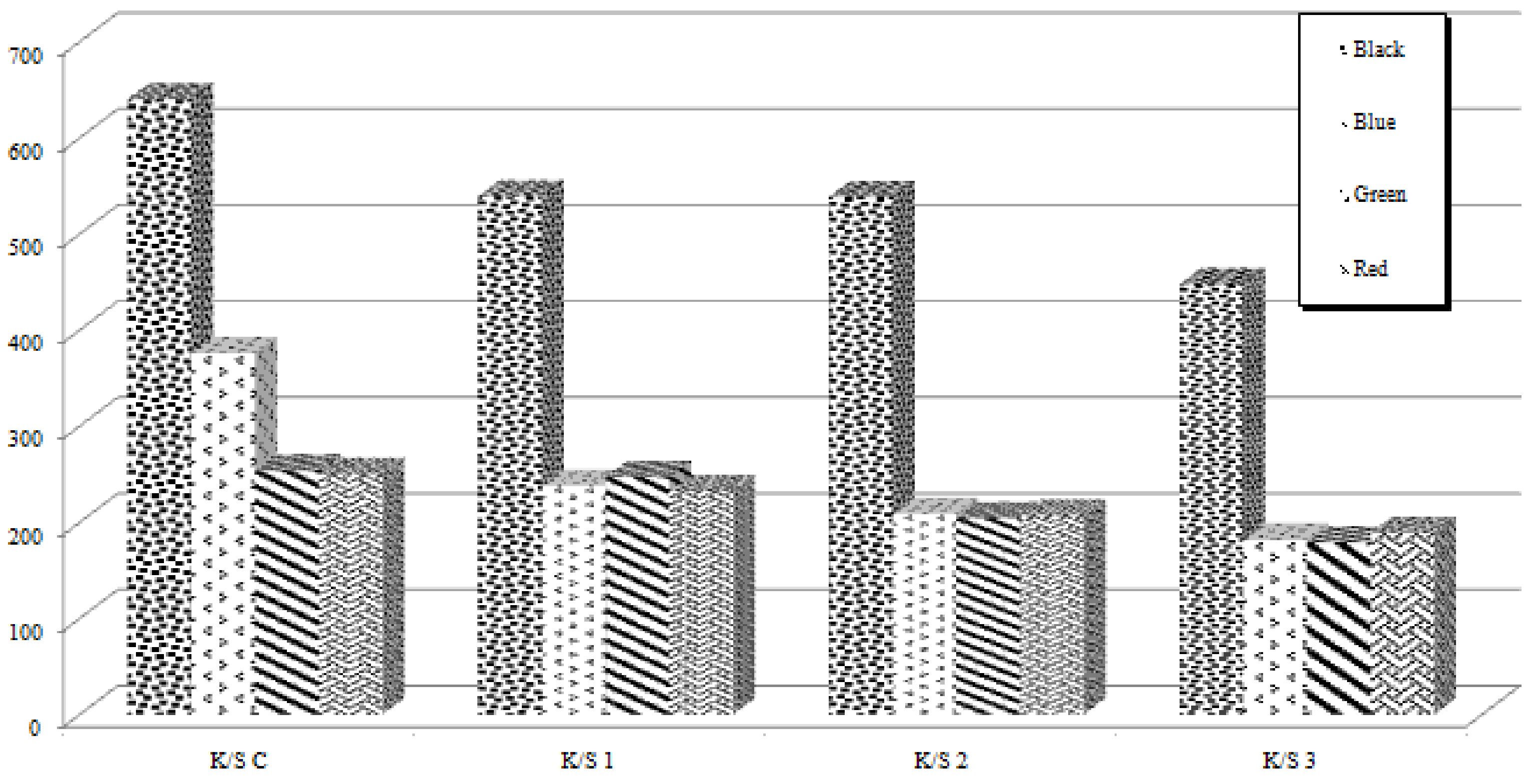

Fig. 7. Colour strength (K/S) values of dyed cotton fabric subjected to multiple washes

Fig. 7. Colour strength (K/S) values of dyed cotton fabric subjected to multiple washes

The yellowness (+b*) and blueness (-b*) value of control sample was found to be higher in red (29.16) followed by green (02.61), black (-01.52) and blue (-13.99). However, there is decrease in yellowness value of all the dyed samples on subsequent washes which indicates that the dyed samples have become bluer in colour. Meanwhile, the percentage decrease in yellowness of all the dyed samples after 15th wash was found to be black (-02.57 %), blue (-01.71 %), red (-01.52 %) and green (-01.35 %).

The colour strength and colour co-ordinate values of dyed cotton fabrics subjected to multiple washes was found to be significant at 5 per cent level of significance.

5. DISCUSSION

The results of the present study on 'Influence of surfactants on fabric behaviour' are discussed in this chapter under the following headings:

5.1 Survey results

5.1.1 Survey I Information on availability of surfactants in the local grocery shops

5.1.1.1 Demographic information of the respondents

5.1.1.2 Forms of surfactants (cleansing agents) available

5.1.1.3 The popular promotion technique adopted by the shop owners

5.1.1.4 Type of surfactants (cleansing agents) purchased by the consumer

5.1.1.5 Form of surfactants (cleansing agents) most preferred by the consumer

5.1.1.6 Salable packages of surfactants (cleansing agents)

5.1.2 Survey II Common stains experienced by the working men and women

5.1.2.1 Dresses used by the respondents at home and for function

5.1.2.2 Fibre content of the dress materials

5.1.2.3 Common stains and stains hard to remove: Experience of the respondents

5.1.2.4 Solvents/reagents used to remove the stains

5.1.2.5 Detergents used for different types of fabrics

5.1.2.6 Effect of surfactants on colour fading: Respondents opinion

5.2 Experimental results

5.2.1 Effect of surfactants on stains

5.2.1.1 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'WG' surfactant

5.2.1.2 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'PW' surfactant

5.2.1.3 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'WBO' surfactant

5.2.2 Structural properties of dyed cotton samples

5.2.2.1 Cloth count of dyed cotton samples

5.2.2.2 Cloth thickness (mm) of dyed cotton samples

5.2.2.3 Cloth weight (GSM) and cloth dimensional stability (%) of dyed cotton samples

5.2.2.4 Cloth dimensional stability (%) of dyed cotton samples

5.2.3 Performance properties of dyed cotton samples

5.2.3.1 Cloth crease recovery angle (degree) of dyed cotton samples

5.2.3.2 Cloth bending length (cm) of dyed cotton samples

5.2.4 Durable properties of dyed cotton samples

5.2.4.1 Cloth tensile strength (kgf) and elongation (%) of dyed cotton samples

5.2.4.2 Cloth abrasion resistance (cycles) of dyed cotton samples

5.2.4.3 Colour strength and colour co-ordinate values of stains on cotton fabric subjected to multiple washes

5.1 Survey results

5.1.1 Survey I Information on availability of surfactants in the local grocery shops

5.1.1.1 Demographic information of the respondents

It is interesting to know that more than $^{1}/_{3}{}^{rd}$ of the shop owners were young, educated and had ventured in the business which clearly indicates that instead of being job seekers, they are job providers. Their hard work, commitment and dedication towards their enterprise has lead them to earn better returns, end of the year. The attitude towards business and earning good returns probably due to the impact of education, where 80.00 per cent of them are learned.

5.1.1.2 Forms of surfactants (cleansing agents) available

It is evident that majority of surfactants (cleansing agents) are available in both powder and cake forms because there are range of brands of surfactants available in the market. In general, the consumers purchase both powder and cakes because the pre-treatment for washing is, soaking. It was express by the consumer that almost all the clothes used to be soaked in soap solution/ in detergent prior to washing. The best form of surfactant is powder which easily dissolves in water. Cakes are mostly used to apply on to the soiled areas to brush and clean. Though most of the powders are white in colour, the cakes are available in yellow, green and blue colours. Probably the colour indicates composition of the detergent, cake brand and uniqueness. However, liquid detergent found to be always in blue colour and available only in 50.00 per cent of the shops may be because of were not much in demand by the consumer.

The branded surfactants (cleansing agents) are available in all the shops irrespective of their cost to make it available for all the categories of income groups.

5.1.1.3 The popular promotion technique adopted by the shop owners

The promotion technique adopted either by the company or shop owner depends upon the locale of the shop, size of the shop, type of consumer visiting and interest of the shop owners. However, there were very limited techniques available to promote surfactants.

The package of the surfactant was most challenging techniques because the consumers always think about carrying the goods safely from shop to home. In fact, they believe in strong, sturdy, portable packages than colourful and attractive. Some of the consumer even preferred surfactants sold in the tiny boxes because it is easy to care and maintain. On the contrary, bills, pamphlets, window display were found to be effective, sometimes. In fact, TV advertisements did not influence the consumer in any way. This clearly indicates that, sometimes the proverb “seeing in believing” does not have impact.

5.1.1.4 Type of surfactants (cleansing agents) purchased by the consumer

From Table 7 it is evident that, all types of surfactants in the form of powder, liquid and cakes were purchased by the consumers which clearly indicate that each individual is unique in their purchasing behaviour. The purchasing practice of a person is influenced by cost, colour, form, volume, cleansing action, experience and influence of either friends or family members. However, it is interesting to know that the grocery shops have inventory of all varieties of surfactants to meet the demand and supply of the consumers.

5.1.1.5 Form of surfactants (cleansing agents) most preferred by the consumer

Table 8 clearly depicts that, cent per cent of the consumers preferred cake may be handy to apply soiled areas to wash small, medium and large articles; the smallest piece could always be used for cleaning the vessels in other words every bit of the cake could be used effectively and efficiently. Similarly, the powders are preferred on par with cakes. However, liquid detergent is exclusively meant to cleans silk and woolens and therefore not preferred always but either sometimes and never.

5.1.1.6 Salable packages of surfactants (cleansing agents)

It's true that the salable packages for cake, powder and liquid are different. The cakes are available in small, medium and large sizes; in fact it is convenient and easy to use small and medium cakes since it is handy to use. The large ones are usually termed as "bar" which could be cut into a size of convenience. Powders are available in different volumes convenient for the consumer to purchase as per their needs. In fact, there is equal response for purchase of ¼th kg, ½ kg and 1kg packets, except 2kg pack. As far as liquid detergent is considered majority purchased either ½ liter or 1 liter packs. Probably, because it can be stored for sufficient long time without any adverse effect on the composition as well simple to store.

5.1.2 Survey II Common stains experienced by the working men and women

5.1.2.1 Dresses used by the respondents at home and for function

From Table 11 (a) & (b) it is learn that majority men preferred pant and shirts for functions as well as home may be because most of them belong to middle age and probably found to be comfortable and descent than jeans, t-shirts, pyjama and kurta and other traditional wear.

Night gown found to be very comfortable, handy, easy to wear, care and maintain and probably descent, since it covers the entire body from neck to ankle and thus, preferred by majority of the working women. Mean while, about 40.00 per cent of them found salwar kameez to be descent, presentable, comfortable and therefore preferred to area at home as well as during function.

Never the less 83.00 per cent of women preferred the tradition Indian sari as the more suitable wear for functions. It's true that, none of the costumes that may be considered as comfortable cannot replace the most elegant, beautiful, womanly wear: the sari. In other words, every woman wants to express the style, fashion, trend and elegance by draping sari in various modes. It is true that, among women's costumes sari will always remain on the top discussion.

However, very meager per cent of working women prefer ghagra choli may be because its not in the fashion trend, presently.

5.1.2.2 Fibre content of the dress materials

Table 12 expressed the fibre content of the dresses used by both working men and women. More than 75.00 per cent of the respondents have cotton dresses, since cotton is king for both home wear and function wear. From the ages, cotton is been used by men, women, children and elders all through the year. Because of its inherent properties like breathability, absorbency, coolness, user friendly, eco-friendly, good conductor of heat and above all ease its drape that expresses grace, satisfaction and modesty. Though polyester is popular because of its few limited properties like hydrophobicity, static charges that creates a kind of physical discomfort to the wearer.

5.1.2.3 Common stains and stains hard to remove: Experience of the respondents

The stains which are commonly found on garments are not usually hard to remove if washed or cleaned immediately. But some of them are hard to remove since they depend on the composition of the stains, affinity between stains and the fabric, and the method by which it is anchored on to the fabric. In the present study combined with some vegetables and turmeric are commonly found and are hard to remove when old. At the same time, the tea/coffee when washed immediately do not leave any stain. Meanwhile, rust and mud were not hard to remove because they are mechanically held on to the fabric.

5.1.2.4 Solvents/reagents used to remove the stains

Table-15 Clearly indicates that almost 80-95 per cent of the respondents, irrespective of the category used soaps and detergents to remove the hard stains. And this is mainly because the aged stains are hard to remove compare to fresh ones where later could be removed by application of simple solvent *i.e.,* water may be cold or warm as per the demand. Soaps and detergents are the surfactants when applied on to the stains, act upon the colouring matter and try to reduce the colour strength. The surfactants do have some per cent of bleaching agent as compositions. In other words it is the bleaching component of the surfactant which tries to fade the colour of the stain.

Mean while, it is imperative from table-16 that all the surfactants do not have some intensity of impact on the stains because the surfactants differ in their composition, the stains differ in the source, the attraction between stain and the fabric vary with fibre content and finally the form in which the stain anchors on to the fabric. The ‘Sx’ is found to be effective in stain removal may be because of its level of action on to the stain, percentage of whitening ingredient in the surfactant, affinity between soap water, stain and the fabric.

However, two detergents viz., coded as ‘N’ and ‘V’ were found to be in-effective may be because of lack of whitening agent or poor graded surfactant.

5.1.2.5 Detergents used for different types of fabrics

The local markets region-wise have distribution of different types of surfactants depends upon the local demand, socio-economic status of the communities, dwelling of the locality, type of garments commonly used and so on. The purchasing power of any commodity mainly depends upon the economic status, education level and occupation of the consumers. A range of surfactants are available in different forms like bar, cake, powder, chips and liquid; some are light-weight and volume-less and others heavy; different colours like green, blue, white and yellow; in packages of 1/4th, ½ and 1kg or liter. Many times the forms of surfactant indicates its applicability for specific type of fabric i.e., liquid detergents for silk and wool. The respondents of both categories used ’Sx’ for cotton, polyester, P/C blended fabrics which clearly indicates its effectiveness on all types of fabrics. The working women found the surfactant ‘R’ to be very effective for all types of fabrics followed by surfactant ‘T’. Meanwhile, working women found the detergent ‘W’ to be effective on all types of fabrics.

5.1.2.6 Effect of surfactants on colour fading: Respondents opinion

The effectiveness of a detergent is assessed or evaluated on the basis of cleansing action, stain removal and adding freshness to the garments. In day-to-day life, people do experience bleeding or fading of colour during laundering. There are several factors which affect fading of the colour viz., poor selection of dye, lack of affinity between dye and fabric, mode of application of colour after treatment, reaction of the dye or colour to water, surfactants, sunlight, perspiration, rubbing and hot pressing. The colour fades because of bleaching ingredient present in the surfactant. As per working women, 'N' and 'W' were found to be poor surfactants since they adversely affected the colour of the fabric.

5.2 Experimental results

5.2.1 Effect of surfactants on stains

The change in the colour is expressed in terms of colour co-ordinates. Even if two colours looks the same to one person there may be slight difference when evaluated with the colour measurement instrument. Colour difference can be defined as the numerical expression of a samples colour to the standard. It indicates the difference in absolute colour co-ordinate and is referred to as 'delta'. These formulas calculated difference between two colours to identify inconsistencies. Defined by the commission international de l'éclairage (CIE) the L* a* b* colour space was model after a colour opponent theory stating that two colours cannot be red and green at the same time or yellow and blue at the same time. L* indicates lightness, a* is the red/green colour co-ordinate and b* is the yellow/blue co-ordinate (*sensing.konicaminolta.us*).

Δ 's for L* (ΔL), a* (Δa) and b* (Δb) may be positive or negative. The total difference (ΔE), however, is always positive.

Δ L = L* - L standard = Difference in lightness and darkness (+ = lighter, - = darker)

Δ a = a* - a standard = Difference in red and green (+ = redder, - = greener)

Δb = b* - b standard = Difference in yellow and blue (+ = yellower, - = bluer)

ΔE = Total colour difference

To determine the total colour difference between all three colour co-ordinate:

$$\Delta E = (\Delta L^* 2 + \Delta a^* 2 + \Delta b^* 2) \times 1/2$$

5.2.1.1 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'WG' surfactant

It is found from Table 19 and Fig. 2 that the colour strength (K/S) of mud stain was found to be dark and obvious compared to curry, pickle and grease at control. But on washing with 'WG' the colour of the stain gradually reduced and curry stain was found to be the highest after 3rd wash compare to pickle which clearly indicates that 'WG' surfactant is very effective in removing the curry stain than mud, grease and pickle. It may also be stated that the surfactant with 10.6 pH acts on the ingredients of curry *viz*., dal, turmeric, masala powder, sour components reasonably than oily items. These results are supported by colour co-ordinate values L*, a* and b* when the L* (17.15 %), a* (-08.61 %) and b* (-51.12 %).

The increase in L* value expresses stain becoming lighter in shade i.e. higher the L* lighter the shade is. In other words L* value and shade of the stain are directly proportional. In support L* value, the colour co-ordinate a* expresses either greener (-a* value) or redder (+a* value) on repeated washes. Greater the minus a* value, greener the shade which is lighter than redder shade. Similarly, the colour co-ordinate b* expressed either blueness (-b* value) or yellowness (+b* value) on subsequent washes. Greater the minus b* value, bluer the shade which is lighter than yellowness where the later is warmer and brighter shade. Hence, after the third wash the curry stain exhibited lighter L* value, -a* and –b* values which clearly indicate that the stain has become in lighter shade compare to grease, mud and pickle.

5.2.1.2 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'PW' surfactant

A similar trend of colour co-ordinates and colour difference values of stains were observed when cleansed with 'PW' surfactant, having pH 9.50. The curry stain, which was quite strong in colour strength next to mud, was brilliantly reduced in the 3rd wash (1.68 K/S value), in fact much better than 'WG' surfactant. Meanwhile, the mud and grease stains were also appeared much lighter after washing with 'PW' cleanser. However, the pickle stain was found to be slightly hardier to remove among the four stains. Nevertheless, the colour co-ordinates L*, a* and b* supported the K/S value of the respective stains correspondingly. The curry stain exhibited maximum lightness (L*, 84.37) higher greener (-a*, 00.43) and higher bluer (-b*, -03.05) values indicating that stain is easier to remove than pickle, that falls in the category of food items. Naik and Kammar (1998) also reported that the curry stain on washing turned to reddish tinge because of the alkali action on the fatty acid. But this stain can be gradually cleansed by subsequent washing. Meanwhile, the grease stain was found to be a mixture of greenness (a*, -0.96) and yellowness (b*, 05.95) values after 3rd wash, which indicates the stain cannot be removed completely but a trace of yellowness remains on the back ground of the fabric.

5.2.1.3 Colour strength and colour co-ordinate values of stains on cotton samples subjected to multiple washes with 'WBO' surfactant

The stains, when cleansed with 'WBO' surfactant, it is found that there is gradual change in the colour strength (K/S) of all the four stains, on subsequent washes. A greater reduction in colour strength was observed with curry and mud after 1st, 2nd and 3rd washes. However, the K/S value did not change much with pickle stain which clearly indicates that this stain is hard to remove with 'WBO' surfactant and may be classified as 'hard stain' 'difficult to remove'. These surfactants are further supported by the values of colour co-ordinates i.e. the lightness (-L*), greener (-a*) and bluer (-b*) were found to be comparatively low after 15th wash in comparison to the values of other stains. Thus, considering the values of colour strength and colour co-ordinates, it may be stated that 'WBO' is effective in discolouration of mud and grease stain and relatively less effective on pickle stain. Samanta *et al*. (2004) also stated that there are progressive increases in per cent soil removal as the number wash cycles increases.

However, the null hypothesis that selected surfactants remove the stains in first wash is accepted *i.e*., there is change in the colour of the curry, grease, pickle and mud stains in first wash.

5.2.2 Structural properties of dyed cotton samples

5.2.2.1 Cloth count of dyed cotton samples

The figures in Table 22 expressing cloth count are found to be consistent after 5th wash. There is increase in the ends and picks per unit area after 5th wash but later in subsequent washes there is no change, which clearly indicates that the fabric has attained dimensional stability in the early washes only, in fact a favorable feature of textile materials used for clothing. Further, ends per inch are double the number of picks per inch, which makes the fabric stronger warp way since, the garments are always cut and constructed length wise. Deshwal *et al.* (2008) also stated that the cotton fabric showed significant increase in the fabric count over control sample after washing.

5.2.2.2 Cloth thickness (mm) of dyed cotton samples

The thickness of the cloth is featured by several factors viz., types of yarn, weave and fabric construction, dimensional change, finish applied and so on. But in this study the test sample chosen is single, which was subjected to vat dyeing in different hues. It is sure that the 'hues' do not contribute to increase in cloth thickness. Hence, it can be inferred that the slight change observed after 5th wash may be due to change in the dimension that led to progressive consolidation of the fabric. In fact, cloth thickness improves the drape, a positive feature of fabric, meant for clothing.

5.2.2.3 Cloth weight (GSM) and cloth dimensional stability (%) of dyed cotton samples

The GSM of fabric determines many qualities, characteristics and end use of the ultimate textile material. Some clothing has relatively high percentage of GSM whereas others have low GSM. The summer shirting, sari, children's clothing, veil etc have to be light in weight where as cotton draperies, bed linen, painting etc have to be heavier. Nevertheless, every fabric has GSM and is contributed by percentage of warp and weft yarns. From Table 22 it is clear that number of ends per inch is greater than picks per inch and therefore the corresponding percentage of warp yarns is higher than weft yarns at control. Though there is not much elevation in the GSM of the test samples after 5th (02.13 %), 10th (02.11 %) and 15th (02.55 %) washes; but this increase is mainly due to progressive consolidation of yarns (Table 22) due to shrinkage (Table 25). In other words the progressive shrinkage lead to consolidation of yarns, that intern enhanced the GSM, accordingly. It is noticed that there is not much change in the GSM after 10th wash, which indicates that the test samples have attained dimensional stability, which is a positive feature for cotton fabric (Table 24 and Table 25).

5.2.3 Performance properties of dyed cotton samples

5.2.3.1 Cloth crease recovery angle (degree) of dyed cotton samples

The cloth crease recovery is the resiliency of the fabric. The angle of the crease recovery objectively indicates the pliability, soft and bending capacity. Higher the crease recovery angle better is the ability of the fabrics to come back to normal shape after crease (Chellamani K.P., 2008). Table 26 reveals about the softness achieve after subsequent washes. The test samples showed better softness in weft way than warp way through higher recovery angle values. This indicates that the cotton test samples have become soft and pliable on laundering because of removal of sizing material (stiffness agent), progressive consolidation of yarns and removal of hairiness of the yarn on mechanical agitation.

5.2.3.2 Cloth bending length (cm) of dyed cotton samples

The bending capacity off the fabric indicates its flexibility, the most important and essential feature that governs 'clothing materials'. The equation 'longer the bending length stiffer the fabric' is accepted and the test results are inferred on this base. Before washing, the fabric was reasonably stiffer, greater in warp way direction may be because of sizing, an important pre loom process. On subsequent washes, it is evident that the fabric has become softer due to release of sizing material, along with wear off of the protruded fibres. The dehairing makes the fabric invariably softer and smoother, in turn reducing the stiffness and roughness. It may be confirmed that washing makes the fabric soft, smooth and pliable.

However, the null hypothesis that the washing affected the performance properties of dyed fabrics *i.e.*, there is change in the cloth crease recovery and cloth bending length after washing.

5.2.4 Durable properties of dyed cotton samples

5.2.4.1 Cloth tensile strength (kgf) and elongation (%) of dyed cotton samples

The tensile strength of dyed cotton samples presented in Table 28a indicated to be higher in control compared to every 5th wash. This may be because in control sample the tensile forces readily displace the cellulose molecules in the amorphous region where in the fibres could easily be stretched, thus the considerable capacity to absorb the applied force. The structural properties that influence the tensile strength of the cloth are cloth count, cloth thickness and cloth weight. In this Table the warp way tensile strength is maximum compared to weft way as the ends per inch is higher than picks per inch.

From Table 28b it can be concluded that there was gradual decrease in the elongation (%) of the samples both in warp way and weft way direction may be due to increase in cloth count, decrease in cloth thickness and dehairing due to hydrolysis of cellulose on wet treatment.

5.2.4.2 Cloth abrasion resistance (cycles) of dyed cotton samples

Abrasion resistance is one of the fabric properties that determines the level of durability and unit is expressed in cycles i.e., higher the number of cycles greater the resistance of the fabric. From Table 31 it is evident that there is decrease in abrasion cycles after every 5th wash compared to control sample may be because of reduction in cloth thickness and dehairing of the yarns of fabric on wet condition and may be due to chemicals present in surfactant which affect the polymer system of the yarn and fibre.

However, the null hypothesis that the washing affected the durable properties of the dyed fabrics *i.e.,* there is change in the cloth tensile strength & elongation and cloth abrasion resistance after washing.

5.2.4.3 Colour strength and colour co-ordinate values of stains on cotton fabric subjected to multiple washes

The impact of laundering on test samples dyed in common four colours of vat dye, indicated that, the colour changed (faded) on washing, but the level or percentage of this change is not same among the test samples. This variation in colour change is expressed in terms of colour strength and colour co-ordinate values. Accordingly to the Table 33, maximum reduction in colour strength was observed with blue and least with black and red after 15th wash. These K/S values supported with colour co-ordinate values of blue samples where greater percent of lightness (+L*) and blueness (-b*) were achieved after 15th wash. Similarly, a remarkable reduction in colour strength of green colour was observed after 15th wash and the corresponding colour co-ordinates (+L*) and greenness value (-a*) were supporting it. From the results it may be inferred that blue and green colours are relatively sensitive to washing compared to black and red. It was found that red colour is sustainable and withstands number of washes where as black colour gradually indicates a tinge of greenness (-a*) and blueness (-b*) than any trace of darkness (K/S), brighter (-L*), redder (+a*) and yellowness (+b*) values.

Hence, the null hypothesis that the selected surfactants affected the hue of the dyed fabric is accepted *i.e.*, there is change in the hue of the dyed fabric after washing with selected surfactant.

6. SUMMARY AND CONCLUSIONS

The present study entitled 'Influence of surfactants on cotton behaviour' was carried out in Dharwad city. The investigation comprised of two parts – survey and experimental procedures. Under survey method two separate self structured interview schedule were prepared and administrated on two categories of respondents *viz*., first schedule on local grocery shop owners (50) to elicit the information regarding the availability of different types of cleansing agents (surfactants) in the local market and second schedule on working men and women (each 30) to gather the information regarding the common stains experienced by them and the mode of treatment to remove them. On the basis of results, the most commonly salable surfactants (cleansing agents) by the shop owners, purchased by the consumers; and common stains experienced by the working men and women were selected for the study. The hand woven bleached cotton fabric was the test sample used for experimental procedure.

On the basis of the survey results three surfactants popularly sold by the shop owners as well purchased by the consumers and four stains commonly experienced by the respondents were selected and further referred in the experimental procedure. The first phase of the experimental procedure focused on impact of surfactants on discolouration of the stains. The white cotton test sample was artificially stained separately with four stains, kept for 24 hours, aged to make them hard, harsh and old. The old stains were cleansed with three surfactants separately up to three cleansings and assessed for discolouration after each wash and expressed in terms of colour strength (K/S) and colour co-ordinates L*, a* and b*.

In second phase, the same hand woven, bleached white cotton fabric was vat dyed in four colours *viz*., black, blue, green and red shades and subjected to 15 washes to assess the impact of surfactant on structural, performance and durability characteristics as well colour strength, after every 5^{th} wash.

The results of the survey and experimental study are presented below:

I Survey results:

Demographic information of the shop owners

- Majority of the shop owners belonged to middle age group (38.00 %)
- Cent percent of the shop owners were educated, however the level of education varied
- Majority of the shop owners (40.00 %) belonged to low income group (Rs.< 6,32,352/-)

Availability of surfactants (cleansing agents) in the selected shops

- As per the survey results, majority of the surfactants locally available are in powder and cake form followed by liquid
- Greater per cent of the cakes were found to be in blue colour followed by Green and yellow
- The style and form of packaging was the important factor considered by consumers while purchasing surfactants
- The most preferred surfactant in powder form was Wl (100 %), Nm (96.00 %) and Td (86.00 %) and purchased always; whereas about 50.00% never preferred Gd and Hk

- The most popularly preferred and accepted cakes were WI (100 %), Td and Nm (each 82.00 %)
- More than 50.00 per cent never showed indication of liquid surfactants
- Irrespective of the form of surfactants, cakes were preferred the most (100 %) followed by powder (94.00 %)
- The shops had inventory of all varieties of surfactants to meet the demand of the consumers and to promote
- Cent per cent of the consumers found cake to be handy to apply on soiled areas as well convenient to wash small, medium and large articles; the powders were preferred on par with cakes
- The consumers purchased the powders available in 1 kg, ½ kg and ¼ kg packets and the liquids either ½ or 1 liters, which could be stored sufficiently longer time

II survey results:

Demographic information of the working men and women

- Majority of the working men belonged to middle age group (43.33 %) whereas all most $^{1}/_{3}{}^{rd}$ of the working women belonged to younger age group (36.66%)
- Very meager per cent of men (06.66 %) and women (03.33 %) were illiterates, however majority of the working men had education up to PUC (26.66 %) and majority of working women were found to be degree holders (36.66 %) as well as post graduate (36.66 %)
- Majority among the men were working with government (53.33 %) whereas women with private (46.66 %) organizations

Types of clothing used by the working men and women

- Night gown was found to be very comfortable, handy, easy to wear, care and maintain and probably descent by majority of working women since it covers the entire body from neck to ankle and thus, preferred
- Being in the middle age group, majority men preferred pant and shirts (76.66 %) for functions as well as home and probably found to be comfortable and descent
- Women preferred the tradition Indian sari as the most suitable wear for functions (83.33 %)
- More than 75.00 per cent of the respondents have cotton dresses, since cotton remains king for both home and function wears

Opinion of the respondents about occurrence of stains

- The most commonly occurring stains as experienced by working men were oil (63.33 %), mud (50.00 %) and bhaji (30.00 %) whereas working women experienced grease and mud (each 43.33 %), ink (36.66 %) and bhaji & oil (each 30.00 %)
- Majority of working women expressed that oil stain is very hard to remove (66.66 %) followed by bhaji and curry (each 50.00 %) and grease (26.66 %) whereas majority of working men expressed oil (30.00 %), grease (23.33 %) and pickle & ink (20.00 % each) is the order of strong stain

- More than 80.00 per cent of the respondents used either soap or detergent to remove the hard stains (96.66 % working women & 83.33 % working men) followed by simple plain water
- Majority of the respondents found the surfactant 'Sx' to be very effective (63.33 % and 56.66 %) followed by 'Td' (26.66 % and 40.00 %) by working men and women respectively and the detergent 'R' (36.66 %) by working women
- Almost 1/3rd of the respondents indicated that the fabrics when washed with surfactants 'Nm' and 'Wl' led to colour bleeding, that ultimately faded the fabric

II Experimental results

Effect of surfactants on stain removal

Colour strength and colour coordinate values of stains on white cotton fabric subjected to multiple washes with 'WG' surfactant

- Colour strength (K/S) value of curry stain was found to be lighter after 3rd wash compared to pickle, which clearly indicates that 'WG' surfactant is very effective in removing the curry stain than mud, grease and pickle stains
- The surfactant with 10.6 pH i.e., acts basic surfactants on the colour ingredients of curry *viz.*, turmeric, masala powder, sour components reasonably than oily items. These results are supported by colour co-ordinate values L*, a* and b* where L* (17.15 %), a* (-08.61 %) and b* (-51.12 %), which indicates the stains are becoming lighter gradually
- The curry stain exhibited lighter L* (80.75) value, - a* (0.67) and – b* (-01.60) value after 3rd wash which clearly indicated that the stain has become lighter in shade compared to grease, mud and pickle stains
- None of the old stains could be washed off in single cleansing, needs 2 – 3 washes where the surfactant acts on the stain each time and tries to reduce the shade of the stain

Colour strength and colour coordinate values of stains on white cotton fabric subjected to multiple washes with 'PW' surfactant

- A similar trend of colour co-ordinates and colour difference values of stains were observed with 'PW' surfactant (pH 09.50) as that of 'WG' surfactant
- The curry stain, which was quite strong in colour strength next to mud, was brilliantly reduced in the 3rd wash (1.68 K/S value), in fact much better than 'WG' surfactant
- The mud and grease stains appeared much lighter after washing with 'PW'. However, the pickle stain was found to be slightly harder to remove among the four stains
- The curry stain exhibited maximum lightness (L*, 84.37), higher greener (-a*, 08.77) and higher bluer (-b*, -03.05) values indicating that the stain is easier to remove than pickle stain
- The grease stain was found to be a mixture of greenness (a*, -0.96) and yellowness (b*, 05.95) after 3rd wash, which indicated that the stain cannot be removed completely since a trace of yellowness remains on the back ground of the fabric

Colour strength and colour coordinate values of stains on white cotton fabric subjected to multiple washes with 'WBO' surfactant

- A greater reduction in colour strength was observed with curry and mud after 1st, 2nd and 3rd washes. However, the K/S value did not change much with pickle stain which clearly indicates that this stain is hard to remove with 'WBO' surfactant having pH 09.70 and may be classified as 'hard stain' or 'strong stain' or 'difficult to remove'
- These results of curry stain are further supported by the values of colour co-ordinates i.e. the lightness (L*, 18.52 %), greener (-a*, -09.29 %) and bluer (-b*, -53.58 %) values which were found to be comparatively high after 3rd wash in comparison to the values of other stains
- Considering the values of colour strength and colour co-ordinates, it may be stated that 'WBO' is effective in discolouration of curry, mud and grease stain and relatively less effective on pickle stain
- Irrespective of the surfactants and its pH, it is easy and simple to remove old curry stain but difficult to remove pickle stain

Effect of washing on physical properties of dyed cotton fabrics

Effect of washing on structural properties: Cloth count (Ne)

- The cloth count increased on washing due to consolidation of yarns after 5th wash (warp - 94 and weft – 48) whereas no change after subsequent washes
- The consolidation was greater in warp way compared to weft way

Effect of washing on structural properties: Cloth thickness (mm)

- There was slight increase in cloth thickness (03.03 % to 09.09 %) after 5th wash but there after not much change was observed in the cloth thickness after 10th and 15th washes

Effect of washing on structural properties: GSM

- Increase in cloth count (warp - 94 and weft – 48) and cloth thickness (0.34 mm to 0.36 mm) collectively influenced the GSM of dyed samples

Effect of washing on structural properties: Cloth dimensional stability (%)

- There was light shrinkage after 5th wash, but the test samples attained the dimensional stability there after

Effect of washing on performance properties: Cloth bending length (cm)

- The warpway bending path was longer (0.73 %) than its corresponding weftway path (0.66 %)
- Before washing, the fabric was reasonably stiffer but on subsequent washes, it become softer due to release of sizing material along with ware off of the protruded fibres

Effect of washing on performance properties: Cloth crease recovery angle (angle)

- Crease recovery angle was inversely proportional to bending length
- The softness achieved after subsequent washes influenced higher recovery angle in weftway than in warpway
- There was gradual increase in crease recovery of both warp and weftways after every 5th (02.56 % and 01.23 %), 10th (05.12 % and 03.70 %) and 15th (06.41% and 04.93%) washes, respectively

Effect of washing on durable properties: Cloth tensile strength (kgf)

- The warp way tensile strength was higher (22.18 kgf) than its corresponding weft way (09.24 kgf) strength
- The tensile strength was higher at control than subsequent washes because the tensile force readily displaced the cellulose molecules in the amorphous region and there was decrease in breaking load after every 5th (04.95 % and 06.06 %), 10th (09.10 % and 11.03 %) and 15th (09.43 % and 09.43 %) washes in warp and weft directions respectively
- A trend of decrease in elongation (%) was observed after every 5th wash because of wear off of the ultimate fabric
- A great reduction in elongation (%) was observed after 15th wash in warpway (from 11.91 % to 27.59 %) compare to 5th and 10th wash compared to weftway reduction (10.46 % to 20.31 %)

Effect of washing on durable properties: Cloth abrasion resistance (cycles)

- The dyed sample exhibited reduction in abrasion resistance on washing
- The reduction in abrasion resistance is because of wearing off of the fabric and chemicals present in the surfactant which affected the polymer system of the fibre
- A great reduction was found in abrasion resistance after 10th wash (54.26 % to 58.77 %) compared to 5th wash (06.01 % to 15.50 %)
- A gradual reduction in abrasion resistance observed after every 5th wash

Effect of washing on colour strength of dyed fabrics

- Maximum reduction in colour strength was observed with blue (08.35 %) and least with black (03.19 %) and red (03.29 %) after 15th wash
- The increase in percentage of L* of test samples after every 5th wash indicated a reduction in darkness making the dyed samples lighter in hue. Higher the L* value greater the lightness
- A great deal of lightness was observed after 15th wash in blue (08.16 %) followed by green (04.49 %), red (02.75 %) and black (02.74 %)
- The descending order of reduction in redness was with green (-02.17 %), blue (-01.27 %), red (-00.96 %) and black (-00.93 %) which indicates green and blue have become yellower
- The descending trend of decrease percentage in yellowness among the dyed samples after subsequent washes was found to be with black (-02.57 %), blue (-01.71 %), red (-01.52 %) and green (-01.35 %) after 15th wash
- Remarkable reduction in colour strength of green colour was observed after 15th wash and the corresponding colour co-ordinates (+L*) and greenness value (-a*) was complimentary to it
- Among the four dyed test samples, blue colour is found to be susceptible for washing followed by green i.e., these colours tend to fade easily when subjected to number of washes
- Red being the warm and dark colour is found to be stronger in colour strength and colour co-ordinates

- Black being a blend of all the hues, is the darkest among the neutral colours. The dark, bold and strong hues either the balck have supported the colour strength (K/S) with corresponding colour co-ordinate (L*, a* and b*) values
- The values of colour strength (K/S) and colour co-ordinate (L*, a* and b*) values are dye sensitive and behave accordingly when subjected to multiple washes

Implications and recommendations

The present investigation entitled 'Influence of surfactants on fabric behaviuor' has provided information on the types of surfactants (cleansing agents) available in the local market and adopted by the consumers. Moreover, the effect of three surfactants on stain removal *viz*., curry, grease, pickle and mud; and colour strength & physical parameters *viz*., structural, performance and durable properties of dyed fabrics on subsequent washes has been emphasized. The stains are obvious on white and light coloured fabrics and less obvious on dark back grounds like black, red, blue and green. It is harder to remove old stains. No stains could be removed in single wash. Therefore, it is recommended to remove the stains, when fresh; first cleanse with simple cold water followed by using quality surfactant. If stain still persist, cleanse the stained area twice or thrice till it becomes lighter. Among the vat dyed test samples two were cool colours (green and blue), a warm colour (red) and a neutral colour (black). The cool colours tend to become lighter on subsequent washes compared to warm and neutral colours. On subsequent washes the cotton fabric become soft, pliable, resilient and more susceptible to creases and wrinkle (inherent property), less hairy and thin. The structural properties influenced the durable properties. In order to restore the colour of dyed cotton fabrics, it is recommended to use mild surfactants.

Suggestions for further study

- Effect of liquid detergents on stain removal and colour strength of dyed fabrics
- Impact of neutral surfactants on colour fastness to perspiration, crockinf, hot pressing and sunlight
- Impact of surfactants on the colour strength (K/S) and colour co-ordinate of naturally coloured cotton fabric
- Impact of surfactants on colour strength (K/S) and colour co-ordinate of cotton fabric dyed with vegetable colours
- Impact of surfactants on removal of stains on silk fabric

REFERENCES

Ahu, D. G., Burcin, D. and Aysen, A., 2014, Colour, abrasion and some colour fastness properties of reactive dyed plain knitted fabrics made from modal viscose fibres. *FIBRES & TEXTILES in Eastern Europe,* 22 (5): 107-112.

Alam, Md. S., Khan, G.M.A., Razzaque, S.M.A., Hossain, M. J. and Minhaz-ul-Haque, M., 2008, Dyeing of cotton fabrics with reactive dyes and their physic-chemical properties. *Indian J. of Fibre & Text. Res.*, 33 (4): 58-65.

Booth, J. E., 1996, Principle of Textile Testing. CBS Publishers and Distributers, New Delhi, pp. 255 – 353.

Carrion-fite, F.J., 2015, Colour change of polyester dyed fabric during washing by ecological surfactants. *The J. of the Text. Institute*, 106 (3): 320-326.

Chellamani, K.P., Nagarajan G. and Vijaykumar, K. A., 2008, Evaluation of comfort properties and dyeing characteristics of fabrics made out of compact yarns. *The Text. Industry and Trade J.,* 46 (2): 21-25.

Deshwal, R., Khambra, K. and Yadav, N., 2008, Effect of soaps and detergents on cotton fabric. *Text. Trends*, 57 (4): 33-35.

El-Molla, M.M., Badawy N. A., AbdEl-Aal, A. Y., El-Bayaa A. A. and El-Shaimaa, H. M. G., 2011, Dyeablity of cationised cotton and nylon 6 fabrics using acid dyes. *Indian J. of Fibre & Text. Res.*, 36 (7): 88-95.

Faiza Ebrahim, F.S., Salwa, and Morsy, M. I., 2011, Effect of surface active agents on cellulosic fabric properties. *J. of American Sci.*, 7 (11): 454-456.

Gogoi, N. and Kalita, B., 2000, Effect of various treatments on the removal of stain, (Part-I). *Text. Trends*, 42 (9-12): 37-40.

Gulrajani, M. L., Amit, D. and Chakraborty, M., 1998, Kawabata evaluation of enzyme-treated cotton knitted fabric. *Indian J. of Fibre & Text. Res.,* 23 (1): 160-164.

Gulzar, A. B. and Chris, M. C., 2015, Kawabata evaluation of PLA-knitted fabric washed with various laundering formulations. *The J. of the Text. Institute*, 106 (2): 111-118.

Hasani, H., 2010, Effect of different processing stages on mechanical and surface properties of cotton knitted fabrics. *Indian J. of Fibre & Text. Res*, 35 (8): 139-144.

Hemen, D., Ledwani, L., Chandwani, N., Desai, B. and Nema, S. K., 2014, Surface activation of polyester fabric using ammonia dielectric barrier discharge and improvement in colour depth. *Indian J. of Fibre and Text. Res.,* 39 (2): 274-281.

Hussain, T., Malik, Z. A. and Tanwari, A., 2010, Prediction of tensile strength of polyester/cotton blended woven fabric. *Indian J. of Fibre & Text. Res.*, 35 (5): 243-249.

Jetendra, K. R., Sudhir, K. R. and Ashis, K. M., 2012, Characterization and application of a detergent-stable alkaline alpha-amylase from Bacillus subtilis strain AS-S01a. *International J. of Biological Macromolecules,* 50 (2): 219-229.

Jiang, W., Fang, Y., Zhu, W., Wang, Z., Chen, Q., Gang, X. and Xuan, S., 2013, Influence of surfactants on shear-thickening behaviour in concentrated polymer dispersion. *The J. of Nanopart Res.,* 15 (1): 1-9.

Kalita, B., 1998, Effect of dry cleaning and laundering on silk fabrics. *The Text. Industry and Trade J.*, 36 (1-2): 52-55.

Kannappan, V. and Santhi, R. J., 2004, Ultrasonic studies on dye stain removal by surfactants. *Indian J. of Chemistry*, 43 (1): 1431-1433.

Kazimierrz, B. and Bemska, J., 2010, Effect of nonionic surfactants on the dyeing process of cellulose fibres with C.I. reactive blue 217. *AUTEX Res. J.*, 10 (3): 64-68.

Khambra, K. and Chanchal, 2000, Effect of laundering on properties of jute/acrylic knitted fabrics. *Text. Trends*, 43 (9): 39-41.

Kulloli, S. D. and Naik, S. D., 2014, Designing eco-friendly fabrics from naturally colour linted cotton. *Asian J. Home Sci.,* 9 (1): 157-161.

Mohamed, H. and Ahlem, L., 2014, A new kinetic model for cotton reactive dyeing at different temperatures. *Indian J. of Fibre & Text. Res.,* 39 (3): 310-313.

Naik, S.D. and Kammar, B., 1998, Impact of cleansing agents on mineral, oily and greasy stains. *The Text. Industry and Trade J.*, 36 (3-4): 39-45.

Nair, A.U., Patwardhan, B.A. and Nachane, R.P., 2013, Studies on friction in cotton textiles: Part II – A study on the relationship between physical properties and frictional characteristics of chemically treated cotton fabrics. *Indian J. of Fibre & Text. Res.*, 38 (2): 366-374.

Necla, Y., Esen, O. and Necdet, S., 2012, Improvement fastnesses and colour strength of pigment printed textile fabric. *J. of Engineered Fibers and Fabrics*, 7 (2): 40-46.

Nihat, C., Halil, i. and Pinar Erdal., 2010, Effect of the particle size of fluorocarbon-based finishing agents on fastness and colour properties of 100% cotton knitted fabrics. *The J. of The Text. Institute*, 102 (6): 483-490.

Preeti, Khambra, K., Saroj, S. and Jeet, S., 2001, Effect of stain removing reagents on the colour of cotton fabrics. *Text. Trends,* 44 (7): 29-30.

Prieto, R. M. and Bakalis, S., 2014, Methodological study on the removal of solid oil and fat stains from cotton fabrics using abrasion. *Text. Res. J.,* 84 (1): 52-65.

Rana M., Khambra K. and Yadav N., 2011, Effect of laundering on flammability characteristics of FR treated cotton fabric. *Text. Trends*, 22 (2): 41-44.

Saeideh, G. K., 2011, The effect of spectrophotometer geometry on the measured colour for textile samples with different textures. *J. of Engineered Fibers and Fabrics*, 6 (4): 70-78.

Samanta, A. K., Mitra, S., Singhee D. and Parekh S., 2004, Efficacy of selective surfactants/detergents as washing agents on soiled white and dyed cotton fabrics. *Indian J. of Fibre & Text. Res.*, 29 (1): 223-232.

Santhi, P. and Moses, J.J., 2010, Study on different reducing agents for effective vat dyeing on cotton fabric. *Indian J. of Fibre & Text. Res.*, 35 (2): 349-352.

Sarkar,S. R., Baruah, B. and Chaulkar, B.N., 1999, Use of surface active agent in cooking and reeling of muga cocoon and its effect on properties of fibre and yarn. *The Text. Industry and Trade J.*, 37 (1-2): 30-35.

Sarkar, S.R. and Munshi, V.G., 2001, Effect of soap and detergent on the strength of the cotton/polynosic blended fabric. *The J. of the Text. Institute*, 39 (3-4): 71-75.

Sarkar, S.R., 2000, Effect of laundering on the aesthetic properties of cotton/polynosic blended fabric. *The Text. Industry and Trade J.*, 38 (1-2): 62-68.

Soleimani, M., Khani, A. and Najafzadeh, K., 2012, Alpha-Amylase immobilization on the silica nanoparticles for cleaning performance towards starch soils in laundry detergents. *J. of Molecular catalysis B: Enzymatic*, 74 (4):1-5.

Was-Gubala, J. and Grzesiak, E., 2009, The kinetics of colour change in textiles and fibres treated with detergent solutions Part II - Spectrophotometric measurements. *Sci. and Justice,* 50 (2): 55–58.

https://textlnfo.wordpress.com

http://www.ask.com/web-question/what-is-the-definition-of-durability

sensing.konicaminolta.us

APPENDIX I

Schedule on market survey of grocery shop owners of detergents

Sample size: 50

I. General information

1. Name of the respondents:
2. Name of the shop:
3. Age:
4. Education:
5. Year of establishment:
6. Annual income:
7. Location of the shop:

II. Specific information: This schedule consisted of set of questions related to cleansing agents

1. Mention the various forms of cleansing agents available

Sl. No.	Form of cleansing Agents	Tick (✓)
1	Powder	
2	Liquid	
3	Cakes	

2. List the type of cleansing agents available in the shop

Sl. No.	Cleansing Agents	Tick (✓)
A	Powder	
1	Ariel	
2	Fena	
3	Ghadi	
4	Henko	
5	Nirma	
6	Rin	
7	Surf excel	
8	Tide	
9	Wheel	
B	Liquids	
1	Rin	
2	Surf excel	
C	Cakes	
	Yellow soaps	
1	Ghadi	
2	Nirma	
	Green soaps	
3	Wheel	
	Blue soaps	
4	Fena	
5	Rin	
6	Surf excel	
7	Tide	
8	Shashi	
9	Swastik	

3. The popular sales promotion technique adopted by the shop owners

Sl. No	Sale promotion technique	Always	Sometimes	Never
1	Advertisements			
2	Bills / Pamphlets			
3	Window display			
4	Packaging			

4. Type of cleansing agents purchased by the consumers

Sl.No.	Cleansing Agents	Ranking		
A	Powder	Always	Sometimes	Never
1	Ariel			
2	Fena			
3	Ghadi			
4	Henko			
5	Nirma			
6	Rin			
7	Surf excel			
8	Tide			
9	Wheel			
B	Liquids			
1	Rin			
2	Surf excel			
C	Cakes			
	Yellow soaps			
1	Ghadi			
2	Nirma			
	Green soaps			
3	Wheel			
	Blue soaps			
4	Fena			
5	Rin			
6	Surf excel			
7	Tide			

5. Form of cleansing agents most preferred by the consumer

Sl. No.	Cleansing agents	Always	Sometimes	Never
1	Cake			
2	Powder			
3	Liquid			

6. Salable package of detergents (Tick)

Cleansing agents	Packages (Quantity)		
Cake	Small	Medium	Large
Package available			

Powder	¼ kg	½ kg	1 kg	2 kg	5 kg
A) Box					
B) Polyethylene bag					

Liquid	¼ lit	½ lit	1 lit
Package available			

APPENDIX II

Questionnaire to collect information on occurrence of most common stains

Sample: Working women and men Sample size: 30 each

I General information

1. Name of the respondent:
2. Age:
3. Education:
4. Annual income:
5. Place / city:
6. Occupation:

II Specific information

1. Which dresses do you wear at home / function?

Sl.No.	Home	Tick (✓)	Function	Tick (✓)
1	Night gown		Sari	
2	Salwaar kameez		Salwaar kameez	
3	Sari		Ghagra choli	
4	Others		Others	

2. What is the fibre content?

   a) Cotton b) Polyester c) Polycot d) Silk

4. Have you experience your clothes to be stained? Yes /No
5. What do you mean by stain?
6. Which are the common stains you have experienced or noticed?
7. How does stain occur?
8. Which are the stains hard to remove? Why?
9. Which technique / method have you adopted to remove the stains?

   i. Wash immediately with water

   ii. Wash immediately with soap and water

   iii. Wash later with water

   iv. Wash later with soap and water

10. Name the detergent which is effective in removing the stain?
11. Which detergent is most useful on cotton / polyester / polycot / silk?

Sl.No.	Dress material	Detergents
1	Cotton	
2	Polyester	
3	Polycot	
4	Silk	

12. Which detergent fades the fabric?
13. Which detergent is harmful for hands?

INFLUENCE OF SURFACTANTS ON FABRIC BEHAVIOUR

SHREELA B. MATTI **2016** **DR. SHAILAJA D. NAIK**
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ABSTRACT

The present study was carried out during 2014-16 at Dharwad with the objectives to elicit the information on most popularly selling surfactants in local market, to assess the efficiency of surfactants on stain removal and to study the effects of surfactants on colour strength, structural, performance and durable properties of dyed fabric. On the basis of survey results, three popularly sellable surfactants in the local market and four common stains experienced by the working men and women were selected for the present study.

Bleached organic cotton sample was stained with curry, grease, pickle and mud and washed with selected three surfactants *viz*., WG, PW and WBO separately upto 3 washes and assessed for discolouration after every wash. To assess the impact of surfactants the white cotton was vat dyed in four colours *viz*., black, blue, green and red and subjected to 15 hand washings. The results revealed that PW was focused to be effective in removing curry, grease and pickle stains where as WBO in removing mud stain. The K/S value (57.14 %) of curry stain was found to be lighter after 3rd wash with PW surfactant than mud, grease and pickle. There was increase in the cloth count and cloth thickness after 5th wash and due to progressive consolidation of yarns in both directions. However, the fabrics attained dimensional stability there after. The test samples showed higher crease recovery in weftway than warpway indicating its softness and pliability. There was decrease in tensile strength and elongation (%) of the test samples both warpway and weftway as well as abrasion resistance may be due to mechanical agitation that lead to wear-tear of fibres and in turn yarns. The fabric dyed in blue and green colours were sensitive to washing compared to black and red. Red sample withstood number of washes where as black gradually indicated a tinge of greenness and blueness.